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“Synergies for a resilient future: from knowledge to action”

Book of Abstracts

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WELCOME MESSAGE

The European Society for Agronomy is a scientific society that aims to build bridges between scientists, not only agronomists, but also colleagues from different disciplines to address the major societal and environmental issues related to agriculture, and to promote the science of agronomy and its use in agriculture and rural development throughout Europe.

If the main audience remains European, with this new edition of ESA 2024, we were 310 participants, coming from 28 different countries worldwide, highlighting the international importance of the ESA network.

The last Congress in Potsdam (Germany; 2022) was dedicated to digitalization for the transformation of agriculture. This edition extended the discussions with synergies between technologies to face an uncertain future. For the new edition, we chose resilience to echo with the ability of agricultural systems to recover from unpredictable, sometimes extreme events, and to highlight the inventiveness of human management to build resilience in its many applications and definitions. At this point of rapid expansion and related promises of technological innovations, the Scientific Committee of ESA 2024 wanted to create a momentum to pause the rapid expansion of technical innovations in soil and crop management and to embed them with more social issues, such as the well-being of farmers and their social connectedness to society at large, over the long-term.

This is the essence of the science of agronomy, nourished by transdisciplinarity but transcending it to become an independent discipline with its own concepts and approaches to meet the challenges of the transformational change we need for a viable future.

The word synergy was also used to encapsulate the idea, perhaps idealistic, but certainly humanistic, of the supreme value of diversity.

We hope that the 18th ESA Congress inspired you to initiate or strengthen synergies. Together, we could promote the role of scientific voices for building a better world for next generation, represented during our conference by the numerous young researchers, PhD and Master students.

Prof. Dr. Edith Le Cadre

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The local organising committee would like to express its gratitude to the staff of l'Institut Agro Rennes-Angers and INRAE for their invaluable contribution to the organisation of the congress. In particular, we would like to thank: Michèle Béguinel, Sylviane Gilabert, Stéphane Guiges.

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Keynote speakers

Synergies between disciplines

Prof. Dr. Mika Tarkka received a MSc in plant physiology in 1995 and a PhD on mycorrhizal symbiosis in 2001 from the University of Helsinki. After working as a research associate for mycorrhizal-bacterial interactions at the University of Tübingen, he moved to the Helmholtz Centre for Environmental Research - UFZ in Halle. He is the Head of the Department of Soil Ecology at the UFZ in Halle and holds an adjunct professor's title at the Institute of Biology of the University of Leipzig. In addition, he is a member of the German Centre for Integrative Biodiversity Research (iDiv) Halle-Jena-Leipzig. Prof. Tarkka's research focus is molecular plant microbe interactions. His particular research interests include the influence of climate change on plant beneficial microbes and their relevance for plant growth and health. He works experimentally to investigate how changes in land use and environment influence the distribution of plant associated microbes, and how the diversity of the microorganisms affects the host plant.

- Keynote speech: **Uncovering rhizosphere microbial resilience and potential to support plant growth** (here)

Synergies between researchers, farmers and society

Prof. Dr. Johanna Jacobi leads the Agroecological Transitions research group at ETH Zürich. She studied Geography, Biology and Social Anthropology at the university of Freiburg. For her PhD studies at the University of Bern, she conducted research together with the cooperative El Ceibo on the resilience of cocoa farms in Bolivia to climate change. After a postdoctoral project at the University of California, Berkeley, on agroforestry, she lived and worked in Bolivia for several years, doing research on food system sustainability and resilience in Latin America and Africa. Her research focuses on agroecology as a transformative science, a practice and a social movement using participatory action research and transdisciplinary methods and political ecology approaches.

- Keynote speech: **Co-creation of knowledge and transformations in agri-food systems** (here)

Synergies between short- and long-term goals

Dr. Guillaume Martin (42) holds a MSc in plant sciences from Wageningen University and a PhD in agricultural sciences from Toulouse University. He is a research director in the Joint Research Unit AGIR (Agroecology, Innovation, Territories) at INRAE’s Occitanie-Toulouse centre. He is also editor for Agricultural Systems. He positions his work in the field of farming systems research and focuses on pasture-based and crop-livestock farming at the farm and territory levels. Since his early career, his ambition has been threefold: (i) to develop tools enabling farmers to design sustainable and resilient systems; (ii) to develop methods informing farmers and farm consultants on the most sustainable and resilient systems and on pathways towards such systems; (iii) to explore the potential of innovative systems improving farm sustainability and resilience. His research builds on systems, interdisciplinary and participatory approaches. He has authored more than 60 articles in international scientific journals.

- Keynote speech: **Reconciling short- and long-term goals in agrifood systems: what role for agricultural sciences?** (here)

Synergies of technologies

Prof. Dr. Simon Cook is an independent consultant who specializes in science-enabled change in agrifood systems: on-farm; within-industries and globally. Graduating from Reading University with an MSc in Pedology and soil survey and from Cambridge with a PhD in applied biology, in 1990 he moved to Australia to join CSIRO to develop wide-area applications of digital soil mapping, based on satellite and airborne remote sensing, to support farm-scale and regional decisions. From this he picked up and led the CSIRO research group on precision agriculture, which developed practical uses of digital technologies for the grains, sugar and wine industries in Australia. In 2000 he switched to global development to lead projects in Latin America, Africa and South-East Asia on behalf of the International Center of Tropical Agriculture, then for the Challenge Program of Water and Food for the CGIAR, and finally as inaugural director for the CGIAR CRP for Water, Land and Ecosystems. In 2016 he returned to Australia to establish the Centre for Digital Agriculture at Murdoch and Curtin universities. In 2022 he returned to Cali, Colombia, where he currently lives. He focusses on the endogenous changes that digital technology enables in agrifood systems.

- Keynote speech: **Is agronomy keeping up with digital agriculture?** (here)

Impact of climate change on maize productivity and nitrogen cycling in the sub-humid tropics: a field case study under rainfall extremes in Zimbabwe (Oral #158)

Abderrahim Bouhenache, Rémi Cardinael, Hugues Clivot, Regis Chikowo, Armwell Shumba, Emmanuel M. Matimba, Hope Mazungunye, Sylvie Recous, Gwenaëlle Lashermes

Presenter: Abderrahim Bouhenache (abderrahim.bouhenache@univ-reims.fr)

Keywords: sub-saharan Africa; mulch; heavy rainfall; drought; 15N labelling

Changes in rainfall patterns and extreme wet and dry events are more frequent and will intensify globally because of global warming disrupting the water cycle (Rohde, 2023). This is particularly the case in Southern Africa with an increasing intensity and frequency of rainfall extremes. These events often lead to water stresses ranging from droughts to waterlogging, which may adversely impact the soil-crop processes (Kim *et al.*, 2024) and reduce crop productivity and nutrient use efficiency. However, studies using rainfall manipulation experiments remain scarce. Most of such existing experiments have been conducted on natural ecosystems such as grasslands and woodlands in the northern temperate regions, with a clear gap on croplands in the tropics and poor focus on interactions with nutrient cycling (Beier *et al.*, 2012).

To better understand the soil-crop nitrogen (N) dynamics under rainfall extremes, a field-scale rainfall manipulation experiment has been carried out in 2022-2023 and 2023-2024 cropping seasons in Harare, Zimbabwe (17°42'13.5"S 31°00'29.4"E) under sub-humid conditions. This is a part of a large 1.5 ha new long-term experiment established since November 2022 and registered within the Global Long-Term Agricultural Experiment Network (https://glten.org/experiments/368). Three main rainfall treatments replicated three times were established: reduced rainfall (-30%), normal rainfall and heavy rainfall (events of 100 mm/24h). The reduced rainfall treatment is achieved with an exclusion system above the maize canopy using transparent shelters covering about 30% of the plots surface. The heavy rainfall events are simulated with an irrigation system, and two events are applied per cropping season. Within these rainfall treatments, the study focused on four cropping systems treatments, resulting from the combination of two N fertilization levels (0 and 80 kg N ha^{-1} yr^{-1}), with or without mulching (0 and 6 t DM ha^{-1} yr^{-1}). A bare soil treatment was also set up and monitored to study the soil functioning without crop. Key variables related to biomass production and N dynamics such as leaf area index, crop biomass and N uptake, yield, soil temperature, soil water and mineral N, mulch decomposition, and emissions of nitrous oxide (N_2O) were monitored from the first cropping season. An in-situ experiment using 15N labelled fertilizer was conducted during the second cropping season to study the fate of fertilizer under the three rainfall treatments with and without mulch. Labelled N fertilizer was applied on microplots as basal application, first and second topdressing using non-cumulative split application approach with both soil and plant N and 15N monitoring at different stages of plant growth.

The first-year results indicate that N dynamics in the soil were slightly affected by rainfall treatments and the presence of mulch. Total aboveground biomass and grain yield were negatively affected by reduced rainfall and absence of N fertilization. Mulch exhibited a buffering effect in topsoil layers, reducing soil temperature variations and maintaining moisture for a longer period during dry spells. The decomposition kinetics of the mulch were little affected by rainfall treatments but was quick, with 50% of initial dry mass decomposed in about 70 days. These results suggest a highly variable impact of rainfall extremes on biomass production, maize residue decomposition and N cycle depending on their timing, intensity and frequency of occurrence. Results from plant N uptake and from the ongoing analysis of the 15N labelling experiment, along with the planned modelling work with the STICS soil-crop model should provide further clarification on the interaction between rainfall patterns and N cycle, as well as the short and long-term consequences on plant biomass production and recycling.

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Comparison of organic and conventional crop management in Estonia since 2008 (Oral #297)

Evelin Loit-Harro, Liina Talgre, Indrek Keres, Ivo Voor, Maarika Alaru, Mailiis Korge, Merili Toom, Viacheslav Eremeev

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Keywords: yield; quality; dietary fiber; microbiological diversity

The aim of agriculture is to produce food of high nutritional quality in sufficient quantity, while being sustainable and taking care of the soil.

The aim of this study was to compare and analyse the impact of organic and conventional growing systems within the same rotation to the yield and quality of spring barley, red clover, winter wheat, field pea and potato, as well as to assess the soil nutrient content and microbiological diversity in time.

The field experiment was established on 2008 on the experimental field of the Estonian University of Life Sciences (58° 22´ N, 26° 40´ E) and the data has been collected since. Soil type is Stagnic Luvisol (sandy loam surface texture, C 1,38% and N 0,13%, pH_{KCl} 6,0). The field was divided by nitrogen treatments: three different treatments in organic plots (Org0, Org I with winter cover crops, and Org II with winter cover crops and manure) and four different treatments in conventional plots receiving mineral nitrogen (N0, Nlow, Naverage, and Nhigh). The five-field crop rotation was based on following order: spring barley with undersown red clover, red clover, winter wheat, field pea, potato.

The average yield in organic system was generally lower compared to conventional system. However, in organic systems, the yield was the most stable. The most fluctuating cropping system was the most intensively managed N3. Protein content was in positive correlation with mineral nitrogen rate. Winter wheat protein content was the highest in N2 and N3, which received 100 and 150 kg of N/ha. Flour water absorption and dough development was the best in conventional treatments with higher N rate. However, dietary fiber content (beta-glucan and arabinoxylan) was only impacted by yearly temperature and precipitation and it did not depend on fertilization. The biomass and diversity of weeds was higher in organic systems, being the highest in Org I by the end of the second rotation. This indicates that the cover crops were not as suppressive as expected.

The content of all studied macronutrients in the soil has decreased over the years. The soil nitrogen content was the least affected by the treatment with cattle manure in organic system. The greatest nitrogen loss was from the soil of conventional treatment with the highest nitrogen rate. The potassium content of the soil decreased the most. The most sustainable in terms of soil fertility was the manure treatment in the organic system, while the conventional system with the highest nitrogen rate was the most vulnerable. Biodiversity and abundance of soil microorganisms depended on soil carbon content. The microbial diversity and abundance increased during the second rotation in most treatments. Decrease in bacterial diversity was seen N0 and N3. Treatments with low to average mineral nitrogen input were favourable for soil microbes

Ground beetle abundance and diversity was also higher in organic treatments. The highest values were detected in Org II, where cover crops and cattle manure was used. The most of the springtails was detected in Org II and N2 treatments, correlating with the higher organic matter content in soil. Treatment N0, where organic matter content was low and pesticides had further inhibiting effect, contained the smallest number of springtails.

Overall, the organic treatment with the winter cover crop and the cattle manure, despite the lower yields, provided the stability and the highest values in biodiversity measurements in weeds, ground beetles and springtails. Conventional treatments with the medium mineral nitrogen input resulted in the higher yield and acceptable quality and it was also favourable to biodiversity in soil and among springtails.

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Evaluating homemade dry manure tea as an alternative to synthetic fertilizers in spinach cultivation (Oral #149)

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Presenter: Hana Lamouchi (hana.lamouchi@cirad.fr)

Keywords: organic fertilization; spinach; north African agriculture; plant-soil interactions; agroecological practices

1. Introduction

In the current agricultural landscape, the intensive use of synthetic fertilizers to meet the nutritional needs of crops, such as spinach, presents significant environmental and economic challenges. Historically, various cultures, especially in North African countries, have turned to organic methods like homemade manure tea (HMT) (Azeez *et al.*, 2014). This tea, obtained by infusing manure in water, is known to facilitate the decomposition of organic matter and enhance nutrient release (Leauthaud *et al.*, 2022). Although anecdotal accounts praise the benefits of HMT in terms of plant growth and soil quality improvement, there remains a lack of empirical studies validating these claims.

The quantity and quality of nutrients provided by these teas are not well-documented (Eudoxie and Martin, 2019).

Given these gaps, this study aimed to assess the impact of HMT on spinach biomass and leaf metrics in comparison to a synthetic fertilizer with equivalent concentrations of nitrogen (N), phosphorus (P), and potassium (K). Spinach (*Spinacia oleraceae* L.) was chosen due to its rapid growth rate, high nitrogen demand for optimal development, and its significant agronomic and nutritional importance (Pandjaitan *et al.*, 2012; El-Saady, 2016).

2. Materials and Methods

The study focused on preparing Homemade Dry Manure Tea (HMT) using a popular North African technique before cultivating Lazio spinach in soil from Cazevieille, France, employing a completely randomized experimental design with five distinct treatments. Treatments T1 and T2 varied HMT dosages, with T1 being a lower typical dose and T2 six times the NPK content of T1. Three control treatments were also established: W (water only), S1, and S2, involving synthetic fertilizers designed to match the nutrient concentrations of HMT doses. The spinach was grown under controlled conditions for 41 days before harvest. Measurements included leaf count and dimensions, stem and petiole lengths, and both fresh and dry biomass weights. Chemical analysis of the aerial parts was conducted to assess nutrient content.

3. Results and Discussion

In our study examining the impact of homemade dry manure tea on the growth, morphology, and nutrient uptake of spinach, we observed that the use of a peasant dose of HMT resulted in a dry biomass comparable to that of a synthetic fertilizer with the same NPK concentration. This finding suggests that HMT, when used in modest amounts, could emerge as a viable alternative to synthetic fertilizers. Plants treated with T1 and S1 dosages displayed leaves noticeably longer and broader than those in the W control group. However, the plant roots did not exhibit significant variations in dry biomass between the different treatments.

Our analysis also disclosed heightened potassium absorption in plants subjected to the T1 and S1 treatments, compared to the W control group. This revelation is in line with previous studies highlighting the positive influence of increased potassium intake on the growth and yield of various plants.

Nonetheless, observations related to the T2 treatment raised concerns. Indeed, plants exposed to this treatment showed a significant decline in dry biomass, morphological measurements, and nutrient uptake. This trend suggests that high doses of HMT might contain components toxic to spinach. Moreover, the high salinity in HMT could play a pivotal role in the observed toxicity in the T2 treatment. It is also conceivable that other factors, such as micronutrient imbalances, or even microbial effects, are influencing these outcomes.

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Variability in arbuscular mycorrhizal fungi abundance and diversity within cocoa-based (*Theobroma cacao* L.) agroforestry systems across pedoclimatic conditions (Oral #200)

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Keywords: arbuscular mycorrhizal fungi; cocoa production; climate change adaptation; soil health; sustainable agriculture

1. Introduction

In the context of global challenges such as climate change, declining soil fertility, and the aging of cocoa orchards, the sustainable production of cocoa in West Africa is under significant threat (Ameyaw *et al.*, 2018). As the region contributes over 70% to the world's cocoa supply, these challenges call for a profound reevaluation of conventional agronomic practices. This requires looking into innovative sustainable cultivation strategies that can bolster crop resilience, enhance soil health, and ensure economic viability for cocoa farmers. Arbuscular mycorrhizal fungi (AMF), which form symbiotic relationships with the roots of cocoa plants, offer a promising mechanism for achieving these goals. The symbiosis between cocoa plants and AMF can play a pivotal role in enhancing nutrient uptake, improving water retention, and increasing resistance to pathogens and environmental stressors (Leye *et al.*, 2015). Given the diverse and complex ecosystems within which cocoa is cultivated, understanding the dynamics of AMF within cocoa agroforestry systems is crucial for developing sustainable agricultural practices.

2. Materials and Methods

This study adopts an innovative methodological approach to assess the impact of agricultural practices on arbuscular mycorrhizal fungi (AMF) communities associated with cocoa plants. Composite soil samples were collected from 110 cocoa agroforestry plantations across the entire cocoa production zone in Côte d'Ivoire. The collected samples were analyzed to determine soil physicochemical properties and AMF spore density. Spore extraction was performed using the wet sieving method as described by Gerdemann and Nicolson (1960). After extraction, the spores underwent meticulous counting and detailed morphological analysis.

3. Results

The analysis of the total density of the spore after wet sieving of soil samples from 110 different cocoa plantations revealed significant variations in spore density between the sampling sites ($p<0.05$). This variability extends to the species richness of mycorrhizal fungi, which was observed to differ among cocoa plantations. Notably, the genus *Glomus*, *Acaulospora*, and *Gigaspora* emerged as the most frequently encountered across the sites. Furthermore, soil pH was found to directly influence mycorrhizal spore abundance, with a notable correlation identified. Specifically, slightly acidic pH conditions (pH < 7) were found to adversely impact spore density, suggesting a sensible balance between soil acidity and the thriving of mycorrhizal fungi populations.

4. Discussion

In alignment with previous studies, the abundance and diversity of the natural communities of arbuscular mycorrhizal fungi are largely influenced by the soil properties in cocoa-based agroforestry systems. The genus *Glomus*, *Acaulospora*, and *Gigaspora* have been identified as generalist symbionts prevalent in numerous rhizospheres highlighting the significant role of soil physicochemical properties on the diversity and abundance of mycorrhizal spores (Pontes *et al.*, 2024). Notably, low soil pH is shown to adversely affect spore density (Droh *et al.*, 2022), underscoring the intricate relationship between soil health and the symbiotic interaction with cocoa plants. The presence of *Acaulospora* across different sites illustrates the potential of specific AMF species in enhancing plant health and soil fertility, thereby advocating for the integration of AMF-based strategies into cocoa agroforestry management.

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Characterising the interactive effects of photoperiod and vernalising temperature on the flowering time responses of pasture legumes (Oral #68)

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Keywords: phenology; adaptation; persistence; breeding; climate

1. Introduction

The use of subterranean clover (*Trifolium subteranneum* L.), an annual pasture legume, combined with correction of soil phosphorus (P) deficiency has led to major improvements in the productivity of both livestock and crop production systems in southern Australia. The climate across this region ranges from Mediterranean through to temperate. Under these conditions, annual plants need to flower at an optimal time in spring to minimise the exposure of flowers and young seeds to frost, whilst also ensuring that seed development and maturation has occurred prior to the onset of the hot, dry conditions of summer. Subterranean clover cultivars with appropriate flowering times have been selected to fit the range in growing season lengths (~5-9 months) across this large agricultural zone. Serradella species (*Ornithopus* spp.) are viable alternatives to subterranean clover and offer an opportunity to diversify the legume base of these pastures, but there are gaps in the availability of cultivars with flowering times that will fill all climatic niches. Certain serradella cultivars also lack stable flowering dates (Boschma *et al.* 2019) and this is a problem for species persistence in self-regenerating pastures. Flowering responses to low (vernalising) temperatures and photoperiod essentially determine flowering date. The aim of this study was to characterise the nature of the interaction between a cultivar's flowering time response to photoperiod and its response to vernalisation and to understand how this interplay influences the time of flowering by each cultivar.

2. Materials and Methods

Two cultivars of yellow serradella (*O. compressus* L., 'Yellotas' and 'Avila'), French serradella (*O. sativus* Brot., 'Erica' and 'Serratas') and subterranean clover ('Coolamon' and 'Goulburn') were subjected, in controlled-environment plant growth chambers, to 'vernalised' (9 weeks at 5 °C), or 'unvernalised' treatments (0 weeks at 5 °C) followed by five photoperiod treatments (11, 12, 13, 14 or 15 h with a weighted mean daily temperature of 18 °C). Appearance of the first flower was measured using thermal time from sowing to first flower (°C d). Critical photoperiods were defined for each cultivar by identifying the minimum photoperiod at which there was no additional decrease in time to flower for unvernalised plants when grown under longer photoperiods. A reverse sigmoidal function was fitted to the data from this experiment and data from a historic dataset (Goward *et al.* 2023). This model described how time to flower by unvernalised plants was modified by growth in photoperiods from 8 to 20 h.

3. Results

Differences were observed between the cultivars in the time to flower when unvernalised and grown in short photoperiods. Under relatively short photoperiods, the 'vernalised' treatment was sufficient to reduce time to flower to a minimum, reflecting the intrinsic earliness of each cultivar. Growth in photoperiods ≥12 h reduced the need for vernalisation to promote earlier flowering. This interaction between responses to photoperiod and to vernalisation differed among the cultivars with some cultivars expressing different critical photoperiods (13 or 15 h).

The reverse sigmoidal model described the interaction of photoperiod and vernalisation responses reasonably well and indicated differences among cultivars in the rate at which the response to photoperiod would override the need for vernalisation.

4. Discussion

This study showed that if plants are not fully vernalised after a mild winter, increasing photoperiods during spring (>12 h) will override the need for vernalisation. This should permit the plant to still flower in a timely manner. As such the interaction of a cultivar's responses to photoperiod and vernalisation provides a safeguard mechanism that protects flowering and seed production. The cultivar-specific responses observed in this experiment indicate there may be significant challenges for modelling flowering time of individual genotypes because of the considerable time and resources required to parameterise factors such as the critical photoperiod of each genotype/cultivar.

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Perennial crops shape the soil microbial community and increase the soil carbon in the upper soil layer (Oral #249)

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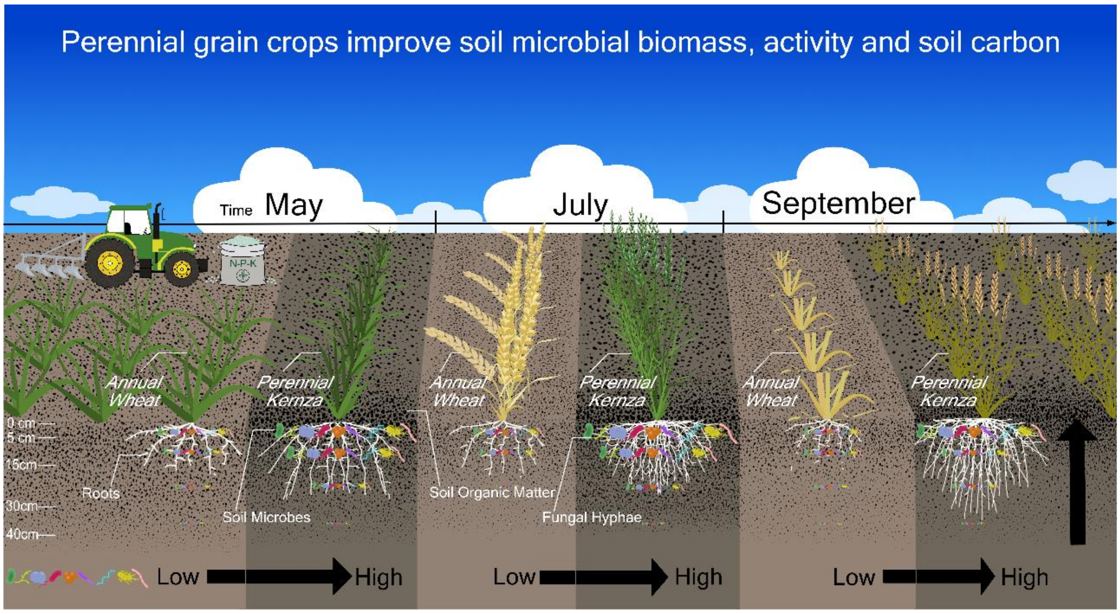
Keywords: perennial; intermediate wheatgrass; microbial community composition; microbial biomass; soil total carbon; soil depth



Soil biodiversity is threatened by intensive agriculture that relies on annual grain crop production, thus leading to a decline in soil functions and ecosystem services. Perennial grain crops have a positive impact on the soil microbial community, but the responsive microbial groups and the magnitude of their response remain uncertain. To better understand how soil microbial community composition is influenced by different crops and their management, we analysed soil microbial biomass and community composition, bacterial growth and soil total carbon in five cropping systems: organic perennial intermediate wheatgrass (IWG, Thinopyrum intermedium, Kernza®) sole cropping, organic IWG-alfalfa intercropping, organic biennial grass-legume mixtures ley cropping, organic annual wheat or rye cropping and conventional annual wheat cropping. The analysis was carried out at three time points under two growing seasons at four different soil depths. After five years, the IWG sole crop had greater amounts of soil total fungi and bacteria, arbuscular mycorrhizal (AM) fungi, saprotrophic fungi and gram-negative (G-) and gram-positive (G+) bacteria compared to annual wheat. Crop perenniality influenced the soil microbial community structure although precipitation, soil temperature and water content were the main drivers of the patterns and temporal variations of the microbial community assembly. Perennial crops with inherent long-term land cover together with reduced tillage and low nitrogen input management increased the proportions of fungi relative to bacteria, AM fungi to saprotrophic fungi, G- bacteria to G+ bacteria, and the growth rate of total bacteria. This resulted in a more active soil microbial community with higher microbial biomass than annual wheat, which contributed to the increased soil total carbon storage in 0-30 cm soil layer in a Scandinavian climate. The findings emphasize the importance of combining a no tillage strategy with long-term vegetation cover to increase soil quality, which in turn potentially improve the delivery of final ecosystem goods.

Influence of organic farming on microorganisms associated to crop plants – from landscape to local scale (Oral #255)

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Keywords: agricultural intensification; plant-microorganisms association; plant microbiota; farming practices

1. Introduction

Intensive agriculture has been promoted since the green revolution in the 1960s to boost crop yields and satisfy increasing food demand (Mann, 1999). Such intensification led to modifications in agricultural practices with higher fertilization, increased pest control and intense varietal selection among others. Additionally, the increase in the overall agricultural land cover led to marked changes in land use at the expense of natural and semi-natural habitats (Tscharntke *et al.*, 2005). Because of these changes occurring at local and landscape scales, agricultural intensification strongly shaped ecosystem properties (Matson *et al.*, 1997) and resulted in an important loss of biodiversity in many taxonomic groups (*e.g.* Hole *et al.*, 2005; Gonthier *et al.*, 2014). Despite the key role of symbiotic microorganisms in plant nutrition and protection, the impact of agricultural intensification on these microorganisms is not fully understood. Organic farming, which has been proposed as an alternative farming system, aimed at promoting more efficient soil natural ecosystem services (*e.g.* organic matter cycling, storage, redistribution of mineral nutrient…), should be favorable for microorganisms. It may promote a higher microbial diversity thanks to lower anthropic disturbance and higher plant diversity. It is also expected to strongly affect species composition and result in changes in plant growth and health.

2. Materials and Methods

We sampled plants in pairs of winter wheat fields (one organic and one conventional) along a distance gradient to the edges (hedgerow *versus* grassy), in 20 landscape windows selected along an uncorrelated gradient of organic farming and hedgerow density. Firstly, we analyzed the relative effect of organic farming and field edge types on endophytic microbial assemblages associated with wheat plants. Secondly, we tested the effect of the farming practices characterizing farming systems on endophytic microbial assemblages associated with wheat plants, and related these changes with wheat performance in the field. To achieve these goals, we collected environmental data through farmer interviews, soil analyses, and plant inventories. We also analyzed root microbiota through next-generation sequencing at vegetative and flowering stages.

3. Results

We demonstrated that organic farming shaped microbial composition and increased fungal and bacterial richness in most phyla. In contrast to bacteria, fungal communities were heterogeneously distributed within fields, having a higher diversity for some phyla close to field edges. Fungi responded more strongly to the field scale while bacteria were more affected by landscape scale. Effect of organic farming at the field level was mostly due to soil characteristics and field management, and a little to plant diversity in the field. Microbial responses were more pronounced at the late developmental stage, likely as a result of accumulative effect of management actions during plant development. Seed production and resistance to pathogens were related to specific phyla that are important for seed production and/or wheat resistance to septoriose.

4. Discussion and Conclusion

The present study provided a better understanding of the effect of organic farming and of its scale of influence on plant-associated microbiota. We showed the positivet effect of organic agriculture at both field and landscape scales on wheat endophytic richness providing evidence that agricultural management needs to be considered at several spatial scales. More especially, we demonstrated that increasing the percentage of organic agriculture at the landscape scale can maintain higher bacterial richness even in conventional fields. We stressed also the importance of soil characteristics and management in shaping microbiota composition and diversity. Plant seed production and resistance to pathogens were related with particular microbes, such as Alphaproteobacteria and Glomeromycota. This work advances our understanding of how farming system, and particular agricultural practices affect plant microbiota, and plant performance through microorganism-mediated changes. It supports the use of microorganisms as pillars of sustainable crop production.

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Availability and nutritional contribution of organic waste products in agriculture, using Sweden as a case study (Oral #146)

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Keywords: biofertilisers; circular economy; nutrient recycling; organic fertilisers

(1) Modern food production largely rely on a linear nutrient flow, with nutrients entering the field as bought fertilisers, or potentially as farmyard manure, but with little return of nutrients from the society. Returning organic waste products is a way of closing nutrient cycles between agriculture and society, contributing to a circular economy where resources are reused (Rosemarin *et al.*, 2020), and maintain or increase soil organic matter content compared to using mineral fertilisers (Kätterer *et al.*, 2011). Moreover, in organic farming, crop nutrition largely depends on manure, and low manure accessibility has been argued to contribute to the low adaption to organic farming in regions where crop production is dominating (Nordin, 2021). The aim of this study was to assess the current availability of the organic waste products biogas digestate, mainly produced from food waste and farmyard manure, sewage sludge (although currently not allowed in organic farming), and other organic nutrient sources. Furthermore, we aimed at comparing the nutrient of these materials to crop nutrient demands of today as well as a future scenario with more land cultivated with organic farming management methods, using Sweden as a case study.

(2) Crop production conditions vary greatly in Sweden, a country that stretch from 55°N to 69°N. It has fertile plains in the south, but also much land that is difficult to cultivate with annual crops and where forestry and animal husbandry dominate. The change in latitude also cause differences in cropping season characteristics. To account for this Sweden is divided into eight production areas and the study uses these production areas when estimating crop nutrient demand and availability. Data on land cultivated with different crops and their yields, and production and nutrient content of biogas digestate, manure, sewage sludge and other waste product-based fertilisers produced in Sweden have been obtained from national statistics and from communication with biogas digestate facilities, a sewage sludge certification body and the Swedish Environmental Protection Agency.

(3) The availability of organic waste products from society (biogas digestate and sewage sludge) suitable for use in agriculture, and their potential to cover regional crop nutrient demand, vary between production areas, with higher availability in areas with much crop production and a larger population size, *i.e.* the southern part of the country. The availability of farmyard manure is unsurprisingly lower in areas with a large proportion of specialised crop production farms. The nutritional quality of biogas digestate compared to farmyard manure is similar for total nitrogen, on average somewhat higher for mineral nitrogen concentrations (kg/t wet weight), and lower for phosphorous and potassium concentrations. Total nitrogen and phosphorous concentration of sewage sludge is substantially higher than those both in biogas digestate and farmyard manure, linked to higher dry matter content. The data are currently being evaluated, scenarios defined and nutrient demands for these different scenarios calculated.

(4) Although biogas digestion of manure can increase its nutritional value (Cavalli *et al.*, 2016) low nutrient concentrations per wet weight and bulkiness of these products are disadvantages, as well as for sewage sludge. There are methods to be used to dehydrate these products or

extract the nutrients from the solid or liquid phase and hence increase their fertiliser value (Monfet *et al.*, 2018). However, this comes at a cost of reduced contribution to soil organic matter and soil fertility. Therefore, these methods are more interesting in areas where there is less crop production and hence longer distances to arable fields and these products could instead be sold to regions with more production.

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DMPP and DMPSA nitrification inhibitors' effect on soil microbial communities in a grassland crop under two soil pH conditions (Oral #83)

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Keywords: microbial diversity; metabarcoding; N fertilization; alpha-diversity; beta-diversity

1. Introduction

Nitrogen (N) fertilization in agroecosystems can lead to non-desirable environmental impacts such as water pollution by nitrate leaching and the emission to the atmosphere of the greenhouse gas nitrous oxide. The application of nitrification inhibitors (NIs) such as dimethylpyrazole phosphate (DMPP) and dimethylpyrazole succinic acid (DMPSA) has been proven to be an efficient management option to avoid N_2O losses when applied together with an ammonium-based fertilizer (Huérfano *et al.*, 2018). Both DMPP and DMPSA have shown that they can induce some changes in non-target microbial populations different from nitrifiers in a single crop-cycle (Corrochano-Monsalve *et al.*, 2021). Nitrification is a process known to be greatly inhibited by low pH conditions, thus the performance of NIs regarding both their effect on nitrifiers and on non-target microbial populations may not be the same depending on soil pH level. On the other hand, liming is a usual management in agricultural soils. Consequently, the objective of this work was to determine by means of a metabarcoding approach the performance of both NIs on soil microbial diversity under a slightly acidic pH condition in comparison with a neutral pH one.

2. Materials and Methods

A three-year experiment with Italian ryegrass (*L. multiflorum* Lam. var. Trinova) crop was carried out in Zamudio (Northern Spain) where two different pH level conditions of 5.5 ("low pH") and 7.0 ("high pH") were maintained, adjusting the pH by means of calcined dolomite application. Within each pH level condition, three fertilizer treatments were assayed: ammonium sulphate (AS), AS+DMPP and AS+DMPSA. NIs were applied at a rate of 0.8% of the ammonium-N of AS. Each year, ryegrass was sown and then cut and fertilized three times, a total amount of 600 kg N ha^{-1} were applied. At the end of the experiment soil samples were taken and soil microbial diversity was analyzed through bacterial 16S rRNA and fungal ITS massive amplicon sequencing using Illumina technology. Sequence quality control, taxonomical and diversity analyses were conducted using QIIME2 2023.9.

3. Results

Alpha-diversity analysis showed that soil pH did not alter soil microbiota richness, while under low pH, AS application induced a decrease in their relative abundance, this decrease not being observed when NIs were applied. On the other hand, beta-diversity analysis signaled that neither pH nor the application of AS had any impact on the variations detected among treatments, while the application of NIs was responsible for 30% of the variation of the bacterial composition and 13% in the fungal composition of soils ($p<0.05$).

4. Discussion

Most studies showing an effect of pH on soil microbiota have stablished comparisons of wide pH-ranges, between either different soils or same soils for an amount of time from twenty to a hundred years (Zhalnina *et al.*, 2015). So, probably pH may have a more evident pivotal effect on microbial diversity when either long-term treatments or a wider range of pH to the one we have assayed are considered. Regarding the impact of NIs, provided that their target microorganisms are ammonia oxidizing bacteria, our results on beta diversity are of special interest because they indicate that DMPP and DMPSA can affect non-target microorganisms, both bacteria and fungi. This points to the need of future investigations on this topic.

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Acknowledgements

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Does no-till cover crop termination improve soil health in the short-term? (Oral #52)

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Keywords: organic farming; no-till vegetables; spring cover crops; aggregate stability; microbial respiration

In intensive vegetable production systems, cover crops are usually incorporated into the soil by disking prior to the subsequent crop. In recent years, silage tarps have gained popularity amongst farmers in Quebec as a suitable tool for no-till cropping systems. Termination of cover crops by roller-crimping is another strategy used by organic farmers. However, these practices have not been studied extensively in vegetable cropping systems in Eastern Canada. Our main objective was to assess the impact of cover crop termination with or without tillage on soil health indicators.

A 2-year field experiment (2022-2023) was conducted on a clay loam at a research site in Saint-Augustin-de-Desmaures, QC, Canada. An annual spring-seeded cover crop mixture was terminated in mid-July, followed by a vegetable crop in both years. In 2022, a mixture of field peas and oats was seeded, while in 2023, the cover crop mixture consisted of field peas and faba beans. Treatments were arranged in a split-plot design with four blocks. Cover crop termination methods were ascribed to main plots. They consisted of 1) roller-crimping, 2) flail-mowing and tarping, 3) flail-mowing and incorporation by disking, and 4) a fallow control with no-cover crop. The subplot factor was the fertilization rate of vegetable crops based on provincial nitrogen recommendations (0%, 50%, and 100%). After the termination of cover crops, broccoli and beetroot were transplanted in 2022 and 2023, respectively. At harvest time, soil samples were collected at a 0-10 cm depth, and soil health indicators were measured using soil-based lab tests.

The use of spring cover crops resulted in a higher proportion of water-stable aggregates (>2mm) and a larger mean-weight diameter of stable aggregates compared to the no-cover crop control. Soil respiration values were higher in the treatments with cover crop than in the no-cover crop control, and soil bulk density was higher in the roller-crimped cover crop treatment than in the other treatments. Broccoli and beetroot yields were lower in the roller-crimped treatment compared to the other treatments. Surprisingly, yields were similar between the no-cover crop control and cover crops incorporated by disking. Nonetheless, our results showed that establishing spring-seeded cover crops into organic vegetable production systems offers some soil health benefits in the short-term.

Spatio-temporal microbial regulation of aggregate-associated priming effects under contrasting tillage practices (Oral #39)

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Keywords: priming effect; no-till; aggregate; soil organic carbon; carbon degradation functional genes

1. Introduction

Soil organic carbon (SOC) sequestration is essential for sustaining soil health and food supply in agroecosystems (Turmel *et al.*, 2015). The amount of organic C stored in soil reflects a net balance between C inputs and outputs (Kuzyakov and Domanski, 2000). Soil is a complex matrix with a spatially heterogeneous distribution of SOM at different spatial scales (Schlüter *et al.*, 2022). Soil aggregate-size classes govern microbial accessibility, nutrient status of habitats, and SOC recalcitrance (Trivedi *et al.*, 2017). Tillage intensity significantly influences The heterogeneous distribution and dynamic changes of soil microorganisms, consequently shaping spatio-temporal patterns of SOC decomposition. However, little is known about the microbial mechanisms by which tillage intensity regulates the priming effect (PE) dynamics in heterogeneous spatial environments such as aggregates.

2. Materials and Methods

Herein, a microcosm experiment was established by adding 13C-labeled straw residue to three distinct aggregate-size classes (*i.e.*, mega-, macro-, and micro-aggregates) from two long-term contrasting tillage histories (no-till [NT] and conventional plow tillage [CT]) for 160 days to observe the spatio-temporal variations in PE. Metagenomic sequencing and Fourier transform mid-infrared techniques were used to assess the relative importance of C-degrading functional genes, microbial community succession, and SOC chemical composition in the aggregate-associated PE dynamics during straw decomposition.

3. Results and Discussion

Spatially, straw addition induced a positive PE for all aggregates, with stronger PE occurring in larger aggregates, especially in CT soil compared to NT soil. Larger aggregates have more unique microbial communities enriched in genes for simple C degradation (*e.g.*, *E5.1.3.6*, *E2.4.1.7*, *pmm-pgm*, and *KduD* in *Nitrosospeera* and *Burkholderia*), contributing to the higher short-term PE; however, CT soils harbored more genes for complex C degradation (*e.g.*, *TSTA3*, *fcl*, *pmm-pgm*, and *K06871* in *Gammaproteobacteria* and *Phycicoccus*), supporting a stronger long-term PE. Temporally, soil aggregates played a significant role in the early-stage PEs (*i.e.*, < 59 days after residue addition) through co-metabolism and nitrogen (N) mining, as evidenced by the increased microbial biomass C and dissolved organic C (DOC) and reduced inorganic N with increasing aggregate-size class. At a later stage, however, the legacy effect of tillage histories controlled the PEs *via* microbial stoichiometry decomposition, as suggested by the higher DOC-to-inorganic N and DOC-to-available P stoichiometries in CT than NT. Our study underscores the importance of incorporating both spatial and temporal microbial dynamics for a comprehensive understanding of the mechanisms underlying SOC priming, especially in the context of long-term contrasting tillage practices.

The carbon footprint of narrow-leaved lupin (*Lupinus angustifolius*) in Germany (Oral #307)

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Keywords: greenhouse gas emissions; *Lupinus angustifolius*

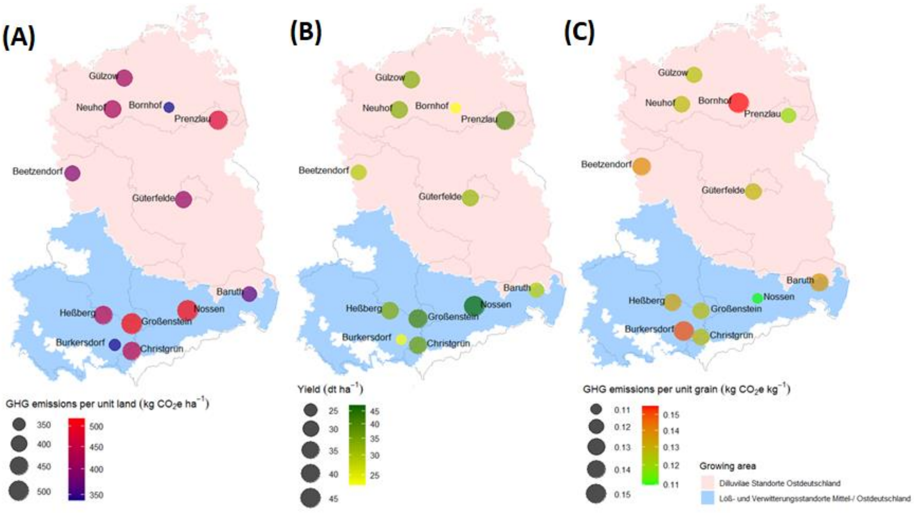

Figure 1. Eastern Germany with 12 locations and two distinct lupine growing areas (south indicated in blue and north in pink); size and color of the circles denote for each location, (A) GHG emissions per unit land, (B) grain yield per unit land and (C) GHG emissions per unit grain (carbon footprints)

1. Introduction

Reducing greenhouse gas (GHG) emissions from agriculture is crucial in combating climate change, as this sector contributes significantly to overall anthropogenic GHG emissions. In crop production major emissions, stem from the production of Nitrogen (N) fertilizer and related nitrous oxide (N_2O) emissions in the field. The broader integration of legumes in crop rotations can potentially support climate change mitigation, as they can fix atmospheric nitrogen through symbiotic relationships with soil bacteria and reduce the reliance on synthetic fertilizers and respectivelyespectiveGHG emissions (van de Noort, 2016). Narrow-leaved lupin (*Lupinus angustifolius*), a legume well-suited well suited to temperate climates with specific nutritional qualities, has the potential to reduce carbon footprints associated with agriculture and human nutrition (van de Noort, 2016). By processing it into protein-rich plant-based milk and meat substitutes, lupin could significantly contribute to reducing the carbon footprint of the German food sector. In this study, weand hence aim to investigate lupin carbon footprints for various locations and over several years in Germany, to understand how lupin growth patterns relate to GHG emissions and to explore its potential for mitigating climate change in key German growing regions.

2. Materials and Methods

In this study, we analyzed GHG emissions from various lupin genotypes across 14 sites in Germany's main growing regions from 2002 to 2015. Data were sourced from post-registration variety trials published in annual reports by state-level authorities (*e.g.*, Jentsch *et al.*, 2017; Zenk *et al.*, 2017). The dataset includes genotype-, location-, and year-specific yield information (grain yield, thousand kernel mass, grain protein content) and management data (timing, type, and amounts of sowing, fertilization, plant protection measures).

GHG emissions associated with lupin cultivation were quantified using a life cycle assessment (LCA) approach, considering all cultivation stages from land preparation to harvesting. The system boundary was defined from cradle to farm-gate, specifically focusing on GHG emissions. Emissions stemming from material and energetic inputs (*e.g.*, diesel for field operations) were estimated using emission factors from established databases, while N2O emissions were assessed using the IPCC Tier 2 approach. Lupin cultivation for all genotypes, locations, and years was assumed to occur on a 500-hectare farm with an average plot size of 20 hectares and an average farm-to-field distance of four kilometers. Data management and LCA calculations were performed using R Studio to comprehensively quantify GHG emissions. Functional units considered were GHG emissions per unit land (carbon footprint land; CFPL), per unit grain (carbon footprint grain; CFPG), and per unit protein (carbon footprint protein; CFPP). Statistical tests, specifically ANOVA, were utilized to assess significant differences in CFPL, CFPG, and CFPP among genotypes, locations, and years.

3. Results and Discussion

Across numerous combinations of lupin genotypes, locations, and years, the carbon footprint per unit land, grain, and protein was assessed. Notably, N_2O emissions were identified as the leading contributor to total greenhouse gas emissions in lupin cultivation, followed by emissions from diesel use, seed sowing, and fertilizer application. GHG emissions stemming from plant protection products comparatively low due to small dosages applied per hectare. Significant differences were observed among genotypes, locations, and years for all functional units investigated (Figure 1). While there is limited potential to further reduce N_2O emissions concerning the carbon footprint per unit land (Figure 1), advancements in breeding and management practices could enhance the carbon footprint per unit grain and protein. To comprehensively evaluate the climate change mitigation potential of lupin and other legumes, conducting a life cycle assessment at the crop rotation level is planned, considering lupin's role in substituting mineral nitrogen for the subsequent crop. Additionally, employing agroecosystems models and adopting a model-based Tier 3 approach for estimating N_2O emissions will enhance the analysis. Plans also include broadening the assessment to encompass the entire value chain, considering production, transport and processing to different food items, to thoroughly assess the climate change mitigation potential of regionally produced lupin-based proteins.

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Increasing circularity – Impacts of co-product management on soil carbon and greenhouse gas emissions (Oral #236)

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Keywords: co-products; REA; soil carbon; nitrous oxide

1. Introduction

In Europe and the UK, farms have typically become highly specialised with little or no integration between crops and livestock enterprises either between or within farms, resulting in an agricultural system that is highly dependent on purchased inputs for the supply of nutrients to both crops and livestock. The consequence of this specialisation has meant there is a risk of soil fertility declining in arable areas. In contrast, in livestock dominated areas, there has been an excessive build-up of nutrients in the soil, increasing the risk of pollution (Watson *et al.*, 2019). Pollution of the environment coupled with greenhouse gas emissions from agriculture has resulted in increasing interest in the concept of the nutrient circularity. Frequently overlooked in assessing nutrient circularity in agricultural systems, is the return of nutrients to the soils which are critical for maintaining soil health and rebuilding natural capital. Co-products, such as crop residues, provide materials that can be manipulated and used in different ways to enhance soil fertility. Here, the effect of co-product use on-farm has been assessed through a rapid evidence assessment (REA). The review focused on assessing the effect of co-product management on soil nutrient status, carbon stocks and nutrient losses.

2. Methodology

The focus of the REA was to assess the effect of the co-product management on soil nutrients, carbon stocks and nitrous oxide emissions. The REA conducted in SCOPUS on 26/2/2023 was restricted to systematic reviews and meta-analysis, and articles published in English. The co-product management options included in the search term were catch crop, grazed and ungrazed cover crops, waste, manure, residues, composts, digestates and straw. Initially 236 papers were identified of which 20 contained data directly relevant to European climates. Papers that reported the results at a global scale were excluded from the analysis. The data extracted was the effect of the application of the co-product on soil nutrients, carbon stocks or nutrient loss relative to the same management without the addition of the co-product.

3. Results

The results indicate that there are few meta-analyses or systematic reviews that report the effect of the use of co-products on soil nutrients and nutrient loss from agricultural systems. Composts and treated manures were only reported in one paper each. The co-products of cover crop residues and manure, crop residues were reported in twelve, seven and four papers, respectively. These papers mainly focused on soil carbon and nitrous oxide emissions. Except for crop residues and soil carbon, the number of observations included in each of the mean data points ranges from 362 for nitrous oxide emissions from manure to 966 for nitrous oxide emissions from cover crops. The effect of including cover crops was to increase nitrous oxide emissions by a factor of 2.25 (range 0.64-5.95), more than doubling the initial emissions. This compares with a factor of 1.8 (0.6-3.63) and 1.49 (0.98-2.16) for manures and crop residues, respectively. The comparable values for soil carbon were 1.08 (1.04-1.13), 1.11 (1.05-1.29), 1.14 (1.03-1.24) for cover crops, manures and crop residues respectively.

4. Discussion

The REA highlighted that there is currently a lack of meta-analyses or systematic reviews that assess the effect of co-product use that is specifically relevant to European agriculture. Although the results from the global meta-analysis may be relevant, it is important to recognise that crops, and pedoclimatic conditions may influence the magnitude of these effects. The results highlight that use of cover crops, manures and crop residues are likely to increase both soil carbon storage and nitrous oxide emissions. Increasing soil carbon is likely to improve the soil structure and improve fertility. However, from a net zero perspective, this needs to be traded off against the increase in nitrous oxide emissions. It is also important to recognise that the papers assessed have focused on soil carbon storage, which may not result in long-term carbon sequestration. This work also highlights the importance of assessing all the flows within the farming systems and identifying opportunities within the entire system to mitigate emissions. The social and economic implications of co-product utilisation also need to be considered.

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Multi-actor strategy to screen lentil landraces for organic agriculture in Lyon metropolitan area (Oral #112)

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Keywords: participatory variaty selection; lentil; pulses

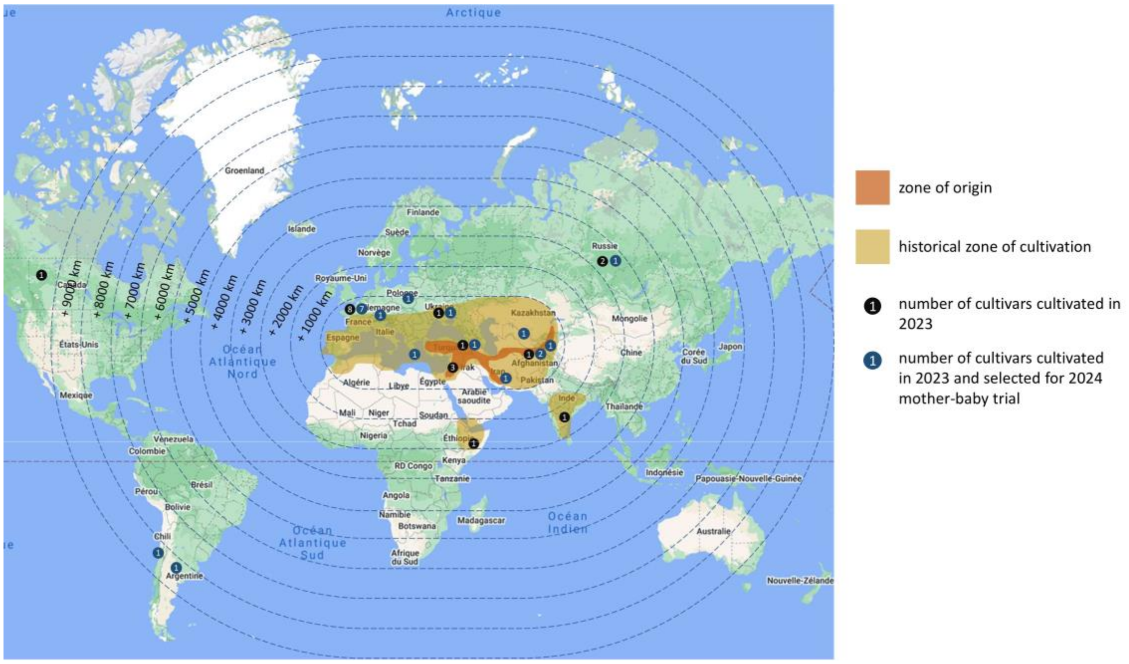

Figure 1. Geographical distribution of the origin of the cultivars studied

1. Introduction

Providing solutions to facilitate agro-ecological, dietary and energetic transitions is a way to limit consequences of the climate change. Due to their ability to fix nitrogen in the soil and their nutritional qualities, pulses are crops that can contribute to these transitions. However, the poor varietal offer in pulses is an obstacle to increase their cultivation, especially for lentils (*Lens culinaris* Medik.). The main lentil cultivar is Anicia: obtained in 1966, it represents up to 80% of the French lentil production (Terre Univia, 2022). Participatory variety selection may lead to an improvement of varietal offer for underutilized crops (Chable *et al.*, 2014; FAO, 2011).

Lyon is one of the cities with the highest increase of temperatures in the South of France: hence, between 1980 and 2009, the climate changes from temperate humid to submediterranean (Lelièvre *et al.*, 2011). In the metropolitan area, various actors including the Metropolis of Lyon, carry a strong political will to screen lentil varieties in order to enlarge the varietal offer and be able to provide nutritious organic pulses to collective restaurants.

The aim of this study is to conduct a multi-criteria evaluation of numerous lentil varieties to select those best suited to the many challenges facing the Metropolis of Lyon.

2. Materials and Methods

This project involves several types of actors: researchers, CRBA (Centre de Ressources de Botanique Appliquée, an associative seed bank), Metropolis of Lyon, the Pauline & Valérie Mercan Foundation, farmers, catering professionals and healthcare professionals.

The first step of the project is to collect varieties from seed banks (IPK genebank, GEVES, INRAE, ProSpecieRara, CRBA). The received samples were cultivated in order to multiply and screen the varieties. Participatory meetings have been organized to identify agronomical and nutritional traits of interest. The chosen agronomical traits were characterized according to established protocols (Ahmad *et al.*, 2021; UPOV, 2015). In the second year of the project, a mother-baby trial has been set up in several on-farm experimental sites according to the methodology developed by Snapp (2002) to select lentils adapted to the various microclimates corresponding to the farms located in the experimental area.

3. Results

110 lentil samples were collected from seed banks and evaluated according to their seed phenotype and distance from their origin center of cultivation. Among them, 35 varieties, representative of the observed diversity, were sown and evaluate in field in 2023, leading to the identification of five different clusters (PCA analysis). The most discriminating traits were the color of the grain, the time of flowering and the yield.

Finally, 14 varieties have been collected in sufficient quantity to integrate a mother-baby trial in 2024 (Figure 1). In addition, five control varieties provided in large quantity by partner farmers and ProSpecieRara have been sown in the five on-farm experimental sites.

4. Discussion

The initial varieties have been pre-selected, particularly from an agronomic point of view, thanks to this first original screening. They are now going to be assessed for morphologic and agronomic traits but also for nutritional traits (analyses of proteins, fibers, minerals, trace elements) which will help to identify varieties and maybe ideotypes corresponding to the criteria of the project’s stakeholders. Moreover, the developed methodology will be applied to other pulse crops (peas and beans).

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Challenges and opportunities for increasing organic carbon in vineyard soils: perspectives of extension specialists (Oral #97)

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Keywords: soil organic carbon sustainability; practices; climate zone; extension perception; vineyard; country

1. Context description and research question

An increasing number of farmers are considering the impact of conservation practices on soil health to guide sustainable management of vineyards. Understanding impacts of soil management on soil organic carbon (SOC) is one lever for adoption of agroecological practice with potential to help maintain or improve soil health while building SOC stocks to mitigate climate change (Amelung *et al.*, 2020). Despite the potential of perennial cropping systems as C sinks, a major part of the world's agricultural landscapes remains dominated by specialized practices and, although winegrowers understand how to improve SOC, they face real or perceived challenges in adopting soil conservation practices. In this study, we analyzed extension specialists' perceptions of the challenges and opportunities to maintain or increase SOC in vineyard soils in two main wine producers, in France and in the United States. Our goal was to characterize current practices and better understand the challenges at the farm level (structural barriers, trade-offs, conflicts of interest, education and training) regulating adoption of practices favorable to SOC. The 4 contexts are USA-cool, USA-warm, F-cool and F-warm vineyards.

2. Method and Theoretical background

To identify universal principles in vineyard soil management, we conducted exploratory semi-structured interviews in both warm and cool climate areas in France and in United States, to get some universal practices and challenges, not depending on climate variation. The results could then, be transposed to any other vineyard. We identified 16 extension specialists in each country; eight in cool climates and eight in warm climates. Our hypothesis was that the structure of the supply chain in each of the four regions (France/warm, France/cool, U.S./warm, U.S./cool) would impact barriers and levers for adoption.

3. Results and Discussion

We found seven SOC-favorable practices already managed in France and USA, both in cool and warm climates. All extension specialists reported that cover crop, organic fertilization, tillage reduction, grazing, agroforestry, mulching and herbicide use reduction are already implemented by some winegrowers and should be further incentivized. We found details about cover crop characteristics including the surface area of cover crop, the diversification of spontaneous and sown the species in cover crop, and turning over the cover crop. Using compost or returning pruning residues to the soil were highlighted by interviewees as important practices for organic fertilization. We found economic, agronomic, educational, conflict of interest and structural challenges to practice adoption. 69% of the extension specialists mentioned the cost of the practice as the first challenge to adoption SOC-favorable practice, and the potential negative impacts of yield. An agronomic challenge identified specifically was concerns over competition of cover crop with vine vigor. Education and training of winegrowers needed included knowledge to implement the practices at the field scale and systems redesign at the farm scale. Conflicts of interest included potential food safety issues associated with livestock grazing, particularly in table grape production. A first structural barrier identified included climate of the location of the vineyard for competition for water and nitrogen, which is a big issue with the actual change of the climate. A second structural barrier identified included planting density for agroforestry in Protected Designation vineyards and availability of organic fertilizers next to the farm. Greater emphasis on addressing the challenges to adoption of SOC-favorable practices is urgently needed to inform national and regional agricultural policies in both countries.

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The agronomic potential for soil carbon sequestration by cover crops in three European countries (Oral #342)

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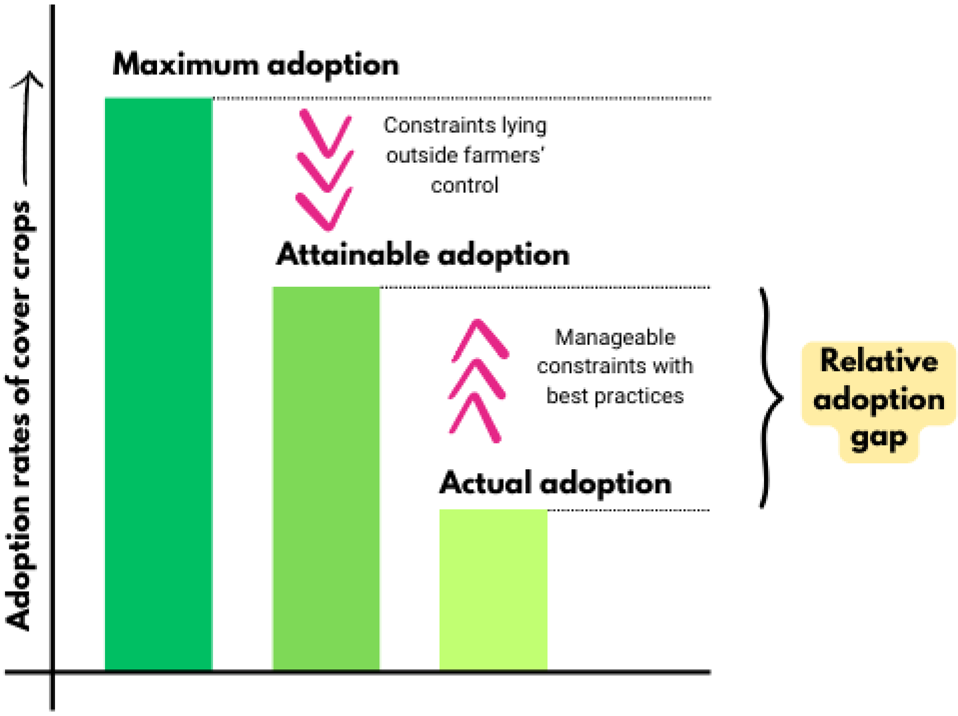
Keywords: soil carbon; cover crops; adoption; climate change mitigation; farmers survey



1. Introduction

Cultivating cover crops is considered one of the most promising practices for agricultural soil carbon sequestration (Kaye and Quemada 2017). However, biophysical estimates of the potential for offsetting greenhouse gas emissions (GHG) by cover crops have been critiqued as unrealistic (Moinet *et al.*, 2023). This is due to the omission of agronomic and socioeconomic constraints, such as the length of the growing season. Understanding and incorporating farmers' views on the feasibility of soil carbon sequestration practices is an indispensable step before implementing any schemes for carbon sequestration in agricultural land.

We developed and tested a methodological framework to quantify the potential adoption of cover crops in three European countries (the Netherlands, Germany and Spain). Using this framework, we answered the following research questions: (1) What is the current adoption of cover crop cultivation? (2) What is the potential and adoption gap for the cultivation of cover crops? (3) Which agronomic constraints hinder further implementation?

2. Materials and Methods

Qualitative interviews were conducted with agricultural experts in each region (n = 8) to gain a deeper understanding of the farming systems and used to formulate a context-specific questionnaire distributed online at the three study sites.

We developed a framework that allowed the quantification of adoption gaps, identifying constraints that lie beyond the farmer's immediate control or those that can be optimised through best management. Data was collected through an online survey among 321 farmers in three European countries (Germany, the Netherlands and Spain). Farmers were asked to report their crop rotation, cover crop cultivation and area of crops sown in spring. Based on these data, we quantified the potential agronomic adoption and relative adoption gap. Afterwards, farmers were asked to evaluate drivers and constraints linked to their adoption gap. Comparing adoption rates across different edaphic and environmental settings provided a context-specific overview of opportunities for increased adoption (Figure).

3. Results

First results show that the current adoption of cover crops varies greatly depending on climate: While almost all farmers employed cover crops in the Netherlands, around 80% of the farmers did so in Germany and only 10% in Spain.

In Germany and the Netherlands, current adoption rates are close to the attainable potential, with further expansion limited due to existing winter cover in the crop rotation. On average, the adoption gaps were around 25% and 20% of the agricultural area in the Netherlands and Germany, respectively, when considering the share of land with a spring-sown crop. In Spain, adoption is constricted by water availability. Only a few farmers adopt cover crops in irrigated arable land.

Agronomic constraints generally impede the further expansion of cover crops. In the Netherlands and Germany, the most cited constraints were related to cover crop establishment, especially after a late harvest of a previous crop.

4. Discussion

Our findings show that, based on growing seasons, there is only a small gap for cover crop expansion in Germany and the Netherlands. Moreover, the continuous implementation of cover crops faces challenges from weather constraints, particularly following late harvests and, in Spain's case, water availability, which make the successful establishment of a cover crop in all fields and all seasons challenging.

Given the narrow-identified gaps and the fact that most of those gaps can be explained by agronomic constraints outside management optimisation, continuous adherence to the practice might not be feasible. Based on these insights, there is a limited agronomic potential for additional C sequestration by cover crops in Europe.

Despite multiple policies and regulations encouraging adoption, based on the agronomic constraints presented here, we estimate that some of the forecasted biophysical potentials of C sequestration are overestimated by at least 70% for our study sites, without considering other limiting factors, such as saturation or leakage effects.

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DEXiPM Grapevine®: evaluating sustainability in codesigned farming systems in a vineyard watershed (Oral #210)

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Keywords: participatory approach; sustainability; viticulture; mediterranean region

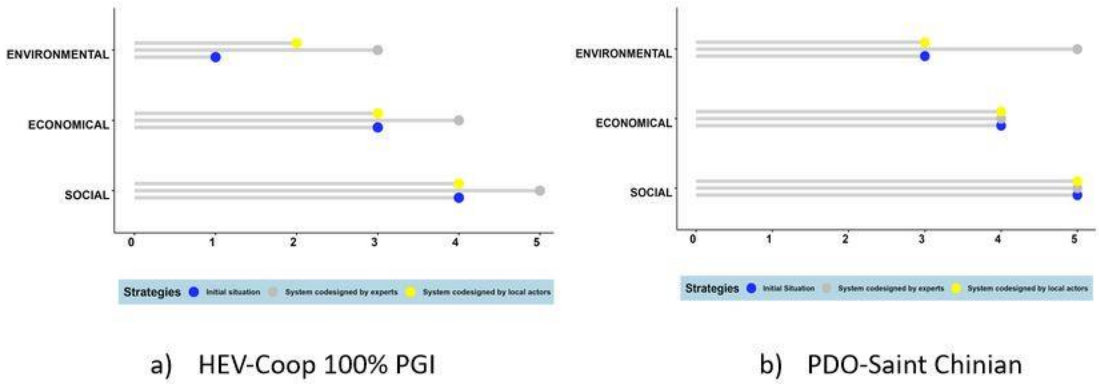

Figure 1. DEXi PM sustainability evaluation of codesigned strategies

1. Introduction

Viticulture is facing emerging challenges not only because of the effect of climate change on yield and composition of grapes, but also of a social demand for environmental-friendly agricultural management. Adaptation to these challenges is essential to guarantee the sustainability of viticulture. Grapevine varieties are susceptible to fungal attacks, insects, and wood diseases (Mian *et al.*, 2023). In 2016, French vineyards exhibited a notably high Pesticide Treatment Frequency Index (Fouillet *et al.*, 2023), thereby presenting potential risks to groundwater, air quality, soil integrity, and human health. Transitioning to low-input viticultural systems is urgent. This study uses DEXiPM (DEcision eXpert for integrated Pest Management) to evaluate sustainability across economic, social, and environmental pillars in low-input vineyard systems. The Rieutort vineyard watershed (France, Hérault) serves as a case study, adopting a participatory approach. Interviews with winemakers characterized the area and its pesticide use. A role-playing game was used to design agricultural practice change strategies. DEXiPM Grapevine qualitatively evaluates innovative and virtual cropping systems. Strategies are simulated to assess sustainability and compared with initial situations. This study focuses on DEXiPM Grapevine simulations and results to identify promising sustainable vineyard systems for broader regional adoption.

2. Materials and Methods

Types of Vineyard Operations Considered: Data from a survey in the Rieutort watershed provided information on 23 vineyards. Four types were considered: HEV-Coop mixed, HEV-Coop 100% PGI, Organic -Saint Chinian, and PDO-Saint Chinian.

Evaluation of Low-Input Vineyard Systems Sustainability:

Presentation of DEXiPM Grapevine Tool: DEXiPM Grapevine operates based on a detailed and transparent tree structure, aggregating simple information to estimate complex variables.

Number of Simulations: Co-designed strategies by experts and local actors were simulated with DEXiPM Grapevine to evaluate their impact at the farm and watershed scales to assess practice changes.

3. Results

Sustainability of HEV-Coop mixed Strategies: Initial situations showed low environmental, medium economic, and high social sustainability. Co-designed strategies significantly improved sustainability across all pillars.

Sustainability of HEV-Coop 100% PGI Strategies: Initial situations showed low environmental sustainability. Co-designed strategies improved environmental and economic sustainability but slightly decreased social sustainability (Figure 1A).

Sustainability of Organic -Saint Chinian- Strategies: Initial situations exhibited high sustainability across all pillars. Co-designed strategies further improved environmental sustainability while maintaining economic and social sustainability.

Sustainability of PDO-Saint Chinian- Strategies: Initial situations showed medium environmental sustainability and high economic and social sustainability. Co-designed strategies significantly improved environmental sustainability (Figure 1B).

4. Discussion

DEXiPM Grapevine highlighted modest sustainability improvements, primarily in environmental pillars across all vineyard types. Expert-co-designed strategies showed better sustainability enhancements compared to locally designed ones. Key practice changes included herbicide elimination, cover crop development, and adopting resistant varieties. However, DEXiPM Grapevine only provides qualitative evaluations of system sustainability and does not simulate changes in pesticide content or yield outcomes. Further studies using mechanistic models could provide detailed insights into these aspects.

5. Conclusion

Adopting low-impact viticultural practices requires system redesign at various scales. The RippViti project aimed to develop and evaluate pesticide reduction strategies at a vineyard territory scale. This study evaluated environmental, economic, and social sustainability of innovative strategies using DEXiPM Grapevine. Most evaluations showed improved environmental performance without compromising economic and social sustainability. The widespread adoption of proposed agronomic strategies could lead to reduced environmental impacts in vineyard practices.

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Acknowledgments

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Researching with, not for, the farmer in four African countries: the InnoFoodAfrica Project (Oral #238)

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Keywords: farmer participatory research; cultivar; management; input; crop quality

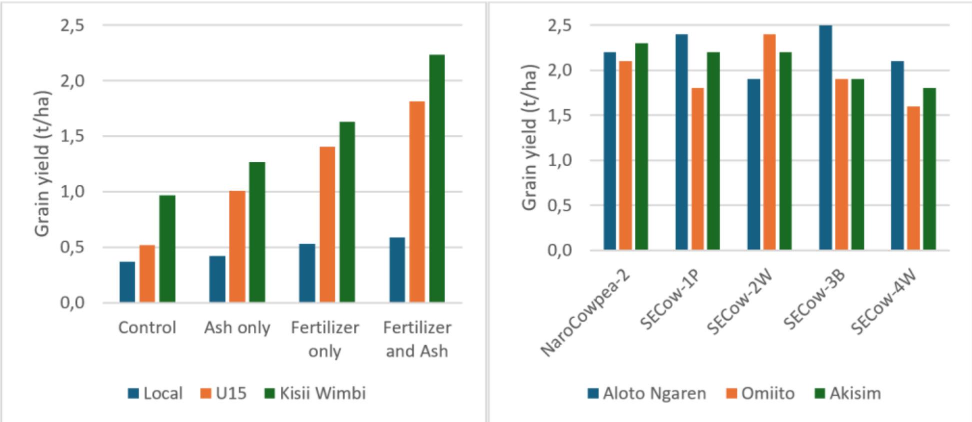

Figure 1. Grain yields of (A) two cultivars and a local landrace of finger millet in Kenya, given no fertilizer, wood ash only, synthetic fertilizer only, and the combination; (right), five cultivars of cowpea in Uganda at three sites

InnoFoodAfrica was a Horizon 2020 project running from 2020 to 2024, with the aim of improving productivity and sustainability of food systems in Ethiopia, Kenya, South Africa and Uganda. The work-package on crop production practices used Farmer Participatory Research (FPR). Experiments in each country tested the impact of certain inputs on modern cultivars and local landraces, with three iterations. Several (usually pre-existing) teams of 10 – 20 farmers were engaged for work on each crop. The crops were faba bean, teff, maize and orange-fleshed sweet potato (OFSP) in Ethiopia; cowpea, finger millet, amaranth and OFSP in Kenya; cowpea, Bambara groundnut and OFSP in South Africa; and cowpea, finger millet, sorghum and matooke banana in Uganda. Seeds and inputs were provided by the project. The farmers did the work under the guidance of local experts and, importantly, made the decisions on how to proceed based on the outputs of the research. Since communities were involved, eating quality of the harvest was investigated and formed an important part of the decision-making process. In the first iteration, the full factorial of cultivars and inputs, with replicates, was established on 2 – 4 farms. In the second iteration, the number of treatments was reduced, the size of the plots was increased, and several “baby trials” demonstrating favoured combinations of cultivar and input were established on participating farms. The third iteration was a scaling-up phase, with fewer but the best treatments in the replicated experiments and more baby trials.

Both genetics and management contributed to improved yields. The best modern cultivars outyielded landraces 1.2-fold to 5-fold, even with low inputs, and the most effective input packages increased yields by similar margins.

One of the key management factors was sowing in rows instead of broadcasting. This enabled weed control by hoeing instead of hand-weeding, and the application of inputs, such as lime in Ethiopia, to only 25% of the plot. To ease the consistency of row spacing, a farmer in Uganda invented a simple row-marking tool consisting of nails driven into a plank towed by ropes.

Farmers chose which treatments to combine. Manure-fertilized amaranth in Kenya had strong stems, while synthetically fertilized amaranth had large seed heads, so the farmers chose a 50 : 50 blend for the next round, producing plants that both stood well and yielded well. Adding a foliar fertilizer, containing micronutrients, boosted yield further. Wood ash, a traditional seed protectant for finger millet in Kenya, boosted yields in combination with synthetic fertilizer (Figure 1A).

Traditional and modern knowledge conflicted when it came to sowing of Bambara groundnut in South Africa. Culturally, this may not happen until after 15 December, but the climate has changed enough that this is several weeks too late for maximum yield.

Dual-purpose crops were not successful. Amaranth and cowpea leaves are traditional green vegetables, but the best cultivars for vegetable use were not the best for seed production, and leaf harvest set back potential seed yield.

Rhizobium inoculation of faba bean was clearly effective in Ethiopia; that of cowpea in Kenya was less so, suggesting that the soils were deficient in more than just N and that the condition of the inoculum was not optimal.

Eating quality was an important determinant of choices. Nitrogen-fertilized OFSP was almost universally watery and of poor texture, unfertilized being much preferred; and in several cases, the second-highest yielding cultivar of OFSP was preferred over the highest-yielding. One new cowpea cultivar, NaroCowpea-2, was praised by the Ugandan farmers for its excellent flavour, although another often yielded more (Figure 1B). When the faba bean crop was harvested, some of the Ethiopian farmers preferred their landrace, but 6 months later said that the new, 2.5x higher yielding cultivar, was just as good.

The project demonstrated several ways in which yields, profits and nutrition could be raised on farms. Continued access to inputs, such as fertilizers, outside the project is a challenge. It is up to each farmer to decide how to proceed.

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Unraveling collective experimentation in diversified systems: constructing Ideal Types (Oral #315)

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Keywords: on farm experimentation; diversification; agroecology; agronomic innovation; multi-actor

The agro-ecological transition confronts the agricultural world, and agronomists in particular, with the need for new, more systemic knowledge on a variety of objects and scales to go towards diversified cropping system (Ditzler 2022). The means that have been implemented for majority crops such as wheat or corn in intensive production systems cannot be deployed for such diversified systems and are not enough to fully equip the transition of agri-food systems (Lacoste *et al.* 2021). It is therefore necessary to rethink the very means of producing this knowledge. Regarding experimentation as a major mean for knowledge production in agricultural sciences, the most common practices remain those led by an analytical approach, within the researchers' controlled environment of experimental stations. Other types of experiment are being developed or reconsidered, such as long-term system experiments (eg Longis *et al.* 2024) or experiments led by R&D with farmers (Salembier *et al.* 2023), or even experiments carried out by farmers themselves (Catalogna *et al.* 2022), these types being interestingly characterized by their collective nature. We therefore assume that innovation towards agro-ecological practices is based on more or less complex combinations of these different forms of experimentation and implies more collective and multi-actor dimension. It is through this prism that we have decided to approach experimentation.

In this communication, we analyzed these diverse processes of experimentation in relation with the way they renew knowledge production. We conducted 31 semi-structured interviews with stakeholders from French institutions, including researchers, advisors from chambers of agriculture or cooperatives, and leaders of development groups. These stakeholders were selected based on their involvement in experimental projects with inter- or intra-organizational partnerships, and who had a role within the experiment that gave them a comprehensive view of it. These interviews were completed by documentary analysis (mainly meeting reports or experiments' valorizations) and participation in events such as trial visits.

The inductive and comparative analysis of these stories of experimentation processes enables us to characterize their diversity according to several axes of interpretation. We in fact identify the diverse intertwining of the "How" (experimental set-ups, in their biophysical and organizational dimensions) and the "Why" (objectives assigned to the implementation of experimentation). This allows us to construct ideal-types (Weber, 1949) of collective experimentations that differently contribute to fuel transitions towards agroecology. This analysis seems to us to be a necessary step towards a better understanding of collective agronomic experiments in the context of diversification of agricultural systems, in order to provide better tools for these complex, multi-stakeholder processes.

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Co-designing through the lens of historical cocoa farming loops to meet current and future needs for sustainable cocoa production in Côte d'Ivoire (Oral #246)

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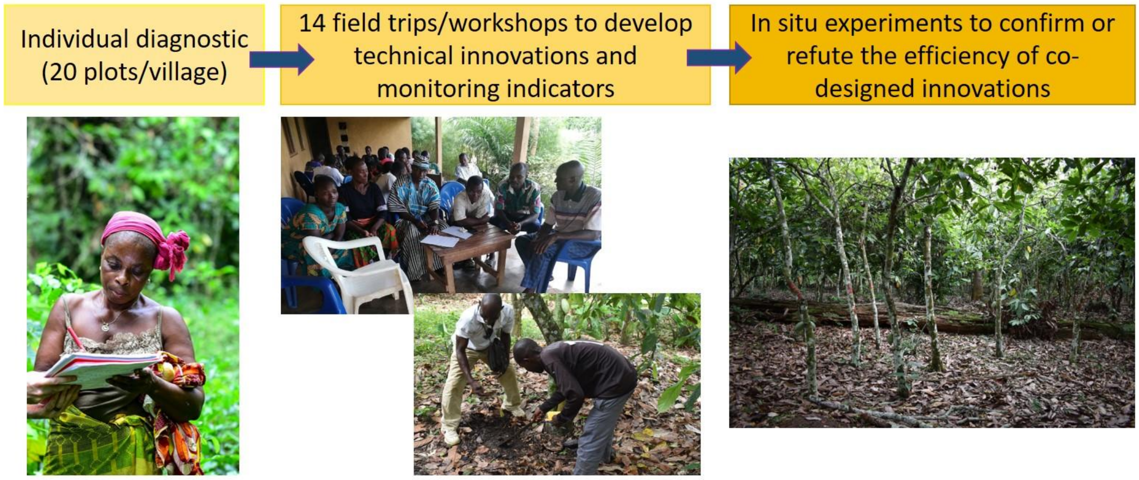
Keywords: co-designing process; local and academic knowledge; cocoa agroforestry; bioinputs



A variety of problems, some of which are common to all three villages (lack of soil fertility and high disease and pest pressure)

Implementation of a similar methodology for the three villages, but with contrasting results in terms of agroforestry and biopesticide and biofertilizer production methods

Customized plot trials with farmers who have taken part in the co-design process (agroforestry and/or biopesticide and/or biofertilizer)

Historically, cocoa cultivation in Côte d'Ivoire has moved from the east in the mid-20th century to the west of the country in recent years. The preferred method of cocoa cultivation is on previous forest land use, after clearing and burning the primary forest and girdling the residual trees (Norris *et al.*, 2010). Today, there are 4.4 Mha of cocoa cropping systems cropped by around one million farmers (FAOSTAT, 2024). The average yield per hectare has been declining steadily for the past twenty years, from 700kg of dry beans per hectare to 500 kg ha^{-1}. In addition, the market price for chemical or organic inputs such as fertilizers and pesticides, which could help alleviate these problems, is substantially rising, while the investment capacity of farm households is declining. As a result, farmers are using few or no inputs to improve soil quality or combat pests and diseases. Consequently, there is an urgent need to find agroecological solutions that farmers can implement autonomously to restore the support, regulation and production functions of their cocoa plots.

With the aim of identifying innovative practices to address these issues, a participatory design process is currently underway in three villages in Côte d'Ivoire, each located within a different historical cocoa-growing loop. The choice to work in three zones where cocoa farming has been established at different periods was made so as to cover a diversity of issues. These zones are broadly differentiated by the age of the cocoa agroforestry systems (CAFS) found there: from ageing in the east of the country (80 years on average), to mature in the center (25 years on average), to young in the west (10 years on average). Working with twenty farmers in each village, the participatory design process involved three stages. Firstly, an individual agronomic diagnosis of the CAFS is led, in the form of an in situ interview with the farmer.

Secondly, fourteen workshops are set up in each village, combining discussions and field work, to (i) define common co-design objectives and (ii) jointly develop technical solutions based on constructive exchanges between farmer and researcher participants. Thirdly, an experimental protocol adapted to the co-design process participants is set up to establish a prototype of these co-designed technical solutions in situ, in the plots of volunteer cocoa farmers who had taken part in the approach.

Problems common to all three villages related to (i) the decline in soil fertility, due to the depletion of soil resources (Tondoh *et al.*, 2015), and (ii) the resurgence of cocoa tree diseases and pests, due to the increase in in food resources for these pests (Rusch *et al.*, 2016) resulting from the significant expansion of cultivated cocoa farms, emerged. Varied local knowledge relative to the pedo-climatic context has led to original solutions, based on agroforestry (naturally-assisted regeneration and nursery seedling production) and the application of organic inputs (biopesticides and compost), which are currently being tested with volunteer cocoa farmers. We compare, analyze and question the different technical choices made between these three zones in relation to the history of cocoa farming and the age of CAFS.

This participatory design approach revealed clear advantages in terms of hybridizing knowledge, and thus enables participants to learn complementary knowledge (Tengö *et al.*, 2014). It is therefore expected to be a driving force in the spontaneous implementation of experiments by farmers to move towards more resilient systems and promote the agroecological transition of cocoa value chains (Alif *et al.*, 2024). However, this approach is still very time-consuming and costly compared with conventional training courses. We question current co-design methods and propose an original way of implementing technical advice with new methods and new tools that would allow upscaling and having an impact on a larger number of targeted stakeholders.

On-farm experiments: farmers and researchers go further together! A synergy to learn about cultivation and postharvest handling of grain legumes in Sweden (Oral #288)

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Keywords: on-farm experiments; grain legumes; postharvest handling; participatory research

1. Introduction

There is a growing interest among farmers and consumers for grain legumes in Sweden and potential in increasing their production and consumption (Röös *et al.*, 2020). This requires better knowledge among farmers and advisors about suitable species, varieties and management practices for different conditions. Since cultivar suitability and management practices including postharvest handling are highly farm-specific, farmers need to gain their own experience (Cristofari *et al.*, 2018). Synergies between the ways of learning of scientists and farmers are highly relevant in this regard. We analysed on-farm experiments designed, managed and evaluated in a collaboration between farmers and researchers. We focus on what farmers and researchers gained from the project and how to facilitate this type of collaboration.

2. Materials and Methods

Farmers in southern Sweden were invited by researchers to form a group in a project aiming to increase cultivation of grain legumes for food. Farmers and researchers collaborated on the definition of the design, management and evaluation of experiments. Fifteen on-farm experiments were performed in 2018 and 2019. Researchers performed measurements on the experiments and organised semi-structured interviews and a workshop to present and discuss the experiments. The researchers collected data on farmers' perceptions of the overall collaboration and critical reflections on the learning process. Data from communications, meetings and field notes were summarised under themes adapted from the framework for farmers' experiments developed by Catalogna *et al*. (2018).

3. Results and Discussion

The farmer-researcher collaboration generated practical knowledge on crop management, strategic knowledge on economic sustainability and knowledge about joint learning.

The experiments on new or relatively new grain legume species like lentil and grey pea often combined several aims related to agronomy: learning about the crop's growth cycle and potential difficulties, testing intercropping and comparing varieties. With relatively well-known crops like fava bean and yellow pea, the experiments focused on establishment methods and weed control or on establishing a relationship with a retailer for human consumption. We identified multiannual experimental itineraries (Catalogna *et al.*, 2022). Several farmers tested more than one novel practice at a time.

Grain postharvest handling steps such as cleaning and selling were considered by farmers to be integral components of the experiments, especially in relation to trying a new crop or testing the impact of a new practice on postharvest handling (*e.g.*, intercropping). The farmers considered one of the main benefits of on-farm experiments compared to researchers' typical on-station experiments to be their larger scale and the possibility to have a holistic approach, assessing feasibility of all steps from accessing seeds to selling products.

The experiments provided site-specific knowledge that was also often relevant to other farmers in the group. Using a collective setting to evaluate experiments accelerated the learning process and stimulated interest in new crops and new practices, leading to new experiments. The on-farm experiments combined advantages of ‘pure’ farmer experiments and ‘pure’ researcher experiments (Hansson, 2019), facilitating deeper analysis and understanding of outcomes. The farmers stated that working with researchers and with their peers increased their motivation to test innovative practices and that the external analytical view of researchers had been instrumental for extracting additional knowledge and deriving alternative conclusions. Farmer–researcher collaborations using on-farm experiments can enhance collective learning by combining complementary perspectives throughout the experimentation process.

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An evidence mapping of participatory modeling methods to use in agricultural living labs (Oral #176)

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Keywords: participatory modeling; living lab; agriculture and agri-food; capacity building; evaluation

ID	Participatory Modeling method	Goal									
		Understand Systems	Social learning	Improve Management	Other (specified below)	Improve policies	Understand values and decisions	Improve empirical (agricultural, economic, ...) models	Understand and steer implementation/transformation process	Understand social systems/power relationships	Improve predictions, projections, forecasting
A	System Dynamics Modeling (SD)	9	9	6	5	10	4	4	1	0	1
B	Role-Play Games (RPG)	11	10	7	9	6	10	3	1	3	0
C	Causal Loop Diagramming (CLD)	7	8	4	3	9	5	4	2	1	1
D	Agent-Based Modeling (ABM)	9	7	9	8	3	5	2	1	2	0
E	Companion Modeling (ComMod)	7	9	6	9	4	5	2	0	1	0
F	Scenario planning/development/building	3	5	5	4	5	3	2	3	0	0
G	Informing/contributing to a numerical model	3	4	4	0	0	3	1	0	2	1
H	Bayesian networking (BN)	5	3	3	0	1	4	0	2	0	0
I	Group model building (GMB)	2	1	0	1	3	2	1	0	0	0
J	Fuzzy Cognitive Mapping (FCM)	4	1	1	3	2	3	0	1	1	0
K	Participatory mapping	3	2	1	3	2	0	1	1	1	0
L	Numerical model prototyping	1	0	2	1	0	0	2	0	0	1
M	(Multi-level) storylines	1	0	0	2	1	0	0	0	1	0
N	Conceptual modeling	2	1	2	1	0	1	1	0	0	1
O	Multi-Agent Systems (MAS)	1	2	1	1	0	0	0	0	0	0
P	Social network analysis (SNA)	0	0	0	1	1	0	0	0	1	0
Q	Shared vision planning (SVP)	0	0	1	1	0	0	0	0	0	0

Figure 1. The number of times a goal and a PM method appeared in the same paper. Note: most papers applied several method and pursued serveral goals

1. Introduction

Participatory modeling (PM) is an approach in transdisciplinary research in which stakeholders are actively involved in the modeling process (Halbe *et al.*, 2018). The aim is to improve the accuracy of quantitative models (*e.g.* hydrological models, yield models) (*e.g.*, Beall *et al.*, 2011; Buchheit *et al.*, 2015) or make qualitative models (*e.g.* actor networks, decision-making processes) (*e.g.*, Bos *et al.*, 2020; Giordano *et al.*, 2021) more realistic. This can contribute to the improvement of policy measures or management, supports social learning or contributes to a better understanding of values and decisions. Although the goals and tasks of PM overlap with those of real-world laboratory research (Maring *et al.*, 2022; McPhee *et al.*, 2021), we found that to date PM has very rarely been applied in living lab research.

2. Materials and Methods

We analyzed 78 case studies and provide a systematic overview of 17 different methods (such as system dynamics, agent-based modeling, Bayesian networking, social network analysis *etc.*) and 10 objectives of PM (*e.g.*, improving policies, understanding stakeholder priorities, improving numerical models, improve system understanding, *etc.*). We show (1) which PM methods were used in transdisciplinary research in the agri-food system and to what extent and in which combination each method was used how frequently, (2) which specific objectives were pursued with which method, and (3) whether correlations existed between individual PM methods and the degree of stakeholder involvement.

3. Results

Our results give insights into research questions and goals currently explored through PM in the agri-food system. Our results show a clear connection between specific methods and specific goals and highlight methods often used together. We also highlight which methods are applicable towards several goals or only towards specific ones, and show significant differences in how often certain methods have been used in our sample. We also found differences in the level of stakeholder participation by method or pair of methods and will provide descriptions of case studies.

4. Discussion

We show ways in which researchers can expand their range of skills and institutions can build capacity through targeted methods training or hiring, and which methods appear to be particularly suitable for living lab research due to their particularly strong stakeholder involvement (we plan to describe specific studies from our analysis). Our results also help reviewers evaluate living lab research proposals that include PM methods by providing case study precedents. Ultimately, we intend to help establish PM more firmly as an approach in living lab research, for example in light of the European Partnership Agroecology and the EU mission "Soil Deal for Europe", which aim to greatly expand living lab research in the agricultural sector in Europe.

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Soil fertility change outweighs climate change impact on maize yield in sub-Saharan Africa, a multi-model study (Oral #191)

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Presenter: Antoine Couëdel (antoine.couedel@cirad.fr)

Keywords: soil-crop simulation; soil organic matter; soil-crop feedback; ensemble modelling; integrated soil fertility management

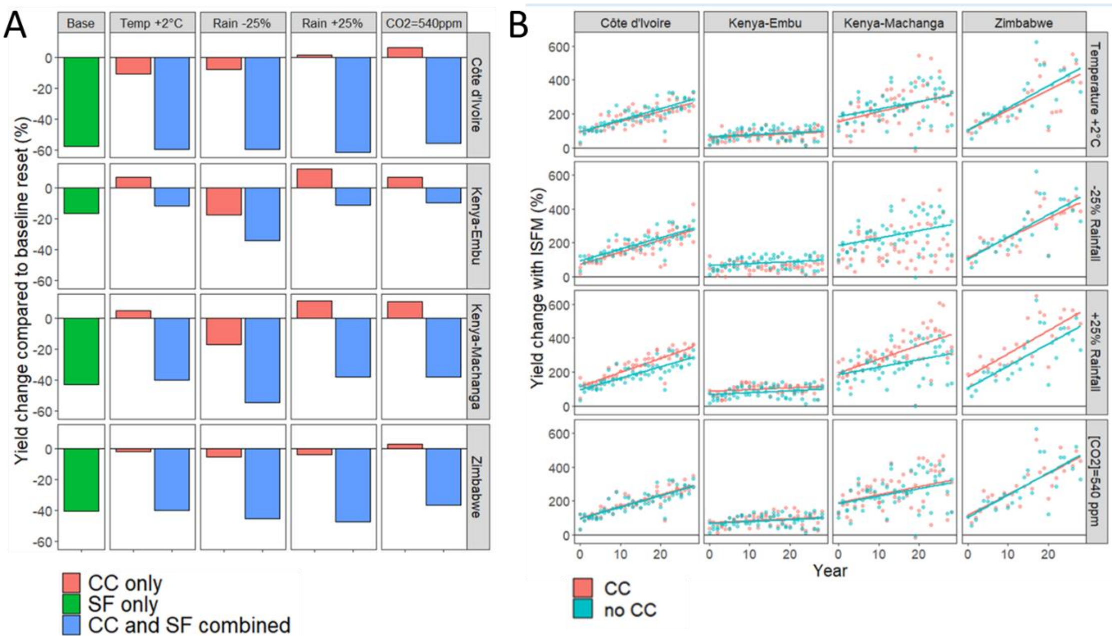

Figure 1. Yield change (%) in no input systems averaged across sites (A) due to climate change only (CC only), soil fertility declines only (SF only), the combination between CC and SF (CC and SF combined). Yield change (%) with ISFM (160 kgN and 4 tC organic amendment) compared to no C&N input over years for the four sites (B). Data are from the median of 16 soil-crop models' simulations

1. Introduction

Sub-Saharan Africa (SSA) faces significant food availability issues largely due to low soil fertility leading to low crop yields. Climate change is expected to exacerbate these issues due to a combined negative impact on crop yield and soil fertility. Integrated soil fertility management (ISFM) implies the combined use of mineral and organic fertilizers and is seen as a solution to increase soil fertility and crop yield, yet it is uncertain how this advantage is maintained with climate change. Soil-crop models are useful tools to assess the performance of ISFM. Multi-model simulations are often more robust than single-model simulations and contribute to understanding and reducing modelling uncertainty (Falconnier *et al.*, 2020).

In this study, we aim to i) evaluate multi-model performances for long-term simulations of crop yield and soil organic carbon (SOC) and their feedbacks (Couëdel *et al.*, 2024), ii) use the calibrated multi-model ensemble to explored the impact on maize yield for scenarios of change in soil fertility and climate variables in four representative sites in SSA with no input and ISFM management (Couëdel *et al.*, submitted).

2. Materials and Methods

We compared the performance of 16 soil-crop models using data from four long-term experiments at sites in SSA with contrasting climates and soils. Each site had experimental treatments including no exogenous inputs and ISFM. Once calibrated and evaluated we used the multi-model ensemble under reset and continuous simulations over 30 years to assess the impact of soil fertility *vs* change in climate variables (temperature, rainfall, and CO_2) on crop yield. In reset simulations, SOC, soil nitrogen and soil water were reinitialized each year with the same initial conditions. In continuous simulations, SOC, soil N and soil water values of a given year were obtained from the previous year's simulation, allowing for cumulative effects on SOC and crop yields.

3. Results

Model ensemble evaluation show that uncertainty increased over the duration of the long-term experiments. SOC simulations uncertainty was largest when organic amendments were applied, whilst yield predictions uncertainty was largest when no inputs were applied. We found discrepancies among models in simulating soil-crop feedbacks due to uncertainties in simulated carbon coming from roots and simulated crop N supply from soil organic matter decomposition. Yet when used as an ensemble, the 16 models enable to reproduce with satisfactory accuracy yield and SOC dynamics in all sites.

In the scenario analysis, most models agreed that with baseline management (no input) the magnitude of yield changed was much larger when considering declining soil fertility with baseline climate (-39%), compared with considering constant soil fertility but changes in temperature, rainfall and CO_2 (from -12% to +5% depending on the climate variable considered) (Figure 1.A). The model ensemble showed that when changes in soil fertility were taken into account, the advantages of ISFM systems over no-input systems increased over time (+190%) (Figure 1.B). This increase in ISFM benefits was greater at sites with low initial soil fertility.

4. Discussion

We found that soil fertility changes had more impact than climate change on maize crop yield in SSA. We argue for the urgent need to consider long-term soil-crop feedbacks in climate change studies to avoid largely underestimating the impact of climate change and ISFM on food production in SSA. The model evaluation also emphasizes the need for long-term experiments in which root and soil N dynamics are monitored. This will provide the relevant data to improve and calibrate soil-crop models, leading to more robust and reliable simulations of SOC and crop productivity, and their interactions.

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Couëdel, A., Falconnier, G. N., Adam, M., Cardinael, R., Ruane, A., Boote, K., *et al.* Soil fertility change outweighs climate change impact on maize yield in sub-Saharan Africa. Under review

Falconnier, G. N., Corbeels, M., Boote, K. J., Affholder, F., Adam, M., MacCarthy, D. S., *et al.* (2020). Modelling climate change impacts on maize yields under low nitrogen input conditions in sub-Saharan Africa. Glob. Chang. Biol., 1–23. doi: 10.1111/gcb.15261.

Rye in a changing climate: insights from crop modelling in key northern hemisphere regions utilizing DSSAT-CSM-CERES-Rye (Oral #274)

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Keywords: cereal rye; DSSAT-CSM-CERES-Rye; GxExM; climate change; GCM

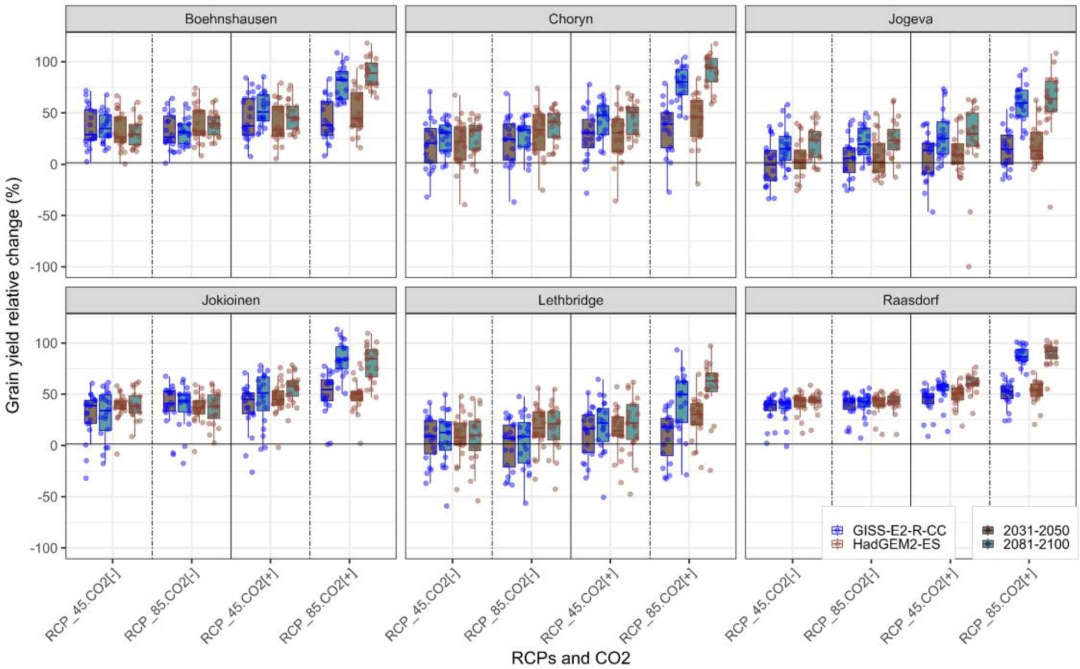

Figure 1. Impact of climate change on relative yield change in rye under different scenarios

1. Introduction

Process-based crop models are helpful tools in studying genotype × environment × management (G × E × M) interactions in agriculture (Boote *et al.*, 2013). With climate change (CC) threatening global food security through increased droughts, higher temperatures, and altered precipitation patterns, understanding its potential effects on crop production is crucial (Challinor *et al.*, 2014). Crop modeling is pivotal for exploring adaptation measures to CC challenges (Asseng *et al.*, 2015). This study focuses on rye, a promising crop in temperate regions due to its high resource use efficiency, adaptability to drought and frost conditions, and low input requirements. Assessing rye production under current and future climatic conditions is essential for adapting cereal production in key northern hemisphere regions. Our research aims to provide insights into the potential impact of CC on rye production, utilizing the adapted DSSAT-CSM-CERES-Rye model to evaluate its effects on crop yields and identify adaptation strategies (Shawon *et al.*, 2022). Additionally, this study enhances understanding of rye's resilience and adaptability under changing climatic conditions, supporting the development of sustainable agricultural practices amidst CC challenges.

2. Materials and Methods

In this study, the LARS-WG6 stochastic downscaling model (Semenov *et al.*, 2002) was used to generate future climate data, calibrated and validated with historical climate data from 1985 to 2020 across multiple locations: Bohnhausen (Germany), Jogeva (Estonia), Jokioinen (Finland), Raasdorf (Austria), Choryn (Poland), and Lethbridge (Canada). Daily climate variables were simulated at these locations by leveraging the statistical characteristics of observed climate data, with interpolation for ungauged locations conducted using the inverse distance weighting method. Weather generator parameters from two global climate models (GISS-E2-R-CC and HadGEM2-ES) were applied under the RCP 4.5 and RCP 8.5 scenarios. The impact of climate change on rye production was evaluated using the CSM-CERES-Rye model, which simulated critical crop characteristics, including phenology, growth, and yield. Simulations covered three time periods: the base period (2001-2020), mid-century (2031-2050), and end-century (2081-2100), providing a comprehensive assessment of rye production under various climate change scenarios throughout the 21st century.

3. Results and Discussion

The study evaluated projected changes in crop yields under different representative concentration pathways (RCPs) for selected sites (Figure 1). Results revealed that by mid-century, RCP4.5 was anticipated to yield an increase ranging from 8% to 48%, while RCP8.5 exhibited a larger increase ranging from 38% to 87%. Similarly, by end-century, RCP4.5 was projected to yield an increase ranging from 14% to 60%, while RCP8.5 was expected to yield an increase ranging from 43% to 93%, taking into account CO2 fertilization. Further analysis of location-specific data may unveil interesting disparities in projected yield changes. Additionally, it's noteworthy that future rye production in the northern hemisphere could potentially benefit from ongoing climate change due to an elongated growing season and increased CO2 concentration.

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Calibrating CERES-Barley for ideotyping climate-smart spring barley under German growing environments (Oral #337)

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Keywords: crop model; dssat; ceres-barley; spring barley; climate change mitigation

1. Introduction

Although breeding progress is contributing to climate change mitigation through increased land use efficiency (Laidig *et al.*, 2021), nitrogen use efficiency (Laidig *et al.*, 2024), and a decreased carbon footprint (Riedesel *et al.*, 2022), increasingly adverse weather conditions exert negative impacts on crop production and food security. Crop modeling serves as a powerful tool to investigate the interactions between genotype (G), environment (E), and management (M) by simulating the plant-soil-atmosphere system. Through *in-silico* experiments, crop models enable the simulation of crop growth, development, and yield formation under future climatic conditions. This study aims to define ideotypes, *i.e.*, *in-silico* genotypes that exhibit high mean yields at high yield stability, and a minimized carbon footprint under different environments using the crop model CERES-Barley model embedded in DSSAT. By calibrating and evaluating the model based on field experiments and multi-environment trials, we aim to generate robust predictions and design a climate-smart *in-silico* genotype.

2. Materials and Methods

To effectively employ crop simulation models, calibration for target genotypes and environments is essential, followed by performance evaluation to ensure accurate predictions. In this study, we use detailed multi-environment phenology, growth, and yield data of the elite barley cv. RGT Planet to parameterize the CERES-Barley model, based on an extensive two-year field experiment in Berlin Dahlem, where we collected growth and yield data under three irrigation treatments and a large dataset consisting of a multi-environment trial dataset covering 33 site years of pre-registration trials from 2014 to 2019. We use the time series estimator tool (TSE) for DSSAT to calibrate cultivar-specific coefficients by minimizing the normalized root mean square error (nRMSE) between simulated and observed data. We then use the parametrized and evaluated CERES-Barley model to investigate yield production under current and future climatic conditions. Through a hybrid method that combines the CERES-Barley crop model and life cycle assessment, we conduct *in-silico* experiments by simulating weather conditions based on the 17 RCP-climate scenarios of the DWD core ensemble (DWD, 2018) from 2006 to 2099. Subsequently, we cluster the yearly data into distinct groups according to environmental conditions (drought intensity, drought timing, extreme weather events, *etc.*) and their corresponding environmental impacts (*i.e.*, carbon footprint). Using these weather clusters, we conduct sensitivity analysis to define various sets of model cultivar parameters, representing ideotypes with different combinations of genotypic traits aimed at achieving objectives such as high yields, yield stability, or low carbon footprint under various environmental conditions and management practices.

3. Results and Discussion

The calibrated and evaluated CERES-Barley model provided robust simulation results for the elite cv. RGT Planet. The simulated yields show an increase in mid-century, under the RCP

4.5 and RCP 8.5, with a lower slope at the end of the century. The ideotyping exercise revealed significant variations in cultivar coefficients and corresponding crop traits across various environmental scenarios and management practices. This assessment facilitated the identification of ideotypes tailored for a maximized yield, yield stability, and a reduced carbon footprint. The results highlight the significance of integrating genotype × environment × management interactions in designing climate-smart ideotypes geared towards climate change mitigation while maximizing agricultural productivity.

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Simulating interactions between farms: adaptive network of biomass flow and individual behaviors (Oral #153)

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Keywords: agent-based model; crop-livestock interaction; farm network; resilience; farm autonomy

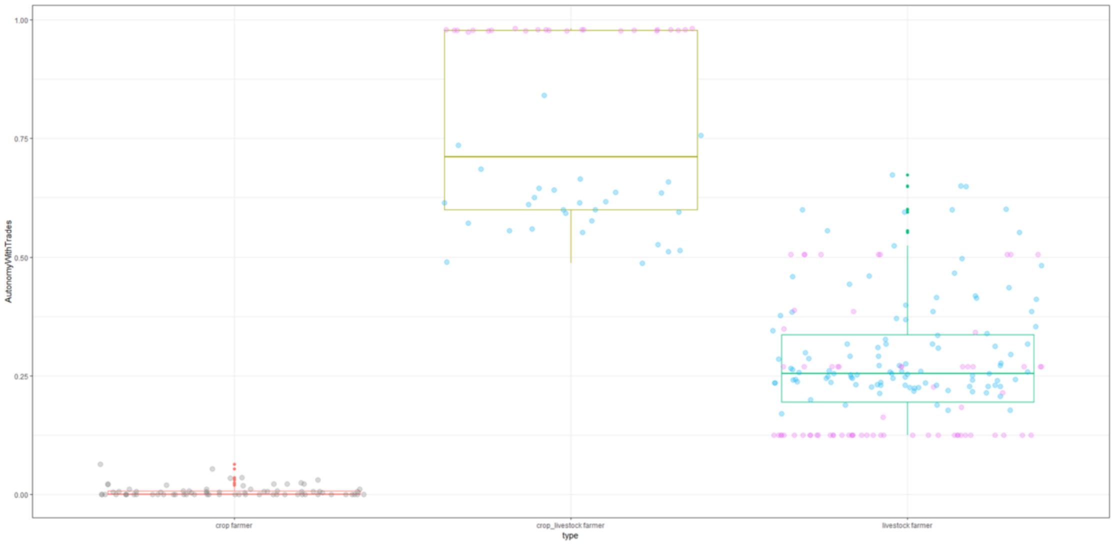

Figure 1. Distribution of local autonomy by farm for the baseline scenario (step 8). Pink and blue dots represent ovine and bovine livestock farms respectively

1. Introduction

Crop-livestock systems at landscape level consist of interactions between farms (often specialized) promoting ecological interactions over space and time between crops, pastures and livestock sub-systems. They can increase resources circularity to satisfy short-term (*e.g.* farm autonomy) and long-term goals (*e.g.* resilience to climatic hazards and agricultural practices change) (Martin *et al.* 2016).

Little research is available on the impact of farms involvement in exchanges of products with other farms (constituting a farm network) on autonomy and resilience, both at farm and network levels.

Agent-based models (ABM) represent individual agents (farms) making decisions and acting independently from each other while considering social behaviors such as social interactions (Huber *et al.* 2018). We aimed to assess, *via* an ABM, the autonomy and resilience of a farm network in a given region in response to different scenarios.

2. Materials and Methods

We built an ABM in which agents are farms (cereal, crop-livestock, and livestock) and the cooperative. At each time step (year), on-farm products (grains, forage, straw, manure) can be traded if needed or in surplus with other farms, the cooperative or the global market. Decisions to trade with another farm are based on a score that takes into account i) the distance to cover, ii) the quantity of biomass that can be exchanged, iii) trust between farmers, representing farm trade habits and evolving according to past trade experiences, iv) individual strategy (preference for exchanged quantity or social connection).

The ABM was implemented on the GAMA platform for the Ariège region (France), then explored with the openmole platform (Reuillon *et al.* 2013). Explorations showed that 300 farms could be representative of the functioning of the region and that stability is reached after 8 steps. This stable state is our baseline scenario from which we will include perturbation to simulate scenarios.

Main outputs indicators for each farm are: i) local farm autonomy: in nitrogen, ratio of quantity of consumed products coming from the farm or other farms over total quantity of consumed products, ii) betweenness centrality: degree of inclusion of a farm in the network.

3. Results

For the baseline scenario, network autonomy is low (0.24), with farm autonomy much higher for crop-livestock farms (0.773), than livestock (0.279) and crop farmers (0.007). This variability is also observed between livestock types: the local autonomy is higher in ovine crop-livestock farms (0.98) than in bovine ones (0.61) and ovine livestock farms have lower local autonomy (0.22) than bovine ones (0.31).

On average, crop-livestock farms have more connections than livestock and crop farms (respectively 3.04, 1.95 and 1.21), and show higher levels of betweenness centrality (respectively 0.019, 0.009 and 0.004).

Mean distance between trading farms is the lowest for protein grain, and differs whether the buyer is a livestock or crop-livestock farm (61km and 27km respectively). Highest mean distances are reached for manure and cereal straw (54km both).

4. Discussion and Conclusion

Our modeling approach combines both technical and social aspects of farm interactions. Based on the baseline scenario results, we showed that crop-livestock farmers are better included inside the farm network, mainly as they can be supplier and requestors. We highlighted that manure is scarce in the region. Crop farmers are bound to a low autonomy in simulations as their only local need is for fertilizers (thus for manure).

We are simulating scenarios of perturbations to compare with the baseline: i) changes in resource availability, to simulate yield variability, ii) farm number, farm structure (crop area, number of livestock heads), iii) new practices (cover crop grazing). New practices may help increase farms' autonomy, while decrease in farm number and increase in farm areas may increase attraction to the local cooperative (*versus* other farms) and/or lead to a concentration of connections between farms. These results could be presented at the conference. They will provide insights on performances and resilience of crop-livestock systems at landscape level facing perturbations.

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What opportunities exist for climate change mitigation in agriculture? A land-based emissions and mitigation measures analysis (Oral #178)

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Keywords: environmental footprint; carbon sequestration; territorial life cycle analysis; land-based solutions; sustainable agriculture

The growing negative impacts of climate change on society and ecosystems necessitate accelerating the transition towards sustainable mitigation solutions. Agriculture is responsible for around 12% of EU greenhouse gas (GHG) emissions (EEA, 2022). Yet, it also offers significant opportunities for climate change mitigation, notably through the potential of agricultural soils to sequester carbon. However, addressing GHG emissions in agriculture requires the disposition of reliable tools for decision-making and the implementation of measures specifically tailored to the territories (Borghino *et al.*, 2021). This study focuses on the Mediterranean island of Sardinia in Italy, which covers almost 24,000 km^2, roughly half of which is used for agriculture. Further attention in this study is given to the Tirso River basin due to its regional significance and representation of Sardinia's diverse agricultural activities, ranging from intensive animal and crop production to marginal, heterogeneous, and semi-extensive production systems, including agroforestry and sheep farming. We present a "cradle-to-gate" life cycle analysis (LCA) applied to the region of Sardinia to i) estimate agricultural GHG emissions, ii) pinpoint the most contributing sectors and sub-regions, and eventually iii) develop mitigation scenarios and evaluate their potential opportunities within the island's agricultural context. Estimates of GHG emissions and mitigation potentials are based on the Tier 1 and Tier 2 methods of the Intergovernmental Panel on Climate Change (IPCC) guidelines for national greenhouse gas inventories. The region's significant dedication to animal sector activities, particularly sheep husbandry, despite its semi-extensive nature, along with intensive cattle breeding in the central and western part, makes it a hotspot for GHG emissions. Most crop production sector emissions result from agricultural machinery and fertilizer use, with intensity varying based on land use characteristics. Measures to improve the environmental performance of the region's agricultural sector are explored, encompassing GHG emissions reduction, avoidance, and carbon stock enhancement in soil and biomass. Among the scenarios analyzed, opportunities emerge from applying sustainable land-based mitigation options such as reduced tillage, organic farming expansion, and agroforestry implementation.

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Farm resilience in Mediterranean agricultural territories: a multi-scale and multi-risk approach in France and Tunisia (Oral #125)

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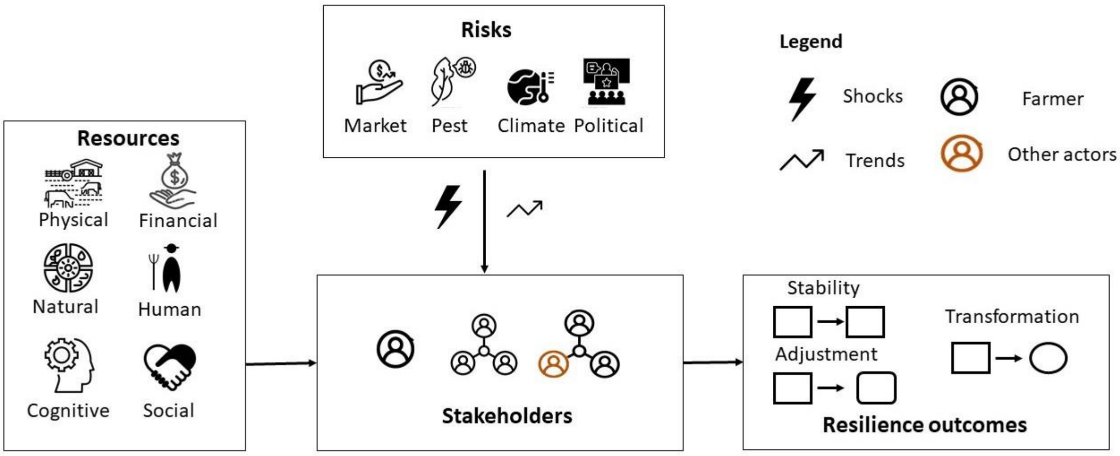
Keywords: resources; risk perception; adaptive capacity; climate change; farming systems



The Mediterranean region is considered a hot spot for climate change with recent acceleration generating major risks in several key sectors, particularly concerning water availability or food production (Cramer *et al.*, 2018). The resilience of agriculture has recently become a critical challenge in supporting farmers in a context of increasing short- and long-term risks. Over the past decade, multiple authors have published resilience frameworks (Meuwissen *et al.*, 2019; Perrin and Martin, 2021). In their review, van der Lee *et al.* (2022) highlighted complementarities between these frameworks, particularly between agroecological and resilience capacities approaches. While agroecological approaches focus on practices with few links with perturbations and capacities, the capacities approaches often inadequately consider farmer's practices. Another gap identified by Darnhofer *et al.* (2016) is the lack of attention paid to relations - between physical entities (*e.g.*, flows of nutrients) and social groups (*e.g.*, power, learning) - in understanding resilience of farming systems.

This study aims to develop an operational framework for assessing the resilience of farming systems, considering both farmer's adaptation strategies in response to perceived risks and the central role of the relations between farms, farmers and their environment (nutrient cycling, advice services, resource sharing, *etc.*), which contributes to their resilience capacities in facing both short- and long-term risks. We apply this framework to two contrasted areas in the Northern and Southern Mediterranean basin.

We assembled a multi-disciplinary research team (agronomy, economy, geography) to develop and operationalize the concept of relational resilience at farm scale. We conduct tests in two areas located in France (Aude valley), and Tunisia (Siliana). In each region, we conduct semi-directed interviews with different types of farmers and with other stakeholders including public institutions, input suppliers or advice services. The objectives of the farmer interviews are threefold. Firstly, we gather their perceptions of climatic risks among other risks, considering the relative importance given to both short-term (*e.g.*, drought, price inflation) and long-term risks (*e.g.*, disappearing resource). Secondly, we document the adaptation strategies they are implementing or planning to implement. Each strategy is detailed as a set of technical and organizational practices aimed at facing one or several perturbations. Thirdly, using practices as a starting point, we identify the resources (individual or collective) and the capacities that farmers mobilized or lacked, in order to adapt. We focus on the relationships linking actors and the elements of the system, considering them as important components for building resilience. Interviews with other stakeholders aim to identify their facilitating or hindering role for each kind of adaptation strategies.

Our framework is structured around four components (Figure 1). Firstly, the risks that are perceived by the stakeholders include different categories of climate risks (*e.g.*, drought, flood, temperature rising) as well as sanitary, market or political risks. Secondly, the resources mobilized are categorized according to the livelihood literature, encompassing biophysical, social and cognitive resources. Thirdly, we specifically examine inter-individual relations: with whom farmers develop adaptations, if they mobilize collective resources, *i.e.* what are the coordination or flows required for adaptation. Finally, resilience outcomes are described based on the evolution of the system during the adaptation process (stability, adjustment or transformation).

Our (ongoing) results show different configurations of adaptation strategies based on local factors (such as resources, climatic shocks) and regional contexts (France, Tunisia). These strategies exhibit a gradient of dependence on both physical and relational resources, which may be used to face short- and long-term risks.

The diversity of adaptation strategies among stakeholders leads us to consider the interactions occurring between actors to mobilize resources, especially for those identified as critical. The next step would be to analyze the property of the social-ecological networks that support resilience (Labeyrie *et al.*, 2024). Such research could aid in proposing frameworks for public policies and support for agriculture in the face of increasing multifaceted risks.

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On-farm assessment of warming impact on winter cereals under different N fertilisation strategies: a Mediterranean case study (Oral #19)

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Keywords: adaptation; climate change; open top chamber; field work

Winter cereals play a crucial role in human diets. The initial impacts of climate change on these strategic crops include yield stagnation and increased yield variability (Olesen *et al.*, 2011). Projections indicate that for every additional degree Celsius of temperature increase, global wheat production could decrease by 6% (Asseng *et al.*, 2015). Climate change impacts and adaptation strategies vary regionally due to interactions with soil, existing climate conditions, and agricultural practices (Olesen *et al.*, 2011). Effective management practices can compensate the effects of climate variability, emphasizing the need for region-specific studies to identify suitable adaptation strategies. In irrigated areas, compensating for reduced precipitation risk can be feasible, but addressing temperature rise presents significant challenges. This study aims to empirically evaluate the effectiveness of different N fertilisation strategies to adapt to warming on winter cereals in Mediterranean irrigated conditions.

An on-farm field experiment was established in the Ebro valley (Sucs, Lleida, Spain; 41°41'50.0"N 0°26'51.1"E) in a surface irrigated area, for 2 winter cropping seasons (2022-2023, 2023-2024) in the framework of the ECO-TRACE project. Winter hybrid wheat (*Triticum aestivum* L.) and barley (*Hordeum vulgare* L.) were cropped on the first and second cropping seasons, respectively, under two climate scenarios: current climate and warming. Passive open-top chambers (OTC) were used to simulate warming, adapted from the design of Welshofer *et al.*, (2018). Six N fertilisation scenarios were also assessed: control (0N); business as usual (BAU), consisting of a pre-sowing fertilisation with pig slurry (220 kg N ha^{-1} yr^{-1}) and top-dressed synthetic fertiliser (70 kg N ha^{-1} yr^{-1}); full slurry (the sole application of pig slurry before sowing at same rate than BAU); full synthetic, including pre-sowing and top-dressing synthetic fertilisation (50 and 120 kg N ha^{-1} yr^{-1}, respectively); and two treatments including a mixture of legumes (*Medicago sativa* L. and *Trifolium repens*), undersown in one treatment as living mulch and in the other as non-living mulch. Treatments were assessed using a split-plot design with 3 replications. Grain yield, its components, above-ground biomass, and their N concentration were measured at physiological maturity. Air (at 12.5 cm), soil (at 10 cm depth), and soil surface temperature were continuously monitored with sensors, along with soil volumetric moisture.

The 2022-2023 cropping season was dry from October until May (110 mm, 39% of the average), offset by 3 irrigation events of 100 mm each. During the reproductive phase, in April and May, mean temperatures exceeded the average by 5ºC, reaching above 28ºC for 7 days. Legumes couldn’t get satisfactorily established. Warming led to an increase of monthly air, soil surface and soil temperature of 1.5 and 2 and 2.4ºC compared to the current climate, respectively, and a decrease of soil volumetric moisture of 12%. Warming reduced grain yield and above-ground biomass production by 20% (6.2 *vs.* 7.6 t ha^{-1}, 14% Hº, $p=0.01$) and 11%, respectively, compared to the current climate. This was related to yields components with i) less grains per spike (34.9 *vs.* 41.9, $p<0.01$), and ii) a lower TGW (39.7 *vs.* 43.9, $p<0.01$) under warming. TGW was also affected by the fertilisation scenarios, with lower values in BAU (35.5 g) compared to full synthetic (41.5 g) and 0N (43.9 g) ($p<0.01$). Warming increased grain and biomass N concentration due to dilution effect (2.21 *vs.* 1.96% for grain, and 1.37 *vs.* 1.14% for biomass, respectively) ($p<0.01$). As result, crops under warming climate, in both BAU and full synthetic scenarios, exhibit reduced uptake of grain N compared to current climate ($p<0.01$).

Fertilisation strategies failed to counteract the significant impacts of warming; instead, some resulted in reduced grain N uptake, indicating lower resilience. Further validation of these preliminary findings will be presented based on the results of the on-going 2023-2024 cropping season.

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New resilient cropping systems for Europe (Oral #347)

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Keywords: cropping system; Camelina sativa; *Brassica carinata*; oilseed; Brassicaceae

1. Introduction

Agriculture is currently facing the challenge of ensuring food security. In addition, climate change affects the sustainability of farming systems by decreasing crop yield and soil fertility (Kakabouky, 2021). Novel agriculture practices, such as the inclusion of alternative crops into traditional cropping systems could be a new solution to pursue environmental benefits. In recent years, there has been growing interest in two easy-to-grow oilseed crops belonging to the Brassicaceae family: *Camelina sativa* (L. Crantz) and *Brassica carinata* (A. Braun). Camelina is a low agronomic input crop which can adapt to different environments and produce oil suitable for multiple bio-based application (Zanetti *et al.*, 2021). Carinata is a resilient crop with high erucic acid contents, thus suited to produce biofuels, including aviation fuels (Seepaul *et al.*, 2021). The present study was carried out to support the development of these two crops within conventional EU cropping systems, and to provide insights on the use of camelina and carinata oil.

2. Materials and Methods

Camelina and carinata were tested in a multi-location trial (Italy and Serbia) in different cropping systems for two consecutive growing season (2022-24). The trials were carried out at the experimental farm of the University of Bologna (Italy) and at the Institute of Field and Vegetable Crops at Rimski Šančevi, Novi Sad (Serbia). Three camelina varieties (CCE44 and CCE117 by Camelina Company, Spain, and Lenka by the University of Poznan, Poland) were evaluated in Italy, whereas two camelina varieties (NS Zlatka and NS Slatka) were investigated in Serbia. Each variety was sown in (strip plots of about 5000 m2) at the end of October. At both sites, sunflower and sorghum were double cropped after camelina (harvested in June) and compared with a common sole-crop system (food crops sown in April). Carinata (sown in autumn 2023) (Nujet350 by Nuseed, France) was intercropped with chickpeas in Italy and with barley in Serbia.

3. Results

During the first growing season, the meteorological conditions in both countries were in line with long-term data. A remarkable difference was recorded in Italy in May 2023 when almost 275 mm of rain caused a soil flooding. In Serbia, temperatures in winter months were higher than long-term data and May 2023 was marked by 131 mm of precipitation. Concerning the cash-cover cropping system, the productivity of camelina significantly changed depending on variety with variety CCE117 which reached the highest seed yield in Italy. In Serbia, the seed yield of camelina was on average 1.6 Mg ha.1. With regard to food crops after camelina, sunflower was successfully in both countries (1.8 and 2.6 t ha^{-1}, in Italy and Serbia, respectively), whereas sorghum showed a too long growing cycle remaining green until November. The harvest of the second-year trial of camelina and the first-year trial of carinata cropping systems is planned in summer 2024.

4. Discussion

From these first results, camelina confirmed its resilience despite adverse weather conditions characterizing the first growing season and achieved seed yields in line with the literature in Serbia. Although no data are available yet on the carinata intercropping system, the crop seems to fit well combined with food crops in both Italy and Serbia regions. It is necessary to keep on searching for new solutions to diversify the structure of farming systems, integrate alternative crops that are adapted to climate change and mitigate water and nitrogen losses, reduce chemical input and CO_2 emissions.

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Syppre: innovative systems to meet the challenges of improving agriculture's carbon balance (Oral #168)

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Keywords: carbon storage; GHG emissions reduction; diversification

In the context of climate change, the reduction of greenhouse gases (GHG) emissions and the storage of carbon in soil must be encouraged to limit global warming. The agricultural sector contributes to 18.4 % of French GHG emissions in which 29 % was associated with crop fertilization (Citepa, 2023). Field crops are part of the problem through the use of fertilizers, as well as to the loss of soil carbon through the important export of biomass non compensated by return of organic matter to the soil. However, technical solutions do exist to improve the carbon balance of field crop farming systems such as cover crop, use of organic fertilisers or reduced use of mineral fertilizers (Pellerin *et al.* 2019).

These technical solutions are mobilized in the innovative systems of the Syppre project in which three French technical institutes on arable crops collaborate (ARVALIS Institut du végétal, Terres Inovia and Institut Technique de la Betterave). This project aims to support the development of innovative arable cropping systems reconciling productivity, economic profitability and environmental protection (Toqué *et al.* 2015). The innovative systems have been tested since 2017 in five French regions specialised in arable crop production: the deap loamy soils of Picardy, the chalk soils of Champagne, the shallow clay-limestone soils of Berry, the clay-limestone hillsides of Lauragais and the humus-rich soils of Béarn. On each site, an innovative system co-designed with regional agricultural stakeholders has been tested in field conditions, and compared to a reference system, which is representative of current systems observed in the region. To meet Syppre's objectives and local issues, the innovative cropping systems mobilize agroecological solutions using a systemic approach, such as crop diversification, modification of soil tillage, introduction of cover crops, cultivar diversity, and biocontrol products. Cropping systems performances were evaluated every year, and different indicators of soil fertility were measured. The carbon and nitrogen stocks were in particular measured at the beginning of the trial and used to simulate the evolution of soil organic status. The carbon balances of cropping systems were calculated with the French Label Bas Carbone methodology.

After 7 years of trials, we observed a great reduction of nitrogen fertilizer use (between -10% and -46%) and GHG emissions (between 0.33 and 0.7 teqCO_2 per year and per hectare) for all the innovative systems compared to the references. Even if all innovative systems do not have a positive effect on carbon storage, all systems have a positive carbon balance. But the economic performances decreased for almost all of them. The presentation will detail the levers used to reduce mineral nitrogen fertilizer amount and improve soil fertility, the effect already visible, and the expected ones in long term scale, the consequences on crop and system performances as well as the effect on carbon balance. It will also discuss the perspectives of interesting solutions to consider in the future, technical or economic.

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Using soil-crop models to investigate the impacts of contrasted livestock integration into cropping systems with climate change (Oral #160)

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Keywords: climate change; resistance; soil organic carbon; soil-crop model; circularity

Food systems are at the core of numerous negative impacts, involving *e.g.* greenhouse gas emissions, biodiversity or human health. To address part of these problems, there were multiple calls to reduce or even suppress animal products in human diets (Tilman and Clark, 2014). However there is still no consensus regarding the extent of reduction of these animal source foods to mitigate the environmental impacts of food systems (Frehner *et al.*, 2020). In addition, climate change poses an enormous threat on crops and livestock, while at the same time, agricultural systems constitute key levers to mitigate climate change. In this context, process-based models are essential to investigate the potential outcomes of prospective scenarios such as keeping highly specialized agricultural systems or suppressing livestock. Such studies are still very rare, most of comparisons in agricultural circularity using mass-flow models which do not allow to investigate climate change scenarios and perform granular analyses of carbon and nitrogen cycles.

In this work, we wanted to study the impacts of contrasting livestock integration on cropping systems sustainability (productivity, soil organic carbon, resistance to extreme climatic events). In that objective, we compared three different 8-year crop rotations contrasting by their level of livestock integration and by the commodities they supply for human diets. Each was simulated with the soil-crop model STICS (Brisson *et al.*, 2009) over a 24-year period of time in Belgian pedoclimatic conditions, in five different climate scenarios: 1980-2010, 2040-2070 (RCP4.5 and RCP8.5), and 2070-2100 (RCP4.5 and RCP8.5). The first one is Business-as-usual with common cash crops of Belgium and in which manure is imported from other livestock farms in exchange of exported straw. The second system is called Vegan, and simulates an agriculture where livestock would be banned. It therefore does not use manure, but all crop residues are incorporated into the soil after harvest. The third system is qualified as Integrated crop-livestock (ICLS). It uses sheep as functional tools to manage weeds and pests through grazing of temporary pastures, which last 2.5 years over the 8-year rotation.

Simulated yield evolutions with climate change varied between crops, ranging from losses (up to -49%) to gains (up to 51%). It appeared that global yield shifts due *e.g.* to CO_2 fertilization effect and higher crop stresses are modulated by the impacts and occurrence of extreme climatic events. The resistance to these extreme climatic conditions is influenced by the contrasting livestock integrations, even when comparing similar crops that are common to the different circularity scenarios. For example, the loss of soil organic carbon in the Vegan system provokes greater stomatic water stresses and lower crop resistance. In the contrary, closely connecting crops with livestock through the integration of temporary grazed grasslands into the rotation increases soil organic carbon, and hence improves soil capacity to retain water.

Finally, this study aims at illustrating how soil-crop models might be coupled with external methodologies to explore the outcomes of potential agricultural circularity scenarios for food systems under historical and future climatic conditions. We believe that extending such comparisons to various agro-pedoclimatic conditions would allow to better understand the impacts of food policies on the climate change adaptation and mitigation capacities of agricultural systems.

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Site conditions determine heat and drought induced yield losses in wheat and rye in Germany (Oral #340)

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Keywords: weather index; heat stress; drought stress; winter wheat; winter rye; variety trial data

Increasing and heat and drought are major abiotic stressors threatening European cereal yields under climate change. So far little is known about the spatio-temporal yield effect of these stressors (Lüttger and Feike, 2018). In this study, we assess genotype (G) × environment (E) × management (M) specific weather-yield relations utilizing spatially explicit weather indices (WIs) and variety trial yield data of winter wheat (*Triticum aestivum*) and winter rye (*Secale cereale*) for all German cereal growing regions and the period 1993–2021. The objectives of this study are to determine the explanatory power of different heat and drought WIs in wheat and rye, to quantify their site-specific yield effects, and to examine the development of stress tolerance from old to new varieties. We use mixed linear models with G × E × M specific covariates as fixed and random factors. We find for both crops that combined heat and drought WIs have the strongest explanatory power during the reproductive phase. Furthermore, our results strongly emphasize the importance of site conditions regarding climate resilience, where poor sites reveal two to three times higher yield losses than sites with high soil quality and high annual precipitation in both crops. Under good site-conditions heat and drought stress hardly cause any significant yield losses. Finally, our analysis reveals significantly higher stress-induced absolute yield losses in modern *vs.* older varieties for both crops, while relative losses also significantly increased in wheat but did not change in rye. Our findings highlight the importance of site conditions and the value of high-yielding locations for global food security. They further underscore the need to integrate site-specific considerations more effectively into agricultural strategies and breeding programs.

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Is rapeseed – service plants intercropping a solution to mitigate biotic stresses? (Oral #170)

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Keywords: winter oilseed rape; service plants; pest insect damages

1. Introduction

Sowing winter oilseed rape (WOSR, *Brassica napus* subsp. *napus*) with other species has been promoted in Europe for the last 10 years. Various advantages were pointed, like enhanced nitrogen nutrition (Lorin *et al.*, 2016), improved weed control (Lorin *et al.*, 2015) and less insect pest pressure (Breitenmoser *et al.*, 2022). However, in the practice, farmers face difficulties to implement this technique, among them the choice of species intercropped with WOSR or the adaptation of the cropping technique.

Herbicides and insecticides are the most common phytosanitary products used in WOSR, with sometimes several insecticide applications in autumn and in spring. The role of service plants intercropped with WOSR in reducing weed pressure and pest damages has been assessed in field experiments, and in a farmers' fields network.

2. Materials and Methods

In order to assess the sowing of service plants with WOSR in the practice, an agronomy diagnosis was performed on 28 farmer's field in the seasons 2018-2019 and 2019-2020. Additionally, the role of the addition of faba bean as service plant with WOSR was investigated in a two-year field trial. The impact of insect pests (*Psylliodes chrysocephala*, *Ceutorhynchus napi*, and *Brassicogethes aeneus*) was monitored over each season according to the standard procedures (*i.e.* number of larvae per plant (Berlese extraction), number of oviposition punctures, and number of insects per plant, respectively).

3. Results and Discussion

The impact of the intercropping on weeds depends on the choice of species. A comparison of services plants species mixtures showed that non-legumes were the most efficient to increase service plants biomass in autumn and therefore reduce weed infestation, even when included in the mixtures at a low density. However, they can also negatively impact WOSR yield due to a high competition for light and nitrogen. Legume service plants were less competitive with WOSR but due to their slow development, their beneficial effect on the system could be low if they don't produce enough biomass.

Among legume species, faba bean combines several interesting traits. With a fast development compared to other legume tested as service plants, it could relatively well compete with weeds without resulting in WOSR yield reduction, as it fixes more nitrogen. In field trials, faba bean was shown to mitigate damage caused by the pest complex of *Psylliodes chrysocephala*, *Ceutorhynchus napi*, and *Brassicogethes aeneus*, while having a positive impact on WOSR grain yield. Subsequent observations confirmed the effect on the pest complex. The mechanism behind these results, direct effect through visual or olfactive disruption or indirect effect through WOSR development are under study.

Sowing WOSR with companion plants has the potential to significantly reduce the impact of weed and insect pests on the cash crop, provided this technique is well managed. However, in the case of high pressure, additional measures are needed to secure high grain yields. Along with other alternatives (*e.g.*, cultivar selection, early sowing, trap strip), this approach could reduce the use of synthetic chemistry in WOSR while supporting crop yield and promoting in-crop biodiversity and functional trophic groups.

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Tracking-down inter-farm collaborations to promote crop diversity (Oral #254)

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Keywords: collaboration; diversity; innovations tracking; crop rotation; farm organization

1. Introduction

Crop-livestock integration and crop diversification are major levers for the development of agroecology and for improving farming system resilience by *e.g.* limiting disease pressure, optimizing the use of nutrients and regulating the water cycle (Lin, 2011; Martin *et al.*, 2016). However, their implementation on the long term by farmers is a challenge, as they require an increased workload and more knowledge. Inter-farm collaborations involving the sharing of fields or a common crop planning, including pastures and crops to feed livestock, appear to be a lever for crop diversification. These organizations are poorly documented in the literature.

In this study, we aim to analyse how farmers collaborate to develop diversified production systems.

This study is part of a larger project conducted with Agrobio 35, *i.e.* the local organic farming syndicate, and a group of farmers that raised the topic of inter-farm collaboration to enhance crop diversification. This project aims at co-designing inter-farm collaborations with the group of farmers and produce transferable knowledge to provide advice to producers.

2. Materials and Methods

To identify and analyse innovative inter-farm collaborations, we use the innovation tracking method (Salembier *et al.*, 2021) organized in five steps:

1) Defining a tracking project

2) Unearthing on farm innovations

3) Getting to know innovations

4) Analysing learnings from the innovations

5) Generating agronomic content

We identified farmers through snowball sampling. We conducted the semi-structured interviews with the farmers involved in the collaboration separately, following these categories:

A) Farm presentation

B) Collaboration presentation

1. Type of collaboration (Who is involved? What is exchanged? What values are assigned and how are they assigned?)

2. Formalization of the collaboration

C) What leaded to this kind of collaboration?

1. Economic, social, geographical context

2. Motivation for collaborating with other farms

3. Major changes in collaboration

4. Perspectives

D) Externalities

1. Diversification

2. Benefits on soil, yield (quantity and quality), use of inputs, biodiversity

3. Agri-environmental, social and economic satisfaction.

The interviews were analysed with qualitative multi-theme coding (Ayache and Dumez, 2011) in an inductive approach. We estimated how inter-farm collaborations impact crop diversity on farms.

3. Results and Discussion

First, we described how the collaborations work and how they are organized. We analysed the formalization between the farmers, the motivations and the development conditions of these innovations. Then, a cross-sectional analysis of the cases enabled us to identify similar groups or trends (*e.g.* type of farm influencing the type of collaboration, or formalization being influenced by the trajectory of the collaboration). Favourable contexts to set up collaborations, common ways of formalizing and difficulties often encountered are highlighted. We focussed on the direct or indirect impact of livestock (*e.g.* feed crops and pastures in the rotations, organic fertilisation) on the crop rotations, in the cases of crop-livestock integration at inter-farm level. We then discussed the impact of these collaborations on crop diversity.

This research contributes to a better understanding of inter-farm collaborations and provide references for stakeholders that can enhance innovation process (Salembier *et al.*, 2021). The results will be shared with Agrobio 35 and the group of farmers of the project.

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Trade-offs in circular agriculture (Oral #334)

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Keywords: nutrient cycling; nutrient use efficiency; cycle count

1. Introduction

Principles around circular agriculture are based on re-using by-products, closing nutrient cycles, minimal feed-food competition, low energy use and low GHG emissions [1]. Moving from current linear to more circular systems is a wicked problem as key trade-offs need to be overcome [2]. The objective here is to provide quantitative insights into such trade-offs and discuss consequences.

2. Methods

We have quantified all N and P flows in the North of the Netherlands (NN) as a starting point to assess the options to improve circularity [3]. Agricultural flows were based on data at farm level and aggregated to municipality level. Flows from processing, consumption, waste and residues were derived from statistical data complemented by available detailed studies. In a next step, future options for integrated crop-livestock systems (ICLS) were evaluated in which feed import and environmental constraints were varied and gross margin was maximized using a linear optimization model [4]. Lastly, trade-offs between land requirements and N intensity in mixed faring systems were assessed for mainstream and organic systems.

3. Results

Within the NN region, farms but also municipalities were specialised. At food system level, losses for N ranged from 181-480 kg ha^{-1} while P losses were 7-31 kg ha^{-1}. Losses were largest in agriculture while recycling of nutrients in the food system was limited. The nutrient use efficiency was 25% for N and 59% for P, reflecting an inefficient and strongly linear system. Moving towards circular agriculture is expected to reduce these nutrient losses. However, potential benefits are not self-evident ICLS without constraints on NH_3 and GHG emissions increased gross margins due to more animals and a larger proportion of intensive crops, resulting in more feed and N imports and consequently more emissions. In scenarios with NH_3 and GHG emission constraints livestock strongly reduced, whereas more cash crops were grown. This negatively affected the gross margin of animal production system, while crop production systems benefitted. Also reducing N intensity increased land requirements exponentially for mainstream systems, while or organic systems least land was required at an N intensity equivalent to 90% of maximum yields.

4. Discussion

Re-integration of specialised crop and livestock systems is a key component of a more circular agriculture. Yet, it comes with trade-offs: ICLS without environmental constraints increases intensity [5]. This work shows that ICLS without limits for NH_3 and GHG increases gross margins, but does not result in desired environmental outcomes and increases feed-food competition. An increase in food-feed competition reduces the area that can be set aside for conserving biodiversity, further amplified when mineral N inputs are reduced or replaced by leguminous cut-and-carry crops. Apparent ecosystem services at farm level by decreasing feed and mineral N inputs may be disservices at the regional scale due to increased feed-food competition. Addressing such undesired feed-food competition and spare land for biodiversity in a circular system requires a shift in diets with a smaller proportion of animal products [6].

Van Selm *et al.* [6] found that reducing feed imports to the Netherlands strongly reduces NH_3 emissions and GHG emissions. We found the same for ICLS: restricting feed imports or imposing NH_3 and GHG emission limits strongly reduced the number of animals and feed requirements. This also implies that the gross margins of livestock sectors decreases. Furthermore, such constraints reduced feed-food competition and increases the available area for cash crops [4], with benefits for cropping sectors.

Current animal production systems in areas with access to cheap feed are very competitive on export markets. Including environmental costs in feed imports through Europe's harbours and pricing GHG emissions are key components to reduce profits and address environmental problems. Resulting revenues can be used to compensate incomes *via* targeted ecoservice payments that are needed to maintain specific habitats that are only found on low intensity farmland. We conclude that policies to address environmental impacts without changing the economic incentives for farmers are rowing against the current.

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How can we make biodiversity conservation an objective for farmers? (Oral #109)

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Keywords: biodiversity; conservation; farmers; management strategy determinants; interviews

1. Introduction

Growing awareness of the need to counter the erosion of biodiversity, coupled with political and social injunctions, are prompting rural stakeholders to build and manage agroecological farming systems in multifunctional landscapes. Biodiversity is a key component of these landscapes, which farmers are called upon to preserve and manage.

When asked about their interest in biodiversity, the majority of farmers say they are interested (Herzon and Mikk, 2007). However, this interest in biodiversity varies according to the taxa considered. For example, when it concerns birds or mammals, the majority of farmers would like to learn more about all species, except those known to cause damage to crops or livestock. When it comes to plants or insects, a distinction is made between "harmful" species and species of interest or tolerated. This perception of biodiversity also varies according to the type of farming considered. Kelemen *et al.* (2013) have shown that organic farmers adopt a more philosophical and holistic vision of biodiversity, linking it to the notion of ecosystems and the interrelationships between the organisms that make them up. Beyond the different types of farming considered, the perception of biodiversity depends on the personal background of each farmer and his or her interests outside professional activity, as well as the more or less biodiversity-rich environment in which the farm is located.

As part of an interdisciplinary project involving agronomists and management scientists, we looked at how farmers integrated biodiversity management and protection into their farm management, and what benefits they derived from it. The biodiversity considered, how biodiversity is integrated into the farm's strategy, and the expected benefits, were related to the farmers' background, production system, and the relationships they developed around biodiversity.

2. Materials and Methods

Thirty farmers were interviewed. These farmers were recruited either directly, or with the help of naturalist associations, chambers of agriculture, or hunting federations. They are located in a wide range of soil and climate conditions and operate a variety of production systems (market gardening, arboriculture, livestock farming, mixed farming - livestock farming, and arable farming), both organic and non-organic.

The interviews were recorded and transcribed in full. The transcripts were double-coded to identify the nature of the biodiversity taken into account, its degree of integration into the farmer's strategy, and the determinants of the farmers' consideration of biodiversity (determinants internal and external to the farmer), as well as the expected benefits.

3. Results and Discussion

Integrating biodiversity into farm projects engages farmers in a change of point of view, where biodiversity says something about the agroecosystem they manage. Whether to enhance the expression of ecosystem services (regulatory processes) or to conserve "wild" biodiversity on the farm. For some farmers, agronomical decisions are taken from a “biodiversity point of view”, by integrating temporal scales longer than that of the cropping season and spatial scales larger than the cultivated field. Their management strategies are guided by contextualized thinking, based on their knowledge of the functioning of their agroecosystems. From this point of view, the farmer's background is a key factor in the level of reasoning behind biodiversity conservation practices.

Whatever the category of farmers surveyed, biodiversity does not appear to be an economic issue for the farm, *i.e.* they do not expect any added value in the marketing of their production.

If we wish to integrate biodiversity conservation as an objective of the farm, in the same way as production, farmers need to reappropriate and recontextualize knowledge that they have little or no training in. Biodiversity then acquires a new meaning and says something about the agroecosystem they manage. Observation of how the agroecosystem works then becomes an imperative condition for change, an essential quality, not only for the pleasure of observing but also for taking ownership.

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Improving relay intercropping of service crop in cereal systems to cope with climate change (Oral #29)

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Keywords: service crop; on-farm experiment; tracking innovation; intercropping; adaptation

Service crops into crop rotations may provide ecosystem services and reduce dependency to inputs. Its relay intercropping into a winter cereal allows better conditions for service crop emergence in spring, compared to summer sowing, with limited risks for crop productivity (Gardarin *et al.*, 2022). Nevertheless, sowing the service crop into an established crop is constraining and may hinder its establishment as the provision of services (Vrignon-Brenas *et al.*, 2016). The risk of failure, increased with climate change, is a serious impediment to the implementation of such practice. This work aims at evaluating options, based on farmers innovations, increasing success of relay intercropping of a legume service crop in cereal cropping systems.

The research program CASTOR (TERRA ISARA) consists first in interviewing inspiring farmers and expert having experience in relay intercropping of service crop. It permitted to identify the main lock-in farmers were facing but also the rationale for action innovative farmers developed to overcome some of them. Thereafter, on farm experiments were designed with volunteer farmers to test some of the identified techniques in different agricultural, soil and climate conditions. 16 experiments were implemented in 2 years, mainly focused on service crop implementation and services evaluation. 2 main factors were crossed: 1/ service crop species and 2/ sowing methods leading to 7 to 10 experimental plots per field. Sowing methods principles were common (1/ broadcast sowing (BS); 2/ BS + harrowing (BSH) and optional 3/ row seeding (RS) but the implementation was adapted to conditions and available machinery. Cash crop, service crop and weeds density, biomass and nitrogen content were monitored from service crop sowing to the next crop harvest. In the same period, soil water and nitrogen dynamics were monitored.

No significant impact on winter wheat yield or protein content was observed. Due to bad climate conditions, the mean emergence rate of service crops was low (~20%). In most cases (12/16 fields), sowing of red clover (cv. Lestris-RC) led to a faster and denser establishment (183pl/m² at wheat flowering) compared to white clover (cv. Melifer-WC-~108pl/m²)(p-value<0.01). WC also led to lower mean biomass production at wheat harvest (125kgDM/ha *vs.* 300kgDM/ha – p-value<0.01) and higher risk of failure (almost 50% of WC treatments presented no clover biomass *vs.* 30% for RC). The mixture of red (50%) and white (50%) clovers (MC) presented intermediate emergence and biomass production.

BS generally permitted low emergence of clovers, whatever the sown species. Subsequent harrowing (BSH) significantly improved this emergence. RS permitted to increase rate of emergence of RC but not WC. WC small seeds were not adapted to some seeders used, making very difficult to control WC sowing density. Yet, WC survival was significantly increased with RS (~25% with no biomass compared to 55% for BS treatments) but this does not lead to higher biomass production. RS only permitted to increase significantly (p<0.01) the MC biomass at wheat harvest to a level almost equivalent to RC treatments (~350kgDM/ha *vs.* ~400kgDM/ha).

White clover, considered less competitive for cash crop, is often implemented by farmers testing relay intercropping. However, competition with an already established winter cereal disqualifies this species in our conditions, as WC is too sensitive to radiation limitation (Frame, 2005), being less adapted to cereal competition. Broadcast seeding of service crop, largely used by farmers clearly underperforms but subsequent harrowing significantly improves the service crop establishment. Some interviewed farmers suggest RS as a way to strongly reduce sowing failure but others feared potential damage to the cereal. If no significant impact on cereal yield was measured, this technique may not be adapted to every condition (*e.g.* soil compaction). It is time consuming and the question of profitability of such technique has to be addressed in comparison with the broadcast seeding with harrowing technique. The machinery used strongly influences the result of the sowing (*e.g.* seeder not adapted to very small grains).

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Higher crop diversity in less diverse agricultural landscapes in Northeastern Germany (Oral #82)

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Keywords: landscape heterogeneity; crop rotation; diversification; explainable artificial intelligence; land use

Planning for sustainable agricultural landscapes requires a comprehensive understanding of the needs of stakeholders. To achieve a sustainable agricultural system, the implementation of different strategies for diversification has been a promising approach. These strategies can target the overall landscape complexity to benefit biodiversity or diversify cropping systems to enhance and stabilise yields. Therefore, diversity at both agricultural field and landscape levels and their interconnection need to be considered (Reckling *et al.*, 2023). However, the impacts of different diversification strategies at different levels are rarely investigated jointly. This study aims to detect the relationship between the diversification strategies at field and landscape levels and to identify potential drivers to understand what synergy and trade-off dynamics of sustainable landscape planning emerge.

As a case study, we studied agricultural landscapes in the Brandenburg region of Germany (Schiller *et al.*, 2023). Crop rotational richness, Shannon's diversity, and evenness indices were measured per-field per-decade as proxies for crop rotational diversity. Landscape diversity was measured using land use land cover types and habitat types with the same metrics. As potential drivers of diversity, we included soil and climate characteristics and the proportion of agricultural and urban areas, along with geographical positions. All spatial information was aggregated within the landscape of 10x10 km in Brandenburg, Germany. We tested the links between all variables using interpretable machine learning methods to identify important modelled associations.

We found that more simplified landscapes with a higher proportion of agricultural area exhibited higher crop rotational diversity (r-squared = 0.2 – 0.6). Also, crop rotational diversity was higher with higher soil quality (r-squared = 0.1 – 0.13). Therefore, different diversity aspects can be found in contrasting regions in Brandenburg, where crop rotational diversity is particularly determined by local soil quality and the intensity of agricultural land use.

The more diverse the crop rotation, the simpler the landscape – This trade-off relationship implies the fundamental trade-off of diversification across scales due possibly to the limited high quality resources like soil for land development. We argue that a comprehensive understanding of the spatial distribution, synergies, and trade-offs of diversification (goals) within a landscape facilitates collaboration and planning among all parties involved in sustainable landscape planning (Duarte *et al.*, 2018). As we move forward, integrating diverse stakeholder perspectives, socio-economic farming conditions, and advanced AI techniques will play a pivotal role in shaping more sustainable landscapes.

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2023: a soil odyssey–HeAted soiL-Monoliths (HAL-Ms) to examine the effect of heat emission from HVDC underground cables on plant growth (Oral #277)

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Keywords: HVDC transmission; earth cable; root growth; thermotropism; HAL-M

Figure 1. Construction of the HeAted soiL Monoliths (HAL-Ms). (a) Subsoil with black duct tape as a root barrier and two transparent tubes offset by 90°; (b) topsoil with an FDR sensor; and (c) finished HAL-Ms in the greenhouse

1. Introduction

Renewable energies for sustainable and climate-neutral electricity production are on the rise worldwide. High-voltage direct-current (HVDC) transmission *via* underground cables gains influence to connect large production sides with consumer regions. In Germany, almost 5,000 km of new power line projects with an initial start date of 2038 or earlier are planned. During transmission, heat is emitted to the surrounding soil, but how this heat affects root growth and yield of the above crop plants is not well known and needs research.

2. Materials and Methods

For that purpose, we designed and constructed a low-cost large HeAted soiL Monolith (HAL-M) for simulating heat flows within a natural soil composition and density. 24 HAL-Ms with a height of 1.56 m and an approximate diameter of 0.56 m were built for this experimental setup. Each contained approximately 400 kg of soil, with a planting area of 0.177 m^2. The foundation of the twelve HAL-Ms was a barrel roller (HBR10, Hillesheim), equipped with a built-in heater. The HAL-Ms were filled with natural top- and subsoil extracted from two different sites near Bernburg and Merseburg (Germany, Saxony-Anhalt), representing the two different regional soil types 12x LOESS and 12x SAND as factor SOIL. For the factor TREATMENT, half of the HAL-Ms with LOESS and half of SAND were heated with constant 50° C (6x HEAT), and the other served as the control group (6x CTRL). For the factor RAIN, three levels (2x DRY 407 mm, 2x MID 528 mm and 2x WET 679 mm) were calculated based on data from 1988 to 2018 by the German Meteorological Service (DWD). We were able to observe root growth, soil temperature and soil water content over an extended time period. The plants were cultivated in three successive growth phases (GPs) simulating crop rotation. To avoid the need for vernalization, spring barley (*Hordeum vulgare*) GP1, sugar beet (*Beta vulgaris*) GP2 and spring wheat (*Triticum aestivum*) GP3 were cultivated.

3. Results

The yield of spring barley during GP1 under the SAND treatment was significantly reduced under the influence of HEAT (423.6 to 261.9 g m^{-2}). RAIN also exerted a significant impact on the yield, with higher values under WET than under MID and the lowest yield under DRY. Moreover, HEAT reduced the yield under the LOESS treatment (without statistical certainty). In contrast to spring barley during GP1, the sugar beet yield was higher under the influence of heat emission, at least under the LOESS treatment (5609.0 to 6608.0 g m^{-2}). RAIN imposed a significant impact on the yield, with the highest values under WET, declining from MID to DRY. There was no statistically significant difference between the CTRL and HEAT treatments for either soil type during GP3, although there was a slightly lower yield under the influence of heat emission. RAIN influenced the yield in a similar pattern to that of previous crops. There was no interaction effect between TREATMENT and RAIN on the yield during the single growth phases.

The root intensity during GP1 under simulated heat emission was significantly reduced at soil depths from 71.0 to 101.5 cm under the LOESSS and SAND treatments. In contrast to GP1, HEAT did not affect the intensity of sugar beet roots during GP2. During GP3, the root intensity at depths from 71.0–101.5 cm under the LOESS treatment was reduced under the influence of HEAT. There was a notable tendency for reduced root growth due to heat emission under the SAND treatment (p value=0.0585).

4. Discussion

We showed that under the simulated conditions, heat emission could reduce yield and root growth depending on crop type and soil. This experimental design can serve as a low-cost, fast and reliable standard to investigate thermal issues from cables of all kinds regarding various soil compositions and types, different precipitation regimes and several crop plants that are affected by similar projects. The HAL-M could serve as a link between pot and field trials with advantages of both and could be an enrichment for many research areas.

Maximizing tree diversity in cocoa agroforestry: taking advantage of planted, spontaneous, and remnant Trees (Oral #111)

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Keywords: cocoa agroforestry; tree diversity structure; tree diversity drivers; Ivory Coast

1. Introduction

Cocoa production is recognized as a main factor of forest loss and biodiversity declined in west Africa[3]. Thus, agroforestry is being promoted to restore a minimum forest cover, to conserve biodiversity, and to reinstate key ecosystem services in agricultural landscape. This introduced the Cocoa Forest Initiative in Ivory Coast and Ghana and several certifications for adequate forest cover in cocoa plantations while ensuring cocoa production[4]. Consequently, millions of trees are distributed in cocoa fields. However, it has largely failed, as very few trees have survived and developed properly[5]. Paradoxically, most forest tree species found in cocoa fields today are from natural regeneration, selected by farmers[5]. Three distinct cohorts of trees associated with cocoa plantations[5]: (1) trees spared during forest clearing (remnants), (2) transplanted or planted trees (planted), and (3) spontaneously recruited trees (spontaneous) after or during the creation of the cocoa plantation. The objective of this study is to understand the structure of tree diversity in Ivorian cocoa plantations and identify the main determinants.

2. Materials and Methods

Across 150 cocoa plots, we inventoried all trees with a diameter at breast height (DBH) ≥ 10 cm present on each plot. Twelve socio-environmental variables were measured/estimated for each plot.

(1) We calculated the Shannon’s Alpha and Beta diversity for each cohort and each pair of cohorts respectively and then expressed them in Hill numbers. (2) We assessed the effects of twelve socio-environmental variables on the alpha diversity of each cohort with a log-normal likelihood model.

3. Results

Alpha diversity in these fields comes from spontaneous and remnant trees, while planted trees exhibit very low Alpha diversity. However, since planted trees show high complementarity (resulting in high Beta diversity) with spontaneous and remnant trees. Several socio-environmental factors explain these different levels of observed diversity. These factors exhibit different effects by cohort.

4. Discussion

Planted or transplanted trees are typically fruit trees[6], Occasionally, commercial timber species are found[5] explained the low diversity observe. The remnant trees which are spared to provide shade for young cocoa plants[4] reflect the level of diversity of the forest preceding the cocoa plantation, a level that is very high[7]. Spontaneous trees mainly come from propagules from remnant trees[1]. That explained the high diversity of remnants and spontaneous trees. Planted trees and remnant/spontaneous are very complementary and can be explained by the exotic or non-indigenous nature of many planted species, particularly fruit trees[6]. Planted, spontaneous and remnants trees have different ontogenetic development Consequently, it is expected that performance trajectories and the factors modulating these trajectories will be very different among cohorts[2].

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Contribution of diversification to resilience capacities of agricultural systems (Oral #138)

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Keywords: robustness; adaptation; transformation; participatory approach; adaptive cycle

1. Introduction

Agricultural systems are vulnerable to pressure from multiple drivers, *i.e.* today's agricultural landscapes are neither sustainable in terms of long-lasting (Agovino *et al.* 2019), nor are farms resilient in terms of responsive to (external) pressures (Meuwissen *et al.* 2020).

Prevailing productivity-oriented management practices have led to structurally simplified landscapes, exacerbating the vulnerability to external pressure (Hermanns *et al.* 2017; Clough *et al.* 2020; García *et al.* 2020). To overcome the difficulties, which are linked to those simplified and intensified systems, there is a trend for diversification (Reckling *et al.* 2023; Beillouin *et al.* 2021) leading to changes and transformation of the agricultural system.

We explored the potential of agricultural diversification at field, farm, and landscape levels for overcoming short-term shocks and long-term challenges. We addressed the three resilience capacities robustness, adaptation, and transformation. We investigated (i) whether diversification can contribute to sustainable landscapes and resilient farms, and (ii) whether a farm can achieve the three resilient capacities robustness, adaptation and transformation simultaneously or whether there are trade-offs among those.

2. Methods

Employing a slightly adapted resilience framework developed by Meuwissen *et al.* (2019), we took a participatory approach to analyse the contribution of diversification options on the three resilience capacities in three research areas in Brandenburg (Germany).

3. Results

Our results show that various agricultural diversification options exist, which mostly aim at one resilience capacity of the resilience framework. However, our analysis leads us to the conclusion that a system cannot simultaneously fulfil all three resilience capacities. It is imperative to consider the concept of the adaptive cycle, as described by Gunderson and Holling (2002), wherein a dynamic systems moves through the distinct phases of exploitation, conservation, release, and reorganization. This cyclical nature was particularly evident in our examination of transformation capacity. While a resilient system should always possess the ability to undergo transformation, the process of transformation needs up so many resources, that afterwards a period of pause is required. Unlike the gradual processes of robustness and adaptation, transformation represents a more abrupt and profound shift within a system.

4. Discussion

The findings underscore the interconnectedness of diversification initiatives and resilience dynamics within agricultural systems. While diversification in general enhances the resilience of agriculture, different forms of resilience aim at different resilient capacities. While robustness defines a stable system, adaptation describes incremental adjustments and responses to changing conditions over time. In contrast to that, transformation manifests as a sudden and significant restructuring or reorganization of the system after which a phase of stability needs to come, as the system needs to recalibrate. they alternate rather than taking place simultaneously. A system is only resilient if it can alternate between all three capacities over a long period of time.

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Is crop diversification an efficient approach to reduce pesticide use? (Oral #26)

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Keywords: cropping system; diversification; pesticide; rotation

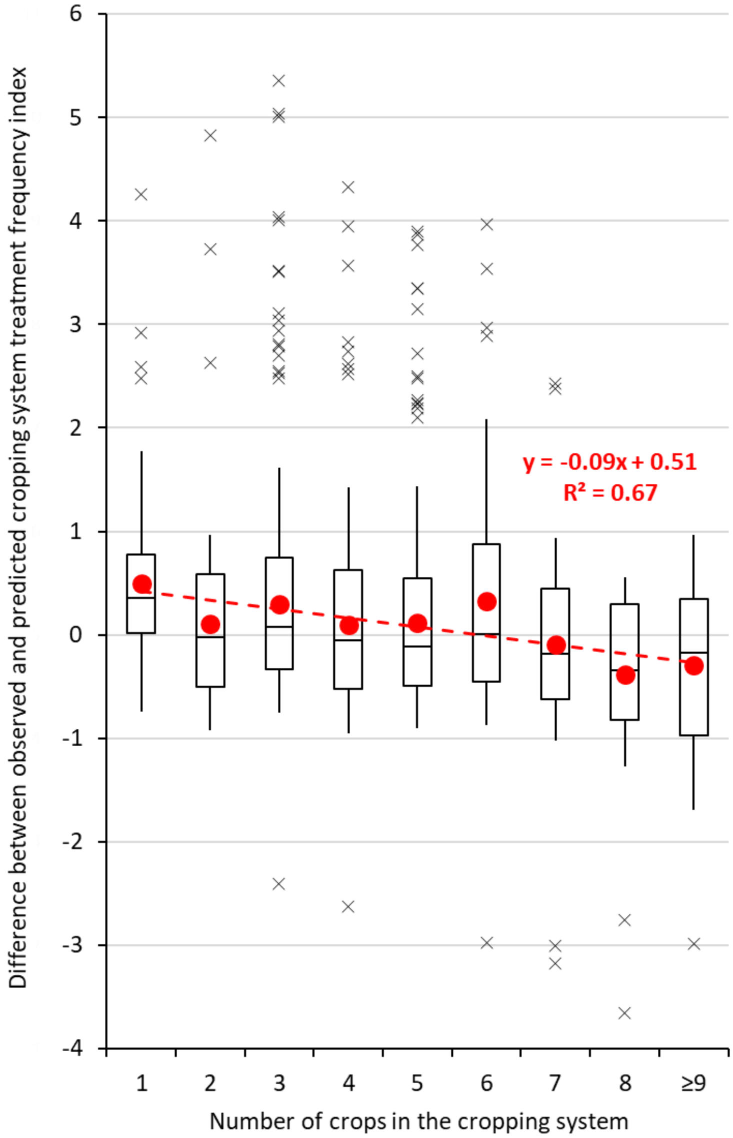

Figure 1. Difference between observed and predicted cropping system TFI as a function of crop number

Diversifying crop rotations in arable farming is considered as an option to regulate weeds, pests and diseases, and therefore to decrease the need for pesticides. However, the potential for reducing the reliance on pesticide through crop diversification had, so far, not been quantified at the cropping systems scale. In this study, we analysed this relationship from 1285 cropping systems described from 795 arable farms of the French DEPHY network. Crop diversity was assessed in each cropping system through the number of crops grown in the pluriannual crop sequence. The reliance on pesticides was measured with the Treatment Frequency Index (TFI), averaged over the same crop sequence. The relationship between TFI and the number of crops displayed a bell-shape curve, with maximum pesticide use for intermediate number of crops. This relationship was strongly driven by the nature of crops grown which varies with crop diversity. Indeed, monocultures were always based on maize, a crop with a rather limited reliance on pesticides in France. Two-crop rotations were often based on maize and wheat (a crop with an intermediate-high reliance). Three-crop rotations introduced oilseed rape (a crop with a higher reliance) while four-crop sequences introduced sugar beet (a crop with a high reliance) and potato (the crop with the highest reliance). On the other hand, the proportion of crops with low to very low reliance on pesticides (such as oat, buckwheat, and temporary grasslands) increased in cropping systems with higher diversity. Since the reliance on pesticides varies drastically across crops (examples of average TFI: 13.5 for potato, 5.5 for sugar beet, 4.8 for oilseed rape, 3.3 for soft wheat, 1.8 for sunflower and maize, 0.6 for alfalfa and 0.4 for buckwheat), the nature of crops grown is a major factor explaining 37% of TFI variance over the whole data set.

We removed the effect of the nature of crop grown by computing the difference between the actual cropping system TFI and the 'predicted' system TFI (weighted average of mean crop TFIs with weight being the proportion of each crop in the cropping system). This reveals that increasing crop diversity significantly decreased pesticide use by -0.09 TFI per additional grown crop (Figure 1). Finally, crop diversity accounted for only 1% of total TFI variance. The remaining variance can be explained by many other factors not considered in this analysis, but known to drive the level of pesticide use (Lechenet *et al.*, 2016) such as climate, soil type, pest pressure, cultivars, sowing dates, fertilisation, mechanical weeding, and strategy for decision to apply treatments.

The significant effect of crop diversity on pesticide use was lower than expected, particularly when compared to previous quantifications of the regulation of pests through crop diversity (Ratnadass *et al.*, 2012; Kremen & Miles, 2012; Larsen & Noack, 2021). Indeed, pest regulation due to diversification can be significant, but not strong enough to impact pesticide use if the regulation does not decrease pest pressure below the thresholds applied by farmers when making the decision of treatments. Analysing pesticide use at the crop level, Guinet *et al.* (2023) also found significant but quite low effects of cropping system diversity, consistently with our results. However, the number of crops is probably not the best indicator of diversity regarding the impact on pest regulation and pesticide use, so further investigation is planned to compare indicators integrating the functional crop diversity.

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Current coupled innovations for glyphosate-free agricultural systems (Oral #40)

Priscila Duarte Malanski, Bruno Chauvel, Marie Thiollet-Scholtus, Chloé Salembier

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Keywords: equipment; collective action; technical system; glyphosate; redesign

1. Context description and research question

Reducing pesticide use such as glyphosate, is a key challenge to support agroecological transition and resilience of farming systems. However, politicians and scientists argue that in certain situations, which they describe as "dead-ends", reducing glyphosate use is particularly difficult because of structural barriers (Reboud *et al.*, 2017). Then, our aim was to shed light on innovations from farmers – focus on technics, equipment and collective action - to reduce the use of glyphosate in two “dead-ends” situations: slopping vineyard and low-till cropping system.

2. Method and Theoretical background

We adapted a tracking on-farm innovation method (Salembier *et al.*, 2021): (i) We identified 16 cases through exploring databases, professional agriculture press, and contacting extension agencies. (ii) We performed semi-structured interviews with farmers about innovation. (iii) We analyzed the systemic nature of innovation thanks to an in-depth inductive analysis of each case, relied on the concepts of coupled innovation (Meynard *et al.*, 2017) and of action logic (Salembier *et al.*, 2021). (iv) We built typologies through a cross analysis of the case studies.

3. Results and Discussion

Three major results emerged: (i) We characterized five types of innovation on collective action that supported farmers’ access to key levers in weed management: 1) sharing resources (*e.g.* equipment, land, herd); 2) sharing labor (*e.g.* shared employee); 3) sharing technical management decision (*e.g.* collective decision in a common crop rotation); 4) developing a new resource (*e.g.* self-building an equipment adapted to sloppy vineyards); 5) accessing agricultural services. This typology corroborates and enhances the findings of Lucas *et al.* (2018). (ii) We identified three types of innovation on equipment to perform weed management: 1) flexible use of an equipment (*e.g.* a seed drill for sowing on straw and on cover crops); 2) combining equipment to perform two tasks at the same time; 3) designing and building a new equipment (*e.g.* under-vine mowing tool for terraced vineyard). (iii) We identified 3 types of coupled innovations. In vineyard: i) managing perennials on moderate to steep slopes (>30%), which is based on frequent tillage, using combinations of equipment (5 cases); ii) managing perennials on steep slope vineyards (30%) by covering the soil in inter-rows and employing moderate tillage under vine, which involves shared equipment and/or workforce (2 cases); and iii) weed management in terraced vineyards (30-40%) while limiting erosion and mitigating the challenges associated with working on steep slopes, through the use of self-built and shared equipment (2 cases). In cropping system: i) coordinating management of crops and livestock, which involved a few field interventions for weed management while also contributing to livestock feeding (*e.g.*, grazing on cover crops) and cost reduction (3 cases); ii) minimizing the harmfulness impact of weeds through the increase diversification of crop rotation, sharing equipment and/or workforce (2 cases); iii) eliminating weed in monoculture by employing precision equipment, as well as pooling workforce (2 cases). Our findings enrich the literature on coupled innovation in weed management strategies (Boulestreau *et al.*, 2022), and it provides evidence on how these systemic innovations work to address technical and organizational issues, which allowed farmers to manage weeds and cover crops in situations considered as strongly dependent on glyphosate in “dead-ends” situations. The innovations identified could inspire other farmers engaged in the redesign of their farming systems to be free from glyphosate.

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Reducing reliance on pesticides through redesigned crop management strategies has contrasting effects on economic performance across farm types (Oral #165)

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Keywords: reliance on pesticides; management strategies; real farm network; transition to sustainable agriculture; farm productivity

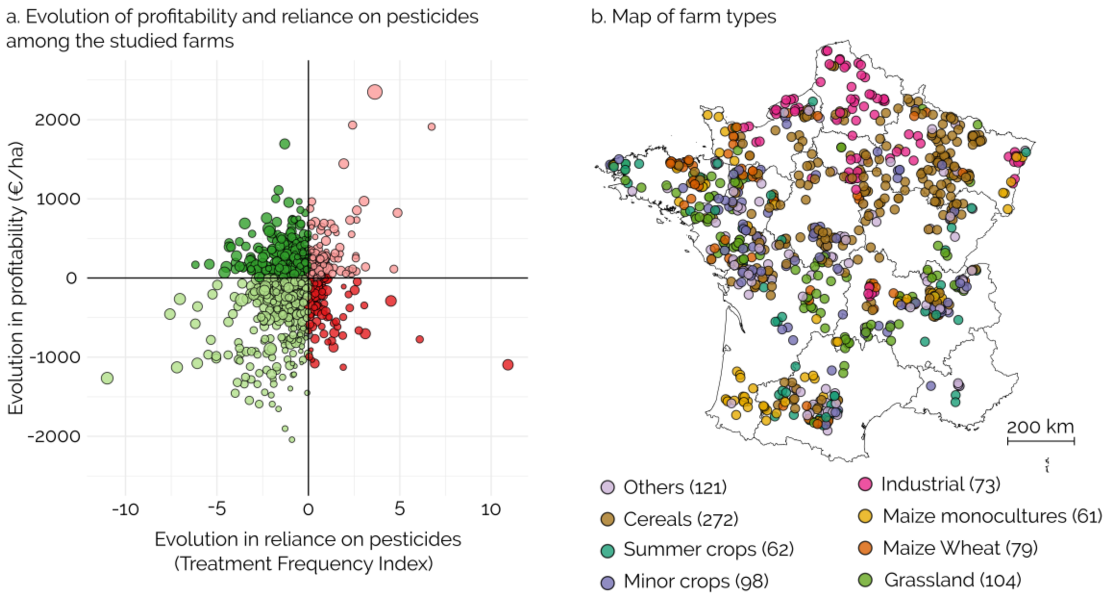

Figure 1. a. Evolution of profitability (y axis) and evolution of the reliance on pesticides (x axis), for 904 farms, over an average period of 9.2 years. The size of the point is proportional to the initial level of reliance on pesticides of the farm and colors correspond to four performance categories. b. Map of the eight farm types used in this study

1. Introduction

Intensive use of pesticides in agriculture has led to negative impacts on human and ecosystem health, and to policies aiming at reducing their utilization. Alternative non-chemical pest control strategies, based on holistic Integrated Pest Management implemented in real commercial farms, have been shown to substantially reduce the reliance on pesticides (Nandillon *et al.*, 2024). Yet, such strategies have remained poorly adopted, partly due to farmers' risk aversion and the general belief that using less pesticides reduces farm productivity and profitability. Bringing clarity on the link between cropping practices used to reduce farm reliance on pesticides and farm outcomes is needed to support practitioners in a transition towards a more sustainable agriculture.

2. Methods

We explored detailed data from the DEPHY network, describing cropping system and crop and pest management in 904 commercial French farms classified into eight farm types over an average period of 9.2 years. We investigated the effects of non-chemical crop management practices used to reduce farms' reliance on pesticides on three metrics of farm economic performances, namely margin (€/ha), production of energy (MJ/ha) and resource use efficiency (Total Factor Productivity). The marginal effect of the change in reliance on pesticides on the change in margin and gross-product was analyzed across the eight farm types. The economic feasibility to reach the 50% objective in pesticide use reduction set by the French Ecophyto National Action Plan and the Farm to Fork strategy was investigated.

3. Results

On average, farm reliance on pesticides was reduced by 20% and farm profitability by 13% (-100€/ha) over the studied period. Cropping practices implemented in order to reduce reliance on pesticides had contrasting effects depending on the productivity metrics used and farm type. Crop diversification was positively associated with Total Factor Productivity and had positive build-up effects on margin. Tillage intensity had positive effects on margin and production of energy. There were farms that reduced reliance on pesticides with increased margin and gross-product in all farm types but this portion differed across farm types. Farms growing large quantities of high value-added crops such as sugar beet and potato most often showed the highest reductions in both gross-product and margin. Increases in margin and gross-product with reductions in the reliance on pesticides occurred most often in farms with much grasslands. Reducing farms' reliance on pesticides by 50% would decrease farm profitability by a further 80 €/ha on average.

4. Discussion

This study brings insight into the consequences on farm economic performances of transitioning to an agriculture using less pesticides. The contrasted effects of reductions in the reliance on pesticides on productivity metrics across farm types illustrate the need to consider multiple aspects of farm productivity when evaluating agricultural sustainable transition. Our results shed light on key crop management practices that should be incentivized by policy makers in order to make progress towards a more sustainable agriculture.

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The effects of increasing the intensity of legume crops or legume/oilseed mixtures in the cropping rotation at research and commercial scale in SE Australia (Oral #216)

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Keywords: legume nitrogen; intercrop; economics; sustainability; farm scale

Treatment	Crop Rotation	Legume Intensity	Applied Nitrogen (kgN/ha/yr)	Total Fertiliser Cost ($/ha/yr)^	Nitrogen fertiliser cost ($/ha/yr)*	Total Chemical Cost ($/ha/yr)^	Total Costs ($/ha/yr)^	Gross Margin ($/ha/yr)	Profit:Cost Ratio	Nitrogen fertiliser Cost (%GM)*	Total chemical costs (% GM)^
Baseline(L)	Canola(L)-Wheat(L)-Wheat(L)	0	87	258	149	336	853	1002	1.25	15%	34%
Baseline(H)	Canola(H)-Wheat(H)-Wheat(H)	0	131	318	224	336	920	1034	1.19	22%	32%
Diverse 3-year	Lupin/Faba-Canola(L)-Wheat(L)	1 in 3	47	169	80	354	792	990	1.32	9%	36%
Intense Base(L)	Canola(L)-Wheat(L)	0	96	281	163	350	920	963	1.12	18%	36%
Intense Base(L)	Canola(H)-Wheat(H)	0	140	335	239	350	981	1017	1.12	25%	34%
Intercrop	Intercrop-Wheat(L)#	1 in 2	35	122	61	254	555	674	1.19	12%	38%
Diverse 2-year	Chickpea-Wheat(L)	1 in 2	27	125	46	377	748	865	1.18	6%	44%

* Calculated from Urea price at avg $1.71 kgN (6-yr avg) - no operation costs were included

^ Total costs include operations such as spreading and spraying expenses

Intercrop – fababean/canola or chickpea/linseed mix

(L) – low nitrogen strategy (conservative)

(H) – high nitrogen strategy (aggressive)

Table 1. The treatments, crop rotations, quantity of nitrogen fertiliser applied and economics from two experiment sites across 6 years in SE Australia between 2018 and 2023

Sowing a legume crop every third year in a crop rotation of cereal and canola can be profitable while increasing the resilience and sustainability of modern farming systems. Some of the benefits include increased soil nitrogen (N) availability and improved rotational and environmental outcomes. In no-till farming systems, sowing large-seeded legumes into retained cereal residues facilitates stubble retention, reduce N tie-up and improves the conversion of carbon-rich cereal stubbles into stable soil organic matter. We explored whether additional benefits to the sustainability and resilience of the farming system was possible by increasing the intensity of legumes by either sowing a legume, or a legume-oilseed intercrop mix every second year followed by a cereal. These effects were explored at both small-plot and larger on-farm paddock scale and explore the reasons for low adoption of pulse crops on commercial farms in southeastern Australia, despite experimental evidence of economic and environmental benefits of these diverse systems.

Two fully phased replicated field experiments (2018-2023) confirmed that legume inclusion in Diverse 3-year cropping rotations can be as profitable as Baseline rotations (canola-wheat-barley) currently favoured by farmers. The average 6-year gross margin (GM) in the Diverse 3-year rotation was 4.3% lower and total chemical costs 5% higher than the Baseline(H) system, however, systems incorporating a legume were less risky (higher profit:cost ratio) with up to 66% reductions in synthetic nitrogen (N) fertiliser usage. The reduced synthetic N in the Diverse system represented only 9% of the total GM compared to 22% in the Baseline(H) system (Table 1). Increasing legume intensity in a Diverse 2-year rotation resulted in a 15-16% reduction in GM compared to the Baseline(H) or Intense Base(H) and 7% increase in chemical costs. However, there was a 63% reduction in fertiliser cost and 81% decrease in synthetic nitrogen costs compared to Baseline(H), which represented only 6% of GM costs for synthetic nitrogen.

Intercrops have focussed on pulse/oilseed mixtures comprising fababean/canola or chickpea/linseed due to specific synergistic benefits related to improved N fixation, reduced disease epidemics such as Ascochyta Blight, Chocolate spot caused by *Botrytis fabae* and *Botrytis cinerea* and to improve legume height and support for improved harvesting. The 6-year GM from intercrop-wheat rotations was significantly lower (34%) compared to the Baseline(H) with similar profit:cost ratio (1.19:1). However, the sustainability and resilience were improved including 75% less synthetic N and 27% less chemicals required (Table 1). The faba-canola mixture generally produced more legacy N compared to the chickpea/linseed. In 2023, an average rainfall year (550mm) with low Ascochyta Blight, the chickpea monoculture grain yield was 3.65 t/ha. T and there was a 58% reduction in chickpea grain yield when linseed was sown with chickpeas in alternate rows with 0.9 t/ha linseed grain yield. In mixed rows and chickpea sown at half rate, the chickpea yield reduction increased to 86% (yield of 0.5 t/ha) and linseed yield increased to 1.55 t/ha (Table 1).

At farm scale, when the business is managed at a high level of efficiency, changing management strategies to include legumes was effective and profitable for growers by reducing the: (i) amount of synthetic N required, (ii) herbicide resistant ryegrass weed seedbank, and (iii) economic fluctuations at the whole-farm level. In 2022 at our paddock scale long-term farming systems experiment, the faba bean/canola intercrop yielded 3.8 t/ha of faba bean and 0.5 t/ha of canola compared to 2.3 t/ha and 3.3 t/ha in faba bean and canola monocultures, respectively. The coefficient of variation was reduced by 30% in the intercrop with 86% less fungicides applied. The canola supported the faba bean crop reducing the disease pressure and yield loss.

Our work suggests outcomes of experimental research on the value of diverse crops into cereal-based systems should be combined with a clear understanding of farm- and industry level constraints in Australia. There are significant challenges moving from a cereal-canola rotation to include a pulse grain at farm scale including capital for machinery and equipment, new farmer skills, pulse grain price volatility, extra grain storage and reduced cash-flow with more grain stored. There’s considerably higher skill levels and extra costs for seed separation at harvest for intercropping farmers. These logistical issues at farm-scale remain a barrier to wider adoption despite promising results at experimental scales.

Canopy anomaly classification using Hybrid ML, a case study on potatoes (Oral #155)

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Keywords: hybrid ML; crop anomalies; crop growth models; AI; potato

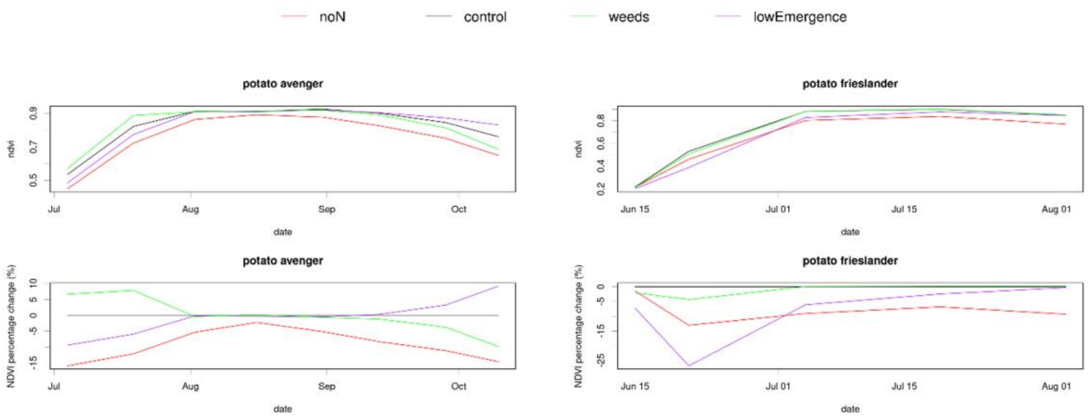

Figure 1. Results from year 1 of experimentation. NDVI (top) and NDVI percentage change compared to control for the two cultivars (Avenger, a late cultivar and Frieslander an early cultivar)

1. Introduction

Crop canopy reflectance is often used as a proxy for crop vitality. While it relatively easy to identify low vitality spots through vegetation indices (*e.g.* NDVI, WDVI, *etc.*) automating the identification of the causes of the low vitality spots remains an unsolved challenge. In fact factors that can cause a drop (or an increment) in vegetation indices, for example water and nitrogen abiotic stress, and biotic stresses like soil and air-borne diseases, and weeds. The objective of this project is to create a model to detect the presence low vigor (*e.g.* poor spots on an NDVI map) and identify its cause for potato crops.

We are developing a hybrid model (Scientific ML) composed a recurrent neural network trained on a synthetic data set generated using a potato growth model (Tipstar), coupled to a canopy reflectance model (PROSAIL). The model will consume time series data of multispectral signatures as well as data on crop management (*e.g.* fertilization, water stress, maturity class), weather and soil to facilitate the identification of the anomaly. The appearance of different stresses at different times in the season will be a major driver of the predicted stress factor, for example low emergence will cause an initial decrease in canopy vigor indicators — like NVDI — that will decrease as the season proceeds and canopy will close. The model will be validated on experimental data described below.

2. Materials and Methods

2.1 Field experiment dataset

In the first year two cultivars were cultivated over 6 plots without replicates and canopy reflectance was monitored bi-weekly through a hyperspectral sensor and a drone multispectral images, along with final yield and bi-weekly SPAD measurements. In the second year (2024) we are repeating the experiment with three replicates and two sites. Preliminary results from the second year of experiment will be presented.

2.2 Synthetic dataset

We generated a synthetic dataset of crop growth and its spectral canopy under multiple stress factors. Crop growth was simulated using Tipstar – a potato growth model – whereas canopy spectra was simulated using Prosail, a radiative transfer model.

The first dataset is a factorial *in-silico* experiment with the following factors: two sites, 10 different growing seasons, two cultivars (one early and one late cultivar), 5 stress factors.

No interaction between the stress factors was simulated (*e.g.* no low emergence and water stress in the same simulation).

The factors that were accounted for in the model are the following:

- Control was simulated as potential yield (no stress factor) by adding ample nitrogen fertilization and irrigation events
- Water stress was simulated by removing irrigation events
- Nitrogen stress was simulated by removing nitrogen fertilization events
- Low emergence was simulated by halving the number of emerged plants
- Weeds – a process that is not present in the crop model – was simulated by increasing the leaf area index input in the prosail parameter at the beginning and at the end of the season.

2.3 Modelling

The models are trained on the synthetic dataset and will be validated on the observed dataset. A first model serving as baseline for model comparison was developed based on difference between the observed NDVI and the NDVI of the simulated causes of anomalies.

3. Results

Results from more complex models, based on recurrent neural network classification and multiple inputs (time series of reflectance at different wavelengths instead of crude indices like NDVI, management information) algorithms will be presented.

Data from the first year experimentation (Figure 1) indicate that the time development of the different stresses, weed stress results in higher NDVI at the beginning of the season, nitrogen stress results in lower NDVI through the season, lower emergence in an initial decrease of NDVI that is recovered as the season proceeds, and individual plants expand.

Preliminary results from the baseline model indicate a good model fitness, with more difficulties in identifying the cause of stress in the middle of the season because of the saturation of the NDVI signal. Results from more complex models will be presented.

Coupling experimentation and crop modeling to evaluate morpho-physiological traits of cotton cultivars in agroecological cropping systems in Benin (Oral #140)

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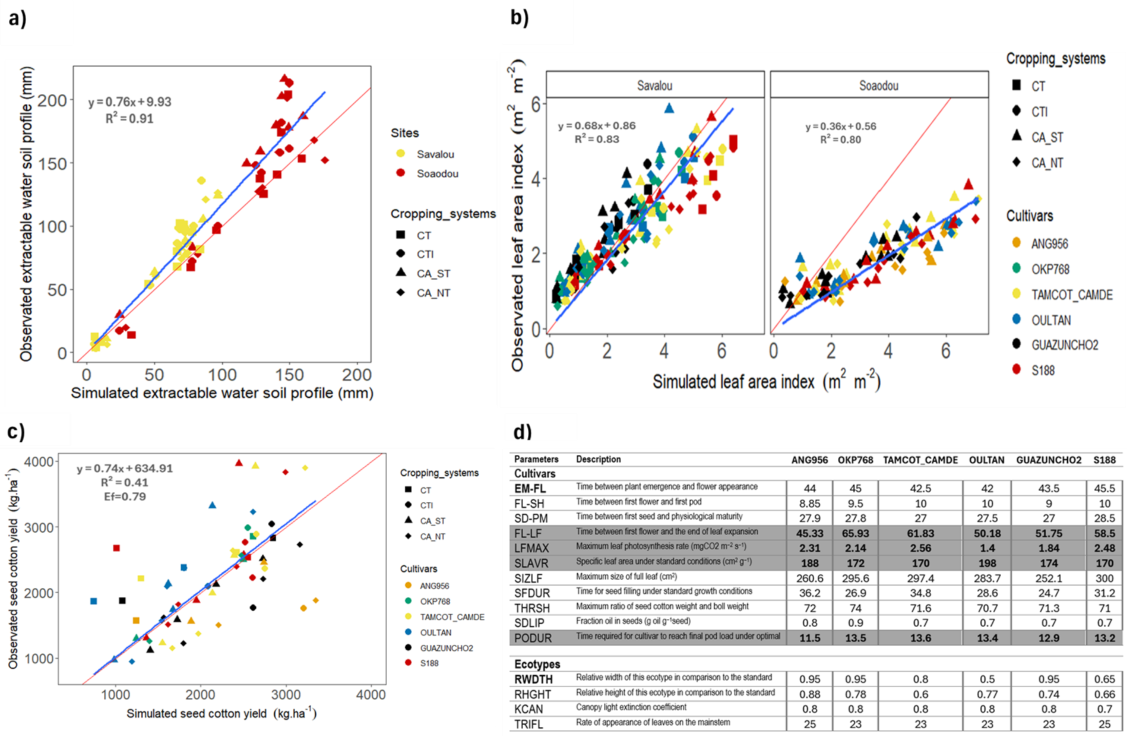
Keywords: tillage; water status; cover crop; nitrogen; CSM-CROPGRO-cotton



Parameters	Description	ANG956	OKP768	TAMCOT_CAMDE	OULTAN	GUAZUNCHO2	S188
Cultivars							
EM-FL	Time between plant emergence and flower appearance	44	45	42.5	42	43.5	45.5
FL-SH	Time between first flower and first pod	8.85	9.5	10	10	9	10
SD-PM	Time between first seed and physiological maturity	27.9	27.8	27	27.5	27	28.5
FL-LF	Time between first flower and the end of leaf expansion	**45.33**	**65.93**	**61.83**	**50.18**	**51.75**	**58.5**
LFMAX	Maximum leaf photosynthesis rate (mgCO2 m^{-2} s^{-1})	**2.31**	**2.14**	**2.56**	**1.4**	**1.84**	**2.48**
SLAVR	Specific leaf area under standard conditions (cm^2 g^{-1})	**188**	**172**	**170**	**198**	**174**	**170**
SIZLF	Maximum size of full leaf (cm^2)	260.6	295.6	297.4	283.7	252.1	300
SFDUR	Time for seed filling under standard growth conditions	36.2	26.9	34.8	28.6	24.7	31.2
THRSH	Maximum ratio of seed cotton weight and boll weight	72	74	71.6	70.7	71.3	71
SDLIP	Fraction oil in seeds (g oil g^{-1}seed)	0.8	0.9	0.7	0.7	0.7	0.7
PODUR	Time required for cultivar to reach final pod load under optimal	**11.5**	**13.5**	**13.6**	**13.4**	**12.9**	**13.2**
Ecotypes							
RWDTH	Relative width of this ecotype in comparison to the standard	0.95	0.95	0.8	0.5	0.95	0.65
RHGHT	Relative height of this ecotype in comparison to the standard	0.88	0.78	0.6	0.77	0.74	0.66
KCAN	Canopy light extinction coefficient	0.8	0.8	0.8	0.8	0.8	0.7
TRIFL	Rate of appearance of leaves on the mainstem	25	23	23	23	23	25

Figure 1. Main results of parametrization and calibration of 6 cotton cultivars in cropping systems in Benin

1. Introduction

Cotton is Benin's leading export crop grown in different climatic zones. As a result of poor farming practices in agroecosystems leading to a decline in soil fertility, coupled with the phenomenon of climatic hazards, seed cotton yields of cultivated varieties are low. Given the context of soil degradation, agroecological practices are proposed as an alternative to conventional cropping systems. The emerging challenge for breeders is therefore to select new cultivars adapted to innovative cropping systems (Gouleau *et al.*, 2021). Crop simulation models can be used to assess growth and yield of different crop genotypes (G) in different environments (E) by using environment-specific weather, soil, and crop management (M) practices (Boote *et al.*, 2001) and help understanding the direct effect of each plant trait or a combination of traits on the G by E interactions for crop yield and other complex traits. The objectives of this study were (i) to evaluate the relative contribution of plant traits driving the G by E by M interactions for cotton yield using CSM-CROPGRO-cotton model from DSSAT, and

(ii) to identify morpho-physiological traits for yield enhancement in agroecological cropping systems in Benin.

2. Materials and Methods

The experimental study was conducted from 2020 to 2023, in two sites (Savalou and Soaodou) representative of contrasted cotton-growing regions of Benin. Approach consisted of (1) carrying out field experiments for the calibration and validation of CSM-CROPGRO-cotton model and determining the yield performance of cotton genotypes (2) launching a sensitivity analysis of the genetic coefficients from the crop model to determine the best values for traits adapted to agroecological cropping systems. According to a split plot design, the experiment compared four cropping systems with cowpea/maize//cotton rotation, namely Conventional Tillage (CT) with a plough, Conventional Tillage with Incorporation of biomass (CTI), Conservation Agriculture with Strip Tillage (CA_ST) and CA with No Tillage (CA_NT). In the three innovative cropping systems (CTI, CA_ST, CA_NT), legumes (*Crotalaria* spp., *Stylosanthes guianensis*) were sown as relay intercrops with maize while cotton was sown as a sole crop. Six different cultivars originated from Benin, Argentina, Uzbekistan, Nicaragua, and USA were compared as subplots in every cropping system. Among other parameters, crop model was parameterized for soil properties and water dynamics, and calibrated for phenology and growth, using a dataset under optimal conditions, then evaluated on other data from the same sites and 2 years.

3. Results

The agreement between simulated and observed data was strong for extractable soil water (Figure 1a), and LAI (Figure 1b) but fair for seed cotton yields (Figure 1c). Our results confirmed that CSM-CROPGRO can be used to simulate the growth and yield of cotton in different environments and cropping systems and for the estimation of genetic coefficients (Figure 1d). The availability of soil nitrogen was better in agroecological systems. The cultivars TAMCOT_CAMDE, S188 and OKP768 resulted in higher yields in the agroecological cropping systems under CA. The traits LFMAX, SLAVR, FL-LF and PODUR were responsible for yield differences and GxExM interactions.

4. Discussion

Maximum leaf photosynthetic rate (LFMAX) is related to traits that maintain high photosynthesis (Boote *et al.*, 2001). In fact, increasing the value of this trait resulted in a decrease of SLAVR, indicating leaf thickening for leaf types like okra S188 or TAMCOT_CAMDE ensuring better nitrogen mobilization and radiation use efficiency, especially in CA systems. Increased availability of nitrogen in CA_ST and CA _NT made it possible to maintain green leaf area, delayed senescence of leaves (FL-LF) and a longer accumulation of reserves during seed filling (PODUR) (Wells *et al.*, 1982) leading to an increase of boll weight.

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Operational yield forecasting and crop management with a digital twin (Oral #57)

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Keywords: digital twin ; potato; yield forecast; nitrogen; irrigation

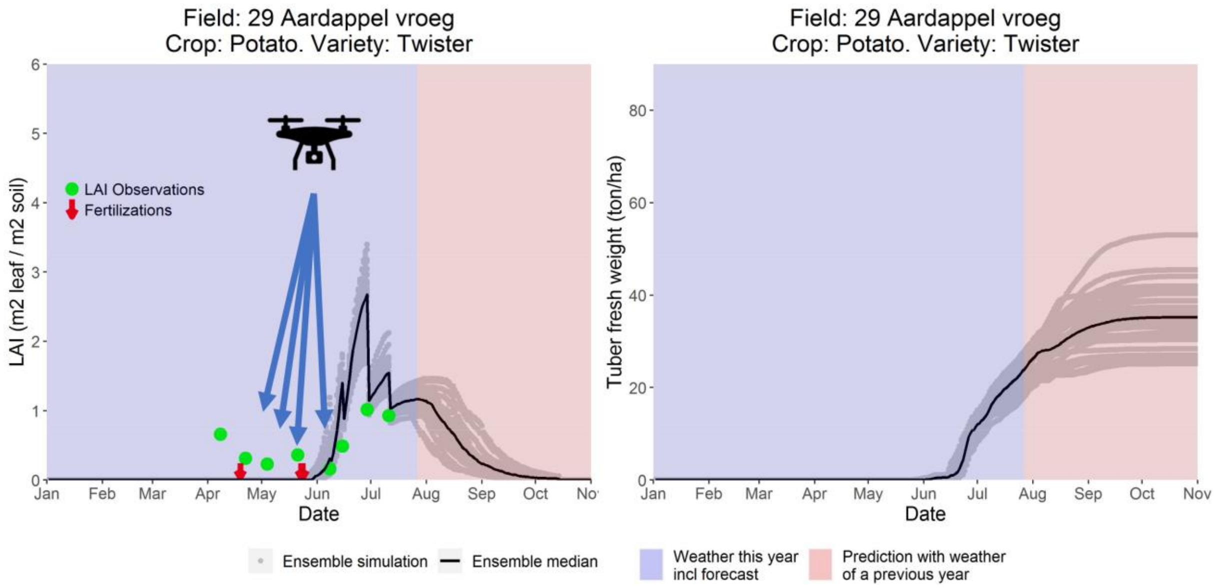

Figure 1. Mid July 2024 forecast of Leaf Area Index (LAI) and tuber yield. Figure showing an ensemble of simulations (grey dots) and median of simulations (black line). Green dots show LAI estimates based on drone images. Four green dots in April-May were pre-emergence and ignored. Green dots mid-June and July cause a downwards correction of simulated LAI. Simulations continue with the downward adjusted LAI

1. Introduction

Crop growth models can provide real-time forecasts of upcoming drought or nutrient deficiencies and can thus in principle be used to support decisions about irrigation and fertiliser application. To be useful for supporting in-season crop management, forecasts need to be (1) frequently updated and (2) sufficiently accurate. This second point is problematic in practice, because crop models tend to deviate from reality, due to insufficient calibration, and because not all relevant processes are included. A digital twin (van Evert *et al.* 2021, Knibbe *et al.* 2022) combines crop growth modelling with updating model state variables based on in-season observations. A digital twin provides daily updated estimates of growth forecasts and also shows how these forecasts are corrected with observations. Ideally, such a digital twin results in greater forecasting accuracy, for the end-user more confidence in model predictions and ultimately more efficient resource management. We developed a fully automated operational digital twin for a strip cropping experiment in the Netherlands.

2. Materials and Methods

The digital twin strip cropping (DTS) has the following properties:

1. Field experiment in centre of Netherlands, with in total 7 crops and 11 strips per crop. Not all crops were modelled

2. Strip specific management data retrieved through Farmmaps platform (Been et al 2023)

3. Location specific soil and weather data retrieved through Farmmaps

4. Bi-weekly drone flights. Stitching and geo-referencing by a private company then imported into relational database as soon as available

5. Two crop growth models used: Tipstar for simulating potato (early and late cultivar), and WOFOST for fababean, onion and winter wheat

6. Ensemble Kalman Filter (EnKF) adjusts model states based on LAI observations derived from drone images, taking into account both the uncertainty in the model (estimated by perturbating model parameters) and the uncertainty in the observation.

7. NMODCOM simulation framework for integrating different models and enabling EnKF

8. Forecasting by stitching weather till present date, a 14 day forecast, and thereafter from a year in the past (*e.g.* 1991, 1992, *etc*). Simulations are repeated 30x with 30 past years to get a plume visualising uncertainty due to future weather

9. Automatic running the digital twin overnight for all 5 crops x 11 strips x 30 weather combinations

10. R-scripts generated daily figures. A new website was developed to present the most recent forecasts every day.

3. Results

Figure 1 presents an illustration of forecasts presented to the farm manager. More daily updated figures are available from https://farmofthefuture.nl/data-precisietechnologie/gewasgroeimodellen/ (in Dutch).

4. Discussion

The work presented represents one of the first operational digital twins in the agricultural domain. Farm managers showed greater appreciation for potential of models to support their decision making because we provided daily updated forecasts and visualized how these were updated with data from drone images (*e.g.* Figure 1).

Scientifically we are still in a pioneering stage. A major advantage of using a filter to update the state variables that it allows to correct the predictions for processes that are not currently in the model, *e.g.* canopy diseases. We are currently working on an advanced version of the digital twin where in addition to leaf area index also soil moisture is updated using satellite images.

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Envirotyping to drive spring barley adaptation in northwestern Europe (Oral #141)

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Keywords: target population of environments; multi-environmental trials; crop modeling; climatic factors; envirotyping

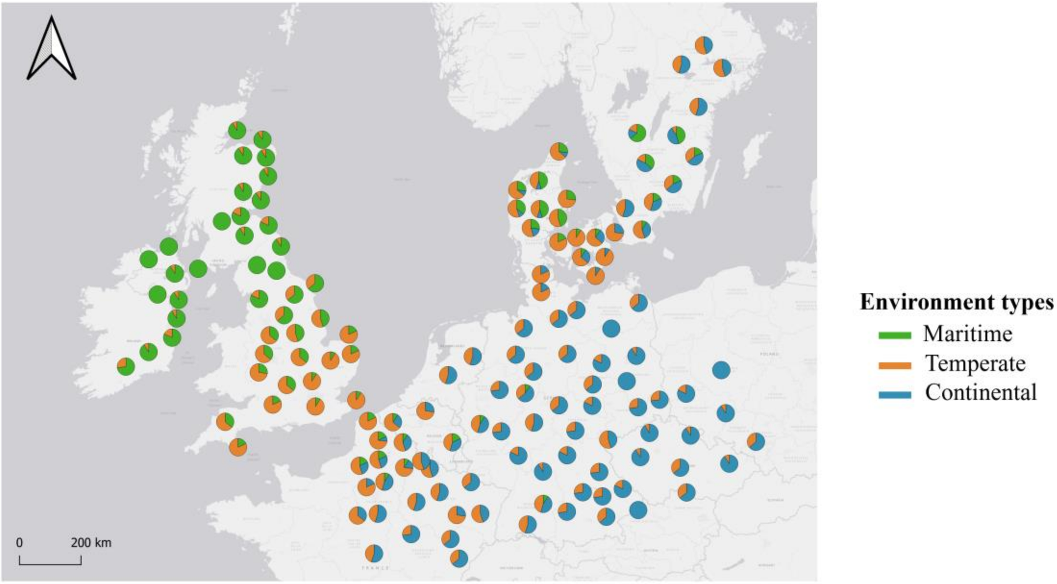

Figure 1. European Target Population of Environments of the two-row malting spring barley. The environment types' were identified based on the genotype x environment interactions drivers. The frequency of occurrence of each environment type was calculated and represented on the map using pie charts

1. Introduction

Adapting crops to climate will be challenged by shifting environments and increasing weather instability impacting both yield potential and stability. Exploring genotype x environment interactions (GEI) sources at large scale to develop outperforming and stable genotypes is an important step. Defining the Target Population of Environments (TPE) across the crop production area – *i.e.*, set of climatic scenarios minimizing GEI – is an approach to identify the specific or broad adaptation of a genotype to climatic scenarios. Crops models are powerful tools to accurately characterize crop environments and the origin of GEI (Chenu *et al.*, 2011). Spring malting barley is a cereal crop largely understudied in plant ecophysiology. This biological model is distributed worldwide and cultivated under contrasting agro-climatic conditions, with a short cycle, lending vulnerability to climate change. Our study aimed to (i) highlight the main eco-climatic factors – climatic variables calculated between two growth stages – driving yield levels and GEI for yields and (ii) define the spring malting barley European Target Population of Environments (TPE) for crop adaptation.

2. Materials and Methods

Yield data from 2015 to 2022 were collected from an European multi-environment trials (MET) network. The phenology-calibrated CERES-Barley model (DSSAT) was used to calculate 91 eco-climatic factors from historical weather data to characterize each environment of the MET. Partial Least Squares (PLS) regression analyses were carried out to identify the main eco-climatic factors impacting yield levels and relative yields of genotypes across Europe (Elmerich *et al.*, 2023). An environmental classification was performed based on the GEI-drivers across 1,450 environments, including tested and untested locations within the European area of production to define climatic scenarios minimizing GEI.

3. Results

Water stress was not identified as a major yield-driver. Results suggested an important contribution of cool temperatures at early stages to explain yields variation sources across the MET. Strong regional contrasts in the critical phenological stages for yield levels were observed. The grain filling period had the lowest influence on yields. Eco-climatic factors driving GEI differed from those of yields. Elevated temperatures during stem elongation, solar radiation and drought during grain filling shown a high contribution to GEI. Thermal amplitude around anthesis also emerged as influent. Three main environment types (ETs) were identified from the GEI-drivers and contrasted in their patterns of temperatures during vegetative growth, solar radiation intensity, and water stress during grain filling. The frequency of occurrence differed in time and space across Europe (Figure 1). Heterogeneity in genotype adaptations to environment types were observed, with genotypes having specific adaptation to one environment type while others with broad adaptation.

4. Discussion

Without limiting assumptions, this approach clarified the environmental sources of inter and intra-annual variability in yields. To adapt to climate change, agricultural practices will need to evolve to minimize exposure to adverse climatic factors during critical growth phases. Shift sowing can be used, but the crop may be exposed to potential critical factors during the short spring-summer season, which includes cold stress or waterlogging. The choice of adapted cultivars will also be a key decision, as their sensitivity to climatic factors differs. The drivers of GEI contrasted with those of yields, allowing the identification of three major environment types minimizing GEI. Performances of the existing germplasm across the TPE showed contrasted responses that can be directly used for product positioning. This work will help breeders to cope with GEI for spring barley breeding, by weighing trials using MET-TPE alignment, defining more efficient trial networks and designing ideotypes for specific or broad adaptation (Cooper *et al.*, 2022).

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Combining artificial intelligence and co-design to build scenarios for an agroecological transition of farming systems (Oral #177)

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Keywords: constraint programming; agroecological practices; market gardening; agroforestry

1. Introduction

To address agricultural challenges, engaging agroecological transition is crucial, necessitating a redesign strategy for productive and resilient biodiversity-based farming systems. However, implementing spatio-temporal design of diversified systems is complex due to the diverse factors that need to be considered, the large number of possible crops combinations in time and space, and the need to combine different forms of knowledge to take account of operational constraints, soil and climate conditions, and agroecological objectives. To support the design of agroecological cropping systems, we propose to combine together AI (constraint programming) which provides formalisms with a high level of expressivity (Challand *et al.*, 2023) with co-design approaches that enable stakeholders with diverse skills and knowledge to collaborate, while putting the farmer at the centre of the design ecosystem. This approach has been applied to one of the most complex agrosystems, the mixed orchard market gardens, to explore crop allocation scenarios with the farmer that take tree growth into account.

2. Materials and Methods

The model AGROECOPLAN, used in this study to generates a spatio-temporal crop allocation solution, has been described in Challand *et al.* (2023). The model is composed of four sets of constraints to take into account pedoclimatic, operational and agroecological constraints: respect the return time of crops, forbid negative spatial interactions (spread of pests, incompatible cultivation operations, shade from neighbouring crops or trees…), forbid unfavourable precedents, forbid impossible locations. The model then optimizes two criteria to propose a cropping plan that maximizes the positive spatial and temporal interactions between crops.

The model was used in a case study one-hectare micro-farm in South of France. The objective was to assign the 60 crops from the cropping calendar to the 80 cropping beds, considering the crop assignments of the last 3 years and the farm's pattern. The co-design workshops were conducted in three steps: (i) identify and formalise the problem through a semi-directive interview with the farmers (ii) run the AGROECOPLAN model to propose a crop allocation scenario (iii) evaluate with the farmer the model's output and performance. If the solution is deemed unsatisfactory, the set of constraints is modified with the farmers to better specify the problem and the model is run again (repeating step 2) until a satisfactory solution is found.

3. Results

The co-design workshops led farmers to formulate three issues that guided the exploration of the scenarios. (i) How to add the maximum green manure beds to improve the agroecosystem performances? (ii) How will the growth of fruit trees change the layout of crops in the future? (iii) What crop area is needed to satisfy all the farmers' expectations? The model was able to find solutions that satisfied all the constraints for each of these three issues. This required several iterations each time to better specify and prioritize the constraints.

To answer the first question, two green manures were selected with the farmers: fodder beet and forage rye. By maximizing the number of green manures, 10 fodder beet beds and 24 forage rye beds were introduced, increasing the total number of positive interactions between crops by 16%. By taking into account the growth of the trees, we have been able to adapt the cultivation plan over long time, allowing crops that need or tolerate shade to benefit from it. Finally, exploration of the scenarios to answer the third question showed that 7 additional cropping beds were needed to find a cropping plan that met all the farmers' expectations. This corresponds to a 9% increase in cultivated area, which was feasible in this case study.

4. Discussion

By integrating constraint programming into a co-design approach, we effectively managed the complex combinatorial nature of designing highly diversified farming systems and took account of farm-specific constraints and farmer expectations. This process introduced a disruptive solution for farmers, providing a basis for discussion on how to evolve their practices in order to strike a balance between integrating agroecological principles and maintaining acceptable operational management. This makes it possible to integrate many internal (soil-plant interactions) and external (management practices, climate) regulations that underpin the resilience of agro-ecosystems.

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Deep learning with limited data availability: self-supervised learning for crop yield prediction using RGB drone imagery (Oral #321)

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Keywords: deep learning; small data; yield prediction; UAV; self-supervised

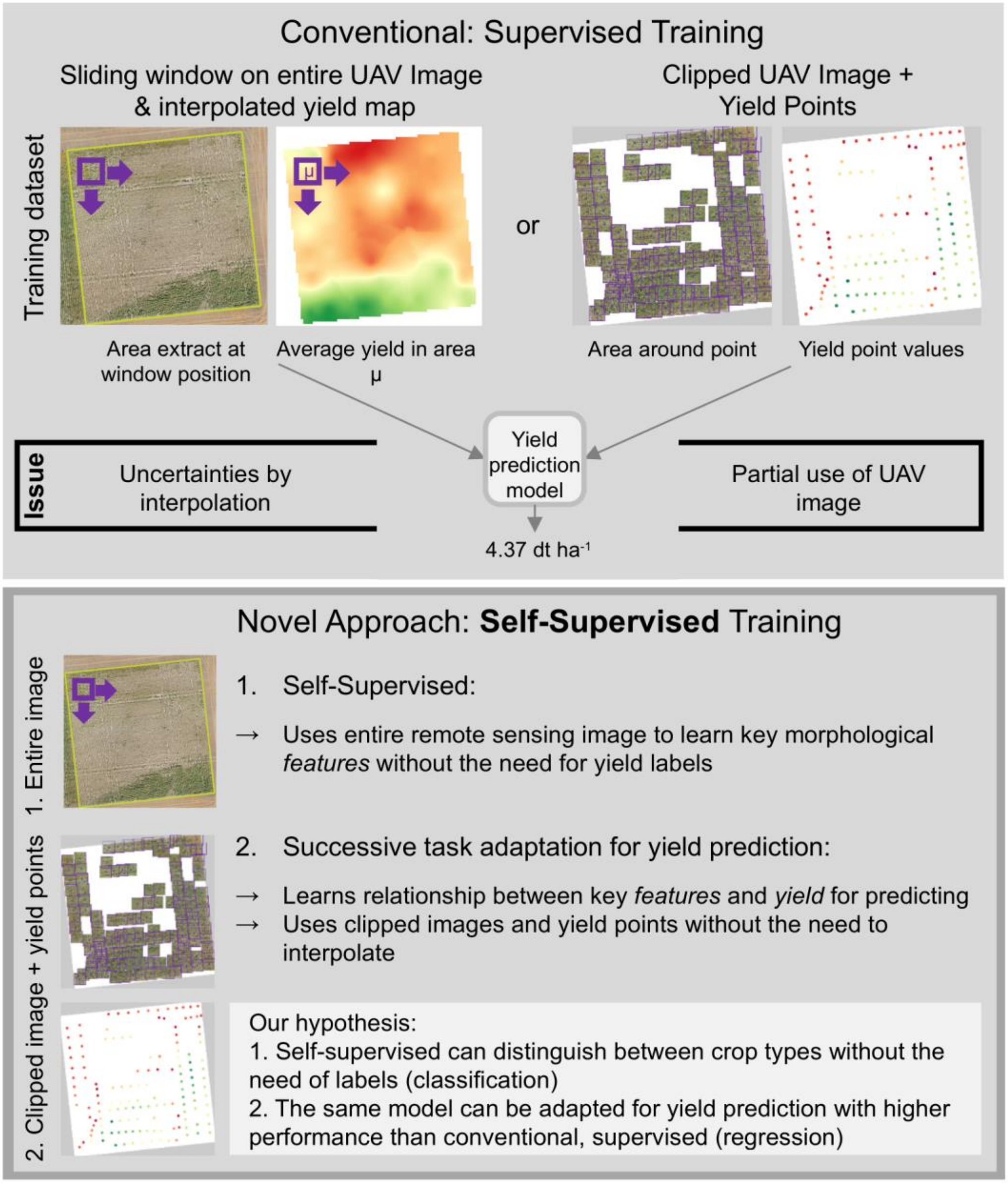

Figure 1. Yield prediction in small fields

1. Introduction

Deep learning-based methods have shown success in predicting crop yield. However, it is still a challenge to train a deep learning model to effectively predict crop yield with only a few labeled observations, especially across small agricultural fields with high heterogeneity. Self-supervised learning (Liu *et al.*, 2021) is a new technique addressing the challenge, but no study has examined the potential for crop yield prediction. Our aim is to investigate the potential of self-supervised learning for yield prediction using RGB drone imagery across multiple crop types. This study explores the synergistic potential between self-supervised learning and RGB drone imagery to address this challenge.

2. Materials and Methods

Our study was conducted at the patchCROP agricultural landscape lab in Brandenburg, Germany, examining four summer crops (lupine, maize, soy, and sunflower) in 2020 (Grahmann *et al.*, 2024). The research utilized high-resolution (~2.2cm) RGB images from UAVs, capturing the crops at the stages from late fruit development to ripening, across diverse small field arrangements (0.5 ha each). At each field, a combine harvester collected around 120 yield points. We employed the self-supervised learning algorithm, VICReg (Bardes *et al.*, 2022), to train a deep learning model on a dataset comprising four crop types and multiple fields to learn key morphological patterns without using labels (amount of fields: lupine = 3, maize = 6, soy = 2, and sunflower = 3). Successively, we adapted the task of the same model for predicting crop yield. The prediction performance was compared to a conventional, supervised baseline model.

3. Results

A key empirical finding was the ability of self-supervised learning to distinguish between crop types without labels based on morphological features. For crop yield prediction, we evaluated the model performance in two ways. Self-supervised showed a high prediction performance when compared between observations and predictions regardless of crop types (Pearson's r 0.83). When prediction performance was evaluated for each crop type, it decreased (lupine, r = 0.4; maize, r = 0.78; soy, r = 0.15; and sunflower, r = 0.43) but was still substantially better for three crop types than the conventional supervised learning model (lupine, r = 0.07; maize r = 0.9; soy, r = 0.07; and sunflower = 0.24). Overall, a median score of r for the self-supervised model was 0.42, and for the supervised model was 0.16.

4. Discussion

Our study demonstrates the promising potential of self-supervised learning in diversified agriculture. We showed that self-supervised learning can make use of large, unlabeled, combined image datasets across different crop and management types to discover key morphological patterns, and then the model can be used for crop yield prediction across crop types at good accuracy. This finding is important because currently so many deep learning models have been developed for different crop and management types independently. Self-supervised learning can unify the efforts and develop a more generalized model that can be applied in various cases. Yet, we also identified inconsistencies in prediction accuracy across and within crop types, emphasizing the importance of careful model evaluation and further development. Our findings advocate for the use of self-supervised learning to overcome data limitations and improve predictive modeling in small-scale agriculture.

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Provision of ecosystem services by biodiversity-based cropping systems in the context of climate change: a 50-year simulation in western France (Oral #327)

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Keywords: biodiversity-based cropping system; long term; crop diversification; nature based solution; agroecosystem; ecosystem services; agroceology

1. Introduction

Biodiversity-based cropping systems are a promising option for agriculture to meet socio-environmental issues under climate change. Yet, the levers that could be employed to establish a system based on biodiversity, such as crop diversification, require a degree of coordination with the underlying agroecosystem processes and the specific requirements of farmers. The long-term impacts of diversified systems are particularly challenging because design and assessment methods are not yet adapted. We hypothesized that crop models, combined with other tools, can be used to assess the impacts of biodiversity-based cropping systems on the provision and stability of ecosystem services over time. In this way, we implemented a disruptive crop succession with the STICS model (Brisson *et al.*, 2003; version 10.0.0) and estimated the long-term (50-year) trade-offs between the ecosystems services of this biodiversity-based cropping system in a temperate oceanic region.

2. Materials and Methods

The STICS model was used to simulate the long-term effects of a biodiversity-based cropping system on three variables: (i) the annual quantity of nitrates resulting from mineralisation in the topsoil (0-60 cm), (ii) the annual quantity of nitrates leached (beyond the sol depth measuring 110cm) and (iii) the annual soil organic carbon stock. These variables represent two regulating ecosystem services: regulation of soil quality and regulation of water quality.

The topsoil characteristics were as follows: 18.8% of clay; pH of 5.9; organic matter content of 2.8%. Historical climate data (1973-2023) from SAFRAN model and DRIAS projection data (2023-2073) were used for two IPCC climate scenarios (representative concentration pathways (RCP) 4.5 and 8.5).

The biodiversity-based cropping system was co-designed through two participatory workshops with local experts (two farmers, two technicians and one researcher). The resulting cropping system comprised 16 crop species (eight cash crops and eight service plants) over a six-year period. In order to facilitate comparison, two additional cropping systems were virtually implemented: a conventional two-species rotation (corn-wheat) that is commonly found in western France, and an agroecological diversified rotation that was recently tested in western France. The simulations were conducted over a 50-year period, with three different climate scenarios considered: the past climate (1973-2023), and scenarios RCP 4.5 and 8.5 (both 2023 to 2073). The evolution of variables was then analysed through time series statistics, using the R software (version 4.3.3). A functional principal component analysis was conducted to characterise each series and to identify temporal patterns. Subsequently, a linear regression model with time interaction was employed to compare the consequences of the biodiversity-based cropping system *vs.* the two additional systems, for each period.

3. Results

The results are still being compiled and statistically analysed. Nevertheless, preliminary findings indicate that the annual quantity of nitrates resulting from mineralisation is higher in the soil where the biodiversity-based cropping system is implemented compared to the two additional systems. One possible explanation for this phenomenon is the supply of N-rich residues by leguminous plants introduced through the biodiversity-based cropping system. However, the higher quantity of nitrates resulting from mineralisation in the biodiversity-based cropping systems is also accompanied by more frequent nitrates leaching events. The soil organic carbon stock decreases in all three situations, but the biodiversity-based cropping system reaches balance earlier than both additional systems, with a higher balance value. These results indicate a positive evolution of the regulation of soil quality service over time for the biodiversity-based cropping system, while the regulation of water quality service deteriorates due to increased nitrate leaching compared to the other systems. The subsequent phase of this research will involve the study of additional variables to assess the contribution of biodiversity-based cropping systems on the provision of other ecosystem services and their stability over time (*e.g.* crop yields for the provisioning service, greenhouse gas emissions for climate regulation).

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Unravelling the diversity of technical operations in diversified perennial-based cropping systems: the case of smallholder immature rubber intercropped with pineapple in Rayong, Thailand (Oral #45)

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Keywords: rubber; intercropping; management practices; Typ-iti method

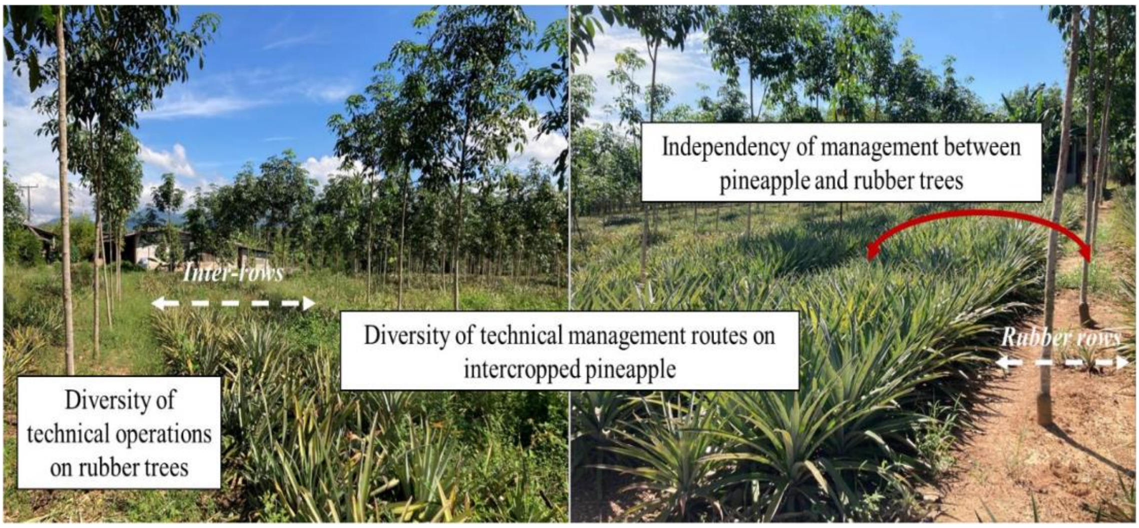

Figure 1. Detailed characterization of technical operations and management at the plot scale in diversified perennial-based cropping systems: Example of Rubber + pineapple immature plantations in Rayong, Thailand

1. Introduction

Diversification practices in perennial-based cropping systems (*e.g.* agroforestry, intercropping, *etc.*) are promoted for their global positive effects on the agroecosystems' performances at the plot scale (Beillouin *et al.*, 2019). In Thailand, intercropping with various crops is often adopted in smallholder rubber plantations during the first four years, to cope with the challenges of the immature period. In the literature, these cropping systems are usually characterized by describing the crop choice in the inter-rows only, without considering the associated technical operations (Simon *et al.*, 2024). This study aims at (1) characterizing thoroughly the diversity of technical operations applied to intercrops and rubber trees and; (2) understanding the relationships between the managements of intercrops and rubber trees.

2. Materials and Methods

We conducted interviews in Rayong province, Thailand, with 24 farmers that had at least one rubber plantation between 1- and 4 years old, intercropped with pineapple. All the technical operations applied on pineapple and rubber trees respectively were recorded on a timeline. The "Typ-iti" method (Renaud-Gentié *et al.*, 2014), combining multivariate analysis, clustering and association rules, was used to explore the diversity of technical management routes (TMRs) adopted on pineapple. The technical operations applied to rubber trees were compared with pineapple management clusters through mixed linear models to analyze possible relationships between managements in the inter-rows and rubber rows.

3. Results

Regarding pineapple management, three initial clusters were observed based on TMR from the soil preparation to the first harvest. Clusters 1 and 2 were constituted of 11 and 8 TMRs respectively, implemented by farmers producing pineapple for industries. They were both characterized by the use of fruit crowns as planting material and an intensive flower induction, but differing in terms of chemical fertilization and weeding. Cluster 3 was constituted of six TMRs, implemented by farmers producing pineapple for local markets, and was characterized by the use of plant suckers as planting material only, with less chemical products used compared to Clusters 1 and 2. A last cluster, named Cluster 4, consisted of TMRs implemented by all farmers, spanning from the first harvest to the second, and was distinguished by a decrease in chemical inputs. A diversity of technical operations was also observed on rubber trees, particularly in the frequency of chemical fertilizer applications, the frequency of weeding operations and the weeding methods used. However, the differences in technical operations applied to rubber trees were not linked to the pineapple management.

4. Discussion

This study highlights the large diversity of technical operations in rubber + pineapple immature plantations. Contrary to expectations and in contrast to what was observed in other perennial cropping systems (Koussihouèdé *et al.*, 2020), pineapple and rubber trees are managed independently. More globally, our results underline the need to not only consider the crop choice but also the possible diversity of technical operations and the plot level strategies of farmers to better understand the variability of performances in a multicriteria assessment (Perrin *et al.*, 2023).

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Adoption of cereal-legume intercropping in France: a matter of outlets? (Oral #21)

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Keywords: crop mixtures; farming practice; diffusion of innovation; factors of adoption

Intercropping consists of growing two or more crop species simultaneously on the same field [1]. Cereal-legume intercrops are a particularly beneficial association, with benefits in controlling the spread of diseases, insects and weeds [2], which can reduce chemical inputs use [3] while improving protein content and yields [4]. Despite all those benefits, cereal-legume intercrops are not widely grown in France as farmers face technical and economic barriers [5,6]. To better support farmers in adopting cereal-legume intercropping, it is necessary to identify the factors favourable to its adoption on farms.

Here, we propose a quantitative study highlighting the factors structuring the adoption of cereal-legume intercropping on French farms. Our objectives are (i) to identify the main factors fostering the adoption of cereal-legume intercropping at the national scale and (ii) to determine the existence of factors at the local level that differ from those observed at the national level.

We used data from the 2020 French Agricultural Census, a national survey conducted once every ten years that provides an exhaustive photograph of the French agricultural situation (Metropolitan France and French overseas departments and regions). The survey follows two questionnaires, one more detailed than the other and only used on a sample of 70,000 farms (from a total of 450,000 farms) representative of French agriculture. We used data from the more detailed questionnaire, focusing on the 43,968 farms specialised in arable crop, mixed crop-livestock or livestock systems, which have the potential to grow mixtures of cereals and legumes. Based on a literature review, we identified 42 variables that can affect the adoption of cereal-legume intercrops. These variables cover aspects related to types of farming, organic and conservation agriculture, agroecological practices, marketing channels and involvement in groups of farmers. Then, we performed a Random Forest analysis to select the most relevant variables among those 42 at the national level. For more interpretability, we represented the results with a Classification and Regression Tree (CART). To account for local specificities, we ran the CART model obtained at the national level on three areas where we identified strong dynamics of adoption based on French agricultural statistics (Centre-East, around Jura department, dominated by dairy cattle farming; South, around Aveyron department, dominated by sheep and meat cattle farming, and Centre-West, around Loire-Atlantique department, a more diversified area, with arable, cattle, and mixed crop-livestock farming).

Our results indicate that in France, organic farming, grain storage on farms, and livestock with feed autonomy for cattle and sheep are the main factors linked with the adoption of cereal-legume intercropping. Grain storage on farms and animal feed autonomy indicate that farmers use their intercrops on farms or sell them outside the agricultural cooperative channels. These findings suggest that the availability of outlets can represent a critical factor in adopting cereal-legume intercropping. Only a few agricultural cooperatives in France collect intercrops, and only in organic farming systems. The belonging to a farm machinery cooperative also came out as a factor favouring the adoption, as it can help overcome technical barriers through shared equipment and knowledge. We found the same factors at the local level but with some specificities. Our results suggest that local dynamics can be created through collective actions in the short term and the development of new market opportunities in the longer term.

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Legume-based crop rotation impacts productivity and resource use efficiency in south-eastern Australia (Oral #222)

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Keywords: cropping systems; ecology; economics; legumes; long-term

Legume-based mixed cropping systems play a crucial role in maintaining crop productivity while reducing reliance on inorganic nitrogen inputs and enhancing resilience under climate change.

Our research provides valuable insights into the long-term economic and ecological implications of adopting specific legume-based crop rotation systems, thus empowering growers to make informed decisions and facilitating widespread adoption.

The study used APSIM simulations to evaluate four distinct crop rotation systems: Canola-wheat (R1), Lucerne-lucerne-lucerne-canola-wheat (R2), Fababean-canola-wheat-barley-fababean-wheat (R3), and Fababean-barley-oat-canola-lupin-wheat (R4), considering varying nitrogen levels (0, 50, 100, 150, and 200 kgN/ha) across different climate scenarios covering historical (1984-2024) and future projections under RCP2.6, RCP4.5, and RCP8.5 (2025-2085) in four contrasting locations (Boorowa, Cootamundra, Condobolin, and Ardlethan) in NSW.

The study revealed notable differences in soil organic carbon increase (R2>R4>R3>R1) regardless of nitrogen fertilizer rates, with diminishing differences among crop rotations as nitrogen level increased. Considering wheat as a benchmark, the highest yields were observed in R1 and R3 (R1>R3) compared to R2 and R4 but yield variability increased. Moreover, the study highlights a relatively greater yield response to nitrogen rates in R1 and R3 (R1>R3). Therefore, integrating legumes such as lucerne, fababean and lupin significantly enhanced soil organic carbon levels while maintaining crop yields, suggesting the potential to achieve optimal yields with reduced fertiliser nitrogen input.

This research highlighted the value of legume-based crop rotations to improved productivity, resource-use-efficiency, and resilience of agricultural systems and offers practical insights for sustainable agricultural practices in southeastern Australia.

Combination of crop production strategies for plant protein production in Europe (Oral #326)

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Keywords: protein-crops; multi-strategy approach; optimization strategies; green transition; organic production

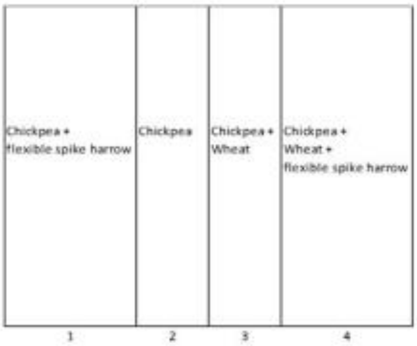

Figure 2: On-farm experiment carried out in Spain to evaluate the combination of mechanical weeding (flexible spike harrow) and intercropping (chickpea and wheat).

Table 3 Weed density per m² before flexible spike harrow pass and percentage of weed reduction after the flexible spike harrow pass

Treatment	Weeds/m2	Weeds * reduction (%
Chickpea	125	42
Chickpea and spring wheat	82	36

*After flexible spike harrow pass

2 combined techniques: **intercropping + harrowing**

- ➢ 70% weed reduction
- ➢ **Efficient strategy for weed control**

Plant proteins are part of the new generation of proteins for the green transition towards a neutral European continent in 2050. The cultivation of protein crops reduces the climate footprint, diversifies production systems and enhances human nutrition. Hence, the SMART PROTEIN EU project has targeted four species to develop sustainable protein supply chains for the future: fava beans, lentils, chickpeas and quinoa. To increase the cultivation area with these species, cropping systems need to be optimized. For this purpose, partners located both in North and South of Europe, tested combined production strategies involving the management of the genotype, environment and production practices for pest and disease control towards productivity enhancement. As weed control strategies, Denmark combined in three species (fava beans, lentils and quinoa) the following strategies: sowing dates (early and late, separated by 7 days) with the preparation of a false seed bed (10 days preceding sowing), and a subsequent harrowing 30 days after sowing. The Netherlands validated a decision support tool, founded in plant pathology data bases, in order to define the best rotation that included fava bean. In addition, they compared the production under conventional *vs* organic (management) with different genotypes of this pulse. In the south of Europe, Spain tested on-farm the combination of species (intercropping with chickpea) with mechanical crop management (harrowing) and in lentils the synergy of the number (1 to 3) and time of harrowing passes (early and late passes separated by 6-15 days). Finally, Italy tested different levels of irrigation (1/3 and 2/3 of full ETo) both in chickpeas and lentils.

Main results outlined that the combination of strategies leaded to the control of weeds. In The north of Europe (Denmark), the implementation of the false seed bed strategy in early sowings of the three protein crops reduced weeds by up to 10% compared with the late sowings as it was revealed by drone images. When this strategy is used and combined with mechanical control, weed prevalence can be reduced. In the southern region of Europe *i.e.* Spain, weed control tested through intercropping (chickpeas and spring wheat) and harrowing gave the following results: compared with the sole chickpea crop, intercropping reduced weed density by 34% whereas harrowing reduced weeds by 42%. The combination of both techniques: intercropping + harrowing reduced weeds in a total of 70% resulting in a very efficient strategy for weed control. In lentils, early harrowing was more effective for weed reduction than late harrow passes (55% *vs* 30% with one pass and 64% *vs* 35% with two passes). The validation of a decision support tool such as Best4Soil helped in the Netherlands to suggest convenient crop rotations with fava beans that reduce risks of yield damage caused by pathogens linked to the introduction of protein crops. The comparison between conventional *versus* organic production of different fava beans genotypes in the Netherlands depicted cultivars tolerant to diseases (LG Viper, LG Cartouche) that can reach interesting yields of up to 5 t ha-1 without the use of chemicals. Finally, in Italy, different levels of irrigation did not have significant differences in chickpea but in lentils, with an irrigation that considers 1/3 of the ETo it is possible to enhance yields by 24% (1.679±0.36 kg ha^{-1}). These experiences in the north and south of Europe highlight the importance of multi-strategy approaches that consider different components, tools and stakeholders. The combination of production strategies can enhance protein production under organic systems. Nevertheless, non-favorable climate events and the lack of adapted genetic materials to the pedo-climatic conditions are important limitations to consider.

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Improvement of chickpea yield through intercropping with common wheat in two Mediterranean locations (Oral #271)

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Keywords: crop diversification; pulses; agroecology; organic agriculture; sustainable agriculture

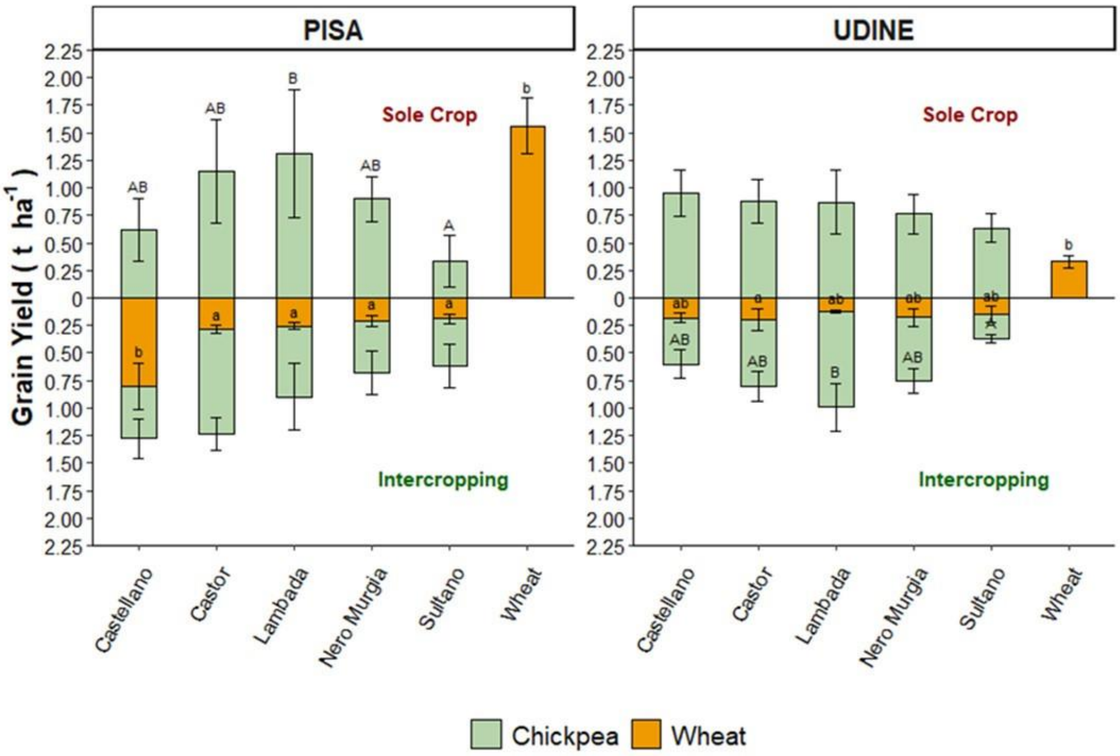

Figure 1. Chickpea grain yield (t ha^{-1}) of the five different cultivars (*Castellano*, *Castor*, *Lambada*, *Nero Murgia, Sultano*) in intercropping and pure stands (green bars). Orange bars refer to grain yield of wheat cultivated in intercropping and sole crop. Values with the same letter are not significantly different at 0.05 confidence level. If there are no letters, there was no significant effect of the cultivars. Data were analysed separately for chickpea sole crop and intercrop. Capital letters refer to chickpea, whereas the lowercase letters refer to wheat. Bars represent the standard error

The growing interest in locally produced plant-based proteins calls for an increased European production of minor grain legumes, including chickpea (*Cicer arietinum* L.). However, the European agricultural area dedicated to pulses is less than 3% of the total arable land. The scarce cultivation of grain legumes is due to multiple factors, among them the low yields coupled with yield instability between years, which derives from the high susceptibility of grain legumes to abiotic and biotic stresses. Nonetheless, the practice of intercropping has been demonstrated to stabilise legume yields. However, there is still few information on the effect of the cultivar on intercropping performance.

The main objective of this study is to evaluate whether it is possible to stabilise the yield of chickpea through its intercropping with wheat (*Triticum aestivum* L.) in a Mediterranean environment. Furthermore, we investigate which chickpea cultivar is most suitable for intercropping. The experiment was organised in a randomised complete block design with four replicates. Three experimental factors were investigated: chickpea cultivar, intercropping and location.

The trial considered five chickpea cultivars, of which three belong to the Kabuli group (*Sultano*, *Lambada* and *Castellano*) and two to the Desi group (*Nero della Murgia* and *Castor*). They are commercial cultivars from Italy (*Sultano* and *Nero della Murgia*), France (*Lambada* and *Castor*) and Spain (*Castellano*). The wheat cultivar used was *Bolero*. Each chickpea cultivar was grown as a sole crop and in intercropping with wheat. The study started in spring 2023 and will end in spring 2025, in two locations: Pisa, Central Italy and in Udine, Northern Italy. Both locations fall under the North Mediterranean climate category, as indicated in the Environmental Stratification of Europe, despite having different rainfall pattern. No pesticides or fertilisers were used, and mechanical hoeing weeding was performed once on the sole The 2023 results show similar behaviour in terms of grain yield and aboveground biomass of both the chickpea cultivars and wheat, with higher values in Pisa than in Udine.

In both locations, on average, chickpea aboveground biomass was lower in intercropping than monocropping, regardless the chickpea cultivars. The biomass reduction due to intercropping was 38% in Pisa and 74% in Udine. Significant differences between cultivars were found only in Pisa and only in intercropping, where the cultivars that produced more biomass than the others were *Sultano* and *Lambada*. In Pisa, at chickpea flowering, intercropping significantly reduced the aboveground biomass of weeds. This underlines the ability of the cereal to suppress weeds in the early stages of legume development. No differences in weed development were observed between the different cultivars.

On average, chickpea produced 33% less when intercropped than when in sole crop. The most performing cultivar was *Lambada*, whereas *Sultano* was the least productive. Wheat grain yield was on average higher in Pisa than in Udine. In both locations wheat grain yield was significantly lower in intercropping, except for the co-cultivation with *Castellano* in Pisa. This is probably due to the lower germination in the field and lower biomass production per m^2 of *Castellano* compared to the other cultivars, which allowed the wheat to produce more (Figure 1).

This study lays the foundation for evaluating whether intercropping of chickpea and wheat can stabilise chickpea yields. Furthermore, the study shows that the cultivar choice is highly relevant for the success of intercropping in a Mediterranean environment. *Lambada* was identified as the most suitable one. The study will be repeated in the following years to establish if indeed intercropping is able to stabilise chickpea yield.

Introducing grain legumes in Mediterranean cropping systems as a strategy to increase their productivity and sustainability (Oral #89)

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Keywords: biological N fixation; grain legumes; on-farm research

1. Introduction

European agriculture is specialized in cereal production, presenting agronomic and environmental risks, and increasing the dependence on imported high-value protein (Watson *et al.*, 2017). For instance, rainfed and irrigated Mediterranean agriculture is highly based on continuous winter cereals and maize (*Zea mays* L.), respectively. The objectives were to i) redesign and assess Mediterranean rainfed and irrigated cropping systems when introducing grain legumes, ii) maximise soybean (*Glycine max* Merr.) performance by exploring later maturity groups than currently used, and iii) study alternative soybean weed management strategies for irrigated single and double cropping systems (SCS and DCS, respectively).

2. Materials and Methods

Redesigned cropping systems were assessed in two on-farm field experiments from 2019 to 2022 and managed under no-till management practices. In the rainfed area, the focus was on diversification with pea (*Pisum sativum* L.), faba bean (*Vicia faba* L.) and a multiservice cover crop as alternatives to wheat (*Triticum aestivum* L.) combined with increasing N fertilization rates (0, 40, 80, 120 kg N ha^{-1}). Under irrigated conditions, crop diversification (soybean introduction) and intensification (from SCS to DCS) were studied as alternatives to continuous maize. In both cases, cropping systems' productivity (energy and protein) and N use efficiency were calculated (Simon-Miquel *et al.*, 2024a, 2023a). At the soybean crop level, the field experiments focused on soybean maturity groups (from 00 to III) for SCS and DCS (Simon-Miquel *et al.*, 2024b) and sustainable soybean weed management strategies including row width narrowing (75 to 37.5 cm), herbicide application and using a roller-crimped rye (*Secale cereale* (L.)M.Bieb.) cover crop for SCS and the two former ones for DCS(Simon-Miquel *et al.*, 2023b).

3. Results

Legumes introduction in rainfed and irrigated cropping systems led to an increase in protein production and a decrease in energy production per unit of surface. Under rainfed conditions, N fertilization increased protein yields, with the faba bean cropping system presenting the highest yields at all N fertilizer rates. Under irrigated conditions, diversification with soybean in the SCS did not lead to an increase in protein production (921 kg ha^{-1} yr^{-1}, on average). Instead, intensification with barley (*Hordeum vulgare* L.)-maize, and especially barley-soybean DCS, showed a higher protein production (1129 and 1778 kg ha^{-1} yr^{-1}, respectively). A range of 17-28% yield increase was observed in cereals following legumes in rainfed and irrigated cropping systems. In the rainfed systems, 18% and 40% of the total N input in the pea and faba bean cropping systems was supplied by biological N fixation, respectively. A positive net N balance (*i.e.* biologically fixed N > exported N) was found in most cases, likely contributing to the pre-crop effects. The use of later soybean maturity groups (II and III) than currently used (00 to I) led to yield increases ranging from 33% to 80% in SCS. Regarding soybean weed management, a reduction of 92% of weed biomass was observed when rye biomass was 11.4 t DM ha^{-1}, whereas no effect was found below 4 t DM ha^{-1}. Narrowing row widths did not affect weed pressure or soybean yield, probably due to the presence of mulches (rye in SCS and barley crop residues in DCS).

4. Discussion

Cropping systems redesign with a larger share of grain legumes is a strategy to increase protein production while reducing the need for synthetic N fertilizer in Mediterranean areas, thus contributing to their sustainability. Such an increase in protein production is accompanied by a decrease in energy production (Notz *et al.*, 2023), although partially offset by the positive pre-crop effects of legume crops on the following cereal. Soybean yield under Mediterranean irrigated conditions can be improved with the use of later maturity groups, confirming previously simulated results across Europe (Nendel *et al.*, 2023). The use of a roller-crimped rye cover crop in a soybean SCS can be an effective weed control strategy, provided enough rye biomass is accumulated before soybean planting.

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Synergies between short and long-term actions to promote crop diversification (Oral #218)

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Keywords: diversification; adaptative management; monoring; evaluation

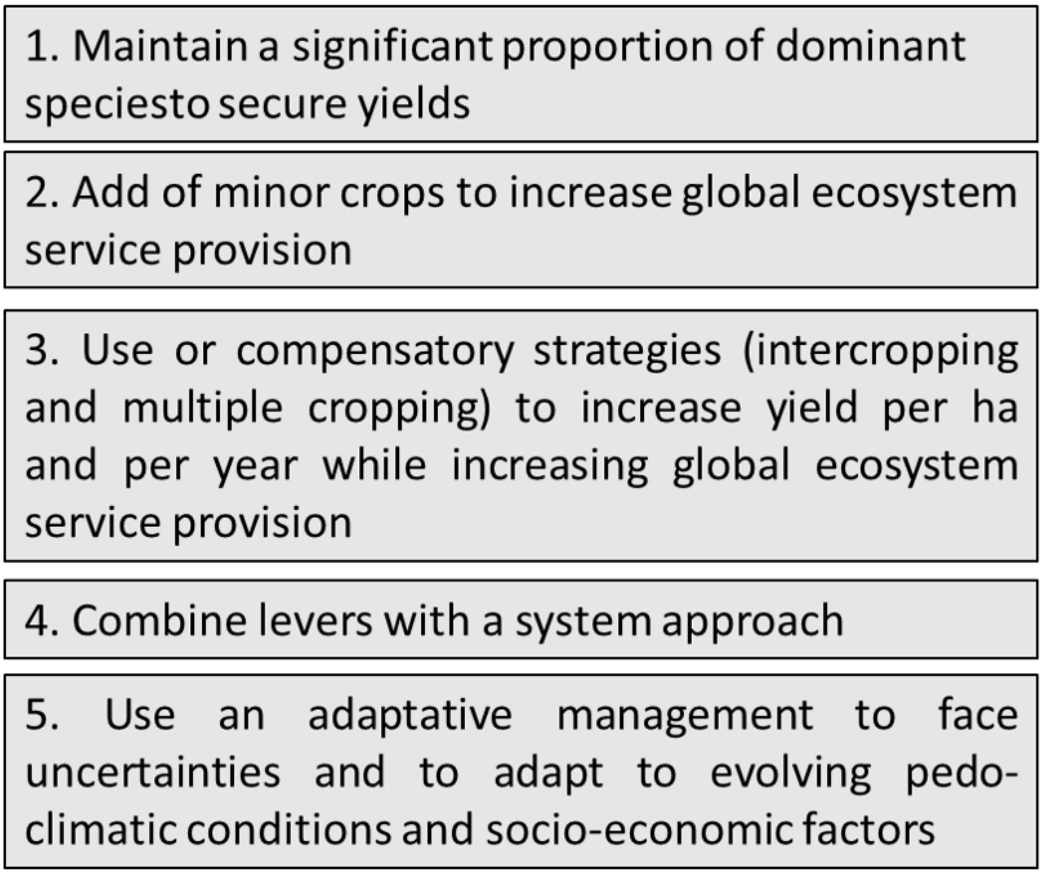

Figure 1. Five ingredients for a successful diversification

1. Introduction

There is an urgent need to redesign cropping systems with the challenge to maintain high productivity, reduce inputs and their associated environmental impacts as well as mitigate climate change. Crop diversification is a key lever to meet this challenge. It means increasing the diversity of crops in time and space using strategies such as rotation extension, multiple cropping, intercropping, and/or a combination of these practices. However, the diversification of cropping systems is limited due to barriers occurring at the farm level, along value chains as well as in the coordination between actors and institutional rules. Based on a European network of field experiments on crop diversification (Project H2020 DiverIMPACTS), this paper aims to demonstrate the need to increase synergies between short- and long-term actions to promote crop diversification.

2. Materials and Methods

We studied the combination of temporal and spatial diversification in a network of field experiments (10 sites, 7 countries). We assessed the benefits and risks of crop diversification during a three-year cropping period and we identified the ingredients for a successful diversification. We considered not only the final performances of the crop sequences but also the trajectories, as well as the adaptation needed all along the dynamics of crop diversification.

3. Results

Designing diversified cropping systems leading to rapid and successful results

Crop diversification did not always lead to positive effects on all sustainability dimensions. However, our results showed that regardless of the starting point and the type of agricultural systems (conventional or organic), it is possible to design innovative crop sequences which relatively quickly, *i.e.* in a 3 year crop sequence, combined higher energy yields, higher gross margins, reduced fertilizer and pesticide use and reduced greenhouse gas emissions, than their respective reference. Through these "successful" sequences, we identified specific rules, or ingredients to increase the benefits and avoid trade-offs (Figure 1).

Having a strong goal of sustainability and resilience with a long-term perspective while adapting continuously the system to face different risks

Diversification is an evolving process with many adaptations needed all along the trajectory due to different sources of uncertainty. Climatic conditions (mainly water conditions) and biotic factors (mainly weeds) were key sources of uncertainty requiring different adaptations in crop sequences. The designed systems and their management were also influenced by the available knowledge. The insertion of a new crop or a new strategy requires technical skills that are mastered progressively. External factors also influence the dynamic process such as opportunities of new markets, evolutions in regulations and climate change. Adapting continuously the diversification process, *i.e.*, crops and practices, is required, to face these different sources of uncertainty.

Assessing ex ante the benefits and risks to help the design of relevant cropping sequences and monitoring continuously the system

We designed a new tool (Keichinger *et al.*, 2021) based on a set of indicators assessing temporal and spatial diversity of a crop sequence. Such an indicator helps the prediction of the ecosystem services provided by a crop sequence and the potential trade-offs to support various actors in their decision-making. An example was given for crop sequences rich in legumes that decrease the use of mineral but increases the risk of diseases. Moreover, we observed that monitoring is key to be reactive to consider how the crops and the whole system evolve. The lessons learnt from monitoring are used to adapt and improve the management in an iterative process both with a short term and long-term perspective.

The need to complexify cropping systems temporarily while removing other barriers at other scales in a longer-term perspective

Increasing the intensity of diversification in time and space can be perceived as a complex process for farmers or advisers. However, we consider that the complexity will be easier to cope with if innovations are designed at other scales: selection of minor crops to improve their performance relatively to dominant species, design of new value-chains solving machine-related problems, new regulations, and undoubtedly agricultural policies promoting crop diversification.

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Opening barriers for lentil agri-food system production in France (Oral #63)

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Keywords: lentil; market; agricultural practices; food system; country scale

1. Context description and research question

Ensuring healthy diets from sustainable food systems is an immediate challenge (Willett *et al.*, 2019). On the one hand, there is an urgent need to limit the environmental impact of production systems while increasing their resilience in the face of climate change. On the other hand, consumer health is also an important point to consider when analyzing food systems (Tilman & Clark, 2014). The aim of this study was to assess locks and levers associated with lentil production at the country scale, in a European temperate climate country like France. The three dimensions assessed in more detail were agro-ecology, food safety and economics, three essential pillars for assessing sustainability and go to synergistic solutions. They were discussed in a broader context of protein and agro-ecological transitions.

2. Method and Theoretical background

Data were obtained through 1-to-1 interviews and questionnaires, on-line surveys, literature search and access of national and international database. On the agricultural dimension, we identified and interviewed thirty-three farmers in different areas in France, reflecting different production systems. On the food safety dimension, we analyzed 607 responses to the on-line survey to assess microbiologic and chemical risks. On the economic dimension, we analyzed 45,885 purchases of lentils products in France, from 13,039 households. Statistical analyses on each dataset were carried out to compute agronomic, food safety and economic indicators. Data were analyzed through different tools (Excel, Stata and R software).

3. Results and Discussion

On the agricultural dimension, first, 88% of farmers emphasized that redesigning crop rotation is a strong lever for sustainable lentil growing systems. Second, we found that farm economic profitability is an essential condition for farmers to produce lentils. Organic or geographical indication areas were identified to secure land allocation for lentil production and farmers' income. Third, lentil production was pointed out to be vulnerable to climate change, with climatic hazards having an impact on yields and thus on economic profitability. On the food safety dimension, the microbiological and chemical risks associated with lentil consumption were assessed as low considering the current consumption of the French population. However, we recommend to be careful in the future if the consumption increases drastically. On the economic dimension, we found that the per capita consumption of lentil-based food products is low, although given the relatively low level of prices, these may not be a limit to consumption. Moreover, we pointed out that the French market strongly depends on imports, and especially on Canada for lentil in can.

Our study revealed that there were still several obstacles to the development of the lentil agricultural and food system in France and that those identified obstacles cannot be neglected if we want to implement a viable protein and agroecological transition in the medium or long term in France and more generally in European countries with temperate climates. Obstacles associated with the agroecology-safety-economy triptych must be compared to the sector's positive effects in terms of health benefits and environmental impact. We recommend therefore to take our conclusions into a more general cost-benefit type approach encompassing these five dimensions in order to holistically evaluate the lentil sector and to place its strengths and weaknesses in relation to other important agri-food system in France such as cereals and meat food systems. Greater research on this perspective could facilitate protein and agro-ecological transitions in France and more generally in Europe as a long-term goal. Besides, nationwide policy measures to support lentil production on the one hand and to encourage consumption on the other hand, should be designed consistently.

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Silvopastoral systems interact with management practices and contribute to mitigate N losses from dairy farms: a case in Brittany, France (Oral #96)

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Keywords: alley-cropping agroforestry; hedgerow; nitrogen balance; dairy farms

Nitrogen (N) losses from agroecosystems threatens the environment. Regions with high livestock densities, such as Brittany (France), are particularly sensitive to this issue. In addition, N losses are expected to increase under the rising intensity and frequency of extreme weather events. Silvopastoral systems, *i.e.*, combination of trees and pastures, are a promising solution to prevent N losses in the short- and long-term. If recent studies highlighted the potential of silvopastures to limit N losses in the close vicinity of trees (*e.g.*, Zhu *et al.* 2020), their contribution remains ambiguous at farm and territory level.

This study aims to disentangle the relations between silvopastoral systems and the regulation of N losses by assessing the farm-gate N balance (FGB; kg N ha^{-1} yr^{-1}) in a gradient of dairy farms of Brittany that either maintained and/or planted hedges and alley-cropping silvopastures. We hypothesized that the farms which adopted silvopastures the most would present lower N surplus due to (i) direct impact of the presence of trees, and (ii) the adoption of farming systems with low N inputs.

Thirty-three farms were surveyed and modelled in order to assess their FGB as a proxy for risk of N losses. FGB was calculated as the difference between N inputs and outputs; with inputs including N from fertilizers, biological N fixation, atmospheric depositions, soil N fixation by free living soil organisms, animal feed, and litter; and outputs including N from exported crops, animal products, manure, and wood. Farms were then classified through hierarchical clustering based on variables of N inputs, outputs, FGB and surface planted with trees. Variation partitioning of the FGB was performed in order to disentangle the impact of trees as compared to the impact of the management of N inputs and outputs.

The variation partitioning revealed that N inputs alone contributed the most to explain the variation of FGB (55.6%), while tree variables alone did not explain its variation. Yet, these latter contributed to explain the variability of FGB when considering their interaction with practices on N inputs (8.0%) and both N inputs and outputs (15.3%). Furthermore, the hierarchical clustering resulted in four clusters with a gradient of farming systems from extensive farming systems with high plantation of silvopastoral systems and low N surplus to intensive farming systems based on high external N inputs and maintaining old hedges.

Our results suggested that the adoption of silvopastoral systems was not in itself a major lever to limit N losses. Yet, synergies between the adoption of silvopastures and the management of N inputs led to lower N surplus at farm scale (*e.g.* no fertilization on the areas planted with trees). The adoption of further practices would enhance the positive impact of silvopastoral systems on the limitation of N losses (Komainda *et al.* 2023; Papanastasis *et al.* 2008). Moreover, farmers that adopted silvopastures favored the stability of N-related processes towards extreme climates events through the use of organic fertilization and the plantations of trees (Mettauer et al, in prep). The conception of silvopastoral systems that take further advantages from the synergies between presence of trees and regulation of N inputs (*e.g.*, reduction of fertilizers inputs next to the trees or use of tree branches as fodder; (Komainda *et* *al.* 2023; Papanastasis *et al.* 2008)) is promising way to limit N losses in the short- and the long-term for regions with high livestock densities.

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The productive performance of intercropping (Oral #65)

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Keywords: intercropping; species mixture; productivity; metrics; meta-analysis

Agricultural diversification is useful for agronomic, environmental, and dietary reasons, but its consequences for productivity are debated. We conducted a global meta-analysis of 226 field trials, and found (as previous meta-analyses did) that intercropping, *i.e.* species mixture, leads to substantial land savings over single crops when the objective is to produce a diversified set of crop products. However, if the objective of production is to maximize grain caloric output from the field, intercropping leads on average to a small yield penalty of 4% compared to the most productive single crop species comprised in the mixture, often maize. On the other hand, intercrops provide similar or greater protein yield than the most protein-productive sole crop in the mixture, especially with modest N fertilizer application. In addition, intercropping provides further ecological services, such as pest and disease control, and improved nutrient cycling. Such intercropping advantages have potential to mitigate the environmental footprint of farming and make cropping systems more sustainable. But we should not expect that in general intercrops will outperform the most productive sole crop that may be grown on a parcel of land. Results were published in the Proceedings of the National Academy of Sciences in early 2023. The presentation will present results of this study in the context of other and earlier meta-analyses, showing that the choice of metric has a critical influence on the conclusions that may be drawn from a meta-analysis or any intercropping study.

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Adapting Italian agriculture to climate change: a MONICA model analysis of chickpea and lentil production for enhanced yield stability in low-input systems (Oral #332)

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Keywords: climate change; legumes; resource efficiency; yield stability

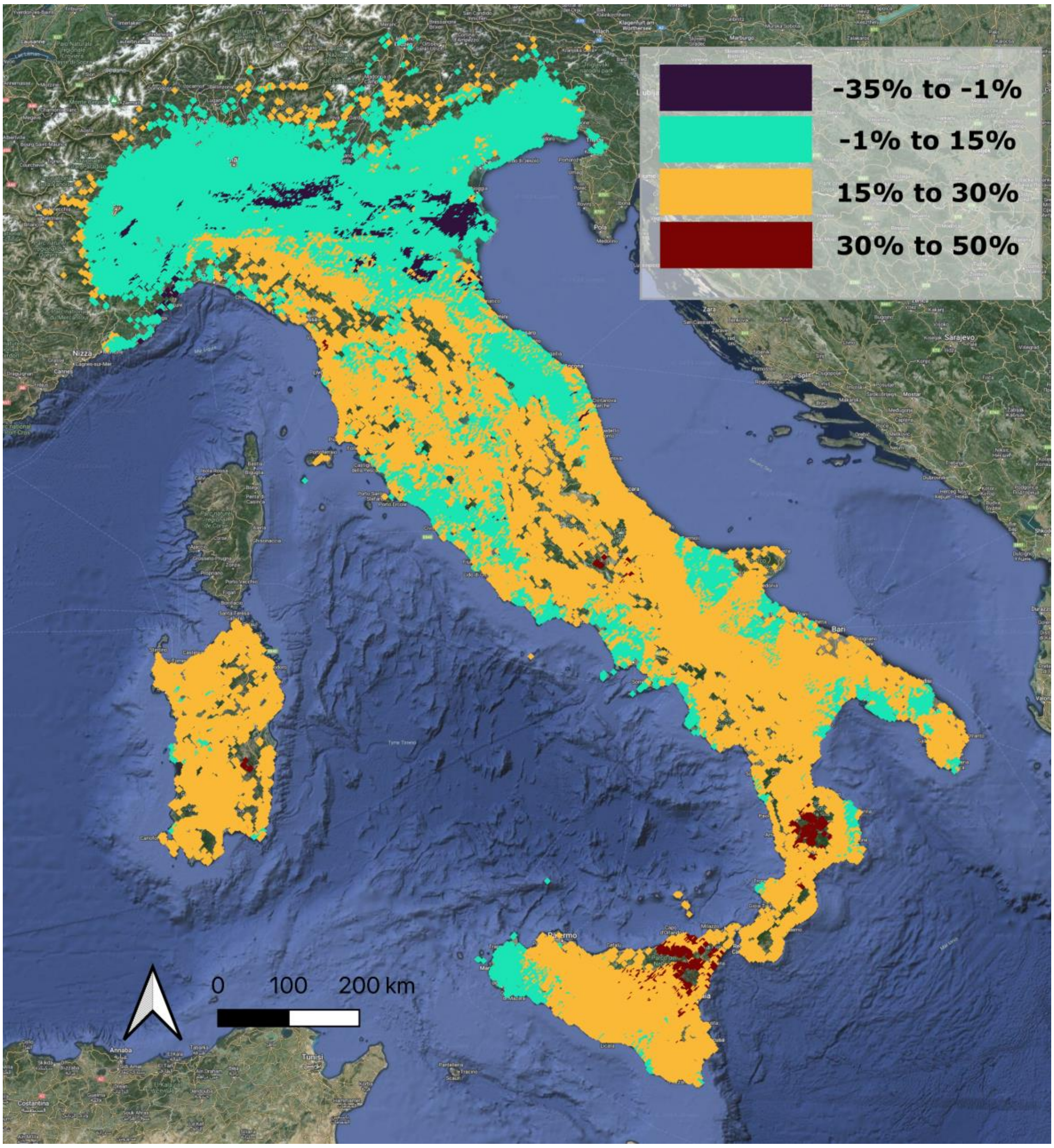

Figure 1. Future relative change of flowering date with respect to the historical baseline

Climate change significantly impacts legume crop production systems, necessitating adaptive crop management strategies [1], especially in low-input agricolture. In response, our study utilizes the MONICA crop model [2], previously refined and validated with chickpea and lentil field trial data from Europe, to forecast the response of these crops to upcoming climate variations throughout Italy. Central to our research are two critical inquiries: firstly, how will anticipated shifts in chickpea and lentil phenology under future climate scenarios affect yields across Italy, and will these impacts be consistent across the peninsula or lead to changes in preferred cultivation areas? Secondly, we explore strategies that Italian farmers could adopt to accommodate these phenological changes, aiming to mitigate yield reductions and maintain stability over time, thereby optimizing legume production sustainably without reliance on external inputs.

The MONICA model, meticulously calibrated for commercial chickpea and lentil cultivars using detailed field trial data, simulates these crops effectively. Deployed across Italy in a 1 km^2 gridded format, the model offers a thorough analysis of how varying climate conditions, particularly drought and heat stresses, will impact crop phenology and yield.

Our study is organized around two separate 30-year simulation intervals: a historical baseline period from 1980 to 2010, and an intermediate future period from 2040 to 2070, examining two different IPCC emission scenarios (SSP2-4.5 and SSP5-8.5). This methodology allows for an in-depth analysis of climate change's effects on the growth and development of chickpea and lentil, particularly examining shifts in the timing of flowering and maturity to assess phenological changes and the associated effect on grain formation.

Initial findings indicate significant changes in phenology (Figure 1, https://ibb.co/kSzN0X9), particularly affecting the timing of flowering and maturity, which in turn impacts the entire crop cycle. The study further explores adaptive strategies by evaluating several aspects such as yield, quality of yield, stability of yield, economic implications, water use efficiency, and soil fertility, focusing especially on nitrogen levels.

The study evaluates four distinct crop rotation and management strategies:

Benchmark: A conventional Italian 4-year rotation comprising legume (chickpea/lentil), wheat, maize, and barley.

Autumn Shift: The Benchmark rotation, but with chickpea and lentil sown in autumn.

Sustainable: Replacing maize in the Benchmark rotation with an N-fixing crop, resulting in a legume, wheat, legume, and barley sequence.

Sustainable Autumn Shift: The Sustainable rotation with autumn sowing for chickpea and lentil.

These approaches are examined under the different various climate scenarios to evaluate their ability to adapt to expected yield reduction. Preliminary results suggest that adjusting sowing dates and altering crop rotations can significantly impact yield, yield stability, and overall agricultural sustainability (in terms of water and nutrient use efficiency). Notably, crops planted in autumn, particularly within sustainable rotations, show promise in adapting to these shifts, potentially resulting in more stable yields and environmental benefits.

Our research seeks to provide Italian farmers with actionable insights, helping them adjust sowing dates and management practices to maintain sustainable legume production under the challenges posed by climate change. Moreover, this study proposes a model that could be extended to other regions and crops, enhancing our comprehension of agricultural adaptation strategies in response to climate change.

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Subsurface Drip Irrigation and other water saving strategies to enhance plant production in a semiarid environment in Morocco (Oral #202)

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Keywords: subsurface drip irrigation; deficit irrigation; mulching; Morocco

1. Introduction

The availability and quality of water resources impose substantial constraints on crop production, particularly affecting arid and semi-arid regions. In the Mediterranean, the climate change driven increase of irrigation requirements by 2080 is estimated to exceed 70 % when taking population growth into consideration [1]. The development and implementation of improved irrigation technologies are acknowledged as vital measures for addressing these challenges.

Among these technologies, Subsurface Drip Irrigation (SDI) stands out as particularly effective in delivering water and nutrients to plant roots. Unlike surface Drip Irrigation (DI), which is widely adopted globally, the utilization of SDI systems remains relatively uncommon. This is particularly noteworthy given the well-documented evidence derived from field research and practical applications in (semi-)arid regions, underscoring the considerable potential of SDI systems in enhancing plant water use efficiency [2]. However, the limited use of SDI systems emphasizes the need for careful adaptation of system design and management to local conditions and agricultural practices to ensure effective implementation.

2. Materials and Methods

A field experiment was conducted in the Fès-Meknès region, Morocco, comparing DI and SDI Systems alongside other water-saving strategies, namely Deficit Irrigation and mulching. Aim of the tree factorial trial in Split-Plot design with four Blocks was to evaluate the effects of the experimental factors on growth and yield parameters for potato (*Solanum tuberosum*) in the summer growing season 2023 from March to July and for field peas (*Pisum sativum*) in the subsequent winter period from October 2023 to February 2024.

3. Results and Discussion

For potatoes, the trial clearly showed the challenging nature of successful and uniform crop germination when using SDI under hot and dry weather conditions. Heterogeneous germination and development patterns under subsurface irrigation led to a significant reduction of tuber yield (30.73±10.45 t ha^{-1}) compared to the DI treatment (40.80±7.41 t ha^{-1}) by about 10 tons per hectare. However, contrasting results of tuber yield from individual, early-germinated SDI potato plants underscored the potential of SDI Systems for this crop.

Results for the field peas cultivated as short cycle crop during the winter period 2023/2024 showed a clear positive impact of mulching, with peas reaching more than 20 % higher yields in mulched *versus* unmulched treatments. Additionally, in line with the results from potato crop, plot yield of peas was significantly reduced when irrigated by SDI (4.67±0.93 t ha^{-1}) compared to surface irrigation (5.33±0.90 t ha^{-1}). Field observations indicated that pea plants growing in SDI plots experienced water stress during early developmental stages, possibly due to the need for the plant roots to adapt to the subsurface water source after an initial period of high soil moisture in upper soil layers due to precipitation. The analysis of yield parameters from single plants supports this theory, showing significant lower numbers of peas per plant in SDI *versus* DI treatment. Anyways, results from single plants also show that subsurface irrigated plants were able to compensate the lower number of peas per plant by higher thousand kernel weight, resulting in a yield per plant at the same level for subsurface as for surface irrigated peas.

In conclusion, the findings underscore the need to implement management best practices for SDI systems in the germination and early development stage of crops. Once plant stands are well-established, SDI has proven to be an efficient irrigation and fertigation system under the semi-arid climate of central northern Morocco, combinable with other water-saving strategies.

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Unveiling the short-term impacts of conservation agriculture: a two-year experiment in the Tuscany region, Italy (Oral #189)

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Keywords: reduced tillage; cover crop; soil compaction; winter wheat; tillage radish

1. Introduction

In the Mediterranean context, conservation agriculture (CA) is gaining importance due to the rising costs of conventional agriculture (CN) (Cicek *et al.*, 2023). Various solutions have been identified to mitigate the initial drawbacks of switching from CN to CA, but yield losses and soil compaction still occur. The aim of the experiment was to assess the short-term effects of switching from CN to CA. In particular, the effect of switching from conventional (CT) to reduced tillage (RT) with and without cover crop (CC) management was evaluated.

2. Materials and Methods

The study was performed from October 2021 to February 2024 (2 growing seasons; GSs) at the Tereto Living Lab of the Tuscany region (Arezzo, Italy). The soil is characterized by a clay-loam texture (sand 23%, Silt 42%, and clay 35%), an alkaline pH (8.2), an initial bulk density of 1.32 t m-3, and a low content of organic matter (1.73%). The climate of the area is Mediterranean, with an average year temperature of 14°C and average annual rainfall of 742 mm. Before the start of the experiment, a two-crop rotation of a winter and a spring crop was applied for more than 5 years with conventional ploughing, leaving fallow for several months. After the start of the experiment, only chisel plough was passed over the RT plots. The experimental design was a completely randomized block design (3 blocks and 3 replications per block) with tillage as the main factor, and CC nested into tillage as split plot. A crop rotation of winter and spring cereals (winter wheat and spring barley, respectively) was applied. Tillage radish (TR; *Raphanus sativus* L. var. *longipinnatus*) was selected as CC between the two main crops compared to fallow management. The biomass and grain yield (GY) of the different crops were determined at maturity. Undisturbed soil samples were collected for bulk density (BD) measurement at the following soil depths: 0-5, 5-10, 10-20, and 20-30 cm.

3. Results

At the beginning of the trial, the average BD was about 1.34 (0.01) t m^{-3}. BD values measured in RT after the 1st GS significantly increased at 0-5, 5-10, 10-20, and 20-30 cm by 3.84%, 7.33%, 4.11%, and 4.36%, respectively, while BD increased in CT by 1.94%, 1.01%, 0.15%, and 1.19%, respectively, compared to the initial values. With respect to the initial values, the average BD measured after the 2nd GS at 0-5, 5-10, 10-20, and 20-30 cm, increased by about 3.54%, 7.33%, 4.04%, and 4.36%, respectively in RT, while it increased by about 3.43%, 6.20%, 7.57%, and 4.33%, respectively, in CT.

GY of winter wheat measured in TR was significantly lower than that measured in CT by about 21%, likewise, GY of spring barley in RT was significantly lower by 41% compared to that measured in CT. Furthermore, the CC biomass in RT measured in the 1st and 2nd GS was significantly lower by 69% and 73%, respectively, compared to that in CT. The GY of spring barley grown after the TR treatment was significantly higher by 21% in RT and by 11% in CT compared to that grown after fallow.

4. Discussion

The study confirms the initial disadvantages of switching from CN to CA, as the effect of RT on soil physical properties was detected just after the TR termination. RT determined a significant increase in BD, which negatively affected crop yield. Moreover, the integration of different CN practices led to a reduction in the yield gap. In particular, the sowing of TR in RT was effective in reducing the yield loss of spring barley. Similar results were reported by Landschoot *et al.*(2019), as they detected a mitigation of yield losses in a RT system by CC sowing. On the other hand, the beneficial effect of TR was limited by the reduction in biomass accumulation in RT with respect to CT.

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Optimization of agricultural land use to support sustainable and healthy diet: a Bayesian approach coupled with soil-crop modelling (Oral #260)

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Keywords: agroecology; food systems; co-construction; optimization; modelling

In recent decades, a significant global shift in our food system was observed, marked by increased consumption of high-calorie diets, processed foods, and animal products. This trend led to a surge in obesity, cardiovascular diseases, and non-communicable diseases [1,2]. To sustain this food system and meet the needs of a growing population, agriculture underwent transformation with the adoption of high-yield crop varieties, chemical fertilizers, pesticides, and mechanization [3]. This transformation brought forth environmental challenges, notably by contributing to 30% of global greenhouse gas emissions [4] and 70% of freshwater use [5]. Conversion of natural habitats to farmland led to biodiversity loss [6], while overuse of fertilizers and pesticides resulted in eutrophication zones [7], and health issues [8]. Various proposals emerged to address these challenges [9], with a key focus on shifting towards sustainable and healthy diets [10]. Reference diets, such as the one proposed by the EAT-Lancet [11] commission or the TYFA project [12], propose universal guidelines for a healthy food supply which respect planetary boundaries.

Taking Wallonia as a case study, the aim of this work is to design cropping systems aimed at locally supporting sustainable and healthy diets, while activating agroecological levers.

Considering i) the estimated needs of the Walloon population based on reference diets [11,12] and ii) the various pedoclimatic contexts and agronomical potentials of Wallonia, the Bayesian optimization algorithm DREAM [13] was used to optimize the allocation of the different agricultural productions within the available land use. From the optimization, cropping systems were designed for each region, in co-construction with stakeholders (scientists, farmers, food chain actors, *etc.*). The mechanistic model STICS [14] was then used to simulate the agronomic and environmental performances (*e.g.*, yield, carbon storage, nitrogen cycle) of some of these cropping systems, under reference pedological contexts, for current and future climatic conditions, to evaluate their sustainability and resilience.

On the one hand, preliminary results indicated that optimizing land use to meet the population's needs should be feasible under current climatic scenarios, with still some spared arable lands. Since the optimization of land use was based upon actual yield, it seemed that the available spared land could mitigate the yield decrease that usually accompanies the implementation of more environmentally sustainable but less productive techniques (*e.g.*, reduction of chemical pesticides or mineral fertilizers).

On the other hand, the initial predictions from the STICS model indicated significant yield increases of 10 to 20% by 2050 (for RCP 4.5 and 8.5 respectively) for potato cultivation, and by 30% for wheat, while no changes were observed for legume crops, and conversely, rapeseed cultivation sees its yields decreased by 20 to 30% compared to the current scenario.

Regarding cereal crops and potatoes, the increases in yields due to CO_2 fertilization is likely to compensate for yield losses due to activation of agroecological levers. However, the predicted yield losses for some other major crops indicate that a redesign of rotations and the implementation of adapted management practices will be crucial to adapt to future scenarios.

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Leveraging plant variety trials for parameterization of DSSAT wheat models in Germany (Oral #261)

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Keywords: DSSAT wheat model; GxExM; parameterization; plant variety trials

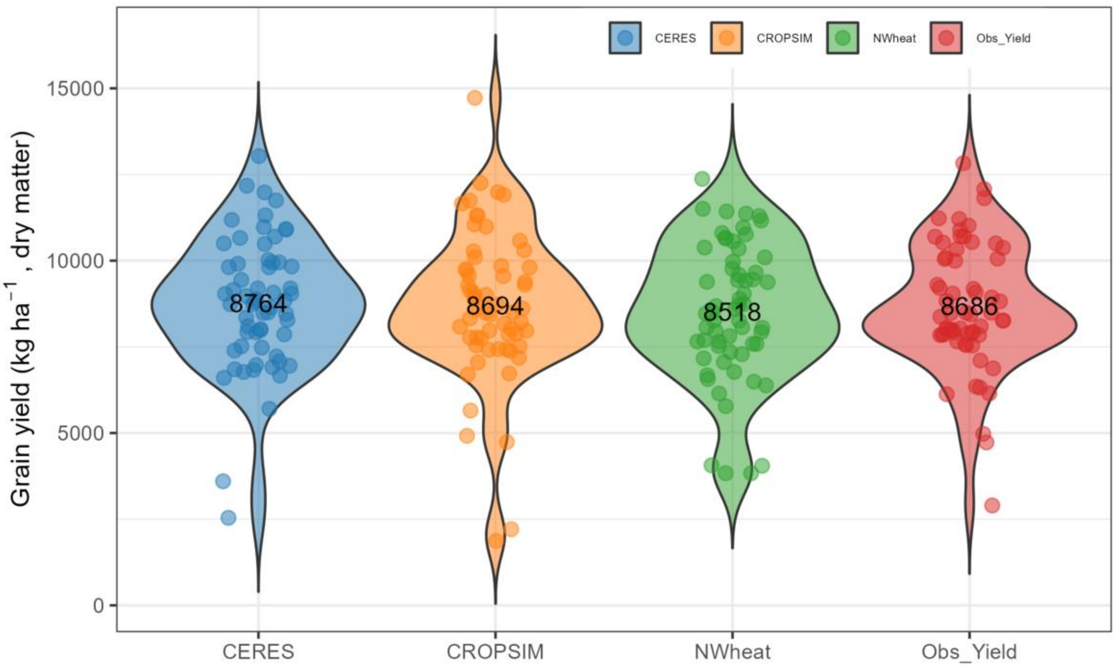

Figure 1. Model specific simulated grain yield distribution compared to observed yield

1. Introduction

Cropping system models (CSMs) are vital tools in agricultural research, typically designed for plot level assessments but increasingly applied across different scales, aiding in understanding how crops respond to various factors like climate change (Asseng *et al.*, 2013). However, when these models are scaled up, they face challenges due to limited data availability for parameterization (Angulo *et al.*, 2013). Researchers use preset coefficients from model developers or previous studies, which can introduce uncertainties into the model-based assessments and respective outputs. It's crucial to accurately parameterize these models to tackle this issue, especially when exploring new locations or crop varieties. One promising approach is utilizing data from crop variety trials to fine-tune the models, ensuring they accurately reflect real-world conditions (Liang *et al.*, 2021). In addition, one needs to consider that even with careful calibration, there is still inherent uncertainty related to model structure (Wallach *et al.*, 2017). By employing a multi-model approach, researchers can minimize these uncertainties and improve the robustness of their predictions (Röll *et al.*, 2021). Our study addresses these challenges by training three wheat models with a comprehensive dataset under German growth conditions, aiming to enhance yield predictions and optimize agricultural practices amidst changing environmental conditions.

2.Materials and Methods

In our study, we employed three wheat models from DSSAT: CSM-CERES, CSM-CROPSIM, and CSM-Nwheat. Ensuring consistent parameterization involved gathering cultivar-specific data from Germany's Plant Variety Trials, supported by detailed growth data from a rain-out shelter trial in Braunschweig (52.296° N, 10.436° E; 75m a.s.l. (Schittenhelm *et al.*, 2014). Soil data originated from the German Federal Institute for Geosciences and Natural Resources (BGR), and daily weather data from the German Weather Service (DWD), at a 1×1 km grid resolution. Model application encompassed four pedoclimatically contrasting sites across Germany: Feldkirchen (southeast, with good soil and high rainfall), Bad Lauchstädt (central, with good soil but limited rainfall), Thyrow (northeast, with poor soil and limited rainfall), and Gudendorf (north, with poor soil but high rainfall). We used the three models to simulate Management × Environment interactions in wheat production covering a span of 30 years (1991-2020). We evaluated the effects of six nitrogen treatments (0, 60, 120, 150, 180, and 200 kg Nitrogen per hectare) under rainfed *vs.* irrigated conditions considering productivity, efficiency and environmental impact of wheat production.

3. Results and Discussion

Our study highlights the effective parameterization of DSSAT-CSM-CERES, DSSAT-CSM-CROPSIM, and DSSAT-CSM-Nwheat using plant variety trial data from diverse locations and cropping seasons nationwide. Using the same dataset, we achieved reasonable accuracy in predicting phenology, while for grain yield prediction, CSM-CERES exhibited an RMSE of 1405 kg ha^{-1}, CSM-CROPSIM 2126 kg ha^{-1}, and CSM-Nwheat 1886 kg ha^{-1}.The distribution of simulated yield compared to observed yield (Figure 1) indicates close alignment, confirming model accuracy. Irrigation consistently increased yields in Bad Lauchstädt and Thyrow across all nitrogen levels, while no significant effects were observed in Feldkirchen and Gudendorf, suggesting sufficient rainfall for optimal plant growth under rainfed conditions. The CSM-CERES model exhibited higher yields at higher nitrogen levels (150N, 180N, 200N) across all locations, while CSM-CROPSIM and CSM-Nwheat showed similar effects in fewer locations. In conclusion, our study underscores the importance of robust model parameterization using diverse datasets, informing agricultural policy and climate change adaptation strategies nationally.

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Breeding progress in terms of carbon footprint reduction for five cereal crops in Germany (Oral #282)

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Keywords: greenhouse gas emission; carbon footprint; breeding progress; genetic and non genetic trends

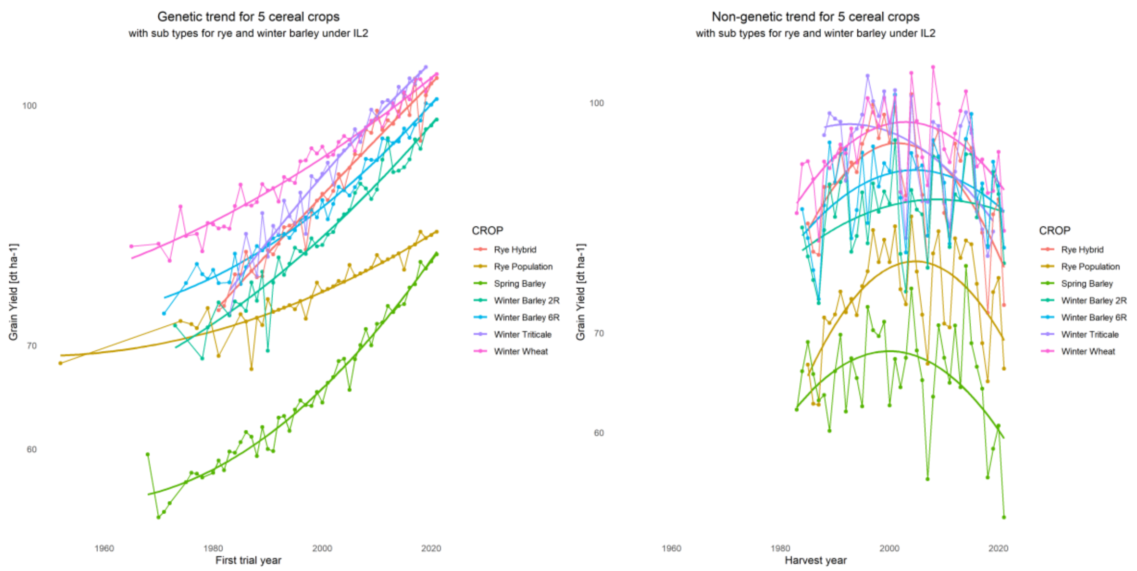

Figure 1. Five cereal crops' genetic and non-genetic yield trend from 1960 to 2021

1. Introduction

This study employs a comprehensive Life Cycle Assessment (LCA) to examine the impact of breeding on yield, greenhouse gas emissions, and carbon footprint trends for five cereal crops (winter wheat, rye, winter barley, spring barley, and winter triticale) over a 39-year period.

2. Materials and Methods

We utilized data from Variety for Cultivation and Use (VCU) trials, analyzing it through mixed model analysis. This method allowed us to differentiate genetic influences from non-genetic agronomic factors.

3. Results

Our results indicate a significant, consistent genetic improvement in yields across all crops, particularly in winter triticale. However, yields plateaued around the year 2000 and subsequently declined, likely due to agronomic impacts from climate change, with rye being the most affected. The analysis of greenhouse gas emissions followed a similar pattern (Figure 1). Notably, the carbon footprint analysis showed a reduction due to genetic improvements, pointing to successful breeding for sustainability.

4. Discussion

The findings underscore the dual role of breeding in enhancing crop yields and mitigating climate change effects. Despite genetic gains, non-genetic factors such as external environmental pressures pose ongoing challenges. The study highlights the critical need for breeding strategies that address these factors to sustain food production and contribute to environmental conservation.

Modelling gene-based, trait-yield relationships in wheat to capture synergies from GxExM interactions (Oral #228)

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Keywords: GxExM; gene-based modelling; trait modelling; wheat

Wheat grain yield is strongly modulated by underlying genotype (G) by environment (E) and management (M) (GxExM) interactions. These interactions are difficult to interpret. Process-based crop modelling has the potential to disentangle the nature of GxExM interactions and assist in developing breeding and management synergies to increase crop performance for target environments. However, current crop models were developed using data collected from outdated cultivars and often assume uniformity of many important physiological traits (*e.g.* leaf size, tillering, resource use efficiency and partition of resources to different organs) across genotypes. Consequently, insights regarding the impact of elite traits of modern cultivars to optimise GxExM are limited.

Advances in trait genetics and digital field phenotyping have enabled large-scale data collection to quantify gene-trait linkages. Incorporating such data with established trait physiological models allows simulations of gene-trait-yield relationships across environments to develop value propositions for elite traits (or wheat lines) across a wide range of geographical regions in current and future climates. Further, the models have significant potential to assist breeding as they facilitate the evaluation of elite traits arising from, and knowledge underpinning targeted breeding efforts to enhance genetic yield potential.

We present recent model development for simulation of grain yield of novel wheat genotypes with the new genetic traits of early vigour and long coleoptiles. Our results revealed that these novel genotypes, coupled with deep sowing, could increase national wheat yields by 18–20% under historical climate (1901–2020) in Australia, with benefits also under future warming. We demonstrate how incorporation of genetic understanding and data into farming systems modelling can enable gene-trait-yield simulations across environments to assist in the design of ideotypes and management strategies to optimise GxExM for increased productivity and resilience of wheat under climate change.

Genetic x management interactions with solar radiation and temperature in the critical period to achieve high cereal and canola yields (Oral #115)

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Keywords: yield; potential; radiation; temperature; management

1. Introduction

Australia is renowned for being a hot, dry and water limited crop production zone. However, parts of the Australian high rainfall zones (HRZ) have a growing season water supply that can in theory support yields greater than reported record yields globally. The physiological basis underpinning higher yields in these regions are relevant to a global audience aiming to raise the yield frontier. Potential yield benchmarking is an important and established method to assess yield gaps and productivity. The relationship between temperature and radiation in the critical period for yield formation, defined as the photothermal quotient (PTQ), has been demonstrated to be an accurate predictor of potential yield in wheat (Fischer, 1985; Rawson, 1987). However, the relationship between yield and PTQ in the critical period for barley and recently identified critical period for canola (Kirkegaard *et al.*, 2018) has received less attention. In addition, these relationships have not been defined for new wheat cultivars, nor for novel farming systems such as spring sowing of barley (*versus* traditional autumn sowing), modern canola cultivars (hybrids) and the most recent crop management practices. Our objective was to compile data from high-yielding canola (> 5 t/ha) and cereal (>8t/ha) crops in Australian irrigated and HRZ crops to explore the relationship between temperature and radiation (PTQ) in the critical period on yield potential and determine which management practices influence growth in the critical period. We sought to determine the frequency with which PTQ was likely to limit yield relative to water and N supply under current management practices and to explore the relationship between PTQ and water supply on yield when other agronomic factors are not limiting. We focussed on the Australian HRZ (> 400 mm growing season rainfall), to make comparisons to other high production areas internationally in Europe, South America, and New Zealand.

2. Materials and Methods

We compiled data from a series of cereal and canola agronomic experiments conducted across Australia's HRZ from 2016 -2023. The data included phenology, biomass, yield and yield components as well as water and N supply, temperature, and radiation in the critical period. Relationships between PTQ in the critical period and yield were compared with simple and accessible seasonal potential yield calculators such as that developed by French and Schultz (1984) for water-limited yield, and more sophisticated daily timestep models such as APSIM (Holzworth *et al.*, 2014).

3. Results

Our extensive dataset reported yields greater than 6t/ha for canola and up to 17t/ha for wheat. These new insights revealed that the relationship between PTQ in the critical period and potential yield required updating for recent wheat cultivars and management. A modified equation could be used to provide a reliable estimate of barley and canola potential yield based on the highest yielding canola and barley crops in Australia's high rainfall zone. These relationships held up well when expanded to commercial crops, including a record 7.2 t/ha canola in Oberon NSW, and cereals including world record crops reported in NZ and Europe approaching 18t/ha. In such high rainfall environments, the relationship between water supply and yield were less reliable determinants of yield potential. Highest yields came from a combination of higher biomass and higher harvest index suggesting the environmental drivers of these traits were favourable in the critical period.

4. Discussion

Our data reveals yield comparable to the highest recorded global yields are achievable in some parts of Australia, despite the national average well below other high production regions. Our data demonstrate that actual and yield potential > 6t/ha in canola, and >10t/ha in cereals, well above the national Australian average, are frequent and could be achieved in the HRZ with appropriate crop management to optimise the PTQ in the critical period. This provides a framework for improvement for growers, agronomists and breeders to re-consider temperature and radiation in the critical period as drivers of yield potential. A future focus for research could consider biomass accumulation and allocation during the critical period to improve yield further.

Use of a crop growth model for supporting variety choice in sunflower (Oral #71)

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Keywords: crop model; variety testing; sunflower; environment characterization; multi-environment trial

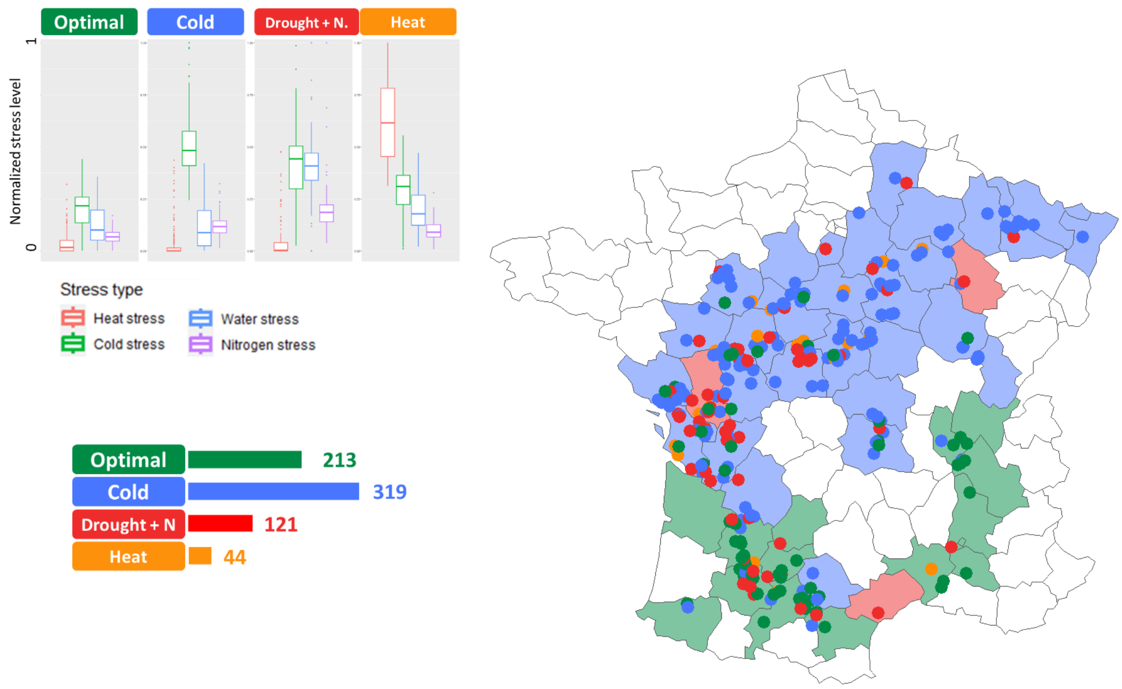

Figure 1. Environmental characterization of the trials used by Terres Inovia for post-registration in France from 2003 to 2020 resulting from the simulation of abiotic stresses with SUNFLO then clustering

Crop growth models - or process-based models - simulate the dynamic responses of a range of varieties (G) as a function of environmental conditions (E) and management practices (M) and hence are appropriate tools to predict and explain G×E×M interactions (Chapman, 2008 ; Wang *et al.*, 2019). Therefore such models could have practical applications for improving the design and analysis of multi-environment trials (METs) used for variety testing and help to identify specific fits between the tested varieties and their optimal cropping conditions (Jeuffroy *et al.*, 2014). Developed for sunflower crop, the SUNFLO model (Casadebaig *et al.*, 2011; Casadebaig *et al.*, 2016) simulates performance-related variables (grain yield, seed oil concentration) and environmental-related indicators (abiotic stress effect on photosynthesis) of a wide range of varieties under contrasting cropping conditions. However it is not clear how actors in variety choice can integrate such models into decision support systems, and how their accuracy is impacted by operating crop growth models at a large geographical scale.

In this study conducted in the frame of a EU project aiming to foster the introduction of new varieties better adapted to varying biotic and abiotic conditions (H2020-INVITE, 2019-2024), the predictive accuracy of the SUNFLO model was evaluated over the key METs conducted in France for registration (GEVES) and post-registration (Terres Inovia) of sunflower varieties from 2003 to 2020, offering an unprecedented range of explored E, M and G modalities (1471 trials, 494 distinct cultivars).

While the model inputs related to management (sowing date, dates and amounts of N fertilization and irrigation) were directly collected from the structures that conducted the trials, the inputs related to climate and soil were derived from gridded public datasets. Daily weather data were systematically derived from the SAFRAN database (8 x 8 km cells) and soil data were extracted from the Geographic Database of Soils of France (millionth map). The cultivar-dependent parameters were collected from independent and routine trials conducted each year by INRAE and Terres Inovia. In this set of dedicated field and semi-controlled experiments, 9 parameters related to crop phenology, leaf architecture, plant response to water deficit, and biomass allocation were measured on a set of 133 cultivars.

Over these two trial networks, the flowering date (n = 3174), grain yield (n = 8652) and seed oil content (n = 6054) were predicted with an error (RMSE) of 5.9 days, 0.89 t/ha, and 5.9 % (relative error of 2 %, 27 % and 12 %, respectively). We concluded that grain yield prediction was not accurate enough to separate among elite varieties when using routine variety trials without additional data on the trial conditions (such as accurate weather records and a sound estimation of available soil water content).

While the model capacity to simulated GxE interactions was not granted, we showed that the simulated G and E effects were accurate separately. We proceeded by clustering trial locations and years into comparable environment-types based on the simulated abiotic stress patterns at trial level (Casadebaig *et al.*, 2022). We showed that the sunflower growing area was composed of 4 types of situations (Figure 1): 45 % « cold », 30 % « optimal », 19 % « drought », and 6 % « heat ». This contextual information was embedded into a prototype of a decision-support system intended for choosing the best varieties (based on trial results) for each type of environment (based on simulation results).

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Digital lean phenotyping methods in the context of wheat variety testing – the cases of canopy temperature and phenology (Oral #135)

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Keywords: plant phenotyping; aerial thermography; canopy temperature; wheat; thermal drift; phenology; senescence; repeated RGB images

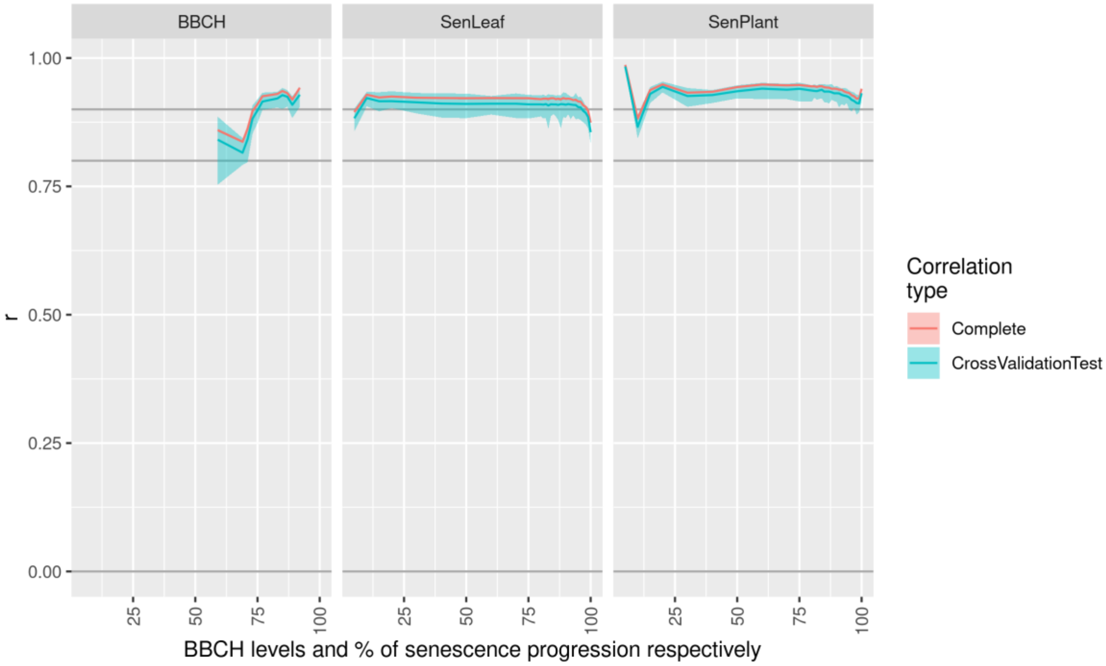

Figure 1. Pearson correlation coefficients between manual field reference measurements and PhenCam based estimates of the timing of phenological stages (BBCH; BBCH values on the x axis), senescence on leaf level (SenLeaf; % of senescence on the x axis) and senescence on plant level (SenPlant; % of senescence on the x axis). The blue shaded area indicates the minimal, and maximal correlation achieved in a 100-fold cross validation based on a random 75%-25% split into training and testing data. The blue line indicates the mean. Correlations when applying the whole dataset are shown in red

Plant phenotyping plays a crucial part in the development of new crop genotypes. In recent years, new digital phenotyping technologies have emerged, especially in the context of high throughput field phenotyping (Furbank and Tester, 2011). Many of these methods need expensive equipment or depend on stationary phenotyping platforms (*e.g.* Kirchgessner *et al.*, 2016). Relatively simple and easy to use methods need to be developed if benefits of new digital technologies are to be transferred to daily use in variety testing or breeding. In this study, the applicability of relatively simple commercially available digital phenotyping devices was tested and improved in the context of wheat variety testing. Aerial thermography is used to evaluate the performance of genotypes by measuring canopy temperature (CT) as a low CT is indicative of the relative fitness of a plant to the environment (Reynolds *et al.*, 2012). Because lightweight thermal cameras for drones are prone to significant thermal drift effects due to a lack of a signal stabilizing cooling (Wang *et al.*, 2023), we propose a new approach to analyze drone based thermal images based on an image-wise method described in Roth *et al.* (2018). Through the inclusion of covariates such as trigger timing and the position of the drone relative to measured plots, temporal trends and viewing-geometry related effects could be mitigated, which improved the CT measurements. Correlations between measurements on 270 experimental wheat plots taken within 20 min were very strong (R = 0.99) and highly genotype specific with generalized heritabilities > 0.95 in many cases. In a second experiment, autonomous PhenoCams mounted on poles 12 m above the field were evaluated for their suitability to track later stages of phenology (BBCH) and senescence (% of senescence progression on leaf- and plant-level) as a replacement for time consuming manual field scorings. Senescence and maturity of wheat could be tracked reliably in the field for three subsequent seasons with strong correlations between field-scorings and image-based estimates (R > 0.8) in a 100-fold cross-validation of a PLSR-based model (Figure 1). For emergence, achieved correlations were poor. Both experiments demonstrated how image-based phenotyping with a simple and affordable setup can be used to derive high quality data relevant in the evaluation of the performance of wheat genotypes in the field.

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Beyond organic *vs.* conventional system dichotomy: importance of management practices in driving agroecosystem multifunctionality (Oral #284)

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Keywords: cropping system; ecological performance; socio-economic performance; biodiversity conservation; trade-off

1. Introduction

Given the backdrop of global climate change, the biodiversity crisis and the energy transition, agriculture must transition from intensive to multifunctional management (Wittwer *et al.*, 2021). Multifunctionality refers to the ability of ecosystems to simultaneously perform multiple functions, thus ensuring the delivery of diverse ecosystem services important for human well-being (Stürck and Verburg, 2017). Agroecosystem multifunctionality studies comparing organic and conventional systems yielded controversial results that could be explained by differences in management practices. Indeed, current knowledge is particularly limited regarding how cropping systems and individual management practices might modulate agroecosystem multifunctionality (Wittwer *et al.*, 2021). This study analyzed how management practices affect agroecosystem multifunctionality and, trade-offs and synergies among underlying functions. We considered three management practice description levels: (i) farming system (*i.e.* organic *vs.* conventional), (ii) combination of management practices that defines a cropping system, and (iii) individual management practices.

2. Materials and Methods

We measured 14 primary variables, used as proxies for seven functions, in 20 conventional and 20 organic winter cereal fields in Brittany, northwestern France. We evaluated biodiversity conservation by considering species richness of carabids, flower-visiting insects and weeds. Predation was quantified by measuring the abundance of pest natural enemies including carabids, spiders, staphylinids, ladybird larvae, and aphidophagous hoverflies. Pest colonization consisted of the abundance of two main pests of cereal fields: aphids and troublesome weeds. Pollination was estimated through the abundance of flower-visiting insects. Food and feed production was quantified using yield (quantity of products per hectare). Quality of life at work was based on the number of working hours in the field. Lastly, income contribution was assessed using costs (labor according to materials used and inputs) and sales of crop production. Generalized Linear Mixed effect Models (GLMMs) were built to assess the effects of management practices on multifunctionality index and each function. Trade-offs and synergies between functions were assessed through Pearson correlations.

3. Results

Multifunctionality did not differ between organic and conventional systems. We found a strong trade-off between functions related to ecological performance and socio-economic performance, especially between biodiversity conservation and food and feed production. Organic systems tended to minimize this trade-off. Our study also revealed great variability in multifunctionality among cropping systems (N = 5) and within each cropping system type. The number of soil interventions and nutrient inputs were the main drivers of agroecosystem multifunctionality and its underlying functions.

4. Discussion

Although organic management did not increase multifunctionality, it was beneficial to biodiversity-based functions, likely due to the absence of applied chemical products. Some cropping systems had similar multifunctionality index value but none maximized both food and feed production and biodiversity-based functions. This suggests that multifunctionality may be achievable *via* different management paths, allowing farmers to choose the strategies most adapted to the particular objectives and constraints of their farm (*e.g.* pedoclimatic conditions, farm machinery, workload). Exploring the effects of individual management practices, we found that the number of field interventions and the fertilization amount are the main determinants of cropping system performance. Logically, fields that require numerous interventions to limit the proliferation of weeds, through mechanical weeding or more frequent application of herbicides, are also those placing greater labor costs on farmers.

We thus demonstrated that beyond the organic *vs.* conventional system dichotomy, combinations of management practices (*i.e.* cropping systems) as well as individual management practices can explain the ecological and socio-economic performance of agroecosystems. In addition, we showed that specific management practices, such as reducing within-field interventions and fertilization amount, could be integrated even in conventional cropping systems to improve agroecosystem multifunctionality.

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Overview of France 2030 interdisciplinary research programs on the agroecological transition (Oral #129)

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Keywords: agroecological transition; climate change; adaptation; mitigation; France 2030

1. Introduction

Global climate change requires that the agriculture sector adapts and mitigate its impacts. The present awareness that six of the nine planetary boundaries have already been exceeded implies that agricultural and food systems reconcile with the environment from which they get natural resources that are depleting (*e.g.*, soil, biodiversity) or whose access is becoming irregular and competitive (*e.g.*, water). Agroecology refers to ecologically and socially responsible agricultural practices that link agronomy and ecology. There are practices that rely on the functionalities offered by diversity and interactions within and across ecosystems with the aim of reducing pressure on the environment and the use of inputs, preserving natural resources (air, water, soil, biodiversity) and reducing the work load and complexity. The agroecological transition takes place in the context of rapidly changing conditions that impact agricultural production: climate change and in particular the increasing frequency of extreme events (drought, floods, temperature variations such as heat waves, cold or frost, *etc.*), changing consumer demands in terms of naturalness. The government roadmap “France 2030” aims at enhancing innovation in various sectors in France, and has identified the agroecological transition among its top priorities.

2. Methods

Public and private stakeholders together with scientists from various agricultural sectors and disciplines (agronomy, genetics, data sciences, social sciences, *etc.*) elaborated a national acceleration strategy referred to as SADEA for “Sustainable agricultural systems and agricultural equipment contributing to the ecological transition”, as part of the France 2030 roadmap.

3. Results

Three large-scale programs have started and support research and infrastructure projects on three complementary themes that contribute to SADEA. The program “Growing and Protecting crops Differently” (2019-2026) aims at finding new crop protection strategies for an alternative to pesticides. The program “Agroecology and ICT” (2023-2031) aims at promoting ICT as a lever for agroecology with four axes that include: 1) Shaping a socio-ecosystem conducive to responsible research and innovation; 2) Characterizing genetic resources to assess their potential for agroecology; 3) Conceiving new generations of agricultural equipment; 4) Developing digital tools and methods for data processing in agriculture, agricultural equipment and decision support. The program “Advanced plant breeding” (2023-2031) focuses on evaluating the potential contribution of plant genome editing (excluding transgenesis) as a complement to current selection tools to rapidly make available a wider range of plant varieties that respond to current and future conditions, in order to meet the urgent challenges facing agriculture (reduction in pesticide use, limited access to natural resources, water scarcity). This program focuses on the genome editing on a panel of agricultural species and agroecological traits, the introduction of genome editing into breeding schemes, and identification of the socio-economic and regulatory dynamics around genome editing. Up to now a total of 27 5- or 6-years projects have been launched by the three programs (see references for internet links).

4. Discussion

Drawing desirable and sustainable agriculture systems by considering the non-negotiable environmental constraints is an interdisciplinary and intersectoral challenge that needs to identify disruptive solutions and to run exploratory research based on sound scientific knowledge. SADEA provides an unprecedented research framework to address issues at the forefront of science that will provide results reducing knowledge gaps and promoting innovative solutions. Collaborations are main avenues to be elaborated by joining public and private actors and by fostering partnerships at European and worldwide levels.

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Reintegrating livestock onto crop farms: a step towards sustainability? (Oral #49)

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Keywords: sustainability; crop livestock integration; resilience; agroenvironmental evaluation; farming practices

In Europe, the specialisation of farms and regions and the disconnection of crop and livestock productions led to major environmental externalities (Lemaire *et al.*, 2014) Still, high-input specialized farming systems are continuing to be developed. Bucking this trend, a few pioneering farmers have intentionally reintegrated (*i.e.* organized the return of) livestock into crop farms in several regions. While reintegrating livestock is often depicted as sustainable, research has rarely examined these systems.

We aimed to assess the practice changes related to livestock reintegration on crop farms and their agroenvironmental impacts.

Following innovation-tracking principles (Salembier *et al.*, 2021), we identified 19 crop farmers having reintegrated livestock in two regions where crop farming predominates: the Toulouse Basin and the Parisian Basin. Farmers' profiles varied in production mode, farm size, crop and livestock species produced, and in the type and duration of livestock reintegration. We conducted interviews to characterize the changes of practice following livestock reintegration and assess their impacts on direct and indirect energy consumption, net greenhouse gas emissions and nitrogen balance (Zahm *et al.*, 2019). All agroenvironmental indicators were calculated at the farm level on a yearly basis, and assessed before and after livestock reintegration.

Data analysis is still in progress, but first results (9 out of 19 farms) show that on 4 farms having reintegrated meat sheep in outdoor systems, either by buying animals or through a partnership with a shepherd, farm nitrogen balance decreased (-0.5 ± 0.3 kgN/ha on average), mostly due to nitrogen exported *via* meat production and, in one case, to reduced use of nitrogen fertilizers allowed by the availability of sheep manure. Energy consumption also decreased (-92 ± 48 MJ/ha), as grazing helped terminating cover crops and reducing mowing in vineyards and orchard inter-rows. When related to the farm utilized agricultural area, net greenhouse gas emissions were almost not impacted (+ 0.02 ± 0.02 teq CO_2/ha) by the return of livestock, as either few sheep were reintegrated, and/or they were present on the farm for a short period of the year. The slight increase was due to livestock-related emissions, which more than compensated the emissions saved by reducing mechanized operations. This was less true in cases of increased area of pasture or grass grown in orchard or vineyard. On the contrary, for the 5 cases of on-farm poultry reintegration, farm nitrogen balance, energy consumption and net greenhouse gas emissions increased (respectively + 3.5 ± 6.2 kgN/ha, + 20 230 ± 18 605 MJ/ha and + 0.13 ± 0.2 teq CO_2/ha), mostly due to high levels of feed inputs (accounting for increases by 93 ± 3% and 81 ± 8% of energy consumption and net greenhouse gas emissions respectively). The fertilization strategy was rarely adjusted according to poultry manure produced on-farm, due to a lack of knowledge on its fertilizing effect. Carbon sequestration associated with converting a crop field into a grass field planted with hedgerows and trees for free-range poultry was more than outreached by indirect emissions from feed inputs.

This study is the first to assess the agroenvironmental impact of reintegrating livestock into specialised crop farms. According to the practice changes implemented, reintegrating livestock can help promote farm resilience by decreasing its reliance on non-renewable resources, through reduced energy consumption and on-farm production of organic fertilisers. This work contributes to produce knowledge on the agroenvironmental benefits of reintegrating livestock into crop farms, which are often advocated in research studies in analogy with integrated crop-livestock systems, but are rarely confronted to data collected on farms.

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Relationship between agrobiodiversity, farming practices, and cocoa health perception by organic and conventional farmers in Côte d'Ivoire (Oral #301)

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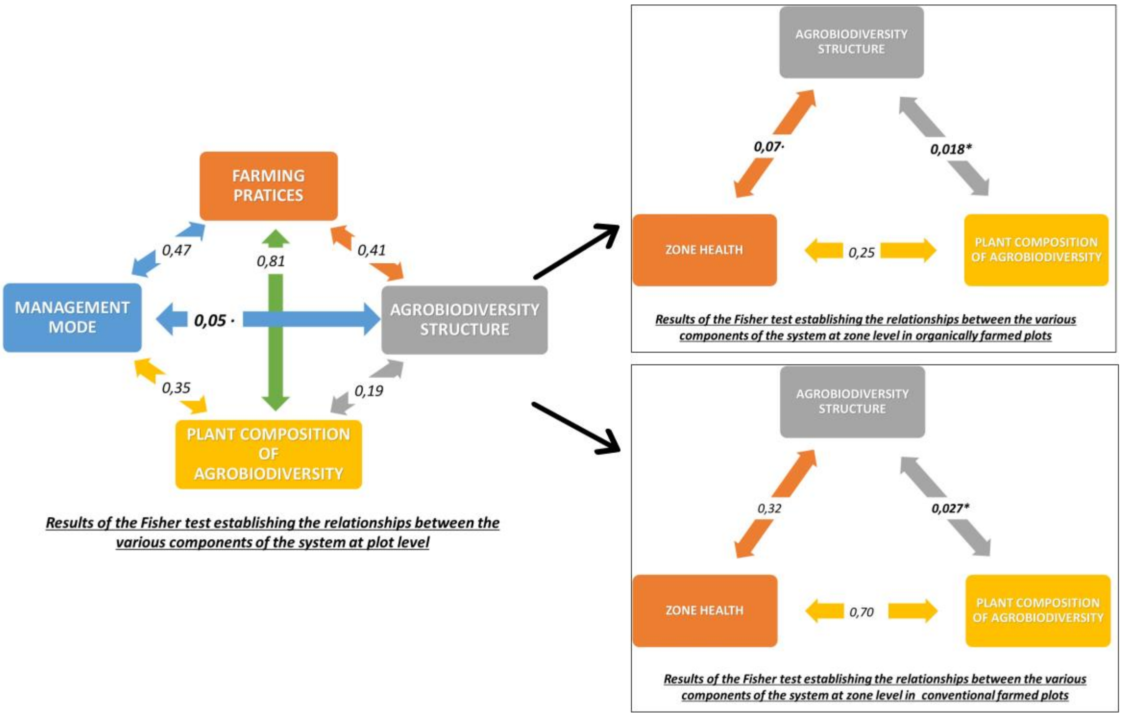
Keywords: cocoa tree; plant health; agroforestry system; salutogenic



Results of the Fisher test establishing the relationships between the various components of the system at plot level

Results of the Fisher test establishing the relationships between the various components of the system at zone level in organically farmed plots

Results of the Fisher test establishing the relationships between the various components of the system at zone level in conventional farmed plots

Until recently, the health of cultivated plants has been approached through "pathogenic" approaches, focusing on chemical control methods against pests. To accelerate the agroecological transition, a paradigm shift is required with "salutogenic" approaches (Döring *et al.*, 2012). These new approaches aim to better understand the natural mechanisms of pest regulation, in order to maintain plant health without using chemical products. Within cocoa-based agroforestry systems (AFS), there is a wide gradient of agrobiodiversity varying in terms of species diversity, planting density, and spatial distribution of plants (Vroh *et al.*, 2019). Moreover, these AFS are managed by farmers who implement distinct farming practices based on knowledge and beliefs rooted in cultural, academic, and experiential heritage (Toffolini *et al.*, 2016). This agrobiodiversity and agricultural management interact with the health of cocoa trees. We hypothesize that there are statistical correlations between farming practices, agrobiodiversity characteristics and cocoa tree health.

To test our hypothesis, we studied 38 AFS in the Agnéby-Tiassa region of Côte d'Ivoire, selected according to gradients of agrobiodiversity and intensity of farming practices. Half of the sample was conducted in organic farming, necessary to assess the effectiveness of natural pest regulations. The other half was conducted in conventional agriculture, which is the predominant management mode for Ivorian cocoa production. To characterize the agrobiodiversity associated with cocoa trees, we conducted botanical inventories, dendrometric monitoring, and mapping. This agrobiodiversity was then studied in two components: (i) plant composition, corresponding to the abundance of each associated crop species, and (ii) structure, including the variables of height stratum, basal area (m² ha^{-1}), species richness, planting density (plant number ha^{-1}) and spatial distribution (aggregated, random or regular). In addition, semi-structured interviews with farmers allowed us to characterize agricultural practices related to cocoa tree health, evaluate their perception of cocoa tree health, and map zones where cocoa trees are considered to be in "good health" (GH) and "poor health" (PH) according to their criteria. We created typologies of practices and associated agrobiodiversity (plant composition and structure) at the plot and zone levels through multivariate statistical analyses. We tested the relationships between these typologies with the management mode (organic *vs* conventional) at the plot level, and with cocoa health at the zone level, using Fisher's test.

Our results reveal that at plot level, although the inputs used are often different, organic farmers have a similar intensity of plot management to conventional farmers. There is a statistically significant correlation (p-value=0.05) between the associated agrobiodiversity structure and the management mode. Organic plots are distinguished by a higher specific richness of associated plants than conventional plots (26 compared to 17), also a larger basal area (10.2 m² ha^{-1} compared to 6.4 m² ha^{-1}) and a higher average stratum (2.01 compared to 1.54). At the zone level, an almost statistically significant correlation is observed between agrobiodiversity structure and zone health, only for plots that are managed with organic farming (p-value=0.07). In these plots, GH zones are distinguished from PH zones by their specific richness with 11.0 *vs* 6.8.

Only structural characteristics of agrobiodiversity distinguish organic *vs* conventional plots: the trees associated in organic plots are taller and wider, and are represented by a greater diversity of species. By maintaining this structure, organic farmers certainly expect more services from agrobiodiversity than conventional farmers. In organic plots, the results at the health zone scale suggest that biological regulation depends on the specific richness of agrobiodiversity. The combination of results obtained at plot and health zone scales suggests that the structure of agrobiodiversity, including species richness, and not plant composition, has a positive impact on the biological regulations that can operate to maintain healthy cocoa trees. They open up new research perspectives to better understand the biotic and abiotic regulations that explain the better health of cocoa trees in GH zones compared to PH zones in organic agriculture. Regular quarterly assessment of the agroecological functioning of these health zones through measurements of the cocoa trees, the soil and the microclimate, associated with an assessment of agricultural practices using activity analysis methods, will help to better understand the links between practices, environment, and cocoa tree health, and thus contribute to identifying and designing more agroecological practices.

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Organic farming and seminatural habitats for multifunctional agriculture: a case study in hedgerow landscapes of Brittany (Oral #113)

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Keywords: aboveground-belowground functioning; agroecology; biodiversity conservation; ecological intensification; ecosystem service

1. Introduction

Given the major impacts of chemical-based agriculture and landscape simplification on biodiversity, alongside climate change and human health, it is urgent to produce food in more sustainable ways (1). Crop fields and agricultural landscapes must promote biodiversity conservation and associated functions, including ecological regulation (*e.g.*, predation, pollination), carbon sequestration, maintenance of water quality, and soil health protection (2). However, quantitative assessment of agroecosystem multifunctionality remains scarce (3), and few studies have simultaneously addressed belowground and aboveground organisms and functions (4). A better understanding of trade-offs and synergies between this wide range of taxa and functions would greatly inform the transition towards multifunctional agriculture.

Interactions between field- and landscape-scale factors are likely major drivers of multifunctionality in crop fields, but remain overlooked. For example, the effectiveness of local agri-environment schemes such as organic farming in promoting biodiversity and associated functions may depend on landscape context (5). In addition, landscape-scale studies are generally restricted to a context of chemical-based agriculture. Frequent agrochemical disturbances might undermine the beneficial effects of increased landscape heterogeneity (antagonistic effect) by preventing or limiting the spillover and population growth of beneficial organisms into conventional fields (6,7).

In this work, we investigated the effects of organic farming at field scale, total length of hedgerow networks in the landscape, and their interaction on the multifunctionality of winter cereal fields. We hypothesized that hedgerow landscapes promote the multifunctionality of crop fields, but also that their beneficial effects are stronger in organic systems, which are more prone to ecological intensification.

2. Methods

We conducted the study in the southern part of the Zone Atelier Armorique, a Long-Term Socio-Ecological Research site in Brittany, France. We selected 40 winter cereal fields under conventional *vs* organic farming, located along a gradient of total hedgerow length in the landscape. In 2019, we collected 21 indicators through sampling of crop fields and interviews with farmers. These indicators were used to estimate five agroecosystem goods: biodiversity conservation, nutrient cycling and soil structure, pest and disease regulation, food production, and socio-economic performance.

3. Results and Discussion

Organic farming had higher level of functionality than conventional farming for many indicators, especially those related to biodiversity conservation and pest and disease regulation, despite a trade-off with food production. Total hedgerow length had much lower influence than organic farming on indicators, although we observed some positive interactions. Granivorous carabid abundance and semi-net margin were maximal in organic fields located in denser hedgerow landscapes. We conclude that reducing agrochemical input in crop fields is necessary to promote agroecosystem multifunctionality, whereas preservation of seminatural habitats alone is likely insufficient. Our study shows that organic farming and preservation of hedgerows are compatible or even preferable. More broadly, our results call for more ambitious research into the myriad possible combinations of farming practices and agri-environmental measures at both field and landscape scales, going beyond the context of chemical-based agriculture.

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A semi-mechanistic phosphorus module for the STICS model: formalization and multi-site evaluation on maize in temperate area (Oral #88)

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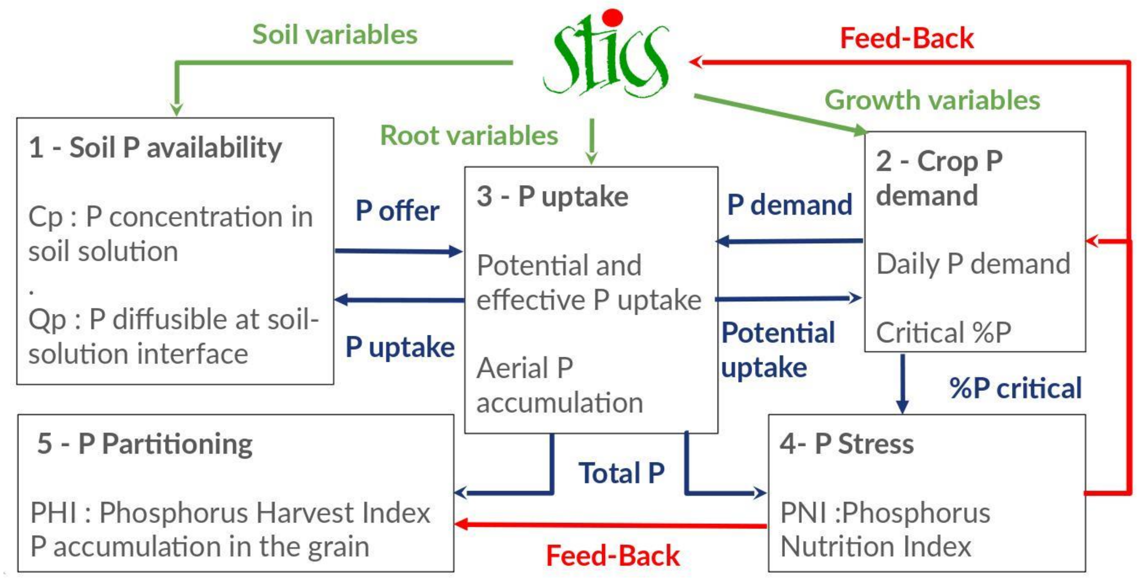
Keywords: fertilization; field trial; soil-crop model; crop response; dynamic simulation



1. Introduction

Crop phosphorus (P) nutrition is one of the key sustainability challenges of the 21st Century (Cordell and White, 2014). Crop models are pertinent tools to study and manage phosphorus in agro-ecosystems. However, P modelling is suffering a delay as compared to nitrogen and carbon. A major reason of this delay is the difficulty in formalizing a semi-mechanistic model that predicts adequately the temporal evolution of soil P availability and crop uptake (Das *et al.* 2019) as well as crop P nutrition status and the feed-back of a P shortage on crop growth.

2. Materials and Methods

We coupled the STICS crop model (Beaudoin *et al.* 2023) with a P module based on the FUSSIM-P model (Mollier *et al.* 2008). The P module is composed of several sub-modules which simulate crop P demand and partitioning, soil P availability and crop P uptake. A major originality of this work is that it relies on soil solution P concentration and P sorption curves (Morel *et al.* 2021) to simulate soil P availability and critical P dilution curves to simulate crop P requirement.

We evaluated the model against a dataset coming from four field trials having deficient to excessive plant-available soil P, located in different site in France mainland. The trials consisted of fertilizing maize with a mineral fertilizer at three application rates (P0, P1, P2), corresponding to no P added or P added at an equivalent to one or two times crop outputs. Model predictions of both crop P uptake and plant growth indicator (yield, LAI, and biomass) were evaluated both graphically and using statistical indicator such as Nash–Sutcliffe efficiency (EF) or root mean square error (RMSE).

3. Results

The model has shown great capabilities in predicting P uptake both dynamically and at the end of the cropping season for the whole dataset (EF >0.75). The model have satisfactory predictions of crop biomass accumulation (EF >0.5) and leaf area index. When considering each fertilization level separately, the evaluation has shown that the model had predicted the fertilized treatments better than the non-fertilized one (Respectively an EF of 0.73, 0.75 and 0.64 for P2, P1, and P0). The evaluation of the latter remains nonetheless satisfactory for both P uptake and plant growth.

4. Discussion

The good performance of the model is promising as they show that the model is sufficiently robust to simulate maize P uptake across a range of soil P availability under contrasting temperate climatic conditions. Despite the relative simplicity of the model that does not account for all rhizosphere mechanisms, it seems able to behave well even under low level of P under the considered conditions. The fact that the model predicted the fertilized treatment better than the non fertilized treatment raises however the question of model performance under conditions of more severe P shortage or even more lower soil P availability status (*e.g.* in tropical soils). Further validations on different crop species and soil and climatic conditions are therefore needed.

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The current state of applying agroecosystem models across large areas (Oral #232)

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Keywords: simulation; modelling; remote sensing; crop yields; ecosystem services

Climate change and other societal targets require strategic decisions in agriculture, at different levels of organisation and spatial context. Process-based simulations models support such decisions by making relevant processes graspable to the stakeholders that formulate a large range of different questions. Many of those questions require model simulations in a larger spatial and temporal context, which in turn generates a number of technical challenges for the model application, including the execution of a vast number of simulations in short time, and suppling relevant data to the models. This presentation gives an overview of where we currently stand in answering questions on crop yield predictions and projections and related carbon sequestration, nitrate leaching, greenhouse gas emissions and water consumption at large spatial and varying temporal scales.

I am using the MONICA agroecosystem model as an example to demonstrate different use cases for data being supplied through remote sensing and artificial intelligence, and the background of the CASSIS simulation infrastructure to run big-data projects. For the first, I will be highlighting several remote sensing activities that aim at supplying input information for (i) initialisation, (ii) driving and (iii) testing the model. These include satellite-based crop type identification (*e.g.* Blickensdörfer *et al.* 2022), detection of irrigation events (*e.g.* Ghazaryan *et al.*, under review) and sowing dates (Main-Knorn *et al.*, in preparation), and high-resolution information of soil properties and groundwater levels accessible to crops. For the second, I will be introducing the CASSIS simulation infrastructure and its unique security philosophy, implemented using Object Capabilities. The CASSIS simulation infrastructure (Berg-Mohnicke, M. and C. Nendel, 2022) supplies all required data for large-area simulations to the simulation model at a press of a button, which makes the application of models for regional to continental research questions much more comfortable.

Presented use cases include climate change outlooks on crop production for the German government, contributions to the greenhouse gas emission inventory of the Czech Republic, upscaling of rewetting scenarios for drained grassland and the quantification of irrigation water use for crop production in Brandenburg, Germany.

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Ghazaryan, G., S. Ernst, F. Sempel, and C. Nendel (under review): Field-level irrigation mapping with integrated use of optical, thermal and radar time series in temperate regions. Int. J. Appl. Earth Obs. Geoinf.

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Comparing historical and modern German wheat cultivars: differences in responses to agronomic management and nitrogen (Oral #42)

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Keywords: agronomic management; nitrogen; yield; yield components; wheat

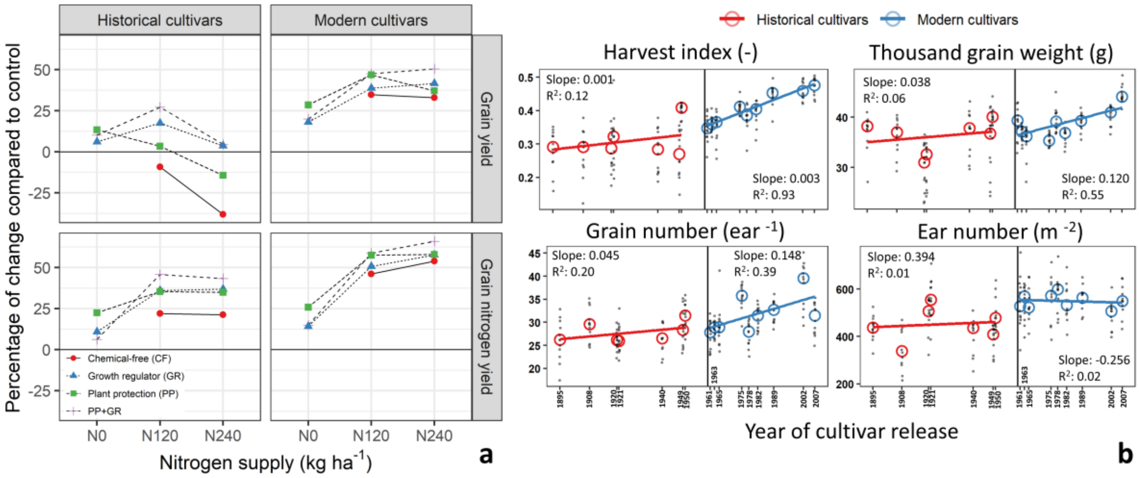

Figure 1. The percentage change in grain and nitrogen yields across various agronomic practices and nitrogen application rates compared to the control treatment for historical (1895-1960) and modern (1961-2007) cultivars (a). The trend of harvest index, thousand grain weight, grain number, and ear number for cultivars released before and after 1960 (b). Each small gray point and large point indicate the mean of a variable per growing season and the median of cultivars across treatments

1. Introduction

Despite the significant improvements in wheat productivity achieved through breeding progress over the past few decades, there remains a pressing need to target even higher yields to fulfil the growing global demand for food. Understanding the response of both historical and modern wheat cultivars to various management strategies is crucial. This understanding can assist in breeding cultivars that demonstrate enhanced productivity and better resource efficiency across diverse environments (Voss-Fels *et al.*, 2019). The current study aimed to evaluate the impact of agronomic practices (plant protection and growth regulators) and nitrogen application rates (0 to 240 kg N ha^{-1}) on both the yield and yield components of historical (1895-1960) and modern (1961-2007) winter wheat cultivars released in Germany.

2. Materials and Methods

The study involved a field experiment over two growing seasons (2018-2019 and 2019-2020), incorporating 16 wheat cultivars released between 1895 and 2007 in Germany. The experiment evaluated three levels of nitrogen fertilizer application (0, 120, and 240 kg N ha^{-1}) and assessed four distinct agronomic practices: chemical-free farming (CF), plant protection (PP, focusing on pest and disease control), growth regulation (GR), and a combination of PP and GR. During each growing season, the main plot consisted of 12 levels, derived from combining four agronomic practices with three nitrogen application rates. The subplots included 16 cultivars, arranged in a split-plot format within a randomized block design that comprised 12 blocks. Sowing and harvesting dates were set to October 11 and July 30 in the first, and October 15 and July 29 in the second season, respectively. The study analyzed several variables, including grain yield, yield components, harvest index, and grain nitrogen yield.

3. Results

The results of the study indicated that the development of new cultivars, the application of different agronomic practices (APs), and the variation in nitrogen application rates significantly influenced both grain and grain nitrogen yields (Figure 1a). Consistent improvements in yield (+32 %), yield components (grain number, single grain weight and ear number), and harvest index (+25 %) were observed across all treatments in modern cultivars developed post-1960, compared to their historical ones (Figure 1). Grain nitrogen yield in historical cultivars was less responsive to increases in nitrogen application rates compared to modern cultivars (Figure 1a). The yield enhancement observed in modern cultivars is largely due to an increase in both the harvest index and grain number, with changes in thousand-grain weight having a smaller impact (Figure 1b). Increasing the nitrogen application rate to 120 or 240 kg N ha^{-1} adversely affected the yield and yield components of historical cultivars. In contrast, modern cultivars exhibited significant yield enhancement from increased nitrogen fertilization, especially when coupled with intensive agronomic practices (Figure 1).

4. Discussion

The study findings showed positive trends in yield and yield components for both historical (1895-1960) and modern (1961-2007) cultivars when management was intensified. However, substantial improvements were observed only in the modern cultivars. Growth variables of historical cultivars showed more enhancement with the application of growth regulators, whereas modern cultivars exhibited greater improvements due to plant protection. Nevertheless, both types of cultivars demonstrated a synergistic response when growth regulators and plant protection were combined. The comparison between the effects of N application rates and agronomic practices (APs) revealed that the impact of N on yield and yield components was considerably greater than that of APs. This predominant influence of N application rates on long-term yield trends of various crop species has also been observed in other environments, including France (Schauberger *et al.*, 2018).

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How can the variety effect in long-term field trials be identified and quantified? A methodological case study (Oral #25)

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Keywords: long-term experiment; variety effect; linear model

1. Introduction

Long-term field experiments are a valuable research infrastructure to provide information about plant × environment interaction and nutrient use. The ‘Eternal Rye’ trial at the University of Halle-Wittenberg, Germany, was established by Julius Kühn in 1878 and is the world’s second oldest long-term fertilization trial. During the long history of the trial, the rye varieties changed at irregular intervals (3-50 years). While such changes are unavoidable during the long duration of the trial, they strongly influence the grain yield. In this study, different approaches are compared to identify and quantify the varietal effect over time in order to evaluate the isolated effect of the fertilization treatments.

2. Materials and Methods

Field trial set-up

The field trial is located in Halle/Saale, Saxony-Anhalt, Germany (https://ltehub.landw.uni-halle.de/eternal-rye). It consists of a continuous cultivation of winter rye with six fertilization treatments. The treatments include the application of farmyard manure, mineral fertilizers (PK, NPK), a combination of mineral and organic fertilization (NPK+FM), organic fertilization, which was ended in 1952 to analyze the after-effects, and an unfertilized control. The treatments are not replicated.

The rye varieties harvested were Saaleroggen (1879-1921), Petkuser (1922-1971), Danae (1972-1974), Dankowski Zlote (1975-1981), Janos (1982-1986), Pluto (1987-1992), Amando (1993-1999), Nikita (2000-2012), and Conduct (2013-2023).

Factorization of grain yield

Factorized grain yields show the deviation of the grain yield of each individual treatment from the annual mean grain yield across all treatments. The factorized grain yield $f_t y$ was calculated as

$$f_t y = x_t y / \bar{x}_y$$

where t is the treatment, y is the year, $x_t y$ is the grain yield for a given treatment and year, and $\bar{x}_y$ is the mean grain yield of all treatments in a given year. A value >1 marks a yield higher than the annual average, whereas a value <1 indicates below-average yield. Due to the annual calculation of the mean value, the breeding progress is not considered and the differences between the treatments become clear.

Adjusted grain yield

In another approach the yield of all earlier used varieties is adjusted for the varietal effect by relating it to the yield level of the most recent variety. For each year this adjustment was calculated as

$$Y_j = ((Y_i - \bar{Y}_1) \cdot s_2)/s_1 + \bar{Y}_2$$

where Y_j is the adjusted annual yield, Y_i is the annual yield that needs to be adjusted, $\bar{Y}_1$ and s_1 are the mean yield and the standard deviation of the previously used variety across all years, $\bar{Y}_2$ and s_2 are the mean grain yield and the standard deviation of the most recent variety (Chmielewski, 2023).

Linear models

To quantify the influence of both treatment and variety on the grain yield, variance component analyses were calculated, using both fixed and random models. Additionally, linear models were used describe the timely development of grain yield within the period of one variety.

3. Results and Discussion

During periods with no varietal change (*e.g.* 1878-1921 and 1922-1971) negative trends in grain yield were detectable. With the introduction of new varieties, grain yield increases, due to breeding progress (Laidig *et al.*, 2021). In recent years, the overall level of grain yield increased considerably, even in the completely unfertilized plot.

The factorization allowed to determine the deviation of yield in the six treatments from the annual mean yield. Annual recalculation of the mean yield helps to quantify differences within one specific year.

Adjusting the grain yield of previously used varieties helped to minimize the influence of the variety on the yield, hence it became possible to analyze the long-term effects of the fertilization under the influence of the given meteorological conditions of each year.

A variance component analysis was calculated in random models, eta squared (η^2) in fixed models, showing that the influence of variety was smaller than of the treatment but still significant.

With the help of linear models, we aim to find a tool to describe the trend of grain yield development within one variety as well as the increase and change of trend after introducing a new variety to the trial. The analyses are not yet concluded but preliminary results are promising.

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A simulation study to quantify the effect of sidedress fertilisation on N leaching and potato yield (Oral #3)

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Keywords: sidedress nitrogen; split nitrogen; nitrogen fertiliser; crop growth model; tipstar

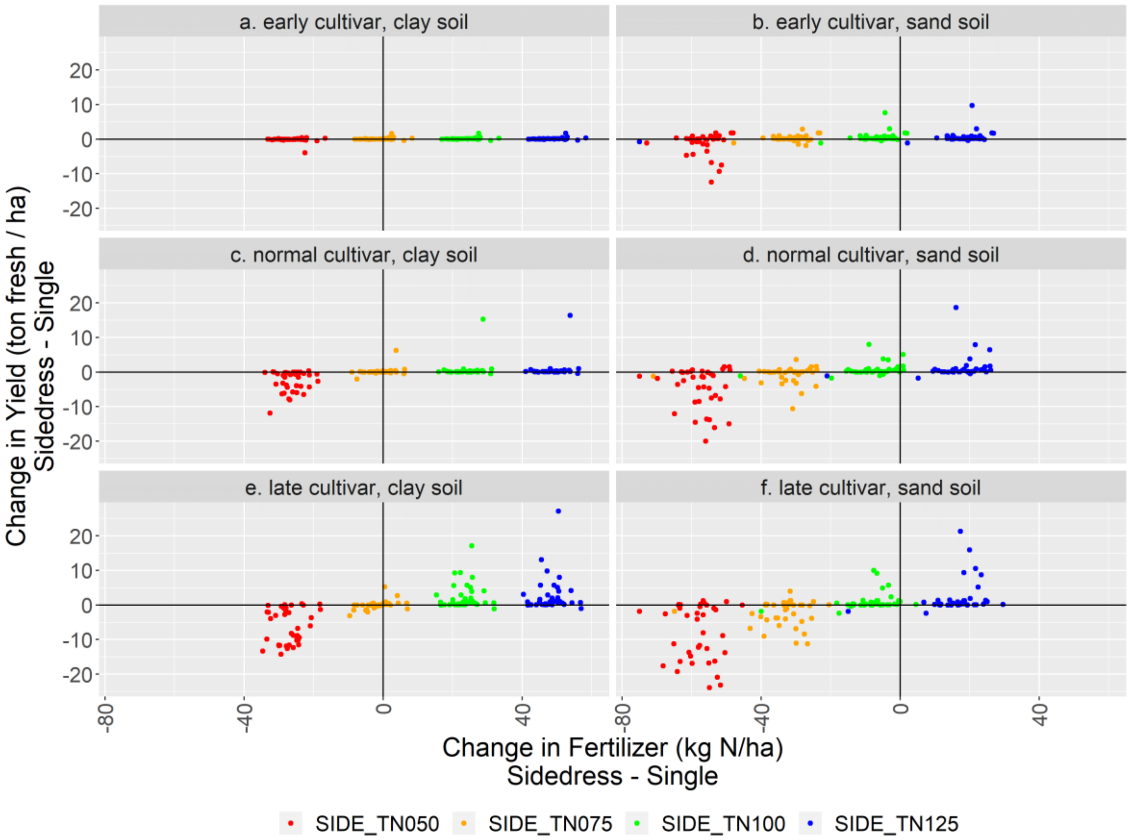

Figure 1. Comparing the sidedress fertiliser strategy with the Single Moderate fertiliser strategy (SIDE *vs* SMOD) in terms of yields and total N applied. Per soil x cultivar x Ntarget (TN) combination 38 dots from simulations in 38 years

1. Introduction

Potato farmers are easily tempted to apply high N rates (Vos, 1999). This runs counter to an increasing interest in society to use nitrogen (N) fertiliser efficiently. The conventional fertiliser strategy for potatoes in The Netherlands is a single basal N application shortly before or after planting. Sidedress or split N application has been proposed as an alternative fertiliser strategy that can increase N use efficiency, either by increasing the yield while applying the same amount of N, or by maintaining yield while applying less N (van Evert *et al.*, 2012).

Most experimental work on sidedress in potato has shown disappointing results, *i.e.* in most cases no yield gains at same N applied. Most scientific research on sidedress has been experimental, experimenting in 2-3 years, with just 1 or 2 soils and often with only one potato cultivar. The objective of the current research was to more systematically simulate possible yield gains or N saving from sidedress.

2. Materials and Methods

We used a potato crop growth model Tipstar (Jansen, 2008) to simulate for 3 cultivars (early, normal and late maturing), on 2 soils (sandy/clayey) and 38 years of weather data for one location in the Netherlands. For each combination we made pair-wise comparisons:

1. SIDE *vs* SREC = Sidedress *versus* single recommended (high) N application – where we hypothesise that sidedressing maintains yields at lower total N applied;

2. SIDE *vs* SMOD = Sidedress *versus* single moderate N application – comparing the two at similar total N applied - where we hypothesise that sidedressing increases yields at similar N applied but only in particular conditions: (a) late maturing cultivars, (b) sandy soils and (c) very wet 60 days period after planting.

3. Results

Figure 1 presents the side-by side comparisons of SIDE *vs* SMOD at different total sidedress N applied by soil type and cultivar. On the clay soil (left column) orange dots show that at similar total N applied, yields are similar with single N and sidedress N, suggesting that on clay soils, little is to be gained from sidedress application. On the sandy soil (right column) green dots show that given a similar total N applied, yields are in most years similar and in a few years higher with sidedress. Closer analysis of model outcomes confirmed the two main hypotheses and revealed that at same total N applied (a) on sandy soils with wet spring sidedress reduces leaching and increases yield (b) sidedress offers greater benefits for late maturing cultivars in which N has more time to leach below the rooting zone and (c) sidedress offers greater benefits in years with high rainfall in the 60 days after planting, which a 16% probability of occurring in the past 38 years.

4. Discussion

These results give deeper insight in the underlying causes of when and when not sidedress offers advantages over the conventional single N application. Understanding these causes allows for generalisations to other crops and other conditions. Results suggest that possible benefits of sidedress are strongly dependent on weather, soil and cultivar. The results also show where crop growth models can play a valuable role in research: they allow for analysing crop fertiliser response in a great range of weather conditions which is particularly relevant when potential benefits of a particular fertiliser strategy (like sidedress) occur only rarely, in specific weather conditions like a very wet 60 days after planting.

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Seasonal partitioning of dry matter and nitrogen of a model perennial grain (*Thinopyrum intermedium*) (Oral #147)

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Keywords: nitrogen uptake; perennial grain; Kernza; nitrogen partitioning

Thinopyrum intermedium subsp. *intermedium* is currently proposed as a perennial grain crop. This crop is multifunctional by providing grain for human consumption, forage for livestock and multiples ecosystem services thanks to its year-round soil cover and its extensive root system. In comparison to annual crops, Th. intermedium prevents nutrient leaching (Jungers *et al.*, 2019) or enhances soil biodiversity (Förster *et al.*, 2023). However, the allocation of resources to grains is low with a nitrogen harvest index ranging from 20 to 50% (Fagnant *et al.*, 2024). This work aims to quantify the proportion of dry matter and nitrogen (N) allocated within the different above- and belowground plant parts during an entire growing season. This first characterization of the N uptake across plant tissues could represent a preliminary step to improve *Th. intermedium* through crop breeding or field management. In this study, we used two experimental field with similar soil types located in the experimental farm of ULiège – Gembloux Agro-Bio Tech, Belgium, during the cropping year of 2022 representing the first and the third cropping year of the fields. *Th. intermedium* seeds originated from the fifth cycle of selection of the Land Institute (Kansas, USA). Biomass of the different plant parts (*i.e.*, leaves, stems, spikes, stem bases, rhizomes, and roots) were sampled at specific phenological stages and their N concentrations were measured. The total aboveground biomass increased until grain maturity and ranged from 13 to 18t of DM ha^{-1}. Within the aboveground biomass, stem bases represented an important proportion accounting from 30 to 54% during the reproductive phase. The belowground biomass sampled until 15cm deep increased until the flowering or the grain maturity and ranged from 4 to 5t of DM ha^{-1} at grain maturity. Rhizomes only represented 4 to 21% of this belowground biomass and were initiated at the flowering during the establishment year. Root biomass of *Th. intermedium* in third year halved between the flowering and the autumn vegetative stage. Concerning N allocations, N amount within stems and leaves decreased at the end of the growing season, that wasn't transferred within spikes. An exception was observed for plants in the establishment year with a weak increase (*i.e.*, 10 kg of N ha^{-1}) of the spikes' N amount from the flowering to the grain maturity. The N amount within stem bases and rhizomes slightly increased from the flowering to the autumn vegetative stage. Roots' N amount stayed constant for plants in the establishment year and decreased from the flowering to the autumn vegetative stage for plants in the third year. This led to a loss of N within the whole plant of 56 kg of N ha^{-1}, that was not observed during the establishment year. The first year represented a phase of field establishment of the crop, where the N and dry matter allocations during the growing season increased within perennial and reproductive organs. By contrast, for a crop in the third production year, we observed a decrease of root biomass accompanied by a decrease of the whole plant N at the end of the growing season, indicating no efficient nutrient recycling through translocation to perennial organs. The release of N-rich root exudates or root tissue turnover could lead to an influx of organic N in the soil, that was suggested by Dobbratz *et al.* (2023) for *Th. intermedium* from the grain maturity to the autumn regrowth.

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On the economics of crop rotation diversification: valuing pre crop and cropping system effects, and accounting for opportunity costs (Oral #299)

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Keywords: crop rotation; diversification; economic valuation; economic analysis

Introduction

Crop diversity in general, and crop rotation diversity in particular, is a key principle in the design of agro-ecological cropping systems for arable crops. Since economic motives are of primary interest for farmers, assessing and analyzing the economic return of crop production diversification is essential for convincing farmers to consider diversified cropping systems for adoption as well as for identifying key elements to be improved in the diversified cropping systems that are currently proposed or developed.

Defining and analyzing the economic value of crop rotation diversification

This article presents a simple approach for assessing and analyzing the economic value of crop rotation diversification. This approach relies on basic economic calculus and on data that describe the technical performances of crop rotations with various degrees of diversity in comparable production conditions.

Pre crop effect value, cropping system effect value and opportunity cost

The economic value of a diversification crop can usefully be decomposed into the sum of three components: the value of the pre crop effects, the value of the cropping system effects and, finally, the opportunity value – benefit or cost – of producing the diversification crop. The last component is purely economic while the two others value the agro-ecological effects of crop rotation diversification.

The proposed approach is illustrated by means of an application considering the insertion of pea in a typical cereal-based rotation, a topic of special interest in the EU owing to the current EU dependence on imported protein for feed production and to the benefits brought by inserting legumes in cereal based production systems.

Simple sensitivity analysis techniques, based on basic calculus, are also shown to be very useful for assessing the effects of the wide variety of components of the economic value of crop diversification. Our case study highlights the effects of the yield of pea and of the prices of fertilizers and crops on the value of pea as a diversification crop.

Concluding remarks

More generally, our investigations for gathering data for applying our approach also revealed significant information lacking, especially for describing the effects of cropping system diversification on yield and chemical input use levels. Documenting these effects is crucial for assessing the economic benefits and costs of crop diversification for farmers. These observations certainly calls for agronomists to pay more attention to the economic features related to their research topics and for economists to better account for the agronomic features of the questions they address when they consider agricultural production practices.

GRAAL – Management of a permanent cover crop by mowing between the rows of a main crop (Oral #174)

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Keywords: organic agriculture; permanent cover crop; mowing; digital technology; diversification

1. Introduction

The current societal, political, and regulatory context is leading farmers to search and develop low-input cropping systems based on agroecological levers. Sowing a permanent cover crop, usually legumes, in organic arable farming systems is an interesting lever for (i) increasing the quantities of N entering the system and which can be used by cash crops (Amossé *et al.*, 2014; Guiducci *et al.*, 2018), (ii) better managing weed flora, through better use of space and increased competition (Amossé *et al.*, 2013), (iii) improving soil fertility (Duchene *et al.*, 2017; Nyawade *et al.*, 2019). One of the major difficulties lies in the management of the permanent cover in cash crops, to prevent it from competing too much with the crop and to provide the targeted services (Verret *et al.*, 2017). To achieve these objectives, an inter-row mowing technique based on precise satellite guidance has been developed thanks to a collaboration with an agricultural machinery manufacturer. This technique was tested on different plots and in different production contexts during the years 2021-2023. The aim of this study is to draw up an initial assessment of the agronomic performances obtained, the difficulties encountered and the levers identified to overcome them.

2. Materials and Methods

The experiments were carried out at 5 experimental sites in France, covering a wide range of agropedoclimatic conditions. On each site, different types of permanent cover were studied (alfalfa, trefoil, clover and sainfoin) and sown between the rows of cash crops with a width of 30 cm. A cash crop control without permanent cover was also established. The cover crops were managed by regular mowing, with 2 to 3 cuts during the cash crop cycle.

Agronomic monitoring consisted of regular measurements of mineral N residues, measurements of the biomass of ground cover returned to the soil and all the components of cash crop yields. In order to collect feedback from the various experimentation managers, interviews were carried out and provided a better understanding of the difficulties encountered in implementing the practice.

3. Results and Discussion

Over the two cropping seasons, difficulties were encountered in implementing the practice of regular mowing of perennial legumes. For all the sites, grain cereal yields in treatments with one or two years old perennial cover were 2 to 25 q/ha lower than those obtained in the controls. These results can be explained by strong and rapid competition from perennial cover crops, poorly managed in particular by (i) difficulties in accessing mowing equipment at the right time, (ii) weather conditions that did not always allow the mower to be used at the right stage, or (iii) poor positioning of crops when sowing. However, protein levels improved overall, partly because of the lower yields. Furthermore, the performance obtained varies between species, with alfalfa phenotypes better adapted to this type of management.

Despite the difficulties encountered, a number of lessons can be learned and a multi-criteria analysis will enable us to dentify the positive and negative effects obtained, and to formalise the obstacles and levers to the implementation of this practice. Many organic farmers and researchers are interested in the results of the GRAAL project (funded by the French Ministry of Agriculture). Overcoming the technical difficulties encountered could mean that managing a permanent cover crop by mowing the inter-row could become a practice that promotes the agro-ecological transition of farming systems.

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Nitrogen uptake of maize, wheat, faba bean, and pea in strip intercropping in the Netherlands (Oral #294)

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Keywords: Europe; strip intercropping; moderate fertilization; nitrogen uptake; temporal complementarity

1. Introduction

Relay strip intercropping with maize has been well studied in China (Li *et al.*, 2020). This system performs well in conventional high-input agriculture partially due to complementary light capture. However, environmental policies aiming at reducing N leaching require reduced N input. In Europe, intercropping has mostly been done by combining cereals and legumes in organic farming in alternate-row or mixed designs (Bedoussac and Justes, 2010), but the absolute yield gain is unstable and constrained due to limited N fertilizer (Li *et al.*, 2020). We here explore the responses of N uptake of cereals and legumes in strip intercropping when applied with moderate species-specific N fertilization, and how these compare to intercrops of two cereals or two legumes.

2. Materials and Methods

Field experiments were done in 2018 and 2019 in Wageningen, the Netherlands. We compared above-ground N uptake (kg N ha^{-1}) of maize (“LG30.223”), wheat (*Triticum aestivum*, “Fanfare”), faba bean (*Vicia faba*, “Nobless”), and pea (*Pisum sativum*, “Astronaute”) in six bi-specific intercrops and four sole crops. Intercrops involving maize were relay systems, with maize sown and harvested later than the companion species. Intercrops without maize were nearly simultaneous systems, wherein the component species had the same sowing dates and similar harvest dates. Sowing delay in relay intercrops in 2018 and 2019 were 45 and 37 days respectively, creating differences in temporal complementarity. Total N application was 170 kg N ha^{-1} in maize, 125 kg N ha^{-1} in wheat, and 20 kg N ha^{-1} in faba bean and pea.

3. Results

N uptake of maize relay-intercropped with wheat or pea was higher than that of sole maize, but only in 2018, the year with greater temporal complementarity between species (less overlap of growing periods). The early-sown species took up more N in the relay intercrops than in sole crops. Combining cereals and legumes in simultaneous intercrops did not improve N uptake of either species compared to sole crops. Thus, relay intercropping with sufficient temporal complementarity allowed an improved N uptake while simultaneous intercropping did not.

4. Discussion

Temporal complementarity improves resource capture in intercrops compared to sole crops (Yu *et al.*, 2015). The early-sown species in relay intercrops benefits from improved access to light and soil resources due to the initial absence of a competitor species in the neighbouring strip. The late-sown maize required larger temporal complementarity to achieve higher N uptake than sole maize. Unlike high-input intercrops reported in China (Li *et al.*, 2011), our cereals hardly had extra access to soil N remaining in legume strips, as the small amount starter fertilizer was fully taken up during legume establishment. In cereal/legume simultaneous intercrops conducted in organic farming, the mixed or alternate-row design allows a high degree of interaction between component species (Jensen *et al.*, 2020). In our strip intercrops, interaction between conspecific species increased, which likely diminished the advantage of complementary N uptake. We conclude that in strip intercrops with moderate fertilization, complementary N uptake was strongly associated with temporal complementarity.

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Tailoring crop diversification strategies to seasonal rainfall can increase crop yields and land use efficiency (Oral #188)

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Keywords: competition; crop diversification; facilitation; intercropping; variability

1. Introduction

Crop diversification is widely promoted as a sustainable intensification strategy due its positive effects on the land use efficiency (LUE) of crop production and its contribution to ecosystem services. Yet, such effects are highly variable, and an increase in LUE can mask decreases in individual crop yields. This can be a problem for farmers, who may value each crop differently. Variability in both LUE and individual crop yield translates into uncertainty for farmers that, alongside land and labour constraints, may discourage adoption of diversified systems.

To reduce this uncertainty, a better understanding is needed of how crop diversification strategies respond to the environment in which they are implemented. In this study, we investigated how yields of maize and legume crops and LUE varied along a rainfall gradient under different diversification strategies on smallholder farms in Zambia. We aimed to determine whether one diversification strategy consistently outperformed others, or whether different strategies should be recommended for regions with different growing season rainfalls.

2. Materials and Methods

We used mixed modelling to explore three years of data (2021-2023) from an on-farm trial network comprising 29 farms spread across two communities of Zambia's Eastern Province and two communities in Southern Province. These three years and four communities (12 site-years) provided a gradient of rainfall in the growing season from 448 mm to 1034 mm.

Five cropping systems were tested on each farm, a maize monoculture (the control) and four maize-legume diversification strategies: a rotation, an alternate row intercrop, a two-row strip intercrop, and a four-row strip intercrop. All diversification strategies were managed under conservation agriculture (CA). However, the maize monoculture and the maize-legume alternate-row intercrop were also tested with conventional tillage practices. The diversification strategies followed an additive design, so that the same maize plant population of 44,444 plants/ha was adopted for all cropping systems.

3. Results

Seasonal rainfall influenced the response of both maize and legume yields to different diversification strategies (P<0.05), but had a stronger effect on legume yields. In drier site-years (<700mm rainfall), legume yields aligned with a gradient in the intensity of shading from maize: highest in alternate row intercrops, intermediate in the strip intercrops, and lowest in the rotation. This suggests that in dry conditions, the shading effect of maize modified the microclimate to the legume's benefit (perhaps reducing heat and evaporation), outweighing the effect of interspecific competition.

Maize appeared to be more sensitive to competition for water. In drier site-years, it yielded lowest in the four-row strip crop, where maize plants are grown more densely within the strip (50cm between rows) leading to higher intraspecific competition. Yields were highest in the rotation, where maize is not tightly spaced (90cm between rows) and does not compete with legumes, but can benefit from their residual effects. Maize was also affected by soil preparation: in both the monoculture and alternate row intercrops, maize yielded relatively more under CA practices in drier site-years, but in wetter site-years, yields were equal (in the monoculture) or better (in the intercrop) under conventional practices.

In terms of the LUE of each cropping system (considering both crops), the alternate row intercrop (under CA only) and the two-row strip crop had higher land equivalence ratios (LER) than other diversification strategies in drier site-years, while the four-row strip crop had a higher LER in wetter site-years. The rotation had a lower average LER than all intercropping systems due to each crop only being present every other year. This difference further increased in dry site-years due to relatively lower legume yields in the rotation.

4. Discussion

Eastern Province typically has higher growing season rainfall (approx. 800mm) than Southern Province (approx. 600mm), so the four-row strip intercrop would be recommended for Eastern and the two-row strip intercrop or alternate row intercrop (under CA) for Southern. Across Zambia, maize is typically preferred as the staple crop, but legumes offer a richer source of protein and have a higher market price. Overall, our results suggest that tailoring the choice of crop diversification strategies to the expected growing season rainfall (using long-term averages and seasonal forecasts) could be a win-win for yields of both crops.

Winter wheat-soy strip intercropping supports natural enemy abundance and pest control in an intensive farming system (Oral #72)

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Keywords: carabids; spiders; pesticide reduction; crop diversification; IPM

1. Introduction

Intercropping is an increasingly popular management strategy to simultaneously support biodiversity, ecosystem services, and yields in agricultural systems. Nevertheless intercropping studies that look at both yield and ESS, such as pest control, are less common and without them it is difficult to find management that works for both farmers and the environment. The objectives of this study were to test several spatial arrangements of soy and winter wheat, row-relay, wide strip, and patch cropping and understand their yield and pest control potential. We hypothesized that the diversified treatments would support more natural enemies and fewer pests than the sole cropping while maintaining similar yields.

2. Materials and Methods

We used an on-farm study in 2022 and 2023 to test how different forms of spatial diversification of soy and winter wheat can affect pest abundance, pest predation, natural enemies, and yields in Eastern Germany. We specifically studied three types of diversified systems compared to conventional sole cropping - row relay intercropping, wide strip cropping (12x150m), and patch cropping (72.5*72.5m). Crops were managed conventionally with input from the farmer. We monitored pests at wheat flowering, collected ground dwelling carabid beetles and spiders with pitfall traps in May and June, and measured predation rates with aphid predation cards installed in the field 3 times per year. Yield was measured with a combine harvester.

3. Results

We found that strip cropping generally supported the highest levels of carabid abundance both years and spider abundance in 2022 while producing equivalent, or higher, yields to the sole cropping. Soy and wheat strips had more beetles than their corresponding soy and wheat patches both years and the cropping treatments supported significantly different community compositions. The relay system failed due to insufficient precipitation but supported intermediate levels of natural enemy abundance as well as the highest carabid species richness as measured by the Chao1 index. The results of patches were mixed with yields and abundances either equivalent or lower than the strips and reference treatments. We found no effect of cropping treatment on aphid abundance but overall aphid infestation levels were very low both years and not correlated to natural enemy abundance. As for pest predation, strip cropping had a 51% (2022) and 36% (2023) increase in aphid predation rates compared to wheat patches and 86% and 10% increase compared to the reference wheat.

4. Discussion

We found that strip intercropping maintained ecological benefits, higher carabid abundance and aphid predation rates, with no yield penalties to the farmers with similar strip yield outcomes found in Canada (Labrie *et al.*, 2016). Strips were likely able to maintain high yields because they are managed identically to their respective sole crop, they act as narrow fields and thus do not require additional driving and can handle pesticides that mixed relay cropping can not. Wide strips may support more natural enemies than patch or sole cropping due to the higher area:border ratio of strips as carabids and spider activity is often higher at edges than field centers (Ávila *et al.*, 2017; Zhao *et al.*, 2013) likely due to increased spatial-temporal resource availability at the edges. While some diversified systems did not perform as well as sole cropping, the strip cropping results show the potential of the system for farmers to diversify their farms in a manner that involves no additional machinery and little additional work.

Performance and stability of wheat variety mixtures: a multivariate analysis (Oral #8)

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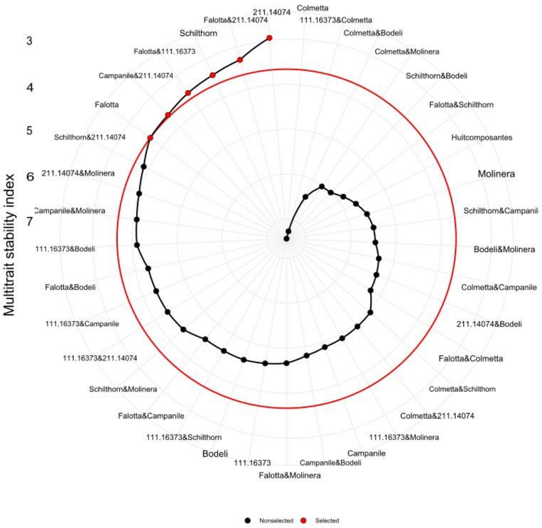
Keywords: variety mixtures; diversification; yield stability; sustainability



1. Introduction

In the face of climate change, improving the stability of food production systems is critical. Increasing diversity in agricultural fields can be a way to stabilize production across time and/or space. Variety mixtures represent a practical way to introduce diversity at the genotype level (Kopp, 2023). In Switzerland, variety mixtures remain rarely used, due to uncertainties and lack of understanding of the processes driving potential benefits for productivity, quality, and stability. This research presents results from a multi-year, multi-site wheat variety mixture experiment investigating the role of variety mixtures to increase crop performance and stability, and the mechanisms underlying these effects.

2. Methods

The experimental design included 8 Swiss wheat varieties in a diallel design (*i.e.* all varieties in pure stand and all 2-variety mixtures) and one mixture combining the 8 varieties. The experiment was replicated three times with a full randomized block design. We set up the field trials in three Swiss sites varying in environmental conditions, during three years (from 2021 to 2023). We measured a variety of agronomic parameters, such as yield, protein content, thousand kernel weight, hectolitre weight, Zeleny, but also functional traits during the growing season, for instance height, heading date, specific leaf area, *etc.* Crop performance and stability was assessed using Weighted Average of Absolute Scores as well as Multi-trait Stability Index as described by Olivoto *et al.* (2019). We examined links between mixture performance, stability, and characteristics of the varieties composing the mixtures with linear regressions, as described in Stefan *et al.* (2023). We hypothesized that mixtures composed of more different varieties – in terms of genetic distance but also morphological, agronomic, or synchronicity aspects – would be more performant and/or stable.

3. Results

Mixtures generally had a positive effect on yield, but not on protein content. Unlike what is commonly assumed, results of the multitrait stability index do not show that variety mixtures universally increase stability (Figure 1). The 6 most stable plots include 3 varieties in pure stands, and 3 mixtures (2 of them including the most stable variety). Regarding traits or mechanisms explaining crop performance and stability, preliminary results indicate that (1) asynchrony of the components is positively linked to temporal and spatial yield stability, as already shown by Stefan *et al.* (2023), (2) the mean performance and stability of mixture yield is negatively correlated with the monoculture difference in specific leaf area (mixtures are more yield-performant when combining varieties with similar specific leaf area) and (3) multitrait stability is better when combining varieties with a high difference in phenology.

4. Discussion

This study investigates the links between performance and stability of wheat variety mixtures and various traits of the mixture components. It uses a multicriteria approach to evaluate crop performance and stability, by including agronomic parameters (such a yield, thousand kernel weight) but also quality parameters (protein content, zeleny sedimentation rate). Therefore, it allows to not only look at productivity, but also at the quality of the grains produced, and the stability of this quality. The complexity of the multivariate responses and explanatory variables requires more in-depth investigation; however, we can already state that our study confirms the defining role of asynchrony in driving yield stability, showing that combining less synchronous varieties (in terms of yield) can act as an insurance to environmental variability. This supports the role of variety mixtures as a promising solution to sustainably increase the stability of wheat production in Europe.

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Phenotypic traits of sunflower varieties vary according to the composition of cover crops (Oral #23)

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Keywords: agroecological transition; climate change adaptation; climate change attenuation; drought; ecosystem services

Cover crops (CCs) are known to improve soil fertility and cash crop performances. Introducing CCs mixtures is a promising approach to increase multifunctionality of the ecosystem services provided by CCs. However, the effect of CC mixtures on subsequent crop yield remain contrasted. Indeed, the extent to which yields are increased by CCs depends on the type and management of CCs, the type of cash crop, the application of fertiliser to the cash crop, the soil and climatic conditions. In the context of climate change, drought is a major environmental factor that limits crop growth, photosynthesis and yield. Sunflower, which is adapted to environments with low N and water requirements, has different drought-tolerance strategies, depending on the variety. However, little is known about the variability in the response of drought-tolerant sunflower varieties to CCs in low-input systems.

The study’s aims were to characterise CC ecosystem services mainly related to C, N and water and how ecosystems services of CC influence responses of sunflower varieties that differed in drought sensitivity. CC and sunflower varieties were organized in a randomized non-complete block design with a split-plot arrangement in 2021-2022 and 2022-2023. CC treatments consisted of a pure grass CC (rye), a mixture of legume CC (purple vetch/fodder pea), 3 mixtures of legume and non-legume CC (faba bean/white mustard/phacelia; fodder pea/rye/ purple vetch and faba bean/indian mustard/phacelia) and a relay CC treatment (forage sorghum then faba bean). The control of CC treatments is a bare soil kept free of weeds mechanically by two passes of a cultivator during intercrop. Sunflower varieties had different drought tolerance strategies for leaf expansion (LE) and transpiration (TR): a conservative strategy for LE and TR (MAS 86OL), a conservative strategy for LE and productive strategy for TR (MAS 89M), a productive strategy for LE and a conservative strategy for TR (MAS 98K) and a productive strategy for LE and TR (CARRERA CLP). Implantation, development, growth, N statue and productivity were evaluated on sunflower varieties preceded by CCs by low- and high-throughput phenotyping measurements. Various variables of growth and development were based on image processing tools using UAV RGB images.

The results indicate that CCs affected late N release absorption by sunflower, increasing the seed filling period. Indeed, maturity stage was delayed by an average of 194 °C.d for Faba bean/Mustard/Phacelia in 2021-2022 and 344 °C.d after Pea/Rye/Vetch in 2022-2023, compared to Faba bean/Forage sorghum and bare soil, which can lengthen grain filling period by average of 342 °C.d in 2022-2023 (equivalent to 17 days in average).

Optimized choice of CC allows equivalent yields to intensively tilled bare soil, while increasing carbon restitution and weed control in low-input agricultural systems. Mixtures with C:N ratio lower than 19 were composed of more than 60 % of legume species biomass led to early and high N uptake from the vegetative stage while other CCs with higher C:N ratio composed of legume and non-legumes led to late and high N uptake after flowering. The composition of CCs led to higher yields compared to other CC treatments but similar yields to intensively tilled bare soil. However, in a multifunctional approach to the ecosystem services provided by CCs, carbon restitution and weed control were higher after CCs than after intensively tilled bare soil. Moreover, these results are similar to those of the study of Ait-Kaci *et al.* (2022) which showed no clear trend of sunflower yield increase after CC mixture with legume in a four-year field experiment.

Sunflower growth can be improved by optimizing the choice of CC and sunflower varieties. During the drought year, higher biomass was observed for productive sunflower for leaf expansion in presence of early and late N release by CCs. Our results can guide sunflower variety selection and CC type and management in low-input systems to better match N release from CC residues with subsequent cash crop response during vegetative and post-flowering phases. Further research is needed to understand the responses of varietal traits to the agroecological system.

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Intercropping in Europe: a systematic mapping study of arable grain crops (Oral #46)

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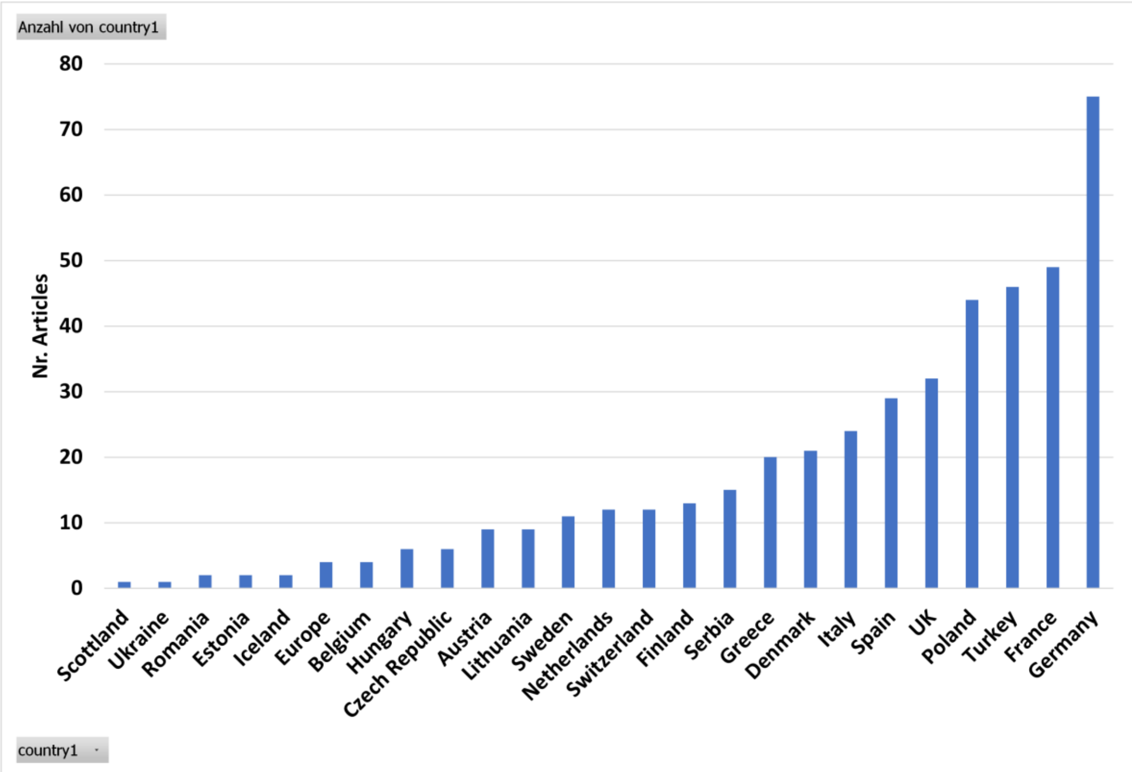
Keywords: intercropping; species mixture; diversification; agroecology; experiments



1. Introduction

In recent years intercropping (IC) has increased in prominence in research globally and produced a large legacy of empirical evidence. A bibliometric study on cereal-legume IC found 4735 articles and revealed that on a continental scale most publications originated from Asia (China 785, India 626), followed by the Americas (1003) and Europe (943) (Landschoot *et al.*, 2024). This wealth of evidence was synthesized in meta-analytic studies, indicating the advantages but also limitations of IC systems. Recently, a global study showed that IC outperformed sole crops (SC) with respect to land use efficiency when the aim was to produce a diversity of products while IC systems are not better but close to SC if the overall highest yield is the goal (Li *et al.*, 2023). In contrast to this strong evidence for their high potential, in Europe IC are still confined to small niches of fodder and biomass production or catch crops while there is a wide implementation gap for food crops (Timaeus *et al.*, 2022). A current challenge is to structure the wealth of empirical research to inform strategic IC research to develop cropping systems that fit the diverse ecological, technological and economic contexts of European agriculture. As one step towards these goals, we conducted a review of IC studies following the systematic map approach of James *et al.* (2016). A systematic mapping approach is able to answer a broad research question and to identify research gaps and facilitate knowledge synthesis. We addressed the following research question: What is the state of experimental research on IC systems with two arable grain crops in Europe?

2. Materials and Methods

We developed a search combining a cereal grain crop and an intercrop search string, that consisted of synonyms for each concept. These strings were combined with an exclusion string for terms that are irrelevant to our research question. To restrict the geographic scope to Europe a country filter was added. The search string was developed iteratively in the web of science (WoS) database and tested against a benchmark list of 30 articles known to be relevant for our research question. The final search string missed only one of these 30 articles and this was considered to be sufficiently comprehensive for our research question. The final search was conducted on November 24, 2023 in the WoS core collection without any time restrictions. References were exported to Zotero to remove duplicates. Screening of titles and abstracts against the eligibility criteria was done in the Rayyan software. Studies needed to include two arable grain crops and be conducted in Europe. Studies that were reviews, meta-analyses, pure modeling or social science were excluded. Full text screening was done manually by reading the pdf files and documentation in an excel database.

3. Preliminary results outlook

The search in WoS yielded 2080 articles. Screening these articles against eligibility criteria resulted in 661 eligible articles from which 621 could be retrieved as full texts. Full text screening resulted in 449 eligible articles. The top five countries with the most studies were Germany (75), France (49), Turkey (46), Poland (44), and UK (32). While data extraction was not yet conducted, the screening already revealed some gaps. Biodiversity conservation effects of IC were only addressed in six, strip intercropping in eight and testing of agricultural technology for IC management in zero articles. The next step is to extract metadata from the experiments describing what has been studied in detail. An analysis of knowledge gaps and knowledge clusters will be presented at the conference.

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Contrasted reaction norms of wheat yield in pure *vs* mixed stands explained by tillering plasticities and shade avoidance (Oral #223)

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Keywords: plant-plant interactions; phenotypic plasticity; tillering; cultivar mixtures; bread wheat

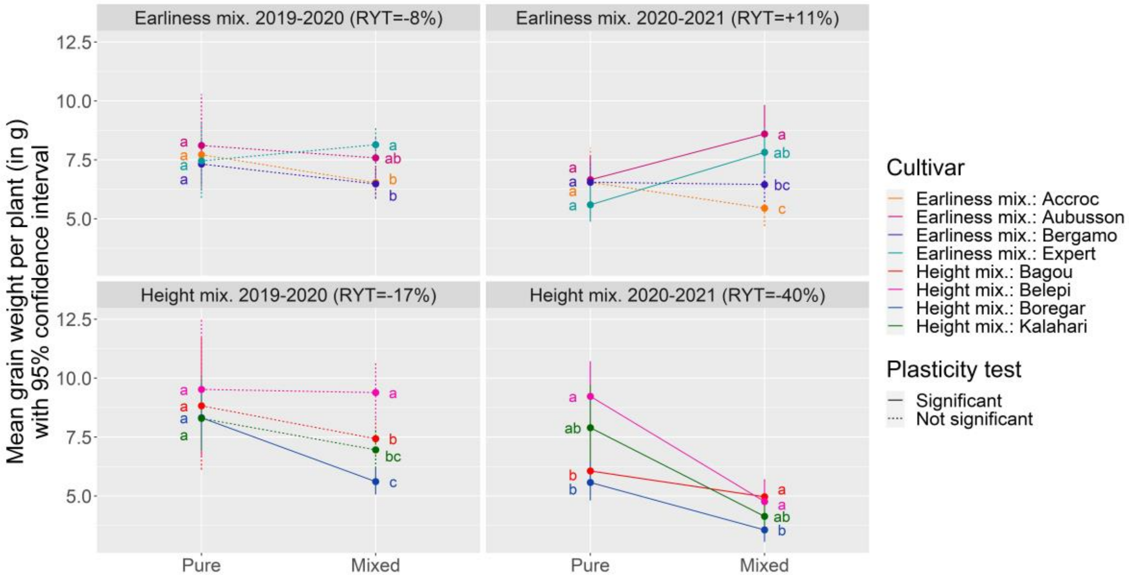

Figure 1. Reaction norms of mean grain weight per plant between pure and mixed stands per cultivar for both mixtures in both years. Vertical segments represent confidence intervals at 95%. Letters indicate pairwise differences between cultivars in pure or mixed stands. Line types indicate if plasticity is significant

1. Introduction

Cultivar mixtures are increasingly used as a practice to diversify crops, notably for cereals such as wheat. Cereal mixtures typically yield higher than the individual components grown in monoculture, although with notable variability (Borg *et al.*, 2018). This variability stems from plant-plant interactions within mixed stands, resulting in diverse plant phenotypes, a phenomenon known as phenotypic plasticity. This study aims to (i) assess the extent of phenotypic plasticity in yield between monoculture and mixed stands, (ii) determine the key yield components contributing to this plasticity, and (iii) establish connections between such plasticities and variations in functional traits such as plant height and flowering time.

2. Materials and Methods

A novel experimental approach relying on precision sowing enabled the phenotyping of each cultivar within mixtures at the individual plant level, focusing on above-ground traits throughout the growth cycle. Eight commercial cultivars of *Triticum aestivum* L. were cultivated both in pure stands and mixed stands in field plots over two consecutive years (2019-2020, 2020-2021), encompassing contrasted climatic conditions. The management strategy included nitrogen fertilization, fungicide application, and weed removal. Two quaternary mixtures were sown, each comprising cultivars with contrasted height or earliness. The spatial layout of cultivars within each mixture was achieved by randomization (Lieng, Richardt and Dodgson, 2012), ensuring that the varietal identity of each plant was known throughout the experiment.

3. Results

Compared to the average of cultivars in pure stands, the height mixture strongly underyielded over both years (-29%) while the earliness mixture overyielded the second year (+11%) and underyielded the first year (-8%). The second year, the magnitude of cultivar's grain weight plasticity, measured as the difference between pure and mixed stands, was significantly and positively associated with their relative yield differences in pure stands (R2=0.51). We found that some cultivars were dominant, *i.e.* more productive, in mixtures and that dominance rankings were maintained over both years (Figure 1). When grain weight plasticity, measured as the log ratio of pure over mixed stand, was partitioned as the sum of plasticities in each yield component, its strongest contributor was the plasticity in spike number per plant (~56% of the sum), driven by even stronger but opposed plasticities in both tiller emission and regression. For both years, the plasticity in tiller emission was significantly, positively associated with the height differentials between cultivars in mixture (R2=0.43 in 2019-2020 and 0.17 in 2020-2021).

4. Discussion

The new experimental design enabled to access to the behavior of each individual plant, and hence to assess plant plasticity in pure *vs* mixed stands. Despite variable cultivar performances in mixture over the two years, some cultivars remained dominant and, unlike common guidelines, dominance was not related to earliness or height at maturity. Our results also highlighted a link between plasticity in tiller emission and height differential in mixture. Both height and tillering dynamics displayed plasticities typical of the shade avoidance syndrome. The early recognition of potential future competitors for resources *via* a light quality signal is a known example of active plasticity and, as demonstrated here, a major component of genotype strategies in mixtures. The decomposition of plasticities developed in this study open avenues to better study plant-plant interactions in agronomically-realistic conditions. This study also contributed a unique, plant-level data set allowing the calibration of process-based plant models to explore the space of all possible mixtures (Blanc *et al.*, 2021).

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Identifying keys of success for relay intercropping of service crop in a winter cereal (Oral #62)

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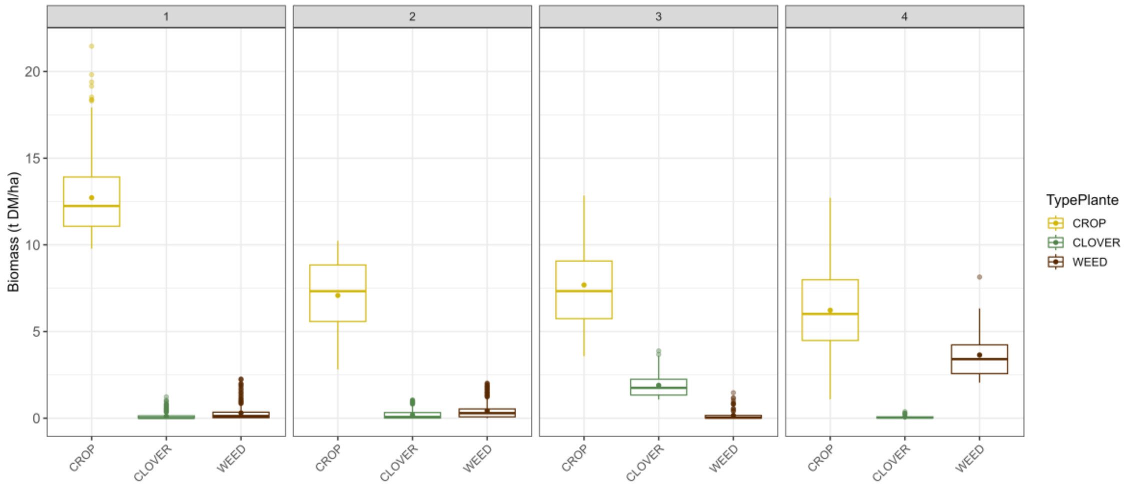
Keywords: service crop; on-farm experiment; conditions of success; agroecology



Introducing service crops into rotations may help to reduce dependency to inputs. Service provision largely depends on biomass production (Vrignon-Brenas *et al.*, 2016b). Relay intercropping into winter cereal may favor conditions for service crop emergence, without impairing cereal yield (Gardarin *et al.*, 2022). Nonetheless, this technique is complex and service crop establishment could fail, preventing its large adoption by farmers. Soil and climate conditions can explain variability of success (Vrignon-Brenas *et al.*, 2016a). It is also the result of competition for resources in a complex system formed by winter cereal, service crop and weeds. This study takes profit from 15 years of experiment on such technique to determine what are the key factors to succeed in establishing the service crop for the provision of expected services.

The database used gathers data from 46 on-farm trials settled in south eastern part of France between years 2008 and 2023. Most of them were organic (39), or in transition to organic (6) or conventional (1). In these experiments red or white clovers were sown as service crops (SC) into a winter cereal (WCC) at the end of winter. A total of 1097 quadrat of 0.25m² sampled at cereal crop harvest were compiled. Cereal, service crop and weeds (W) dry biomass were measured at cereal harvest. A Hierarchical Clustering on Principal Components permitted to determine typical groups of situations. Other data were collected such as crop and weeds density at cereal flowering, characterization of soil, climate and agricultural (crop sequence and management) conditions. A multivariate regression tree (MRT) was built as a first exploration on how these data explained SC biomass variability.

4 groups (G1 to G4) of situations are statistically defined. Mean dry biomass measured at cereal harvest for all groups are 9 T DM/ha, 0.5 T DM/ha and 0.3 T DM/ha for cereal, weeds and clover respectively. G1 represents situations where WCC biomass is high (12.8 T DM/ha) and largely dominant, preventing W and SC to grow (respectively 0.3 and 0.1 T DM/ha in

average). In the other groups, WCC biomass is much lower (mean dry biomass of the group of 7.1, 7.7 and 6.2 T DM/ha in G2, G3 and G4 respectively). G2 gathers situations where growth conditions appear to be constraining and total (WCC+SC+Weeds) biomass production is low. G3 situations presented high SC biomass (1.9T DM/ha) and reduced W biomass (0.2T DM/ha). G4 situations are the exact reverse with high biomass of W (3.6T DM/ha) and almost no SC (0.1T DM/ha). The latter gathers few situations (n=54), mainly corresponding to one field trial. MRT suggests that, except in some rare instances where climate conditions are especially favourable, SC biomass is largely penalized first by WCC higher biomass. Clover density at wheat flowering lower than 250pl/m² is also penalizing SC biomass production (n=667). Rainfall accumulation and/or fine soil texture appear to be favourable for this SC density, provided that W infestation is controlled.

Vrignon-Brenas *et al.* (2016a) mentioned a minimum SC biomass of 0.5T DM/ha to ensure weed regulation after WCC harvest. Such SC biomass is rarely observed here while situations with almost no SC biomass at cereal harvest are much more frequent. Competition with WCC appeared to be the first cause of SC failure. The threshold of penalizing WCC biomass determined here corresponds to highly productive organic conditions but reduced conventional ones. It suggests that this technique is poorly adapted in such conditions, at least without changing WCC sowing (*e.g.* interrow width). Situations of group 4 highlights how important it is that weed infestation is moderate to permit clover establishment. Finally, the analysis we process here suggest that some soil and climate conditions are more favourable for SC establishment and survival. Further analyses are needed to better define these conditions.

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Differences in growth features between species are driving cereal-legume intercrop yield (Oral #239)

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Keywords: agronomy; ecology; machine learning; intercrop

Crop diversification is increasingly promoted as a mean to improve the sustainability of agriculture while maintaining a sufficient level of food production [1]. Intercropping is a farming practice that combines at least two crop species in the same field for most of their growing periods [2], and where the two components are harvested and eventually sorted. Since plants vary in their ecophysiological functioning, a mixture of different crop species could improve the resource use efficiency, relative to its component species grown separately in sole crop. Mixtures between cereal and legume species are a prime example, on one hand because of their complementarity in nitrogen use [3], on the other hand because of its technical operationality [4].

Reports from meta-analysis [5] overall indicate that intercropping is a candidate practice for sustainability, based on its increased productivity per unit area. However, reports based on the outcomes of field experiments [6] indicate that these benefits are largely context-dependent [7]. We argue that shifting from a broad logic linking diversity to productivity to an understanding of how species features impact crop productivity is key to developing intercropping practices. More precisely, we propose to assess how the difference between associated species features are linked to the mixture productivity.

For that, we gathered a set of 37 field experiments in Europe [8] containing species-dependent measurements along with mixture and sole crop productivity. We first characterized each species by summarizing time series for plant growth (leaf area, height, biomass) into key features such as maximum value, rate or delay in growth. We then quantified plant-plant interactions with indicators based on differences between these features (*relative trait distances* in community ecology). We also characterized the cropping environment using climate and soil variables, including an indicator related to the plant nitrogen status (nitrogen nutrition index NNI, [9]).

We modeled the mixture performance as a function of environment and plant-plant interactions using a mixed-effect random forest (MERF, [10]), which is a method combining a machine learning and a mixed effect model. We used two steps to interpret our model and identify which features were important for the mixture performance. We first reduced the set of features to focus on using a stringent variable selection process during model fitting [11] and then ranked the selected variables by estimating their contribution to the variance of the mixture performance (variable importance).

We showed that features related to inter-specific plant interactions (differences between species within the mixture) were more selected and important than the ones related to species response to mixture (differences between managements). The selected features thus mainly indicated that competitive processes shape the outcome of a mixture. Among them, the difference in biomass accumulation rate, representing the strength of the competition, was consistently more important than other features. Overall, the yield of a species in mixture was positively correlated to its dominance, here captured by its stature (height, leaf area, biomass), at the expense of the associated species. Features related to the climate and to cultivars were not selected.

While we miss features related to below-ground interactions, our study contributes to understanding how management options, such as species choice or nitrogen management, have an impact on the mixture performance through their effect on the competitive strength of one given associated species.

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Temperate silvopastoral systems promote nitrification stability in the context of climate change: a case study in Brittany, France (Oral #58)

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Keywords: nitrogen cycle; agroforestry; microbial resilience; extreme weather events; structural equation modeling

Extreme weather events, such as extreme rainfall and flooding events, are expected to increase in frequency and intensity. Such events are known to disturb major biogeochemical cycles such as the nitrogen (N) cycle (Greaver *et al.* 2016). As a result, N losses from the agroecosystem to the environment will increase, leading to the alteration of soil, air, water, and biodiversity. Hence the adoption of biodiversity-based practices has gained attention as a way to increase internal regulations that limit N losses. By combining trees and grasslands, silvopastoral agroforestry is adopted in temperate regions with high livestock densities as a solution to prevent N losses while providing other ecosystem services. However, little is known about the regulation of the N cycle in temperate silvopastures, especially under extreme rainfall and flooding events (Kim and Isaac 2022). Here, we present recent results obtained on nitrification, a key process involved in the regulation of N losses, and its stability under flooding stress in two silvopastoral systems (hedgerow *versus* alley-cropping) of Brittany, France.

Nitrification potential and stability were assessed ex situ for soils sampled at three distances from the trees (0.5, 1.5 and 10m) and for two silvopastoral systems (hedgerow and alley-cropping). Nitrification potential was first measured in stress-free conditions and was explained by variables related to vegetation, soil physicochemical properties, and soil organisms (Mettauer *et al.* 2023). Then, the resistance and resilience of nitrification potential were measured immediately after four weeks of flooding stress and four weeks after the end of the stress, respectively. Resistance and resilience were considered as proxies of nitrification stability, which was explained by soil physico-chemical properties using a multigroup latent structural equation modeling (ML-SEM). The used ML-SEM enabled to test the causal relations that may explain nitrification stability and examine if similar causal patterns are shared among the distances to the trees and the silvopastoral systems.

Under stress-free conditions, spatial patterns of nitrification potential differed between the two agroforestry systems. Nitrification potential was on average 1.5 times higher in the tree row as compared to the grass-alley in the alley-cropping system, while in the hedgerow system, nitrification potential was on average 40% lower in the grass-alley next to the trees as compared to under the trees and the middle of the grass alley. These results were mostly correlated with the spatial patterns of soil pH. Under flooding stress, resistance was significantly higher under the trees of both systems while a boost of nitrification (27% to 35%) was recorded in the grass-alleys. Resilience did not differ among the distances and the two systems. The ML-SEM approach revealed that nitrification stability was positively related to higher soil organic carbon content and lower soil bulk density in the alley-cropping system. Yet, these relations were not confirmed in the hedgerow systems as none of the tested ML-SEM model fitted to the results obtained in this system.

Our results underlined the impact of the silvopastoral design on the regulation of nitrification. If the adoption of silvopastoral systems can mitigate spikes in N losses from grass alleys right after a flooding stress, results under stress-free conditions revealed higher risks for N losses in the tree rows of the alley-cropping system. Hence, trade-offs between higher risk of N losses under stress-free conditions and their limitation under stressed conditions may exist in these systems, while hedgerows seemed to promote more stable and lower nitrification in both conditions. Through the ML-SEM, our study further encourages the adoption of specific management options (improvement of soil organic matter and bulk density) as sources of external regulation of N losses under extreme climate events.

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Human urine precipitates as a phosphorus source for lettuce in hydroponics for long-term crewed space missions (Oral #329)

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Keywords: plant nutrition; nutrient recovery; organic waste; human urine; hydroponic cultivation

Soilless cultivation of plants during long-term crewed space missions will be essential to produce vital supplies such as clean water, food, and oxygen while sequestering atmospheric CO_2. Fertilizer replenishment during these missions will be cost-prohibitive, so nutrients will need to be recycled from waste. Human urine is being explored as a source of nitrogen and phosphorus for plants, as it contains high concentrations of both. During urine storage, its urea gets hydrolyzed, which increases the pH and triggers the precipitation of circa 30% of the phosphorus contained in the urine. No study has yet offered a thorough analysis of the speciation of this precipitated phosphorus, nor of its solubility for use as a nutrient source for plants in hydroponics.

Our research investigates precipitates issued from stored human urine and from treated human and synthetic urine. We report the complete phosphorus speciation of the urine precipitates, using X-ray diffraction, Fourier-transformed infrared, and solid-state nuclear magnetic resonance spectroscopies. We also address the extractability of phosphorus from urine precipitates using anion exchange membranes and nutrient solution at pH≈6 as predictors of phosphorus availability for plant uptake. Finally, we assess the availability of phosphorus from urine precipitates to hydroponically grown lettuce.

We found that urine precipitates are predominantly composed of well-crystallized struvite ($(NH_4)MgPO_4 \cdot 6H_2O$), as well as of kovdorskite ($Mg_2PO_4 \cdot 3H_2O$), and amorphous calcium phosphate ($Ca_3(PO_4)_2 \cdot xH_2O$). Circa 70% of the phosphorus contained in the urine precipitates was extractable for plant nutrition, most of it derived from magnesium phosphate minerals. Plant experiments are underway aiming to confirm that this 70% of extractable phosphorus contained in the precipitates is available to lettuce grown in hydroponics.

To conclude, our research offers a valuable approach to nutrient recovery in space or any closed system, while improving the current understanding of waste recycling for terrestrial crop production.

Effect of bio-based phosphorus fertilization on biofortification and root architecture of durum wheat in a rainfed agrosystem under mediterranean climate (Oral #353)

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Keywords: bio-based fertilizer; micronutrients; biofortification; root architecture; circular economy

1. Introduction

The future scarcity of phosphoric rock stocks is forcing to nutrient recycling at a societal scale by producing the so-called bio-based fertilizers (BBFs), allowing phosphorus (P) recovery and reuse in crop production. However, BBFs present a huge variability because they are produced from a wide range of agro-industrial by-products and different nutrient recovery techniques (*e.g.* composting, digestate, incineration, P-precipitation). P fertilization considerably affects not only P nutrition and crop yields, but also certain micronutrients bioavailability, such as Zinc (Zn) or Iron (Fe). These elements are essential for crops and, in addition, necessary in human diets. Low dietary intake in human diets produces many health problems, known as "hidden hunger". P fertilization also affects root architecture traits, influencing accessibility to soil nutrients and, consequently, crop performance and quality.

2. Materials and Methods

In order to study how different P-BBFs affect crop micronutrient uptake and soil exploration (root architecture), a rainfed field experiment was conducted using 11 different BBFs to evaluate the effect on root development, micronutrient availability to crop, and grain biofortification in durum wheat (*Triticum durum*), particularly sensitive to Zn deficiency in calcareous soils. The molar ratio of P to micronutrients was also studied since it determines the digestibility of these micronutrients. The effect of BBFs was compared with commercial mineral P fertilizer (superphosphate) applied at the same rate.

3. Results and Discussion

Limited yields were produced due to thermal stress and water scarcity during the trial. Despite not all BBFs performed equally, most BBFs increased Fe and Cu concentration while no significant differences were observed in Zn or Mn concentration in wheat grain. The molar ratio in wheat grain was also significantly affected by the P source, in particular the P: Fe ratio. This ratio was not affected by commercial mineral P supply but BBFs affected differently ranging from an increase of P Fe ratio with a variation of 24% to -50% when compared with non-fertilized control. BBFs obtained from sewage sludge ashes and poultry manure fertilizer presented the best performance in increasing micronutrient uptake and biofortification of Fe, Cu, Mn, and Zn. However, some organic BBFs with low P concentration (such as olive husk compost, or vermicompost) produced a negative effect on Fe concentration, probably due to sorption processes to organic matter that reduced its bioavailability under water deficiency. Higher root biomass was found in the BBF treatments that presented higher biofortification (sewage sludge ashes and poultry manure fertilizer), presenting up to a 22% increment of root biomass compared to non-fertilized control. A higher specific length express of roots was found in organic BBF treatments such as olive husk compost or plant digestates In this case, a lower nutrient bioavailability of organic BBFs would have produced an increase in root exploration of soil, which could make plants more resilient under water and nutrient scarcity conditions. Present results evidence the ability of BBFs to increase grain yield quality and modification of root development and morphology. However, variability among BBFs should be considered.

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From soil to yield: unraveling the role of microbiome diagnostics in enhancing biofertilizer efficiency (Oral #157)

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Keywords: arbuscular mycorrhizal fungi; biofertilizer; on-farm experiments; maize; microbiome

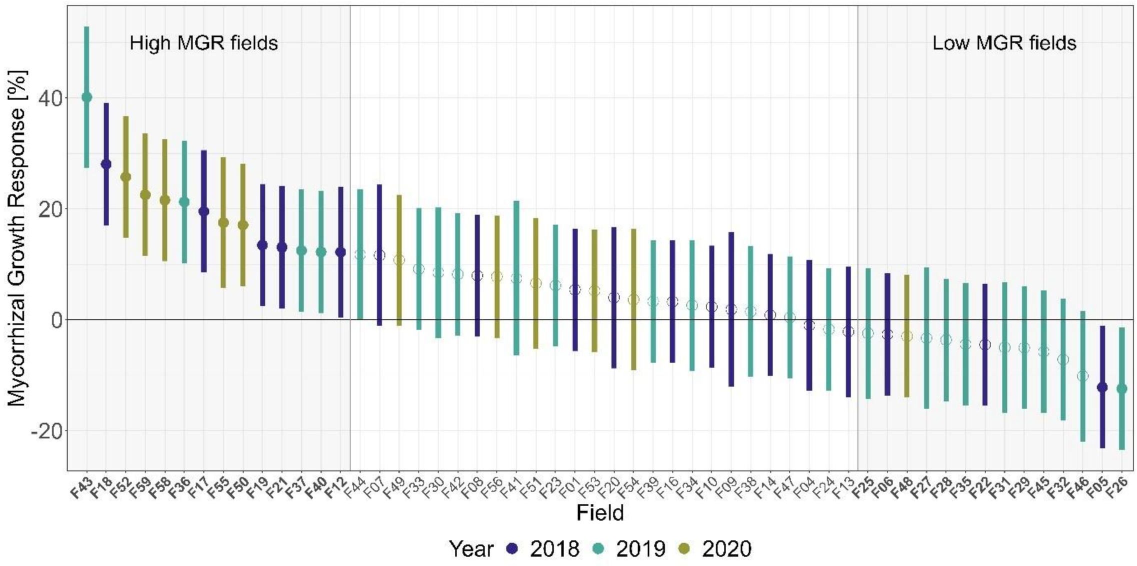

Figure 1. Mycorrhizal growth response (MGR) varied from −12 to +40%. Plot shows mean values (circle), as well as the confidence interval of MGR for each field (n = 8 independent plots), colors show year of experiment. Significant differences are highlighted by filled circles

1. Introduction

Excess use of mineral fertilizers can lead to eutrophication of rivers and lakes and biodiversity loss. Alternatives include the use of biofertilizers such as arbuscular mycorrhizal fungi (AMF). AMF form a symbiosis with most plant species, where they contribute to plant growth by providing essential nutrients such as phosphorus. However, the success of AMF inoculation is context dependent. To tackle this variability, we propose the development of microbiome diagnostics to predict successful inoculation with biofertilizer.

2. Materials and Methods

We conducted 54 field trials in Northern Switzerland where maize was inoculated with *Rhizoglomus irregulare* SAF22. We calculated the mycorrhizal growth response (MGR) which is the percent change in biomass of inoculated plots compared to control plot. Soil properties were analyzed using classical chemical and physical parameters. The soil fungal community was characterized by long-read sequencing. AMF root colonization was assessed by microscopy. The root AMF community was sequenced with primers amplifying preferentially mycorrhiza. We used various statistical methods to predict the MGR based on the soil parameters and the soil microbiome.

3. Results and Discussion

In one quarter of the fields, inoculation with AMF increased yield significantly (Figure 1). Surprisingly, the degree of mycorrhizal growth response did not depend on mycorrhizal root colonization, whether assessed by either classical microscopy approach or by sequencing of the root microbiome. Soil parameters alone proved insufficient in explaining the response variability. However, integrating soil parameters with the soil microbiome resulted in a model that could explain up most of the variation in plant growth response. Furthermore, our investigation of the root microbiome unveiled intriguing dynamics. In most fields, the inoculated AMF led to a reduction in the abundance of native AMF. Moreover, in fields with high mycorrhizal growth response, the introduced strain decreased the abundance of several pathogenic strains, suggesting a possible mechanism whereby the introduced AMF effectively outcompetes root-associated plant pathogens, leading to enhanced maize plant growth. Overall, our study underscores the utility of soil fungal indicators as strong predictors of inoculation success.

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Impact of saline water Irrigation and biostimulant use on growth and phytocannabinoid profiles in fiber hemp (*Cannabis sativa* L.) (Oral #150)

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Keywords: abiotic elicitors; bioeffectors; secondary salinization; marginal land; LC-HRMS

1. Introduction

Soil salinity affects more than 935 million hectares globally, especially in arid and semi-arid areas, and represents over 20% of the world's irrigated territories. Intensified by climate change – through higher evaporation rates, changes in precipitation, and sea-level rise – and human activities such as the overuse of fertilizers and unsuitable farming techniques, soil salinity presents a substantial challenge to both the environment and agriculture (Elmeknassi *et al.*, 2022).

The increasing issue of saline soils, leading to challenges such as drought stress, ion toxicity, and hormonal imbalances, highlights the need for salt-tolerant crop systems (Akram *et al.*, 2021). Salinity affects crops differently, depending on exposure duration, salt type, and genetic factors. Fiber hemp, with its adaptability to morphological, anatomical, and physiological changes under salt stress, including alterations in xylem vessel lumen (Guerriero *et al.*, 2017), stands out as a viable option. Soil salinity's effect on enhancing secondary metabolites like essential oils and carotenoids (Bernstein *et al.*, 2010) further underscores hemp's versatility. Its capacity to produce varied industrial products from different parts, despite saline conditions, suggests hemp as a sustainable solution for salt-impacted agricultural regions.

2. Materials and Methods

The present study examines the effects of saline irrigation on hemp, utilizing NaCl solutions with electrical conductivities (EC) of 2.0, 4.0, and 6.0 dS m^{-1} (S1, S2, and S3, respectively), against a tap water control (S0). Furthermore, it explores the efficacy of a plant-based biostimulant, specifically a legume protein hydrolysate, in counteracting the adverse impacts of saline irrigation on both crop growth and its phytocannabinoid profile.

3. Results and Discussion

Water salinity and biostimulant application significantly impacted on the growth parameters of hemp, without notable interaction between these factors. Freshwater (S0) and low salinity (S1) treatments produced similar biomass yields, averaging 12.6 Mg DW ha^{-1}, aligning with results from other studies (Struik *et al.*, 2000). The highest salinity level (S3) significantly reduced total biomass by nearly half across all plant parts, while moderate salinity (S2) also led to decreased growth, especially in total and leaf biomass. Biostimulants application significantly boosted hemp growth, with total biomass, stems, leaves, and inflorescences increasing by up to 50%, even under salinity stress. Despite the reduction in crop growth by 7%, 30%, and 48% across S1, S2, and S3 salinity treatments respectively, biostimulant application mitigated the adverse effects of salinity, including potential toxicity and nutrient imbalances. Importantly, our analysis reveals that hemp demonstrates a medium-low tolerance to salinity, with less sensitivity to higher EC levels compared to other fiber crops like flax according to data reported in FAO Paper 29.

Collected data unveil the influence of salinity on Cannabis sativa's phytocannabinoid spectrum, with a notable increase in CBD levels under higher salinity conditions and a decrease in other cannabinoids like Δ9-THC. Through PCA and ASCA analyses, it is clear that sample origin and salinity levels significantly shape phytocannabinoid profiles, without any significant interaction among the variables considered.

Our study sheds light on hemp's adaptability to salinity, suggesting that tailored cannabinoid profiling and management strategies can refine hemp varieties for designated uses, from industrial to medicinal. In addition it emphasizes the significance of biostimulants in reinforcing plant resilience and yield.

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Improving the bread making quality of winter wheat on organic farms using biogas digestate as a nitrogen fertiliser (Oral #360)

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Keywords: biogas digestate; nitrogen; nutrient management; on-farm trial

Organic winter wheat is characterised by variable grain yield and quality. To bridge the yield and quality gap while minimising the potential environmental impact, nitrogen management needs to be improved. The aim of the study was to examine how organic farmers can achieve the bread making quality of winter wheat by modifying their management practices. A one season field study was conducted on organic farms to understand the response of winter wheat grain yield and protein content to biogas digestate fertilisation depending on field properties and historical management. On-farm trials were set up on ten organic farmers' fields in Västra Götaland County in southwest Sweden.

In 2021, the selected fields had a grass-clover ley, which was ploughed before winter wheat was planted in the autumn of 2021. The trials had a randomised block design with four replications, including three in cremental N rates from split doses of biogas digestate (60, 120, 180 kg N ha^{-1}), and one unfertilised control treatment (N0). In addition to winter wheat grain yield and protein content, soil nitrogen supply (SNS) and general soil characteristics were also determined. To understand the variability across fields, information about the ley pre-crop was also recorded. Farmer fertilisation practices were investigated and compared to biogas digestate application.

The results showed that the application of biogas digestate significantly increased grain yield and protein content at all application rates. In contrast, in the unfertilised plots (N0) the grain yield was positively correlated to SNS, which ranged between 40-130 kg ha^{-1}, whereas there was no signif icant relation to the grain protein content. When looking at individual fields, only a few farms were able to reach the optimum yield with the biogas digestate rates applied in the trials, *i.e.* the wheat crop could have responded further to a higher N-rate. The same pattern was observed for the grain protein content, where four out of ten trials gave a sufficient protein content (11.5%) to get the price premia for organic wheat, showing the po tential for targeted nitrogen management depending on site characteristics. The variation in field properties between the farms was mainly related to clay content, total soil carbon and mineral soil nitrogen concentration in the autumn, and total weed biomass. The nitrogen management practices that the farmers applied differed from field to field, with variations in choice of N source and N amount. As a result, the winter wheat yield between farms varied, with a six-fold increase from 2 to 12 tons ha^{-1}, as did the protein content, from 8 to 14%. Results from the farmer practice plots did not reflect those obtained when applying similar amounts of N in the form of biogas digestate.

This study demonstrated how the bread making quality of organic winter wheat can be improved using grass-clover ley as a pre-crop in combination with biogas digestate application. The grain yield was also dependent on the long-term build-up of soil fertility, which was affected by the soil nitrogen supply measured in the unfertilised plots.

Our findings raise the need to further investigate the potential of alternative soil amendments and nutrient sources, potentially suitable for organic certification, and how they can contribute to the circular economy and sustainable nutrient management in organic farming systems.

Developing Hi-sAFe-machine learning hybrid approach as a field-specific decision support system for agroforestry systems (Oral #276)

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Keywords: agroforestry; alley cropping; poplars; crop rotation; life cycle assessment; winter wheat; oilseed rape

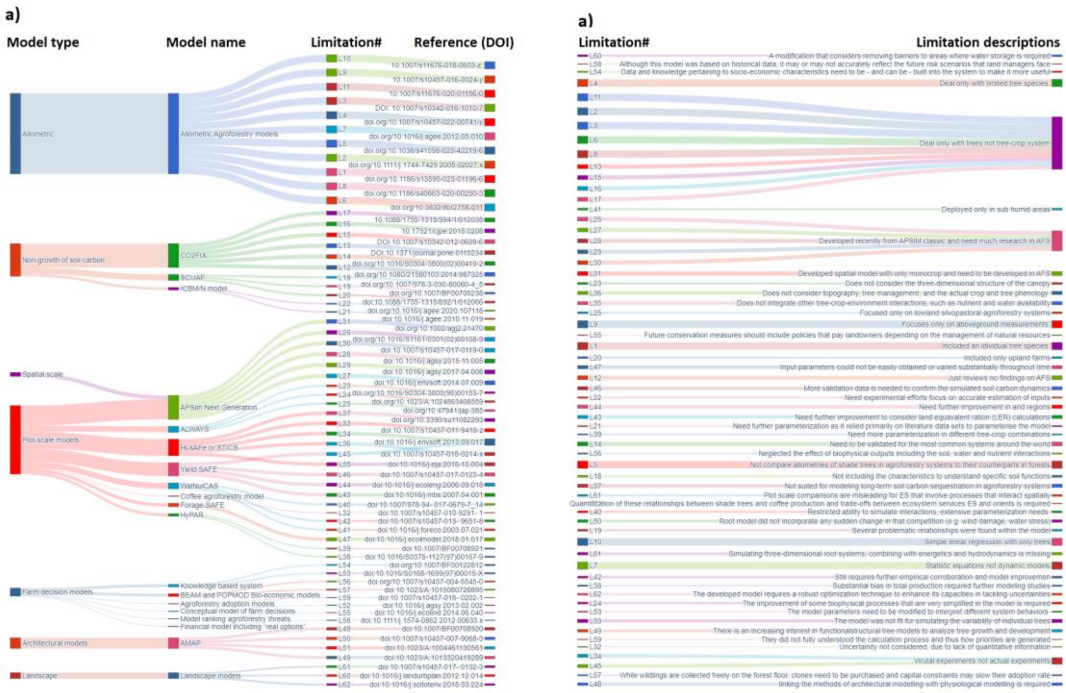

Figure 1. Current agroforestry models and their limitations. (a) the main group of models (model group), the name of the model in each group, the limitation number and the related reference as DOI. (b) the brief description of limitations for each limitation number. The thicker the node and arrow the larger the limitations

1. Introduction

Germany aims to achieve carbon neutrality by 2045, with focus needed on the agriculture sector where agroforestry systems (AFS), such as alley-cropping, can serve as effective carbon sinks by cultivating perennial woody plants alongside annual crops or grasslands. According to Beillouin *et al.* (2023), AFS are the most effective agricultural measure for increasing organic soil carbon content in proportion to area. Furthermore, the establishment, maintenance, and harvesting of the tree strips incurs additional expenditures and greenhouse gases (GHGs) emissions. AFS feature reduced wind speeds and altered evapotranspiration dynamics compared to normal arable farming systems (Markwitz *et al.*, 2020). The Hi-sAFe model is a 3D model considering competition and facilitation, which are significant mechanisms explaining positive biodiversity-productivity relationships in biodiversity ecosystem functioning research, even though it does not explicitly incorporate biodiversity as a driver for outcomes like crop yield. Machine learning approaches are increasingly being used as data-driven tools to extract patterns and insights from the ever-increasing stream of geospatial data (Reichstein *et al.*, 2019), but they have received less attention thus far in AFS.

2. Materials and Methods

Following extensive review, we found that the existing DSS lacks decision-making aids for cultivation recommendations and assessing AFS's actual climate change mitigation potential, gaining different limitations (Figure 1). The Hi-sAFe agroforestry model (Dupraz *et al.*, 2019) outperformed other models offering a unique 3D and spatially explicit framework to analyze tree-crop competition for light, water, and nitrogen. Incorporating factors such as climate, soil characteristics, species interactions, and management practices, Hi-sAFe provides a comprehensive platform for understanding the complexities of agroforestry systems. Microclimatic impacts, such as radiation (shading), temperature, humidity, and wind, depending on the distance to the wood strip and strip orientation, as well as the width, height, and density of the wood strip, are simulated in daily time steps for different woody features.

3. Results and Discussion

Multi-year (2009-2016) crop yield of oilseed rape and winter wheat in the narrow and wide crop alleys at different spaces from trees (0, 1, 4 and 7 m) were used in parameterizing Hi-sAFe. Since the model couples the pre-existing STICS crop model (Brisson *et al.*, 2003) with a new tree model, we first calibrated STICS for diverse crops under conventional arable farming conditions. To ensure, deploying the model at spatial explicit in different environment, we integrated the Hi-sAFe model with machine learning algorithms such as Artificial Neural Network (ANN) and Convolutional Neural Network (CNN) as well as partial life cycle assessment for simulating yield and GHG in AFS at a robust and spatially explicit scale, allowing for a global assessment of GHG reduction potential.

4. Conclusion

The current approach combines Hi-sAFe with machine learning to fill the limitations of the past data driven tools, dataset, and models, creating a robust DSS for agroforestry systems. The EUS is designed to allow farmers and consultants across Germany to virtually create a wide range of agroforestry systems on their property, as well as find the best sites and methods for maximizing productivity and climate change mitigation.

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Understanding and designing spring wheat/faba bean intercropping systems by virtually testing cultivar traits and management options (Oral #234)

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Keywords: crop model; crop diversification; cultivar traits; crop management

Cereal/legume intercropping allows for reducing inputs while achieving higher crop yields on the same land than expected from the monoculture crop yields of the constituent species. However, several studies have shown that the performance of intercrops depends on the genotypes chosen, crop management, and environmental conditions. Yet, evaluating multiple genotypes on various sites and under different climate and management conditions is not feasible to investigate all possible combinations (genotype × genotype × environment × management) of intercropping in field trials. Given the complexity of mixed cropping systems, crop models can be beneficial for testing hypotheses about the key factors driving competition and compensatory growth between species. Therefore, we conducted a virtual experiment to examine the interactions between a combination of varying plant heights, daily root elongation rate of species in intercropping, and nitrogen input to identify ideal traits and conditions that enhance the performance of spring wheat/faba bean intercropping at Campus Klein-Altendorf, Germany. Combining these three factors resulted in 1024 unique combinations. The simulation was conducted in the SIMPLACE (Scientific Impact Assessment and Modelling Platform for Advanced Crop Ecosystem Management) modeling framework (Enders *et al.*, 2023). To consider climate variability, 100 years of synthetic climate data were generated by the stochastic weather generator LARS-WG (Semenov and Brooks, 1999) from historical weather data of 21 years (2001-2021). The simulations were run with a model solution in the modeling framework *i.e.* SIMPLACE (Intercrop model) which was previously calibrated and evaluated. During the scenario runs, the model was annually reinitialized two months before sowing to provide identical initial soil conditions. Moreover, a 100-year-long time series of weather data was clustered to high, medium, and low rainfall determined by the cumulative precipitation during the primary growth period (April to July), aiming to examine the interplay between precipitation levels and various management strategies.

The preliminary results suggest that there is considerable variability in the land equivalent ratio (LER) across different combinations of traits and fertilization rates. Considering each trait and management separately, while keeping other factors at the default value, the variation in plant height seems to have a minimal impact on LER, although there is a trend indicating that a combination of short spring wheat with tall faba bean genotypes leads to lower LER. This phenomenon is likely due to the faba bean intercepting a significant portion of light but being less efficient in its utilization. The partial LER of both species linearly varies with variation in plant height because the radiation interception of one species is inevitable at the expense of the other species, since both species are relatively short stature plants, spatial niche differentiation is negligible. Rooting depth appears as a critical factor governing LER, with combinations of shallow rooting spring wheat and deeper rooting faba bean cultivars exhibiting higher LER, demonstrating the spatial complementarity of water usage. Additionally, it is observed that higher nitrogen inputs result in lower LER compared to no input, underscoring the potential suitability of intercropping under conditions of low nitrogen input.

Considering the interaction of all three factors (nitrogen input, plant height, and rooting depth) and yearly variability, in a high rainfall growth period, optimum LER can be achieved under conditions of low nitrogen input when tall and shallow rooting depth spring wheat are intercropped with relatively short but deeper rooting faba bean cultivars. However, in low rainfall conditions, high LER can be achieved as long as the differences in rooting depth of the species are high enough for spatial complementarity of water use regardless of which species has a deeper rooting system. This suggests a complex interplay of factors influencing LER, highlighting the importance of careful selection and management of crop combinations in intercropping systems. Furthermore, expanding testing to encompass multiple traits, indices of intercropping performance, and management options under varying soil conditions is essential for developing comprehensive guidelines for optimizing intercropping systems.

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Exploring the potential of wheat-soybean intercropping as a climate change adaptation in crop production (Oral #87)

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Keywords: diversification; agro-ecosystem modelling; cropping system; sowing date; yield

1. Introduction

Due to climate change and agricultural intensification, crop production has been negatively influenced since the early 2000s. Yet, crop production needs to be doubled to feed the growing population by 2050. Crop diversification has the potential to enhance yield stability and increase sustainability under climate change (Birthal and Hazrana 2019; Bowles *et al.* 2020). Intercropping, referring to two or more crops growing in the same field simultaneously is a vital option in crop diversification, which has been studied to outperform sole cropping in productivity, yield stability, and resilience to environmental stresses. Process-based crop models have been employed to simulate crop growth under future climate scenarios but focus only on main-stream cropping systems. To gain insights into intercropping of its essential mechanistic process and explore its potential adaptation strategy under climate change, we employ wheat-soybean relay-row intercropping as an example to: a) establish a low-parameter required crop model that can capture the light-competition of intercropping. (b) Investigate how climate change influences wheat and soybean yield in both sole and intercropped systems. 3) Explore to what extent a combination of intercropping and sowing date adjustments offset the negative impacts of climate change on crop productivity and save cultivated area.

2. Materials and Methods

A two-year field experiment was conducted in Münche¬berg, Germany. Winter wheat and soybean in sole and Relay intercropping were cultivated in both rainfed and irrigation conditions. Field observations were used for model calibration and validation. The model is a revised version of the agro-ecosystem process-based model MONICA specified for relay-row intercropping, based on the 'Horizontal Homogeneous Canopy' model. Three general circulation models (GCMs) and two emission scenarios were employed to simulate the sole and intercropping wheat and soybean yield in Germany. Different sowing date combinations for wheat (six dates) and soybean (four dates) were tested under both moderate (RCP 2.6) and extreme (RCP 8.5) climate scenarios.

3. Results

By integrating the light-competition module into MONICA, and combining intercropping-specific calibration, the model showed acceptable prediction accuracy under both rainfed and irrigated conditions. The upscaling simulation to Germany showed that compared to the historical period (1981-2010), wheat soybean relay-row intercropping can achieve higher land-use efficiency (median Land Equivalent Ratio: 1.21, CV: 8%) than sole cropping under the futuristic high emission scenario (2031-2060). Even though, intercropping will decrease the total yield by 9% (median Transgressive Overyielding Index: 0.91, CV: 11%) under RCP 8.5. Optimizing sowing dates for component crops in intercropping can elevate productivity and land-use efficiency, with the highest value found when wheat is sown 30 days earlier and soybean plant 10 days later. The intercropping under the high-emission scenario has higher median LERs and lower

CVs than that under the low-emission scenario, indicating its potential to stabilize crop yield under climate change.

4. Discussion

The intercropping version of MONICA focuses on the light competition, while below-ground competition regarding water and fertilization remains out of our scope. This simulation study was based on the experiment conducted in Germany, more field experiments involving various locations, component crops, or cultivars should be conducted for wider adoption possibilities. Under the current management level, transforming from sole cropping to intercropping increased the land-use efficiency but did not increase the total yield production. Optimizing sowing dates can aid the yield penalty but considering the feasibility of shifting sowing dates, fine-tuning and adapted machinery for intercropping are required. The indicators LER and TOI mainly emphasize yield production. Ecosystem services empowered by crop diversification were not evaluated in this study.

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Ability of the STICS soil-crop model for simulating performances and inter-specific interactions in tropical cereal-legume intercropping (Oral #159)

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Keywords: intercropping; calibration; competition; complementarity; agroecology

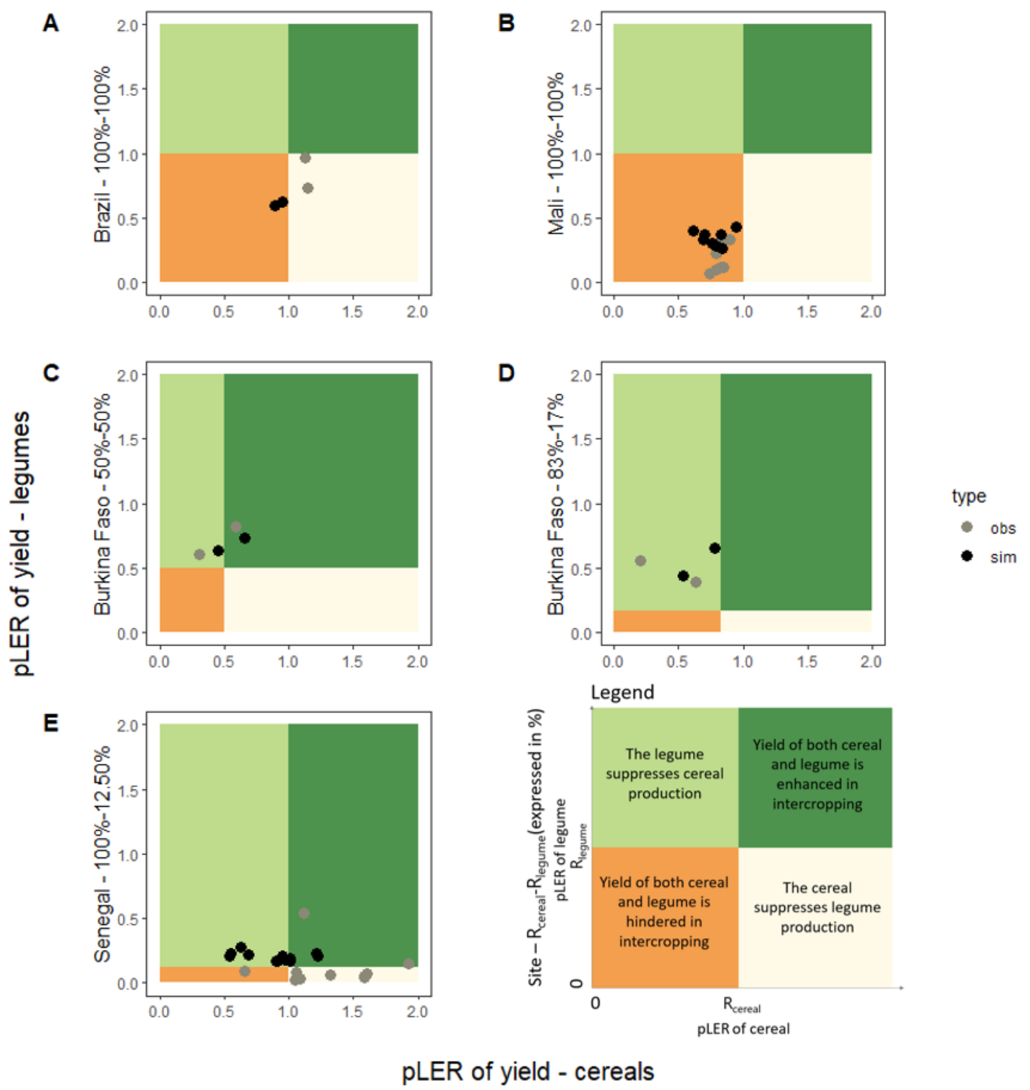

Figure 1. Graphical representation of partial LER (land equivalent ratio) of intercropped cereal and legume adapted from Justes *et al.* (2021), showing all possible outcomes in terms of interactions when intercropping a cereal and a legume. The legend of the figure describes the type of interaction at stake in intercropping when a combination of cereal and legume pLER falls in one of the areas of the graph. The calculation of the limits of each area depends on the relative density of the crop in intercropping compared to sole cropping (Rcereal and Rlegume). All study sites and all cereal and legume relative densities in the mixture compared to sole cropping are represented

1. Introduction

Intercropping offers the prospect of providing greater and more stable yield than sole-cropping in the face of climate change and increased climate variability. Cereal-legume intercropping is common in tropical cropping systems, but often with low legume density and limited or no nutrient inputs. Combining intercropping with integrated soil fertility management is a solution for promoting sustainable intensification. Long-term experiments investigating the impact of variations in soil and climate on intercrop performances are scarce throughout sub-Saharan Africa. Several models were designed to simulate intercropping, however their robustness and accuracy in reproducing intercropping functioning and performance have never been extensively evaluated for a range of tropical environments. This work aims to evaluate the robustness and accuracy of the STICS soil-crop model in simulating productivity and crop interactions for contrasting cereal-legume intercrops in tropical conditions.

2. Materials and Methods

The STICS model (Beaudoin *et al.*, 2023) was tested using data collected in on-farm and on-station experiments in Mali, Senegal, Burkina Faso, and Brazil. Various combinations of cereals (maize, sorghum, and millet) and legumes (pigeon pea and cowpea) were compared in sole cropping and intercropping. The experiments included contrasting spatial patterns, fertilizer inputs, crop varieties, sowing dates, and cereal/legume densities. The model was calibrated on sole cropping, and evaluated on intercropping. Observed and simulated partial Land Equivalent Ratio (pLER) was calculated to evaluate the ability of the model in simulating competition and complementarity effects in intercropping.

3. Results

We found that the STICS model had similar accuracy when simulating cereal grain yield of sole crops and intercrops. Model accuracy in simulating legumes was lower with intercropping compared with sole cropping. The model correctly reproduced competition and complementarity effects in intercropping between cereals and legumes in Mali and Burkina Faso and came close in Brazil (Figure 1). In Senegal, the model overestimated legumes' pLER and underestimated cereals' pLER, indicating that interspecific interactions where not correctly simulated for legumes with very low yields. Over all sites, the model simulated a reduction in legume yield due to light competition and a decrease in cereal yield due to competition for nitrogen. On the contrary, water stress had little effect on simulated yield, competition, and complementarity effects between crops.

4. Conclusion and Prospects

This study provides evidence that the STICS model simulates intercropping with a good genericity and acceptable accuracy in contrasted tropical conditions, where legume yields are not too low. We are currently refining the calibration of the model and testing its latest version (beta version 11; Vezy *et al.*, 2023) to better define the validity domain of STICS for tropical intercropping.

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Modelling the spatial distribution of light capture in strip intercrops (Oral #289)

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Keywords: Europe; strip intercropping; light capture; modelling; border row effects

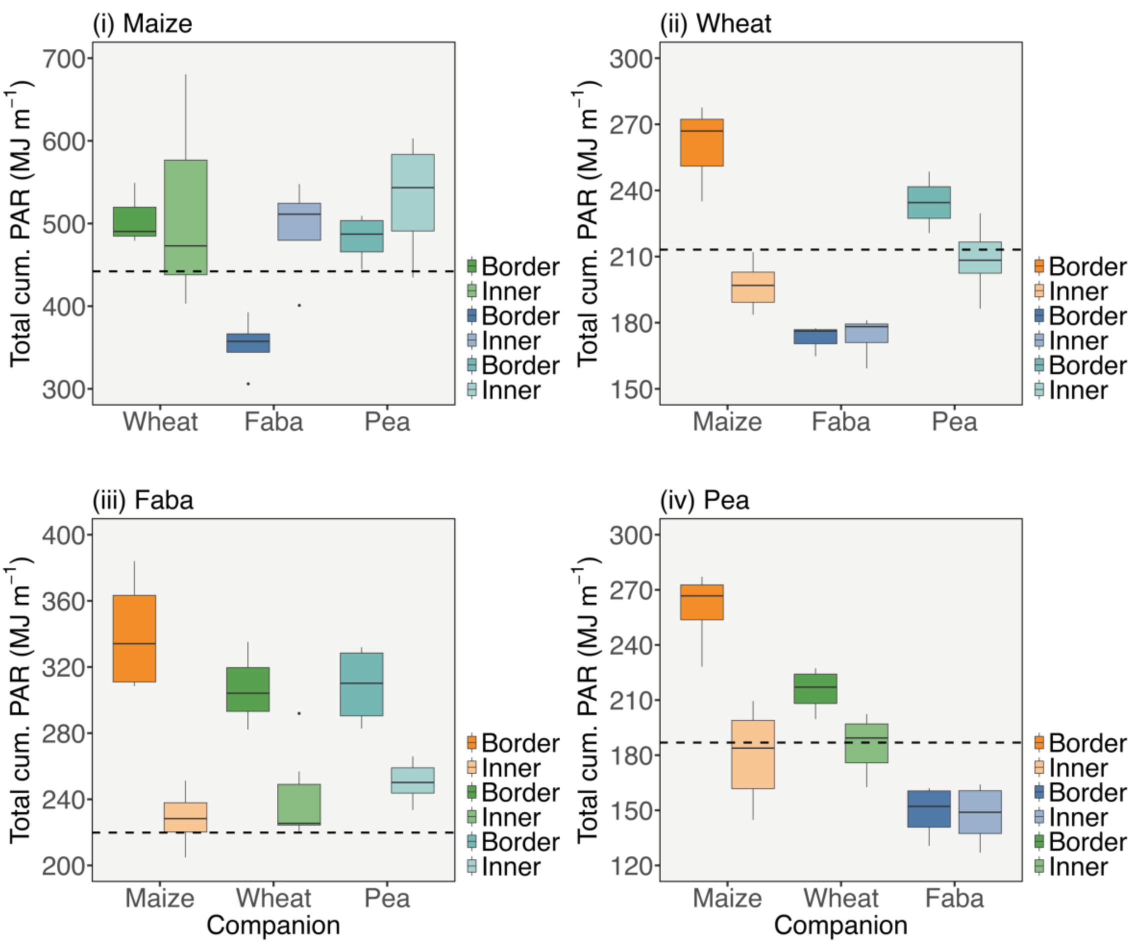

Figure 1. Total cumulative photosynthetically active radiation (cum. PAR) captured by the four species in different rows in different intercrops. Each panel represents a focal species. Different colours represent companion species and colour densities row positions. The dashed line is the monocrop light capture of the focal species

1. Introduction

Strip intercropping is a form of species mixture where the companion species are grown in narrow strips to allow species-specific management. Strong interspecific interactions occur between plants in the borders of these strips, whereas plants in the middle of the strips mostly compete for resources with conspecifics (Zhu *et al.*, 2015). Light capture differs greatly between inner and outer rows of strips and is probably a driving force for yield effects in strip intercropping. However, light capture per row is hard to quantify. Here we use a ray tracing model to quantify how intercropping affects light capture in different rows of a strip.

2. Materials and Methods

We conducted a modelling study, based on a field experiment performed in 2019 in the Netherlands (Wang *et al.*, 2023). The experiment involved six bi-specific strip intercrops including maize (*Zea mays* L.), wheat (*Triticum aestivum* L.), faba bean (*Vicia faba* L.), and pea (*Pisum sativum* L.). Maize was sown five weeks later than the other three species. Each species was grown in 1.5 m-wide strips with three rows for maize, and six rows for the other three species. We reimplemented a ray tracing model (Gijzen and Goudriaan, 1989; Wang *et al.*, 2017), using measured plant height and leaf area index as model inputs, to estimate light capture per row in intercrops and monocrops.

3. Results

In the modelled relay intercrops, the early-sown species all captured more light in the intercrop border rows than in the inner rows and monocrops due to the initial absence of neighbouring maize (Figure 1). Inner rows of the early-sown species did not show such light capture advantages. Compared to monocrop maize, border row maize in intercrops only captured more light when growing with wheat and pea, but not with faba bean because faba bean was taller than wheat and pea, and caused substantial early shading on maize, which was only partially compensated after faba bean harvest. Inner row maize captured more light in all intercrops. The simultaneous intercrops without maize did not show complementarity for light capture, and any (light capture) advantage for one species was offset by a disadvantage for the other species. Faba bean substantially reduced light capture of wheat and pea in all intercrop rows, whereas the faba bean itself only obtained a substantial increase in light capture in the border rows, and only a slight increase in the inner rows.

4. Discussion

This study indicates that relay intercrops, which exhibit temporal complementarity, are more efficient in capturing light compared to simultaneous intercrops, where species coexist for most of the season. These results align with the light capture advantages found in maize/wheat relay strip intercropping in the Netherlands (Gou *et al.*, 2017; Zhu *et al.*, 2015), suggesting that the positive effects of temporal complementarity in light capture apply to both cereal/cereal and cereal/legume combinations. The early-sown species benefited from border rows capturing more light in the early season. The late-sown maize increased light capture in both border and inner rows after the early companions had been harvested, with significant decreases in border rows with tall-statured companion species, highlighting the importance of early season competition. Use of the ray tracing model allows analysing species or variety combinations, strip widths and sowing dates are suitable for light-capture-efficient intercropping.

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Which contribution do agricultural practices and biological control make to regulating populations of *Psylliodes chrysocephala* in oilseed rape? (Oral #9)

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Keywords: cropping system; stem flea beetle; conservation biological control; flower strip; agroecological pest management

Psylliodes chrysocephala is among the main pests of oilseed rape in Europe and is mainly managed with insecticides. Increasing insecticide resistance and health and environmental concerns have highlighted the need for alternatives to chemical control, such as conservation biological control. Conservation biological control can be enhanced by (1) providing resources to beneficial organisms in and around crop fields, like providing parasitoids with resources through sowing flower strips, and (2) by redesigning cropping systems to promote bottom-up and top-down processes contributing to natural pest control.

Using an observational approach based on a network of farmers' fields, we assessed the effects of cropping systems and flower strips on *P. chrysocephala* and their regulation throughout their development cycle. We selected fields in the Paris Basin grown under organic farming, under soil conservation practices, and conventionally, with many intermediary practices. Some of the fields contained a perennial flower strip sown in 2018. Observations on the autumn phase of *P. chrysocephala* cycle were carried out in 2020 and 2021, and those on the spring part of the cycle in 2019 and 2020, with 20 to 30 fields monitored each time.

The damage caused by *P. chrysocephala* is mainly depending on the number of larvae present in the oilseed rape plants in winter. An initial hypothesis was related to the presence of residues on the soil surface, favoured in no-till farming, which could hinder the movement of *P. chrysocephala* on the soil surface. At the field level, we observed direct effects of certain practices, such as a negative effect of insecticide treatments (halving the number of larvae) and a higher presence of larvae with the occurrence of ploughing. However, we did not observe any effect of residue covering the soil surface on the amount of pest larvae. The percentage of soil covered by total vegetation (crop, companion plants and weeds) or by companion plants and weeds alone had a negative effect on the number of pest larvae, with a threefold reduction of their number when the total vegetation cover increases from 10 to 100%). Finally, of the predators present on the soil surface (carabid beetles, harvestmen), only spider activity-density had a slight negative effect on the number of pest larvae per plant. At the landscape scale, inter-annual variation in oilseed rape area within a radius of 1000 m influenced the number of *P. chrysocephala* per plant, with an increase in larvae quantities when the oilseed rape area decreased between the previous and the current year.

At the end of winter, *P. chrysocephala* larvae were on average 30% parasitised by microhymenoptera parasitoids (*Tersilochus* sp.), with considerable variation between fields. Parasitism was slightly higher (but not significantly) in insecticide-untreated fields with a flower strip than in insecticide-treated fields without a flower strip. In addition, flowering and nectar-providing weeds in the field had a positive effect on parasitism levels.

At the end of their development in oilseed rape stems and leaves, larvae fall to the soil surface before pupating underground, where they are highly vulnerable to predators. Using sentinel prey similar to *P. chrysocephala* larvae, we observed that approximately half of the prey was consumed within 24 hours, with no difference between cropping systems. Camera observations coupled with sentinel prey revealed that larvae were mainly consumed by carabids (64% of predation events) and secondarily by rove beetles, ants and chilopods. These are generalist predators that are functionally redundant, resulting in homogeneous predation rates between cropping systems, despite observed differences in the composition of ground-dwelling predator communities between cropping systems.

In conclusion, *P. chrysocephala* populations can be limited throughout their life cycle. Growing oilseed rape with service plants in the autumn and the presence of floral resources in the spring, for example in flower strips, are two ways of promoting this regulation. We have also verified and validated the fact that *P. chrysocephala* spend the summer in forests and that flower strips are not a favourable habitat for these pests during their summer diapause. The biological control by predators and parasitoids occurs after the damage has been done to the crop. It does contribute to reduce pest populations only in the following year, which argues in favour of multi-annual and territorial management of *P. chrysocephala* populations.

Modelling fungal diseases in intercrops (Oral #267)

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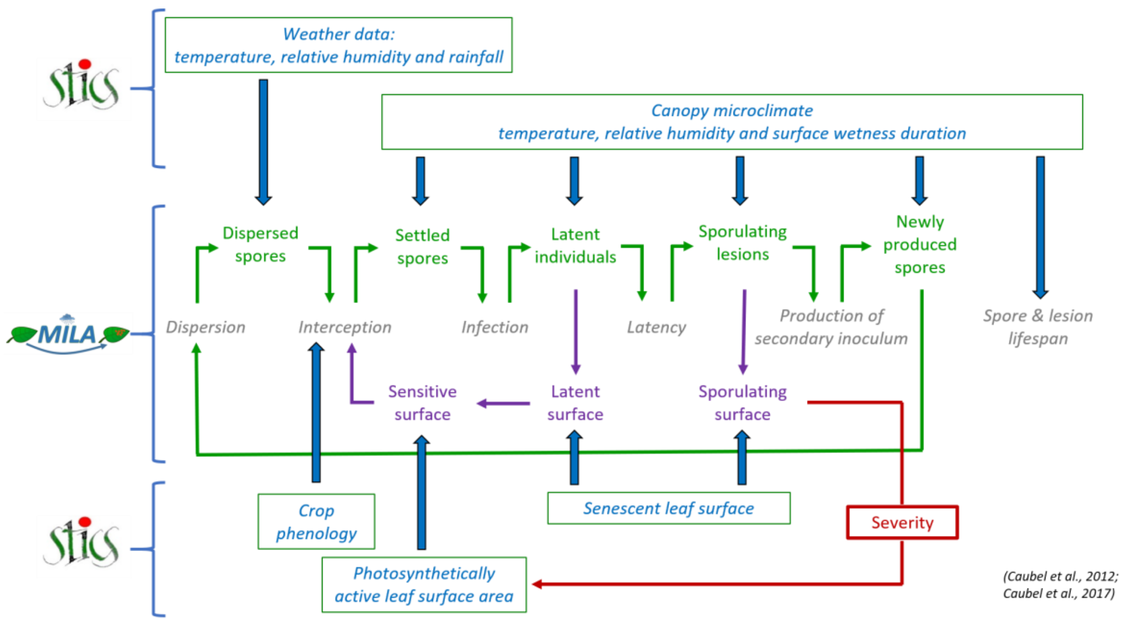
Keywords: agronomy; epidemiology; modelling; intercropping; plant-microbe interaction



1. Introduction

Intercropping is a management practice inspired by the interaction between the biodiversity of an ecosystem and its resilience under stress. Intercropping is of strategic interest in the face of climatic and environmental issues, having already shown the capacity to bring beneficial outcomes on production and ecosystem services (for example Gardarin *et al.*, 2022). However its ability to regulate pests and diseases, and thus reduce pesticide use with limited yield loss, is less well characterised and generally assessed separately from other services. An integrated approach would allow the design and adaptation of these systems considering all of the services they provide.

Such an approach can be found in the modelling of plant-microbe interactions within a soil-climate system. To our knowledge, modelling work conducted so far on diseases within intercropping systems has been limited mostly to cultivar mixtures and functional processes focused on epidemiological dynamics. We have found limited works dealing with interspecific diversification, crop development and larger ecosystem processes, alongside the main drivers of an epidemic.

Based on previous modelling work (Caubel *et al.*, 2017) on the coupling of a generic disease model (MILA) with a crop model (STICS), our aim is to adapt MILA from a single crop context to a bi-specific intercrop system, using STICS intercropping options (Vezy *et al.*, 2023).

2. Proposed method

Our work rests on the following steps: a comprehensive review of the literature to create an inventory of the processes for fungal disease regulation in diversified canopies, and the short-listing of two modelling approaches to develop and test within the MILA-STICS framework.

STICS is an integrated, deterministic, process-based model which runs at a daily time-step using input variables related to climate and soil as well as the cropping system including its management practices. MILA simulates the dynamics of disease severity and the development of fungal pathogens depending on crop phenology, developmental stages and canopy microclimate. Thanks to STICS daily calculations of canopy characteristics (LAI, microclimate, *etc*.), MILA can provide feedback on the progress of an epidemic throughout the simulation period.

The two alternatives to be tested will be chosen in order to compare two contrasting approaches: one resting on hypotheses which simplify the system, the other on more realistic hypotheses. Some leads may be found in Levionnois *et al.* (2023) and Calonnec *et al.* (2012).

3. Expected results

The main fungal disease regulation processes at play in diversified canopies stem from the dilution and barrier effects on spore dispersal and interception as well as the effect of the modification in canopy microclimate on infection success. STICS already covers calculations of mixed canopy microclimate so adapting MILA resides only in the modification of the dispersal and interception modules by inserting the dilution and barrier effects.

Our testing procedure will involve studying the model behaviour in terms of coherence for the simulation of spore dispersal, and its sensitivity to canopy parameter modifications (*e.g.* height of the two species, leaf and/or plant density, interrow distance, *etc*.).

The new version of the MILA-STICS model will simulate the growth dynamics of the crop and the development of the epidemic as a function of practices, soil and climate, considering the close interactions within the system comprising the host crop, the pathogenic fungus and the non-host crop. Built in a generic manner, the model will be used to search for crop management that maximise the regulation of the pathogen while maintaining the provision of multiple services in a context of global change. Studying the intercropping system as a whole allows to work on trade-offs between disease control and other benefits of diversifying cultures for a given system, to test various crop arrangements and management practices to optimise outcomes and to run long term simulations to include climate change.

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Effects of light quality and quantity on tillering dynamics and investment in reproduction of the perennial grain crop *Thinopyrum intermedium* (Oral #70)

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Keywords: *Thinopyrum intermedium*; tillering; light quality; light quantity; grain yield

1. Introduction

Agronomic studies on the use of intermediate wheatgrass (*Thinopyrum intermedium*) as a perennial grain crop show a grain yield decline over the years, which calls for a better understanding of the link between *Th. intermedium* vegetative development and investment in reproduction. Recent data suggest that density and row spacing might influence yield components in *Th. intermedium* (Fernandez *et al.* 2020; Hunter *et al.* 2020). Light is a major factor driving morphological and physiological changes with plant density. It could influence grain yield, both indirectly through tillering and directly by affecting yield components. Tillering is critical for the reproductive stage of perennial grasses and is very plastic to the light environment: notably a decrease of the red:far-red light ratio (R:FR ratio) is known to reduce tillering (Casal *et al.* 1985). Therefore, this study addresses the effects of light quantity and quality on the tillering dynamics and yield components of *Th. intermedium*.

2. Materials and Methods

Plants were sown in a growth chamber and vernalized for 7 weeks at 3 leaves. In total, 72 plants were transplanted and placed in a tunnel under light filters. Five R:FR treatments were tested: 1.09 (natural light), 0.55, 0.44, 0.30, 0.17. Between 27 and 29% of PAR was transmitted by the filters. A control was added with a R:FR of 1.1 and 96% of transmitted PAR.

Each new tiller was marked every week, specifying order and position on the mother tiller. Haun stage was noted for every tiller, every week up to flag leaf stage. Then, heading and flowering were noted. New tillers developing after flowering of the main stem were not monitored. Height of the main stem was measured up to flag leaf. All plants were harvested when a majority of spikes was mature. At harvest, the total number of tillers, rhizomes and spikes were counted. Plants were dried (40°C for 3 days) before weighing vegetative dry biomass. Measures for each spikes included dry weight, number of spikelets, number of florets on 3 spikelets (basal, middle, apical), number of grain and grain weight.

3. Results

In the control, height of the main stem was significantly shorter throughout its development and the difference with the other treatments kept increasing over time. Interestingly, no significant effect of R:FR was observed on height except for lowest R:FR treatment (R:FR=0.17). R:FR treatments had more impact on tiller number. Lower PAR reduced tiller emergence, so did lower R:FR. Differences between R:FR treatments were only significant between the 1.09 and the 0.44 and 0.30. Both primary and secondary tillers emergence were inhibited by decreasing PAR and R:FR, and tertiary tillers mostly appeared in the control. Surprisingly, the lowest R:FR treatment had the highest number of tillers after the control and the 1.09. Phyllochrons of main stems, primary and secondary tillers were affected by R:FR treatments, but within each treatment only the control had significantly different phyllochrons between tiller orders. Effects on yield components are still under study (sample being processed) and will be presented during the conference.

4. Discussion

These results highlight that tillering plasticity to the light environment is high in *Th. intermedium*. This means that current populations of *Th. intermedium* should be very sensitive to plant density, leading to competition for light and adaptation to light quality. Therefore, increasing light penetration at the base of the canopy at specific times of the crop cycle (using planting density, cuttings and post-harvest management practices) may be an agronomic lever to manage tillering dynamics and investment in reproduction over the years, although it has to be tested in field conditions. Furthermore, this study provides physiological information on the tillering dynamics and leaf development of *Th. intermedium* for different tiller orders, which can be used to favour productive tillers.

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Implementation of Halophyte/Tomato cultivation systems in Moderately Saline Soils (Oral #154)

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Keywords: salinity; intercropping; sequential cropping; micropropagation; crop production

1. Objectives

Most arable lands in Mediterranean countries are located in arid and semiarid regions, where water and soil salinity, water shortage and nutrients deficiency in soils are the major constraints affecting food and fodder production. In this context, halophytes emerge as alternative cash crops to be used in sustainable saline production systems, due to their ability to cope with soil and water salinization and to restore biodiversity. The overall objective of our research is to develop sustainable and environmentally friendly new farming and producing systems based on the use of halophytes.

2. Methods

For this purpose, two complementary approaches using the halophyte *Arthrocaulon macrostachyum* have been implemented:

(a) Intercropping and sequential cropping systems between tomato (*Solanum lycopersicum* var. Sargento) and the halophyte in saline soil conditions. The goal was to improve tomato yield in a cost-effective biological way while providing halophytes as value-added crops.

(b) Micropropagation of elite halophyte germplasm. The control of plant micropropagation is a prerequisite for fundamental research but also for applied purposes such as saline agriculture, site rehabilitation, or endangered plant preservation.

3. Results

(a) Sequential cropping altered tomato plants physiology, which was reflected in changes in the antioxidant metabolism and photosynthesis performance as well as in the quality of the fruit. Remarkably, sequential cropping increased 20% tomato production with respect to monoculture.

(b) We achieved efficient micropropagation protocol for *A. macrostachyum* using shoot explants derived from *in vitro*-grown seedlings. Superior genotypes were selected from explants grown in high strength and NaCl content medium, which were then rooted and acclimatized to *ex vitro* conditions. A comprehensive characterization including determination of oxidative stress parameters, photosynthesis efficiency and mineral nutrient contents was done during this process.

4. Conclusions

This research (1) sheds light into the physiological and biochemical mechanisms underlying tomato/halophyte interaction, (2) provides a solid *in vitro* platform for the production of elite *A. macrostachyum* germplasm for ulterior uses, independently on seasonal variations and with prospect of scaling up, and (3) highlights the applicability of halophytes in biosaline agriculture.

Interspecies diversity in morphological responses of a panel of crop and weed species to water stress (Oral #94)

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Keywords: morphological plasticity; water stress; crop/weed competition; climate change; biomass allocation

1. Introduction

Weeds are the most damaging pest for yields in arable crops, as they compete with the crops for light, minerals and water (Oerke, 2006). Because of climate change, crop-weed competition for water is expected to increase.

As water use and crop-weed competition depend on plant morphology (Moreau *et al.*, 2022), we investigated the interspecies diversity in morphological responses to water stress on five weed species (*Abutilon theophrasti* Medik., *Alopecurus myosuroides* Huds., *Avena fatua* L., *Geranium dissectum* L., *Tripleurospermum inodorum* (L.) CH Schultz) and two crop species (*Triticum aestivum* L. - soft wheat and *Brassica napus* L. - rapeseed), that co-exist in temperate arable cropping systems and pedoclimates.

We focused on traits involved in light competition (Colbach *et al.*, 2019):

- Leaf area to leaf biomass ratio (SLA): efficiency to produce leaf area (for photosynthesis and transpiration) from a given leaf biomass.

- Height to aboveground biomass ratio (HBR): ability to grow taller from a given aboveground biomass (for radiation interception above the canopy).

- Leaf to aboveground biomass ratio (LBR): leaf production efficiency from aboveground biomass.

- Root to total biomass ratio (RBR): propensity to explore soil to uptake water and nutrients.

2. Materials and Methods

A greenhouse experiment was performed on a platform equipped with automatic watering systems. Plants were grown in nutrient-rich individual pots, with seven levels of water availability, ranging from 10% to 95% of field capacity. For each species × water treatment combination, five plants were sampled at two phenological stages (early and late vegetative or early vegetative and flowering, depending on the species). Morphological traits were analysed in response to a water stress index. Generic non-linear regressions were fitted, whose response parameters were to characterise interspecies diversity.

3. Results

For all species, SLA decreased whereas HBR increased with increasing water stress index. RBR and LBR varied less. For most species × stage combinations, the proportion of biomass allocated to roots (*vs* aboveground organs) increased. LBR response to water stress depended on the combinations (increase, no effect or decrease). *G. dissectum* and *A. theophrasti* were the most responsive species for all traits, especially at the flowering stage.

Most species × stage combinations enhanced water uptake ability (RBR increase) and lowered water demand per unit leaf biomass, but some favoured one mechanism. At low stress levels, *G. dissectum* and flowering *A. theophrasti* favoured water uptake ability (RBR increase without SLA decrease) whereas early vegetative *T. inodorum* only reduced demand per unit leaf biomass (SLA decrease without RBR increase). Late vegetative rapeseed and *A. fatua* kept a better light-interception potential (high HBR).

The species effect explained most of the variability in parameter values, followed by growth stage. In contrast to weeds, water-stressed crop species tended to increase the proportion of biomass allocated to their roots. Most water-stressed dicotyledonous species increased the proportion of aboveground biomass allocated to leaves whereas monocotyledons favoured stems.

4. Discussion

This study provides new insights on comparative ecology of crop and weed responses to water limitation, and is the first to compare the morphological plasticity of such a wide range of weed species. Trait responses are consistent with the literature (Monaco *et al.*, 2005; Chahal *et al.*, 2018; Moreau *et al.*, 2022). Species × stage combinations had diverse behaviours, which involved different response mechanisms to water stress, in line with Basu *et al.* (2016)'s plant classification from ‘water savers’ (that reduce transpiration) to ‘water spenders’ (that maximise water uptake). To our knowledge, no studies identified clade- nor status-dependence of RBR and LBR responses to water stress. Additional research is needed to characterise other species and identify generic trends to predict the behaviour of a wider range of weeds. Our formalisms will feed a 3D mechanistic model (Colbach *et al.*, 2021) to predict the outcomes of future climate-dependent crop-weed interactions (Cournault *et al.* 2024, second presentation in this congress).

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Does the application of nitrogen fertilizers on the crop sowing row change the crop-weed competition in low-herbicide cropping systems? (Oral #78)

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Keywords: weed; nitrogen; competition

1. Introduction

Promoting biological weed regulation by shifting resource availability and use from weed to crop may provide an option for a more sustainable weed management. Light is generally the main resource for which crops and weeds compete in conventional cropping systems. But, with the need to reduce mineral nitrogen fertilizer use, better management of crop-weed competition for nitrogen may become crucial. Especially, applying nitrogen fertilisers locally on the crop sowing row (rather than broadcasted across the whole field) could make more nitrogen available to the crop to the detriment of weed plants (mainly located in the inter-row) (Ditomaso 1995). This option could be valuable for crops with wide-spaced rows and early nitrogen requirements (as nitrogen fertilisers could be applied at sowing time), such as sugar beet. Studies on the placement of nitrogen fertilisers on the sowing row focussed on the environmental and economic advantages of this technique. However, the consequences on crop-weed competition have been less studied, and no references are available on sugar beet. In this context, the present study was conducted with a two-fold objective in order to determine:

(O1) To which extent placing nitrogen fertilisers on the sowing row affects the dynamics in space and time of nitrogen in soil,

(O2) The consequences of on-row nitrogen application on crop-weed competitive relationships.

2. Materials and Methods

O1 was addressed in a field experiment (2021 and 2022), while O2 was addressed by combining the results from a field experiment (2022) and a systematic review of the literature.

The field experiment was conducted on sugar beet in the Somme region (North-Western France). Two nitrogen application techniques were compared: a field-wide broadcast *vs.* an on-row application. The dynamics of soil mineral nitrogen were monitored with measurements at two depths, four distances from the sowing row, and two or three dates after sowing (from 7 to 45 days). In addition, in 2022-2023, sugar beet and weed biomass was measured about four months after sowing. In parallel to our field experiment, the literature was reviewed following the method of Mahé *et al.* (2022) without restriction on crop species and geographical region.

3. Results and Discussion

Results from our field experiment showed that the amount of nitrogen in the soil was greater around the point of application when nitrogen fertiliser was applied on the sowing row (*vs.* broadcasted). This effect persisted over time but faded away. It was visible in the superficial soil layer in both years, but was visible in the deeper layer only the rainy year.

Despite significant effects on soil nitrogen dynamics, applying nitrogen fertilizers on the sowing row (*vs.* broadcasted) did not significantly affect sugar beet and weed biomass in our field experiment. This finding contrasted with that of our systematic review of the literature showing that, in most cases (10 out of 12 articles in total), crop growth was increased and/or weed growth decreased when nitrogen fertiliser was applied on the sowing row. This discrepancy between results from our field experiment and those of the literature may be due to differences in the studied crop species, their spatial arrangement (interrow distance) and geographical area.

4. Conclusion

Placing nitrogen fertiliser on the sowing row (*vs.* broadcasted) does modify soil nitrogen dynamics, but the consequences on crop-weed competition vary. Therefore, this technique can help to promote crop *vs.* weed growth, but not systematically, and further studies are needed to better understand the conditions of success.

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Predicting plant available water holding capacity of soils from crop yield (Oral #303)

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Keywords: inverse modelling; APSIM (agricultural production systems simulator); soil digital mapping; with-in field variability

1. Introduction

Within field variations of plant available water capacity (PAWC) of soil is one of the major causes of spatial yield variability in dryland agriculture systems, as PAWC interacts with pre-season and in-season rainfall and other climatic variables to determine crop growth and final yield. Quantification of such variations helps to better understand the changes in soil texture and subsoil constraints to inform spatially explicit management practice.

2. Method

We developed and tested a general inverse approach to estimate PAWC from crop yield and yield maps. The agricultural production systems model (APSIM) was used to simulate wheat yield on synthetic soils with contrasting PAWC and climates. The simulated results were used to develop an empirical model to relate simulated yield to PAWC. The empirical model was inversely used to predict PAWC from observed crop yield. Potential prediction ability was quantified using independently simulated wheat yield on actual soils. The actual ability was assessed with measured wheat yields and PAWC. We also further extend this approach to predict and map in-field variations of PAWC from yield maps of single and multiple crops. Soil PAWC maps were produced based on inversely predicted PAWC using crop yield maps together with in-field management information, and compared with: 1) available water capacity derived using laboratory-measured soil properties, and 2) soil types derived from proximally sensed soil spectra and ground geophysics for four representative farms in Australia.

3. Result

The approach had higher accuracy for sites with high rainfall or dominant summer rainfall. It could potentially provide acceptable PAWC predictions across contrasting climate regions (prediction error < 37 mm, 33.5%). The prediction error using crop yield against measured PAWC was <25 mm (26.5%). Our results demonstrate that soil PAWC can be reliably predicted from crop yield. The predicted PAWC maps matched well with within-field spatial variation of soil types, and well reflected the impact of soil constraints (*e.g.* salinity), and soil classifications from soil survey and local experience. This demonstrates that the predicted PAWC from crop yield using inverse modelling can reflect the soil physicochemical variations within-field.

4. Discussion

This approach provides an alternative way to predict PAWC rather than directly measuring it *via* soil sampling, with profound implications for reducing labour and costs. The generated PAWC maps can be combined with process-based modelling to predict crop yield and yield zones and to inform spatial field management and soil sampling.

Sensitivity of nitrogen leaching reduction by winter cover crops to management interventions at landscape scale (Oral #300)

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Keywords: APSIM; modelling; N leaching; sensitivity analysis; catch crops

1. Introduction

Nitrogen (N) leaching losses to groundwater are an environmental risk in intensively managed agricultural systems. Among others, an adaptation strategy to mitigate such pollution risks is to reduce the fallow (bare soil) period duration by sowing cover crops after the winter grazing of forage crops (Carey *et al.*, 2018). Cover crops can take up excess residual N after previous crops, reduce N concentration in drainage water, and reduce drainage volume through transpiration (Thapa *et al.*, 2018). However, the effectiveness of cover crops to mitigate N leaching depends on plant growth, and is largely influenced by local environmental and soil conditions, in addition with farmer's management decisions (Malcolm *et al.*, 2022). This makes it difficult to quantify the benefits of cover crop adoption across large areas to inform regional environmental planning.

2. Methods

In this study, we use a variance-based sensitivity analyses to spatially estimate the contribution of different management factors (plant population and sowing time) to the effectiveness of cover crops to mitigate N leaching losses (Crosetto *et al.*, 2000; Teixeira *et al.*, 2017). The Agricultural Production Systems sIMulator next generation (APSIM-NextGen) oats model was first tested against field data for two New Zealand locations with contrasting climates (Southland and Canterbury) to verify prediction accuracy. The model was then set up to calculate the effectiveness of cover crops to reduce N leaching in relation to a fallow (control) treatment at 5 km resolution considering contrasting management options characterised by sowing times from June to October and populations of 150 and 300 plants/m². Two soil types were considered: 1) a deep stony sand soil, and 2) a very deep, heavy silt loam.

3. Results

Results showed that the sensitivity to management varied spatially, with considerable share of variability explained through factor interactions, particularly for more complex model outputs such as N leaching amounts. Overall, N leaching losses were more sensitive to sowing time than plant population in both soils, with this pattern being more pronounced in the deep stony sand soil. The results also indicate that the cooler region (Southland) was more sensitive to sowing time than warmer one (Canterbury). In both regions, the sensitivity index of N leaching also exhibited spatial patterns in response to changes in temperature profiles with elevation.

4. Discussion

These results indicate that cover crops effectiveness to reduce N leaching varies within and across large regions. Similarly, spatial variation in the sensitivity to management parameters differed in response to environmental conditions. Therefore, management interventions should be included in detail in spatial analysis models, to allow more accurately estimate variability in cover crop effectiveness across a landscape.

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Developing a model to simulate carbon cycling and water competition in vineyard (Oral #92)

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Presenter: Luisa Leolini (luisa.leolini@unifi.it)

Keywords: biogeochemical cycles; crop modeling; inter-row grass cover; vineyard management

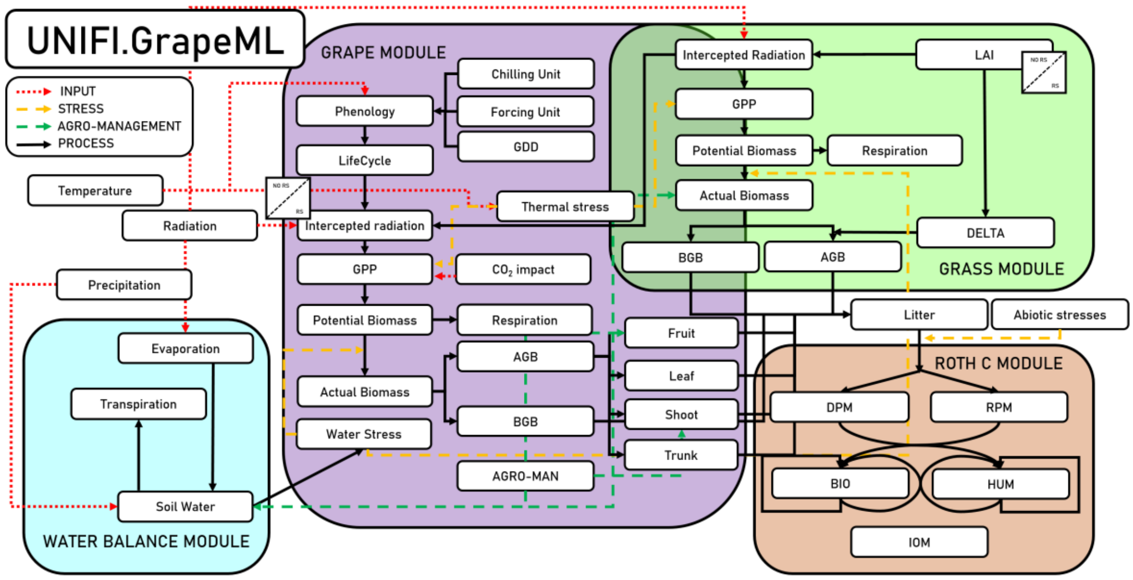

Figure 1. UNIFI.GrapeML workflow

1. Introduction

The synergy between different technologies such as field sensors and crop models is fundamental for crop monitoring growth and yield, while assessing climate change impacts at both field and broader scales. In the perspective of climate change mitigation, the implementation of biogeochemical cycles within crop models is essential to evaluate water and carbon (C) fluxes and C sequestration capacity of the agro-ecosystems. This requires an accurate monitoring of those cropping systems in which the atmospheric C can be stored and long-time sequestered in biomass compartments (*i.e.* vineyards and orchards). In this work, the first version of UNIFI.GrapeML model (Leolini *et al.*, 2018), previously based on the radiation use efficiency approach for simulating biomass growth and development, was implemented with modules simulating water competition between tree and grass layers and soil carbon fluxes. Methodological approach (Figure 1) and preliminary results are presented here.

2. Materials and Methods

The UNIFI.GrapeML model was initially coupled with the GRASSVISTOCK model (Leolini *et al.*, submitted), which included the grass and soil carbon modules (RothC model, Coleman &

Jenkison, 1996), to account grass growth dynamics, water competition and carbon fluxes in vineyards. The grass module was calibrated and validated under different climates in Italy (Torgnon: 45.84°N, 7.58°E and Borgo S. Lorenzo: 43.95°N, 11.35°E) to simulate daily fractional transpirable soil water (FTSW), net ecosystem exchange (NEE), gross primary production (GPP) and ecosystem respiration (Reco) in agro-pastoral systems. Currently, this module is integrated in UNIFI.GrapeML, and under testing, for evaluating its capability in vine biomass C-partitioning and inter-row grass growth in Mediterranean vineyards.

3. Results

The first results provided by the grass module showed satisfactory performances at simulating biomass (Torgnon: r = 0.68; RMSE = 72.79 g m^{-2} dry matter; Borgo S. Lorenzo: r = 0.78; RMSE = 67.46 g m^{-2} dry matter) and FTSW (Torgnon: r = 0.88; RMSE = 0.13; Borgo S. Lorenzo: r = 0.95; RMSE = 0.13) in pastures. Daily C-fluxes simulations, carried out only at Torgnon, confirmed the goodness of the simulations (NEE: r = 0.60; RMSE = 0.02 Mg C ha^{-1}; GPP: r = 0.84; RMSE = 0.02 Mg C ha^{-1}; Reco: r = 0.67; RMSE = 0.02 Mg C ha^{-1}).

4. Discussion

The simulation of ecophysiological processes (*i.e.* biomass growth, water and C fluxes) of plant species is challenging in cropping systems composed of multiple vegetation layers such as vineyards and orchards. To our best knowledge, current grapevine growth models are not able to well represent ecosystem fluxes, since processes such as water competition between vegetation layers and soil organic carbon turnover from different residues are still not included (Moriondo *et al.*, 2015). In this context, the implementation of UNIFI.GrapeML is a fundamental step to reduce uncertainties in the dynamics of biomass growth, soil water content and soil C fluxes estimates, thereby promoting optimization of agronomic practices with regards to productivity and climate mitigation.

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A crop forecast-based approach for in-season nitrogen application in winter wheat (Oral #91)

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Presenter: Marlene Palka (marlene.palka@zalf.de)

Keywords: crop forecasts; nitrogen fertilisation; winter wheat; on-farm experiments; economic return to applied nitrogen

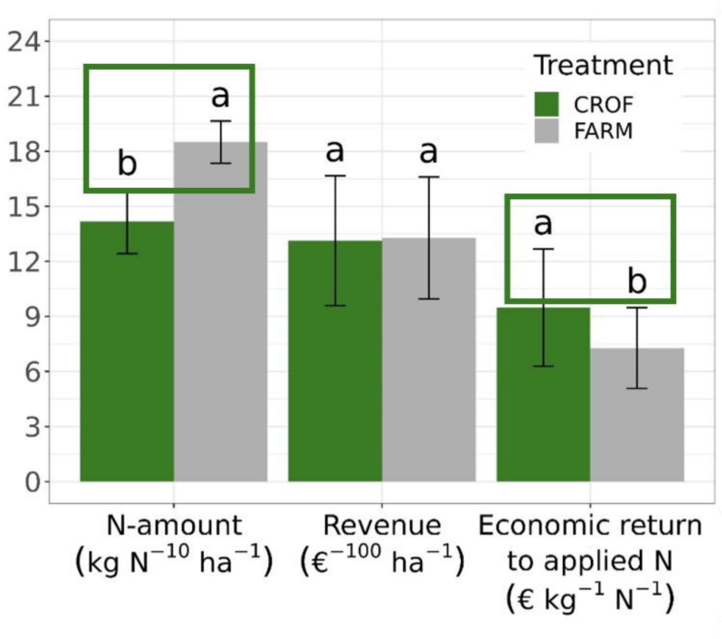

Figure 1. Total amount of nitrogen applied (N-amount), revenue, and economic return to applied N (± standard deviation) of winter wheat in Eastern Austria, fertilised according to crop forecasts (CROF) and farm practice (FARM). Lower case letters indicate significant differences between treatments ($p<0.05$)

1. Introduction

While agricultural production is among the main drivers of anthropogenic climate change, projected effects of climate change and climate variability increase the pressure to provide food in sufficient quantity and quality at the same time. Inadequate nitrogen (N)-fertilisation practices, that fail to consider seasonally variable weather conditions and their impacts on crop yield potential and N-requirements, cause reduced N-use efficiency. As a result, both the ecological and economic sustainability of crop production are at risk. Forecasts of crop yield and development have thus been promoted as promising means towards more targeted fertilisation practices. The aim of this study was to develop a season-specific crop forecasting approach that allows for a targeted N-application in winter wheat while maintaining farm revenue compared to empirical N-fertilisation practices. Traditionally, crop forecasts are based on climatological records. Evidence that future growing conditions will deviate from historic averages and the improvement of weather forecasting skill gave reason to move to crop forecasts that use seasonal weather forecasts for this study instead.

2. Materials and Methods

The present crop forecasts were generated using the process-based crop model SSM iCrop (Soltani and Sinclair, 2012) combined with state-of-the-art seasonal ensemble weather forecasts (SEAS5, Johnson *et al.*, 2019) downscaled to a 1 km grid over the case study region of Eastern Austria. Forecasts included key N-management variables, such as phenological stages (PHEN), above-ground dry weight and grain yield (GRNY), total N-uptake (CNUP), as well as plant-available soil water and mineral N-content. Precise predictions of PHEN were required for an accurate timing of N-fertilisation, while GRNY and CNUP forecasts defined the amount of N (N-amount) applied.

Throughout the season, these variables were forecasted through monthly iCrop runs for three winter wheat on-farm experiments in Eastern Austria. iCrop was supplied with observed daily weather data from sowing until the last day of each previous month, and downscaled seasonal forecasts from then until harvest. To quantify the operational potential of using these crop forecasts for in-season N-fertilisation, each experimental field was divided into two treatments: (i) FARM, where N-amount was applied according to common farm practice, and (ii) crop forecast (CROF), where N-amount was applied such that forecasted mean GRNY and protein content (PROT) met FARM levels but forecasted CROF economic return to applied N (ERAN) was increased through a reduction of N-amount compared to FARM.

Each field was treated as a complete block. Significant differences in ERAN were tested through an ANOVA model, including block and treatment as fixed effects.

3. Results and Discussion

Results from the three on-farm experiments showed a reduction in NAmount of -23.42% (-43.33 kgN ha^{-1}) when implementing CROF compared to FARM. While maintaining revenue from high-quality grain sales (PROT>14%), lower N-amount led to a significant benefit of +30.22% (+2.20 € kgN^{-1}) in ERAN (Figure 1).

Prior to this study, iCrop was extensively parameterised and tested against comprehensive field datasets in the target wheat production region (Manschadi *et al.*, 2022). For applying the present approach and extrapolating the results of this study to other production environments, iCrop (or any other crop model used) first needs to be adapted and parameterised to capture local conditions well. However, under the projected increase in non-average growing conditions, in-season N-application is expected to further benefit from crop forecasts in the future overall.

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Using low-cost NIRS method for helping smallholder to detect nutritional deficiencies and imbalances (Oral #84)

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Keywords: non-destructive analysis; NIR spectroscopy; smallholders; fertilizer

Lack of control over fertilization is one of the major factors in the yield gap between smallholders and large oil palm plantations (Monzon *et al.*, 2023). The diagnostic tool known as leaf analysis method is used by a large number of plantations to manage their fertilization and relies on annual leaf analysis and specific long-term experiments (Dubos *et al.*, 2022). However, this method is not accessible to smallholders, mainly due to the cost of annual leaf analysis. As a consequence, major imbalances in fertilization are generally observed. The most important nutrients to monitor in this crop are N, P, K and Mg (Woittiez *et al.*, 2017). However, current methods to measure leaf nutrient status are long, costly and require hazardous chemical reagents. Recent developments in near-infrared spectrometry (NIRS) have made it possible to create increasingly low-cost measurement equipment, without the need to transform the leaflets (Prananto *et al.*, 2020).

We tested the possibility to use a small portable infrared spectrometer (Nirone S2.2 Evaluation Kit from Spectral Engines) in order to make fertilization management more accessible for smallholders. This spectrometer has a reduced spectral range of 1750-2150nm which has been selected in a prior study testing the correlation between leaflet contents with various spectral ranges. A total of 92 leaflets composite samples were taken from several plots of smallholders and large plantations in West Africa. The plots were located in marginal hydric conditions of Benin and in more favorable conditions of Nigeria, in plantations with different nutritional status, age and plant materials, allowing a large range of variability. Spectral Measurements were taken directly on fresh leaflets on the frond 17, using in classical leaf analysis. Laboratory measurements were got according to the standard methodology of Leaf Analysis. PLS regressions after preprocessing the spectra were used to set up predictive models for the concentration of N, P, K and Mg in the leaves. Goodness of predictions was evaluated by crossvalidation with 10 folds.

In our conditions, the measured values (in % of DM) ranged from 1.5 to 3.0 (N), from 0.10 to 0.17 (P), from 0.23 to 1.03 (K) and 0.12 to 0.69 (Mg) which corresponds to leave nutrients content generally observed in oil palms plantations. A satisfying accuracy between measured and predicted nutrients contents was generally observed but depended on the considered nutrient. For instance, N was the better predicted nutrient (RMSECV=0.19). In contrast, Mg was quite poorly predicted (RMSECV = 0.092). In terms of error, the proportion of samples predicted with an error > 20% was lower for N and P (2% and 1%, respectively), compared to K (30%) and Mg (60%).

Our results showed that using a portable and cheap infrared spectrometer could be used to easily and quickly predict nutrients contents in a wide-range of nutritional conditions. However, compared to the standard leaf analysis methodology, prediction accuracy is lower especially regarding Mg and K. In a context of advices to smallholders, the trade-off between time, cost and precision is in favor to lower cost even if it means being less precise. This technology appears interesting to (i) detect situations with severe deficiencies and/or imbalances and (ii) educate smallholders to best management practices.

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How do Community Supported Agriculture in Norway and the UK get members to eat more vegetables and be more content? (Oral #263)

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Keywords: community supported agriculture; short food supply chains; sustainable production methods; dietary transition; organisation models

There is need for a transition of the food system towards more sustainable cultivation methods and more plant-based diets (Billen *et al.*, 2021; Willett *et al.*, 2020). Community supported agriculture (CSA) may have a positive environmental impact locally and increase vegetable intake among members (Medici *et al.*, 2023). It is a format for provisioning food locally, where consumers to various degrees are involved in the production process. In this study we search to identify factors that have a positive impact on members' contentment with CSAs and that contribute to increase their consumption of vegetables. We also explore differences between CSAs in Norway and the UK in terms of organisational models and member characteristics.

In collaboration with CSA network organisation in the UK and Norway, an electronic survey with CSA members was performed in the two countries, and the data was analysed as summary statistics and with correlation and regression analyses.

The results show that, compared with the British, Norwegian CSA members participate far more actively in the cultivation and harvesting of the vegetables, and they more often make the prepayment for the whole season. In both countries, CSA membership was perceived to have caused improvements in members' life quality, physical and mental health, and vegetable intake, corroborating with other studies (Mills *et al.*, 2021; Zepeda *et al.*, 2013). Regression analyses show that members who participated more actively in the CSA, who were concerned about environment when buying food, and who received more of their vegetables through the CSA, were also more satisfied with their CSA and had a stronger perception that their vegetable consumption level has increased as a result of their membership. Members with lower education were more likely to have discovered new vegetables through the CSA. Correlation analyses find that vegetable quality and affordability is associated with higher contentment, and that learning how to cook and grow vegetables through the CSA is associated with higher consumption of and interest for new vegetables.

Overall, the results indicate that CSAs stimulate contentment with organisational models which imply active participation of members. However, despite their more active involvement in the growing process, Norwegian CSA members are not more satisfied with their CSAs than the British. This could be explained by British CSAs high involvement of members in social activities, which might have a similar effect as a more practical involvement. Members' emphasis on environmental aspects indicates that sustainable production methods are important for CSAs to remain attractive. However, CSAs in both countries must be able to supply good quality and affordable vegetables in sufficient quantities to keep their members happy. For vegetable consumption to increase through CSA membership, it could be beneficial to provide courses on how to grow vegetables, and information about how to cook them.

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Integrating crop and livestock beyond farm level: how serious games may help co-designing collaborations between neighbouring farmers (Oral #131)

Julie Ryschawy, Solène Pissonnier, Myriam Grillot

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Keywords: landscape; crop-livestock integration; collective organization; agroecology; participative approach

Crop-livestock integration is a theoretical ideal for sustainable agriculture. Albeit decreasing due to limiting factors at the farm level (*e.g.* work constraints), crop-livestock integration beyond farm level is seen as a promising option. However, local integration between neighbouring farms requires collective redesign to address organizational issues faced with increasing levels of spatial and temporal coordination (Asai *et al.*, 2020). Specific methodologies are needed to co-design scenarios of crop and livestock coordination beyond farm level, involving a diversity of local actors.

We aimed to show how serious games can be used to cope with this challenge. We focused on supporting co-design of scenarios in two French regions considering neighbouring farm collaboration to reintegrate crop and livestock.

Two serious games, Dynamix and Oviplaine, were built using the same principles: i) a participatory approach taking multi-actor needs and objectives into account (*e.g.* livestock farmer, shepherd, crop farmer) (Barreteau *et al.* 2014) , ii) facilitate exchanges between farmers to build collective strategies, iii) consider technical changes at farm level and organizational changes at farmer group level, iv) include a spatially-explicit board game (map of the region).

Dynamix allows co-designing flows of grain, fodder and manure between neighbouring farms taking storage and transportation into account. Albeit Dynamix includes animal tokens, grazing on neighbouring farm is not its core. Oviplaine is an adaptation of Dynamix focused on cover crop grazing on crop farms. It allows to design day-by-day grazing itineraries for herds from plot to plot. Both games include simulation models allowing to consider supply-demand balanced for each type of crops and grassland, and seasonal variations in production. In Dynamix, a multicriteria evaluation of the co-designed scenarios allows to discuss benefits and trade-offs at the individual farm and group levels.

We applied the games with two groups of farmers: i) Dynamix in south-western France, with 4 crop aiming to diversify their cropping systems and to sell grain and fodder to livestock farmers and 5 livestock farmers interested in local and non-GMO feed for their animals; ii) Oviplaine in a specialized crop area, in the Parisian Basin with 4 crop and 1 livestock farmer aiming to build an itinerary for the herd.

Dynamix helped to quantify technical scenarios for each farm and equilibrate a local supply-need balances with 81.4 tons of cereals, 25.6 tons of protein crops, 120 tons of hay and 154 tons of manure. As crop farmers did not want to spend time dealing with storage and transportation of exchanged materials, two complementary organisational options were considered: i) plan one-on-one collaborations with individual livestock farmers able to store grain and fodder and ii) involve a local cooperative to facilitate logistics and agreements, anticipate needs and find more farmers if necessary.

Oviplaine helped the participants to build an itinerary from September to February. Some plots could be grazed during a few days, others for a few weeks. Seasonal availability of resources was estimated according to climate and crop farmers practices. The map helped to discuss the possible routes, access to water, possibilities to fence the plots, escape risks and eventual fallback zone in case of raining and damages on fields.

Both approaches confirmed the importance of working with spatially-explicit board games, tokens and maps to facilitate discussions and planning between participants. They allowed taking into account the spatial, temporal and organizational aspects. Both approaches are complementary. While Dynamix considers a larger diversity of actors, including famers and possibly third-party to organize logistical aspects over a year, Oviplaine focuses on the technical aspects of day-by-day cover crop grazing to follow the herd’s itinerary. Applying the serious games on two case-studies with different contexts, actors and challenges revealed their strong potential. Games can easily be scaled-out to other agricultural contexts.

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Stakeholders' perceptions of climate change and challenges for grain legume adaptation to future climate in France (Oral #133)

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Keywords: grain legumes; adaptation; climate change; knowledge for action; survey

1. Introduction

In Europe, increasing the area cultivated with grain legumes has been identified as a lever to mitigate and adapt to climate change. However, climate change will also impact these crops (Marteau-Bazouni *et al.*, 2024). It is thus necessary to explore adaptation options to sustain grain legume performances in the context of climate change.

To better design innovations for adaptation, it is important to consider the needs and activities of stakeholders (Beveridge *et al.*, 2018; Cerf *et al.*, 2012). Although several studies have surveyed producers and experts for their perceptions of climate change and adaptation in Europe (*e.g.*, Peltonen-Sainio *et al.*, 2020), no data are available for grain legumes.

The objectives of this study were to assess (i) stakeholders' perceptions of climate change and its impacts on grain legumes, (ii) the actions they imagine to develop innovations for adaptation, and (iii) the knowledge that is currently available, as well as the knowledge they would need to implement these actions.

2. Materials and Methods

We conducted 32 semi-structured interviews with stakeholders involved in different stages of grain legume value chains in France. Participants were identified with a snowball sampling. First, we selected advisors from 10 regional Chambers of Agriculture to cover a large part of the French territory. Participants were then asked for contacts in other professional sectors: cooperatives and industries (11 participants), extension services (6), and seed breeding and multiplication (5). We analyzed interview recordings to identify stakeholders' perceptions of climate change and possible adaptation options related to their activities. We then derived profiles of stakeholders based on their perceptions of climate change and adaptation.

3. Results

A majority of participants reported that climate change has already negatively impacted grain legumes' performances. They reported a rise in the occurrence of heat stress, milder winters with cold snaps, and an unequal repartition of rain characterized by an increased frequency of drought periods and heavy rains, which represent major constraints for pea, faba bean, and lentil management and performances. The impacts of climate change on biotic pressure (weeds, pests, pathogens), on the frequency of extreme events, and on the interannual climate variability are considered among the main challenges for adaptation. Conversely, the average temperature increase is regarded as an opportunity for species such as soybean, lentil, and chickpea, especially in the northern half of France.

The participants proposed various contributions to climate change adaptation, such as experimenting or supporting the experimentation of agronomic levers, breeding grain legume varieties adapted to changing climate conditions, supporting the introduction of new species, creating value to secure producers' income in spite of climate variability, and sharing knowledge on grain legume cultivation or climate change. Each profile was associated with different innovations, space and time scales for action, and knowledge needs.

4. Discussion

Although the participants have observed, tested, and imagined numerous adaptation options, they perceived that climate and technical constraints, as well as sociotechnical lock-ins, limit the effectiveness of these adaptations. Producing and sharing knowledge among the various stakeholders is thus a challenge to support the adaptation of grain legume cultivation to current and future climate. We propose here an original synthesis to gather ideas and identify future research areas.

Our results raise the need for new methods to handle adaptation to climate change, balance short-term and long-term objectives, and establish synergies between researchers and various stakeholders to design effective adaptation strategies for grain legumes.

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Activity analysis through the course-of-action research program: an innovative method for analyzing farmers' practices (Oral #302)

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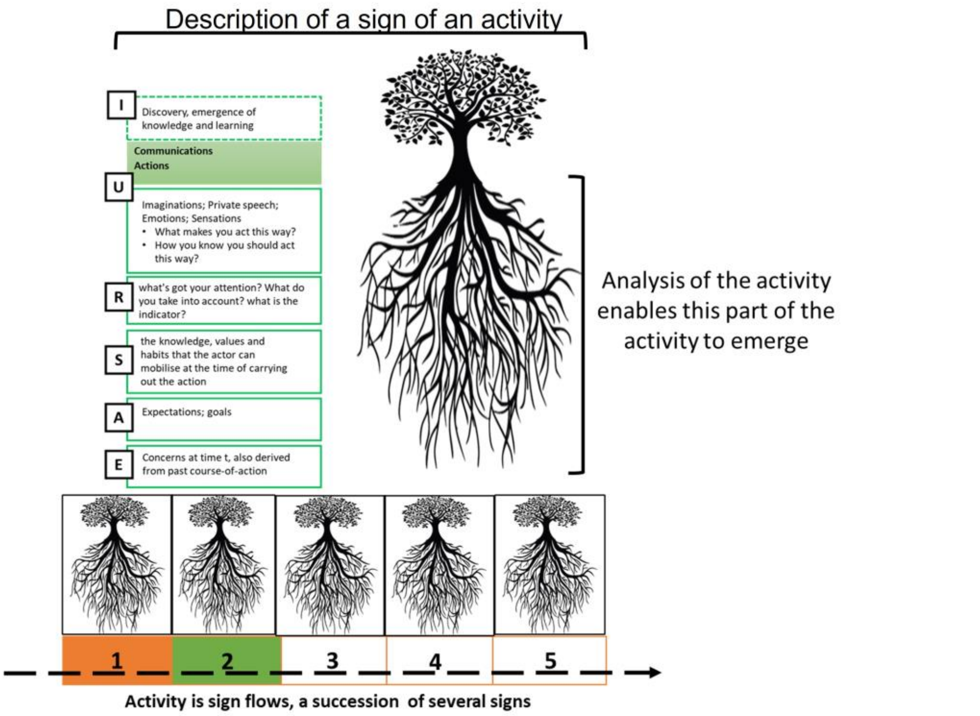
Keywords: activity analysis; agricultural practices; plant health; cocoa agroforestry systems



The sign considered as a tree with its visible part and its invisible part (the tree root) (Astier et al., 2003 ; Theureau, 2010; Azéma, 2017)

Figure 1.

Moving towards sustainable and input-efficient cropping systems involves analyzing farmers' practices, particularly those related to managing plant health. Understanding the knowledge they use and the underlying logic guiding their practices (Altieri, 2004) is crucial. Agronomy often focuses on describing and evaluating the technical sequences adopted by farmers but pays less attention to their specific knowledge and implementation methods. Farmers have various ways of assessing their agroecosystem health, using different criteria, indicators, and threshold levels (Toffolini *et al.*, 2016). This diversity is reflected in their choice of diverse agricultural practices to manage crop health.

Therefore, our objective is to specifically analyze how Ivorian cocoa farmers manage cocoa tree health during the implementation of practices. To achieve this, we used the Activity Analysis method from the field of education sciences, specifically the “Course of Action” research program. This program studies human activity in various social domains and situations. A course of action refers to "the activity of a stakeholder in a specific state, actively engaged in a specific physical and social environment, belonging to a specific culture, which is meaningful for him/her, or can be shown, narrated, and commented on by the stakeholder at any moment of its unfolding to an observer-interlocutor under favorable conditions" (Theureau *et al.*, 2003). A stakeholder's activity is defined as the dynamic of asymmetric interactions between him/her and his/her environment, meaning these two parts in this series of interactions do not have the same level of influence. In our case, activity represents the implementation of a farming practice resulting from interactions between the farmer (the stakeholder) and the cropping system (the environment).

The activity analysis methods, as described by Theureau (2010), aim to closely approach the reality of farming practice implementation. They seek to understand the inherent complexity of these practices and highlight key indicators. This approach considers activity as a succession of signs (Theureau, 2006).

In this study, we applied the activity analysis method, specifically self-confrontation and simultaneous, deferred, and interruptive verbalizations, to a sample of eight cocoa-based agroforestry systems – four managed organically and four conventionally – in the Agnéby-Tiassa region of Côte d'Ivoire. These plots differ in associated agrobiodiversity (high or low) and agricultural management intensity (high or low). We hypothesize that cocoa farmers' plant health management practices vary and are influenced by the structure and composition characteristics of the associated agrobiodiversity, whether in an organic or conventional plot. Activity analysis has allowed us to highlight varied rationale explaining the diversity of practices implemented for cocoa tree health management, clearly linked to associated agrobiodiversity. This original method allows us to understand these practices more in detail compared to a classic agronomic diagnosis. This interdisciplinary approach, borrowing from education sciences to adapt a method to agronomic sciences, should lead to the emergence of new knowledge and a better understanding of health management practices. This will be particularly useful, among other things, for contributing to the co-design of innovative and sustainable cropping systems.

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Co-building organic agriculture expansion scenarios with increased nitrogen autonomy at territorial scale: the case of Morlaix communauté (Oral #106)

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Keywords: local stakeholders; circularity; nitrogen; territory; autonomy

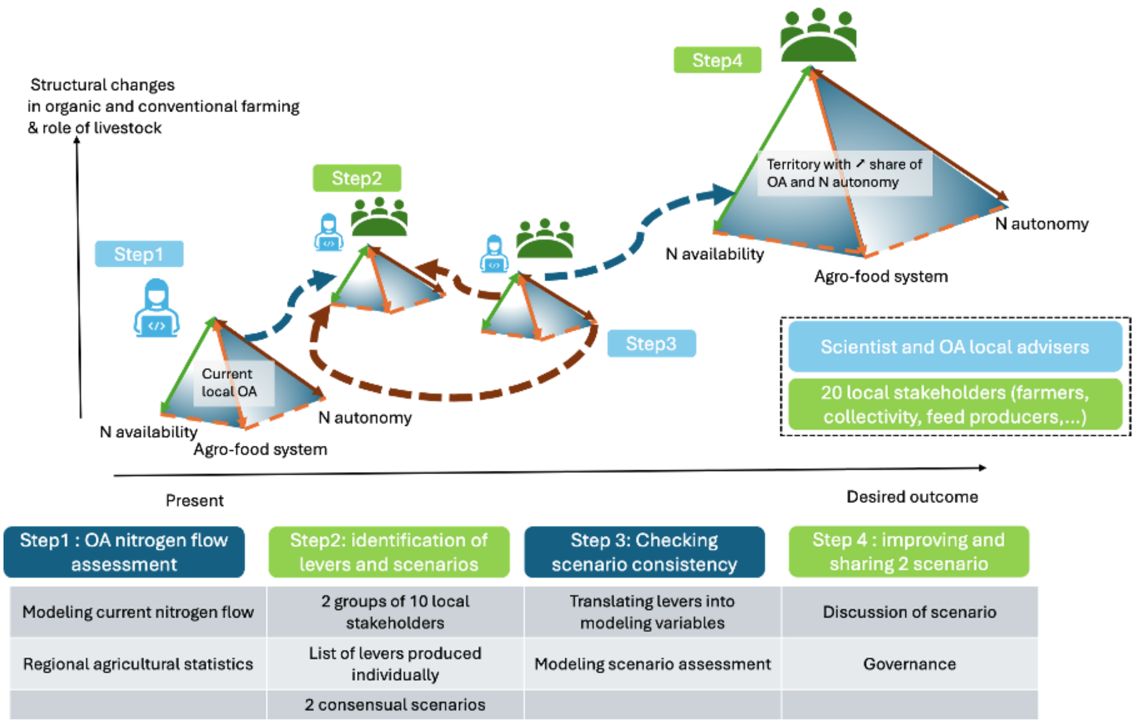

Figure 1. Four-step process for participatory modeling of organic agriculture (OA) expansion scenarios (adapted from ref. [4])

1. Introduction

Organic agriculture (OA) has been identified as key strategy in the European Green Deal to increase the agricultural area dedicated to OA from the current 10% to 25%. One of the key challenges to achieve this goal is the careful management and improved circularity of nutrients, particularly nitrogen, which is a limiting factor for the expansion of OA agri-food system [1]. Recent papers suggest that focusing on the territorial or landscape level can effectively enhance agri-food system sustainability [2]. Similarly, participatory modelling scenarios have shown promise in designing a more sustainable future for the agri-food system. However, existing frameworks lack the ability to assess the complementarity of OA and conventional agriculture within a territory. Here our analysis aims to co-build scenarios with local stakeholders to expand OA to 30% of total agricultural land. By incorporating insights from local stakeholders into a nitrogen budget model, we assess the consistency of two co-built OA expansion scenarios with increased nitrogen autonomy.

2. Materials and Methods

The study focused on Morlaix Communauté district, a high livestock intensive district in Brittany covering 39 772 ha with 10% OA. Our research was conducted in four steps adapted from the participatory design agroecological pathways methodology designed by ref. [4] (Figure 1). The first step involved assessing the current nitrogen flows of OA by calibrating the ALPHA N-budget model [5] using regional agricultural statistics on agricultural productions and land use. Steps 2 and 3 consisted of scenario workshops with 20 territorial stakeholders divided in two groups (representing a wide range of perspectives including dairy, poultry and vegetable farmers, local officials, OA feed producers and water management entities) aiming to reach 30% OA. In steps 3 and 4, we translated qualitative drivers from the stakeholders in quantitative drivers based on existing literature and applied these values in the two scenarios.

3. Results

Our analysis highlights that current OA nitrogen autonomy in Morlaix Communauté stands at only 56%. The territory produces close to 34 $kgN \cdot ha^{-1} \cdot yr^{-1}$ with 60% of animal products. The main N input is biological nitrogen fixation accounting for 41%., followed by conventional manure for 34%, imported feed for 13%, and atmospheric deposition at 12%. Overall nitrogen use efficiency of OA is around 40%. During the workshops, local stakeholders listed nearly 100 levers to increase OA in the territory. Two third of cited levers primarily address economic and social changes with a significant focus on land use changes and current scattered parcels. The remaining third of these levels enhanced its nitrogen autonomy in case of expansion. These latter levers were used to develop two main scenarios that focus on variations in OA crop and livestock mix, the incorporation of legume crops and the level of integration of crop and livestock mix. These factors all contribute to the circularity of nitrogen in the territory.

4. Discussion

In both OA expansion scenarios, contrasting pathways are observed to achieve increased nitrogen autonomy levels of 60 and 70%. Livestock plays a pivotal role in these scenarios by effectively balancing nitrogen flows within the system, especially through the use of manure to fertilize OA crops. However, there is a critical contextualized trade-off to consider regarding the livestock density threshold and nitrogen autonomy. We provide concrete examples of agri-food systems scenario transition co-developed with local stakeholders emphasizing the potential enhancements through the integrating other environmental dimensions such as the energy functioning of OA, or phosphorus and carbon flows.

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Forestry transition interaction and farm trajectories on pioneer fronts: insights from Amazon Basin in Guaviare and Paragominas (Oral #345)

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Keywords: farm trajectory; agroecology; women role; deforestation; bifurcation

In the Amazon agricultural is a major driver of deforestation and losses of biodiversity. Understanding farm trajectories may provide insights into new pathways for the development of sustainable territories.

This research conducted in the pioneer fronts of Guaviare and Paragominas aims to explore the contributions of different farm trajectories to the establishment of sustainable territories. We emphasize the significant role of family work group dynamics, of women and agroecological principles in shaping farm trajectories and fostering territory sustainability.

Patches within the study sites were selected based on spatial factors such as land use, roads, settlements, and forest transition status (conservation, regeneration, degradation, and deforestation), as well as trades off between agricultural development and environmental conservation identified through interviews with key informants. Drawing from existing literature on farm trajectories in the Amazon Forest and key informant interviews, we constructed six archetypes representing the possible farm trajectories in the study sites and that correspond to most common trajectory patterns (*e.g.* substance slash and burn, pasture intensification in beef cattle, cattle in land expansion). Through a snowball sampling technique, we conducted 55 semi-directed interviews with both male and female farmers.

We found three additional archetypes highlighting ongoing shifts in trajectory patterns, influenced by factors such as local markets and land propriety rights. Our findings also revealed that farm trajectories limiting forest degradation or deforestation are found in farms presenting financial constraints or with aged farmers. In patches with favorable territorial conditions, such as accessible roads and supportive public policies, the first phases of trajectories are always associated to deforestation. However, in later stages of farm trajectories farmers tend to use agroecological principles while some of them kept on deforesting.

Bifurcations within work groups such as separations, illnesses or deaths of the heads of the family are were a driver of the observed trajectories, however, change of the number of family members did not affected trajectories. Women play a fundamental role in stable trajectories, by performing most of the agricultural tasks performed by men, by participating to the management of the farm and through their off-farm activities. Our findings indicate that women who are alone tend to be in an unstable phase of their farm trajectory.

This study provides valuable insights into the complex interactions between farm trajectories, forest transition, and sustainability in pioneer fronts.

Past and present farm trajectory patterns should be discussed in order to analyze the extent to which sustainable farm pathways can be built in the future.

What motivate West African cocoa farmers to value trees? Taking the 4Ws approach to the heart of the field (Oral #64)

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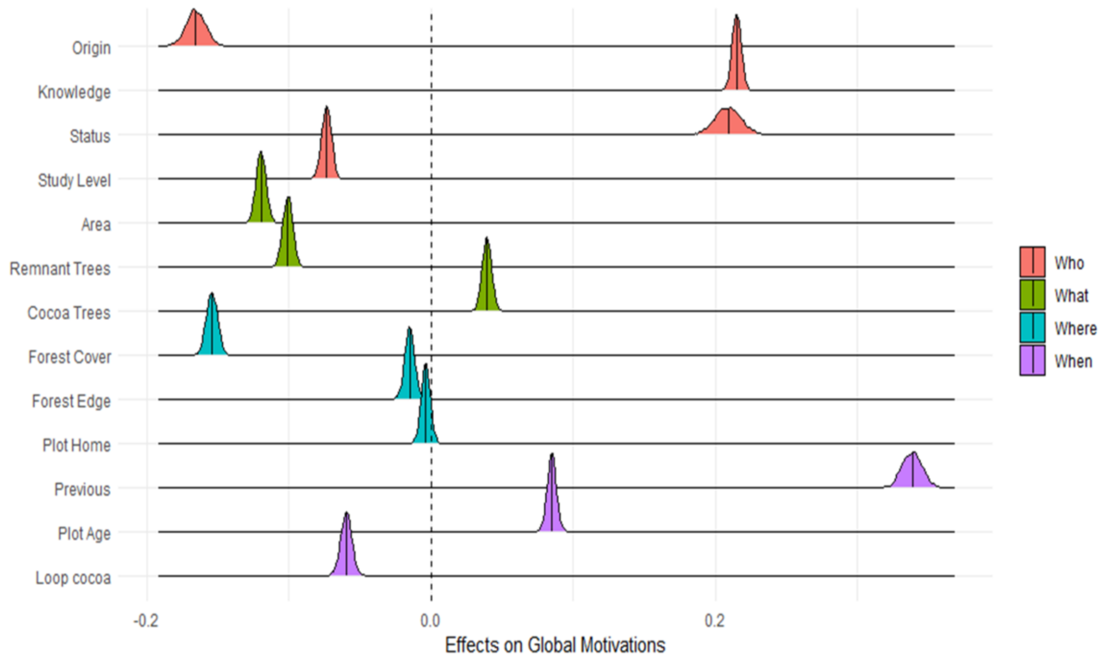
Keywords: cocoa agroforestry; farmer's strategies; use values; 4Ws approach; Côte d'Ivoire



1. Introduction

West Africa, the primary cocoa-producing region globally, has experienced significant deforestation over the past decades, largely attributed to the expansion of cocoa cultivation by small-scale farmers. Farming cocoa represents generally the main source of income for farmers (Sonwa *et al.*, 2019). In efforts to restore forest cover, states have implemented large-scale policies aimed at promoting agroforestry (Dieng & Karsenty, 2023). Most studies aimed at understanding farmers' strategies for adopting agroforestry have remained highly disciplinary, often lacking a comprehensive consideration of all social (Who?), historical (When?), geographical (Where?), and ecological (What?) determinants underpinning farmers' motivations in tree valorization.

2. Materials and Methods

Drawing from a sample of 150 farmers responsible for managing 12,096 trees, by surveys we (i) quantified farmers' motivations for 10 material and immaterial uses of trees and (ii) explored by stone-ranking method (Sheil *et al.*, 2004), the relative importance of the 4Ws in explaining overall motivations, specific to each use, as well as the varying levels of specialization in farmers tree management strategies.

Analysis of data was carried out in Bayesian framework using an adapted form of the Monte Carlo Hamiltonian sampler (Carpenter *et al.*, 2017):

$$X_p \sim P(\lambda_p) \text{ with } \lambda_p = e^{(\sum_{i=1}^{i=n} \quad (\theta_{cov} * Cov_i))}$$

where X_p representing motivation types, λ_p the parameter of the Poisson model, the effect of covariates i was then tested by incorporating them into an exponential function.

3. Results

Findings indicate that the value attributed to trees by cocoa farmers is strongly influenced by various variables underlying the 4Ws: the identity and history of the farmer in charge of managing the plot are indeed important, the specific characteristics of the plantation, the territorial context in which it is situated, and the historical trajectory of the plot are equally significant, yet the effects of each 4W determinant depend on the material and immaterial uses considered.

4. Discussion

To encourage cocoa farmers to optimally diversify the valorization of their trees (Codjo *et al.*, 2017), two significant levers are identified: (i) enhancing farmers' abilities to recognize trees and (ii) reducing cocoa tree density by eliminating less productive individuals from the field. From a political perspective, it is urgent for stakeholders involved in promoting agroforestry to consider all dimensions of the farmer-field system (Sanial *et al.*, 2023). The diversity of farmers' life trajectories (Who), cultivated landscape variations (Where), eld diversities (What), and historical trajectory distinctions (When) present both constraints and opportunities with which farmers must contend to transition towards the much-desired agroforestry systems.

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The importance of understanding and examining the moral dimensions of farmers' economic life for their culture of cooperation (Oral #362)

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Keywords: farmer cooperation; moral economy; ethnography; moral sentiments

Cooperation in rural areas has become an important research objective in recent years. As part of efforts to revitalize rural areas, researchers have often examined the economic and environmental dimensions of cooperation. Agricultural economists have emphasized the importance of farmers' market cooperation in reducing costs and increasing the competitiveness of family farms in the food supply chain. Other research has discussed the importance of farmer cooperation at regional and environmental levels for the conservation of biodiversity and ecosystem services. Many researchers have investigated why farmers do not collaborate despite the benefits and have identified the lack of trust and diversity of value systems as the main barriers to successful and long-term collaboration in rural areas (Ostrom, 2007; Riley *et al.*, 2018; Westerink *et al.*, 2017).

The ethnographic research was also based on the question of why farmers do not cooperate, but focused on the under-researched moral dimensions of farmers' cooperation. It examined the moral sentiments, motives and actions of farmers, who consequently have different experiences with and views on formal and informal forms of cooperation in their rural communities. The study was conducted in north-eastern Slovenia, where other researchers have identified the need for greater economic and environmental cooperation between farmers (Erjavec *et al.*, 2016). The research methodology was based on focused ethnography (periodic short-term fieldwork) and 7 months of participant observation. The researcher conducted more than 50 semi-structured interviews between 2018 and 2023, mainly with members of farming families, but also with agricultural extension workers, priests, journalists, representatives of agricultural companies and organisations, and others. The collected empirical material was analysed using the moral economy approach, which focuses on people's conceptions of a life worth living, their attributions of responsibility for a decent life, and their perceptions of injustice in economic relationships (see Narotzky and Besnier, 2014; Sayer, 2011; Thompson, 1993).

The ethnographic study has shown that farmers often associate their well-being with their ability to invest systematically in the development of the farm. According to the farmers, their economic situation has become increasingly unstable over the last 15 years. This has had a negative impact on their culture of cooperation, as they have traditionally activated family networks and imposed new responsibilities on close relatives in uncertain times. In addition, farms have been abandoned and farmers find it difficult to work with so-called reliable and comparable production partners as there are not many farmers nearby. This is also the case because in practise there are many moral judgments and sentiments of envy, resentment and injustice towards other farmers. According to the respondents, the moral sentiments arise due to land abuse, unequal informal sharing of machinery, collapse of cooperatives, cheating by traders and lack of entitlement to subsidies. Moreover, farmers do not cooperate because they believe that they cannot change and overcome the power imbalance in the food supply chain.

All this shows that the farmers interviewed will find it difficult to unite for various reasons. They emphasise that they need a just and hardworking person to restore and maintain their culture of cooperation. In the socialist past, this function was often performed by local researchers and agricultural advisors, who are no longer as present in rural communities as they were in the past.

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Balancing profitability, protein production, and pesticide reduction: what are the levers for action for French arable farms? (Oral #31)

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Presenter: Salomé Kahindo (s.kahindo@ieseg.fr)

Keywords: crop farms; profitability maximization; protein supply; pesticide reduction; activity analysis

The agricultural sector has experienced significant changes over time. The current issue lies not only in enhancing its economic and productive performance but also in safeguarding the environment. Thus, the interest of this work that investigates ways to balance farmers' profitability with environmental preservation and food supply goals. Our contribution to the academic literature is threefold. Firstly, we provide a detailed examination of three agricultural strategies – maximizing profitability, enhancing protein production, and minimizing pesticide usage – assessing their impact on farmers' income, operational expenses, and environmental sustainability. Secondly, we conduct an opportunity cost analysis using the profitability maximization scenario as a reference point, highlighting the financial trade-offs inherent in pursuing varied agricultural objectives. Thirdly, we employ an innovative methodology that considers prices as an optimization variable within activity models, offering a more comprehensive and realistic evaluation of agricultural economics. We apply data envelopment analysis to panel data from the Meuse department in France for the period 1991-2017. We show that optimal profitability is achieved by increasing farmers' income while simultaneously reducing operational costs, including pesticide use. In contrast, while the protein maximization strategy leads to an increase in pesticide costs, the pesticide minimization strategy slightly diminishes protein yield. The opportunity cost analysis emphasizes significant trade-offs: pursuing protein maximization incurs additional costs compared to the profitability-centric approach, as reflected in the balance between yield increase and cost changes. Similarly, adopting the pesticide minimization strategy amplifies the opportunity costs even more when contrasted with prioritizing profitability. Our findings suggest that achieving a balance among the three scenarios requires improved crop management and practices, with price adjustments playing a secondary role. The opportunity cost analysis emphasizes the need for a paradigm shift towards farming systems that balance economic returns, environmental stewardship, and food nutritional quality, particularly by integrating protein-rich crops into longer crop rotations. This transition is crucial for the sustainability of agriculture and the well-being of future generations, marking a significant step towards a more resilient and food-secure world.

French Tea Time: an economic analysis of the emergence of tea production in France (Oral #190)

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Keywords: farm typology; market channel; tea production; cooperation

In a context of agro-ecological transition, territorialization of food systems and adaptation to climate change, new agricultural products are increasingly appearing in areas where they were not historically present. These new productions may particularly rely on consumer preferences for geographical proximity and strong territorial identity (Atallah *et al.* 2021). They represent an opportunity to diversify existing farms or may be associated with the development of new economic models and market channel strategies, as shown by Hill et al (2023) on hemp production in the US.

In France, tea production, although still at an early stage of development, is expanding with the arrival of new producers, particularly in the Brittany and Occitanie regions. This trend raises a number of interesting scientific questions: how to structure a new industry based on a food product that has no history in the region? What are the associated economic models and relationships between stakeholders in the sector? What are the opportunities and motivations for developing new local production of an already highly globalized commodity? As in the case of other crops that are re-emerging in certain French regions such as saffron (Girard and Navarrete, 2005) or hops (Rousselière *et al.* 2023), we hypothesize that the challenges facing tea production in France relate in particular to production and installation costs, strategies for market positioning and efforts to structure the sector in a sustainable and collectively beneficial way.

In order to characterize the development of this new sector and to identify the motivations and obstacles encountered, we conducted a series of exploratory semi-directive interviews with 13 tea producers at different stages of their project. Our results show a certain diversity in the profile of producers. Unlike traditional agricultural installations, the majority of respondents did not come from farming backgrounds and were not as closely linked to the usual organizations such as local Chambers of Agriculture, land operators, farming unions or inter-professional organizations. The process of setting up a tea farm therefore tends to follow an individual logic. However, we have identified a dynamic network of producers structured around two sub-groups of individuals, each led by producers who were pioneers in tea-growing experimentation in France. Finally, by asking respondents about the level of trust they have in their professional partners, our results show that a higher level of trust is associated with more frequent (more than once a month) and more local interactions.

We discuss the possible ways in which the sector could evolve and underline the importance of a more integrated and collaborative approach in order to meet the collective needs inherent in the early stages of any emerging new food chain, such as the need to develop a technical reference system or to adopt specifications clarifying the territorial dimension. In terms of policy implications, we discuss that such strategies of novel crop choices may be a lever for inciting young farmers setting up and may directly contribute to agricultural development by strengthening local food systems with more diverse productions but at the same time, in order to be sustainable, cooperation and communication between producers and within the supply chain is key to ensure quality and commonly accepted rules.

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Spatiotemporal suitability analysis of sorghum in Germany under climate change (Oral #14)

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Keywords: sustainable agriculture; crop modeling; thermal units; chilling stress; drought stress

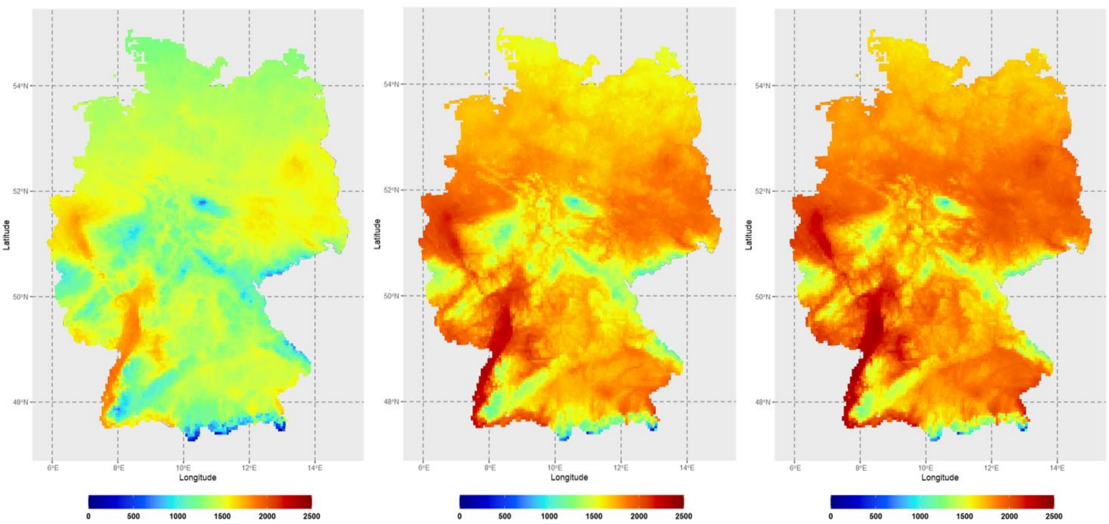

Figure 1. Germany-wide available thermal units (TU, °C) of the growing season of sorghum under historical (1976-2005 (left)) and future climate conditions (2031-2060, RCP4.5 (center) and RCP8.5 (right)). The growing season is not fixed in different scenarios

Introducing new crops that can thrive under changing climate conditions is crucial for sustainable agriculture. Sorghum (*Sorghum bicolor* L.) shows promise as a C4 crop due to its high heat and drought stress tolerance. Its deep root system may contribute to increased soil organic carbon, supporting climate change mitigation. However, one of the challenges in expanding sorghum production in higher latitudes and altitudes, such as Germany, is its low tolerance to chilling stress and the risk of low temperatures, especially during early and late seasons. There is limited information about sorghum production potential in different regions of Germany and its role in climate change mitigation. Achieving optimal crop yield depends on matching available thermal units with the cultivar's requirements. This study aims to develop an algorithm to determine optimal sowing dates, growing season length, and suitable maturity groups for sorghum cultivars and assess the climatic water balance in various regions of Germany.

To reduce this knowledge gap, a spatiotemporal analysis was performed on 13,785 grid cells (5kmx5km) all over Germany. This analysis incorporated a dataset spanning 30 years of historical weather data, as well as projections of climate change based on 12 distinct climate scenarios for the time period between 2031 and 2060. Temperature and rainfall thresholds were employed to create weather indices (WIs) and develop the algorithm. The growing season starts after the last freezing temperature, provided that there is sufficient rainfall (>20 mm) to ensure emergence and the average temperature of five consecutive days is above 15°C. Later, the growing season ends after the first cold temperature happens, provided there is not enough GDD (<20°C) to recover from cold stress and/or complete seed ripening in the next two weeks. Finally, the cumulative thermal units between the start and end dates were calculated using a three-segmented function. This calculation aimed to quantify the duration of the growing season for different maturity groups of cultivars. The cardinal temperatures utilized in the function were obtained by fitting a thermal-time model to the data obtained from an extensive germination test on new cold-tolerant sorghum hybrids tailored for German conditions in constant temperatures ranging from 10 to 40°C with 5°C intervals.

By the middle of the century, better growing conditions are projected to be available for sorghum cultivation, as a longer growing period with more heat can be used for growth and yield formation (Figure 1). This is due to the warming in the main growth phase, particularly in lower altitudes caused by climate change, and at the same time, to the possibility of earlier sowing and later harvesting. While experimental sorghum cultivation has so far been limited primarily to southern Germany, the analyses show that parts of North Rhine-Westphalia and Brandenburg already offer suitable growing conditions. In the future, suitability for cultivation will increase significantly in most regions, and it is expected that varieties with later maturity and correspondingly higher yield potential can also be cultivated with a lower productivity risk.

Further analyses will investigate sorghum's potential cultivation advantage, particularly in regions with an increased risk of drought stress, using phenology models and degree-days as a stress index. Sorghum has demonstrated higher yield stability and levels than maize in trials conducted in dry locations and years with low precipitation, including in 2022 in the Bavarian State Research Center for Agriculture (LfL) field trials in the dry region of Lower Franconia at the Schwarzenau site. These findings highlight sorghum's suitability for cultivation in regions prone to drought stress.

Additionally, the ongoing climate chamber assessment at the Julius Kühn-Institut, Kleinmachnow, aims to quantify the effects of different temperature regimes. This assessment focuses on physiological and morphological development in the early sorghum growth stages. Finally, the research aims to parametrize a process-based crop model through wide north-south gradient field trials and run a comprehensive simulation to provide Germany-wide insights into the yield and stability of sorghum *versus* maize, identify promising regions for sorghum cultivation in Germany, and understand its complex responses to climate, soil, and water balance.

Managing soybean within field variability through variable seeding technology (Oral #156)

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Keywords: soybean; seeding variable rate; cultivars; Brazil; precision agriculture

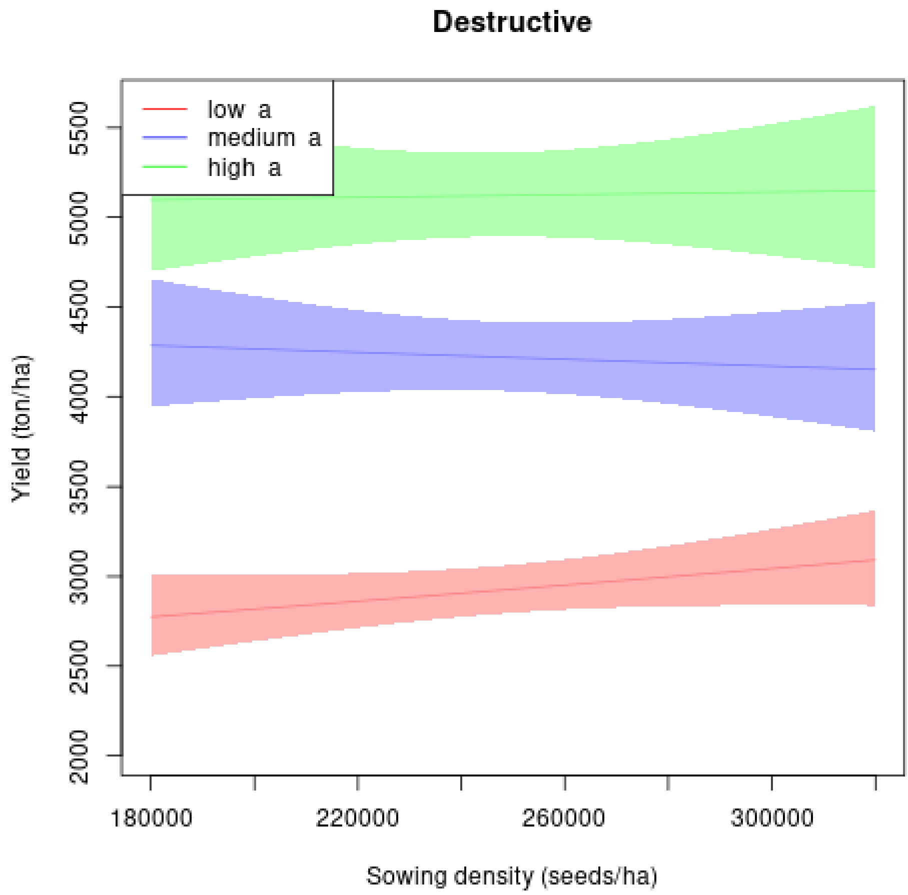

Figure 1. Effect of increased sowing density on yield by zone, measured either destructively. The predicted values are marginalized over year and cultivar, the shaded area is the standard error of the prediction

1. Introduction

We investigated whether varying soybean seeding density and cultivar can tackle within-field variability by conducting a field experiment in Southern Brazil. We tested two hypotheses: that optimal seed density is higher in low yielding environment (HP1) and that high-yielding cultivars perform better than stable ones in high yielding environment and vice-versa (HP2). Three studies have been recently published suggesting that the optimal agronomic seeding rate of soybean is higher in low yielding zones than in high ones: Corassa *et al.* (2018) for Brazil, and Gaspar *et al.* (2020) and Carciochi *et al.* (2019) for North America. These three recent studies on the interaction of zone x sowing density used large datasets coming from various different fields within large ecological regions, however no study – to the best of our knowledge – investigated the effect of the interaction variable rate x zone at within-field level. We further formulated and tested the following three non-mutually-exclusive hypotheses to explain why agronomic optimal seeding rate is higher in low yielding environment: higher seeding rate in low environment increase leaf area index in early stages (HP1.1), plants in low yielding environment have a lower plastic response to density (HP1.2), and lastly that plants in low yielding zones have a lower emergence rate (HP1.3).

2. Materials and Methods

We tested the hypotheses in a two seasons factorial experiment where 3 cultivars x 4 density x 3 environments were tested in 50x50 m plots on a 124 ha field in Southern Brazil, that has been cultivated with precision agricultural techniques over the past 20 years. During the two seasons we measured yield both using a harvest monitor and destructively by analyzing yield components (pods/plant, beans/pod, bean weight), leaf area index using a linear light ceptomer, soil moisture.

3. Results

Our results support the hypothesis that low yield environment have a higher optimal seeding rate (HP1). Despite the bias in the measurement between destructive and harvester the relation between seeding rate and yield was similar (Figure 1). Based on yield measured using the destructive approach, a seeding rate of 320k seeds/ha instead of 180 produced an increment of 11.4 % (SE. 7.9) in low, a decrement of -3.1 % (SE. 7.1) in medium, and an increment of 1.0 % (SE. 7.3) in high. We further observed that in low environment higher seeding rate induce a stronger initial canopy growth than in medium and high zones (HP1.1). We also observed a stronger correlation between the number of pods in high and medium zones than in low ones, suggesting that the yielding environment where a plant is grown influence its plasticity (HP1.2). We did not find evidence supporting neither HP 1.3 (lower emergence in low yielding environment), nor hypothesis 2 (interaction genotype x zone).

4. Discussion

Our results on low yield zones having a higher agronomic seeding rate (HP1) extends at within-field scale similar observations developed at regional scale by Carciochi *et al.* (2019; Corassa *et al.* 2019). The existence of an interaction zone x density both at regional and within-field level induces us to think that in both case low zones are water limited. However at regional scale the major driver of water limitation is the amount of precipitation, and the soil-type , whereas at field scale topography and soil texture – that are often correlated – are a major driving factor. We observed that stable cultivars outperformed the high-yielding cultivar in all zones, the lack of interaction management zone x cultivar could be due to the fact that the 2 experimental years were extremely dry.

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Yield sensitivity to pre-anthesis heat waves in wheat and barley (Oral #142)

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Keywords: grain number; fertile floret number; yield components; biomass

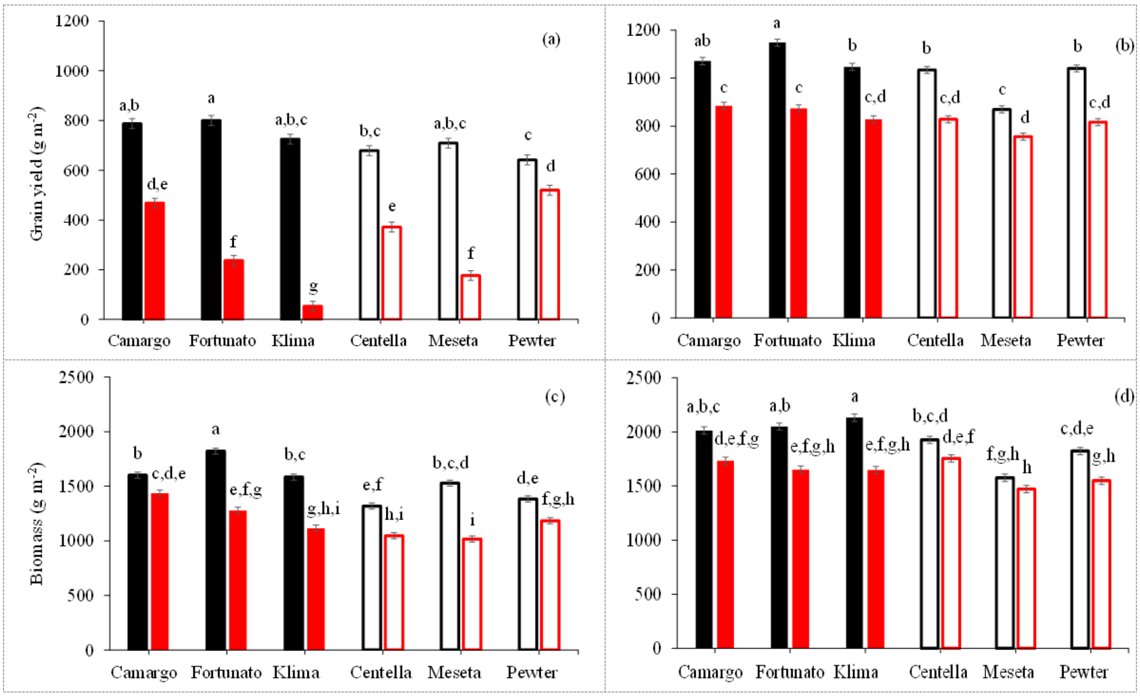

Figure 1. Grain yield (g m^{-2}) and biomass at maturity (g m^{-2}) of wheat cultivars (closed bars) and barley (open bars) exposed to ambient temperature (black bars) or heat waves (red bars) during pre-anthesis period for experiments 1 (a and c, respectively) and 2 (b and d, respectively). Different letters show significant differences among means of the treatments at each temperature treatment according to LSD Fisher comparison test (P ≤ 0.05)

1. Introduction

Climate change is increasing the frequency and duration of heat waves worldwide, decreasing growth and yield of most field crops [1]. In this scenario, it is crucial to recognise any differences in sensitivity between wheat and barley, crops that are grown alternatively in the same fields. As far as we are aware, there are no field studies comparing wheat and barley responses to heat waves. Therefore, we compared yield sensitivity of these two cereals to pre-flowering heat waves, analysing the responses of grain number per unit area (GN/m^2) and its components under field conditions.

2. Materials and Methods

Irrigated and fertilised field experiments were conducted for two years (Exp 1 and Exp 2) at Bell-lloc (NE Spain). Treatments consisted of three well-adapted and high-yielding cultivars of bread wheat (Camargo, Fortunato, Klima) and two-rowed barley (Centella, Meseta, Pewter), exposed to two temperature treatments: unheated (control) and heated plots during 10 effective days in pre-flowering, using portable tents with transparent polyethylene films [2].

At anthesis, we determined the fertile florets number /spikelet. At maturity, we determined yield, biomass, spikes/m^2, GN/m^2, GN/spike and GN/spikelet.

3. Results

Heat waves resulted in reductions in yield that were different between cultivars and years (Figure 1). The effect was much stronger in the first than in the second year (Figure 1). Averaging across the cultivars of each species, the reductions in yield were higher in wheat than barley in Exp 1, but mainly because the extreme sensitivity of Klima and the very small sensitivity of Pewter, the other two cultivars of each crop had similar reductions (Figure 1a). Yield reductions were similar between species in Exp 2 (Figure 1b). It must be noted that the actual heat load reached with the portable tents was noticeably higher in Exp. 1 than in Exp 2, and also slightly higher in barley than in wheat. Biomass reductions were in general smaller than yield reductions (*i.e.*,19% on average across experiments) and similar in both crops and experiments (Figure 1c,d).

As expected, yield reductions were mainly associated with GN/m^2 decreases (Exp 1: R^2=0.93, P<0.001; Exp 2: R^2=0.79, P<0.001). The reductions in GN/m^2 could not be explained by the spikes/m^2 (P>0.05) but by GN/spike, being the relationships stronger in Exp 1 than in Exp 2 (R^2=0.97, P<0.001 *vs* R^2=0.37, P=0.03). Overall, heat waves slightly decreased the number of fertile florets/spikelet, but substantially decreased the number of grains/spikelet.

4. Discussion

Heat waves exhibited a clear effect on the reproductive ability, affecting more the reproductive output than the vegetative growth, and increasing grain abortion across the whole spike. GN/m^2 reduction seemed to have been related to an increase in the fertile florets lability to set a grain, as heat waves did not affect spike survival (spikes/m^2) and the slight decreases in the spikelet fertility (fertile florets number /spikelet). As heat has been shown to negatively impact reproductive organ viability leading to yield losses in field crops, detrimental effects on pollen, ovule viability [3,4], and/or ovary size [5] might have been responsible for the observed results.

The higher yield reduction observed in wheat compared to barley could be related to the differences in the flowering timing, which was earlier (10d in Exp 1, 16d Exp 2) in barley than in wheat. Therefore, the background temperatures were higher during the grain filling onset in the latter (average maximum temperature for 10d after anthesis was ~4°C higher in wheat in both experiments), when abortion of grain set could still occur compared to the more phenologically advanced barley.

Interestingly, the magnitude of yield loss per unit heat load (estimated as yield difference relative to the degrees of increase in the average mean air temperature of each crop-experiment combination) in both experiments was higher for wheat than for barley (on average, 149 *vs* 79 g/m^2 ºC, respectively).The different sensitivity could be in part related to higher yield potential of wheat compared to barley (on average 930 *vs* 829 g/m^2, respectively). Indeed, differences between both species tended to disappear when estimating yield loss per unit heat load as a percentage of control yield, 84 and 90% on average across experiments for wheat and barley, respectively.

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New scales of development for wheat and barley (Oral #119)

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Keywords: development; phenology; growth; cereal; decimal code

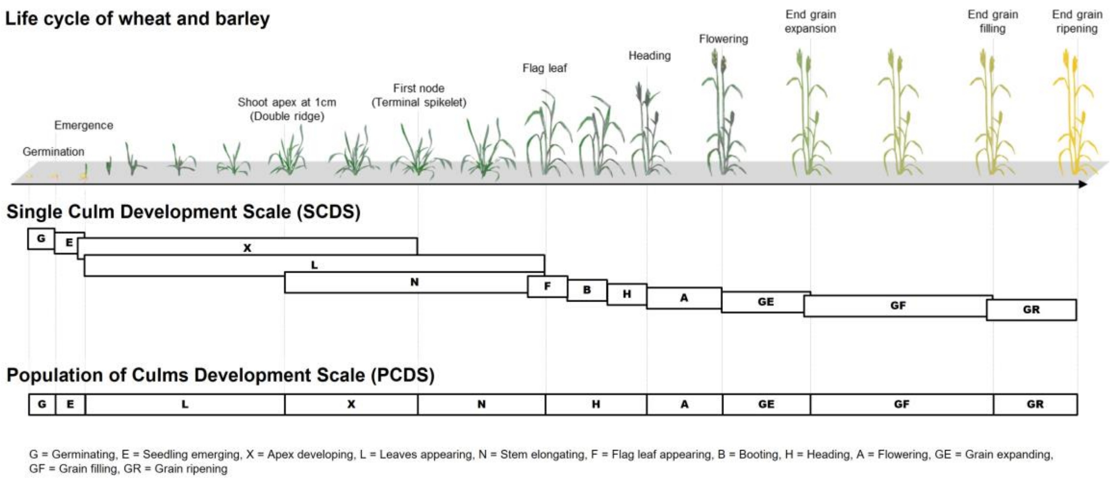

Figure 1. The Single Culm Development Scale (SCDS) and Population of Culms Development Scale (PCDS) applied to the life cycle of wheat and barley. Adapted from Celestina *et al.*, (2023a)

1. Introduction

Wheat (*Triticum aestivum*) and barley (*Hordeum vulgare*) are cereal grain crops vital for global food security. Adapting crop life cycles and agronomic management to changing climates is critical to increase yields to meet anticipated global demand. The study of crop species development and phenology has thus never been more important or urgent. Such studies depend on the ability to reliably measure and communicate crop development with repeatable and reproducible protocols.

2. Methods

New scales for assessing the development of wheat and barley were created as part of a national Australian project (Hunt *et al.*, 2020) to improve the accuracy of cereal phenology modelling in APSIM-NG (Holzworth *et al.*, 2018). The scales were developed and tested on a panel of 64 wheat and 32 barley genotypes that were grown in controlled environments with limiting or saturating photoperiod and vernalisation conditions (Bloomfield *et al.*, 2023), and in time-of-sowing field experiments across Australia at sites with diverse geography and climate (Celestina *et al.*, 2023b).

3. Results

The two new scales of wheat and barley development are the Single Culm Development Scale (SCDS) and the Population of Culms Development Scale (PCDS) (Celestina *et al.*, 2023a). The SCDS defines progression through the lifecycle of an individual plant, whereas the PCDS accommodates population variation in the timing and duration of lifecycle events in a crop canopy (Figure 1).

The SCDS has twelve phases that are disaggregated into stages and is measured on the primary culm of a single plant. Phases in the SCDS may occur concurrently within a single culm. Using the SCDS, a user makes a single observation at one time point to obtain an instantaneous measure of development. For example, a grower or their agronomist might use the SCDS for a rapid assessment of development in the field for the purpose of aligning crop inputs with optimal development stage.

In comparison, the PCDS has ten phases that are delimited by stages and is measured on all culms in a population. Phases in the PCDS are discrete and sequential. Using the PCDS, a user makes multiple observations over time to retrospectively determine the timing of stages and duration of phases. For example, a plant breeder might use the PCDS to compare the time taken for different cultivars to reach 50% anthesis in field evaluation experiments.

4. Discussion

Compared to existing scales of development such as a the widely-used Zadoks decimal code (Zadoks *et al.*, 1974), the SCDS and PCDS describe development in terms that are unambiguous, objective and quantitative, and they are presented with protocols that ensure repeatable and reproducible results. These new scales distinguish between plant- and crop-level development; they merge and fill gaps within existing published scales; and they are compatible with modern technologies such as simulation modelling and automated image analysis.

The SCDS and PCDS have been successfully used for the parameterisation and validation of the APSIM-NG cereal phenology model and the development of a scheme to classify wheat and barley cultivars based on relative lifecycle length (Celestina *et al.*, 2023b). These applications of the new scales demonstrate their utility and highlights their potential to facilitate ongoing advances in agronomy.

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Impact of heat and drought stress on yield and subsequent germination of oilseed rape (*Brassica napus* L.) seeds (Oral #317)

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Keywords: heat stress; drought; oilseed rape

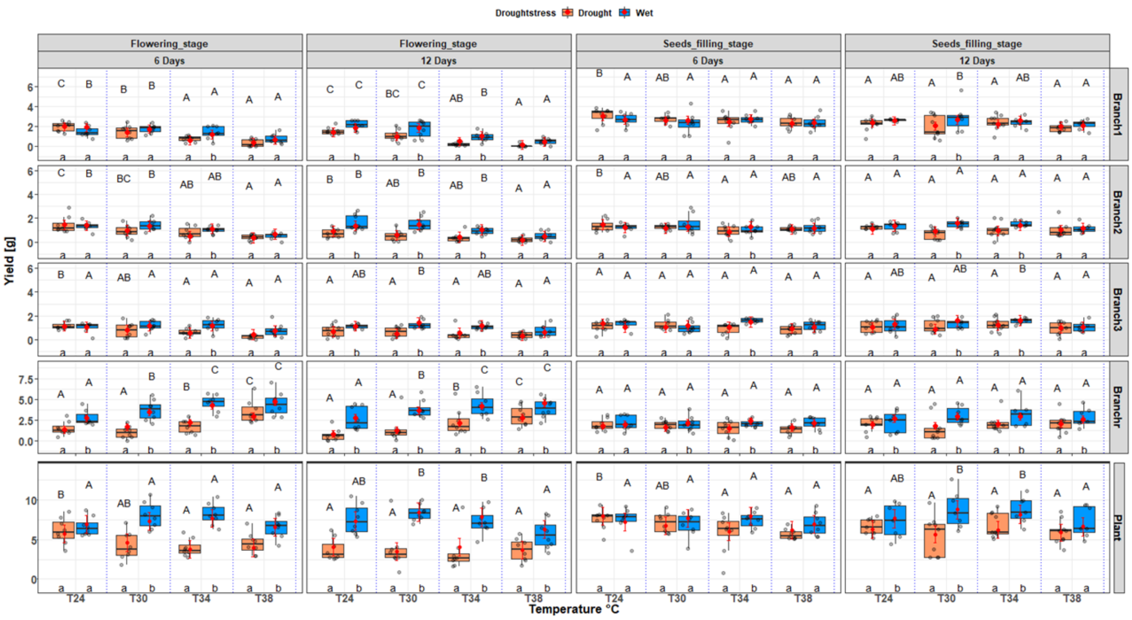

Figure 1. Effect of heat (24, 30, 34, 38 °C) and drought (drought *vs.* wet) stress on seed yield during flowering *vs.* seed filling under 6 and 12 days of stress treatment on the main stem (Branch1), first side branch (Branch2), second side branch (Branch3), rest of the plant (Branchr) and the whole plant level (plant). Significant ($p<0.05$) differences between drought stress treatments are indicated with small letters and between heat stress treatments in capital letters

1. Introduction

As climate change accelerates, the frequency and severity of extreme weather events, such as heatwaves and droughts, are on the rise (Rashid *et al.*, 2018; Egli *et al.*, 2005). These challenges significantly impact oilseed rape (OSR; *Brassica napus* L.), a globally important oil crop, as it faces increased exposure to adverse weather conditions and abiotic stress (Rashid *et al.*, 2018). However, little is known about abiotic stress effects on OSR growth and yield formation as well as the seeds' subsequent germination ability. Hence, this study aims to explore the impact of heat and drought stress on OSR during different phenological stages.

2. Materials and Methods

We conducted a pot experiment in controlled greenhouse chambers growing single OSR plants cv. Ability in 2L pots filled with local topsoil. We applied four experimental factors to test their single and combined effects, 1.) four levels of heat stress, 24°C, 30°C, 34°C, and 38°C applied for 14 hours with a four-hour adjustment period and 16°C night temperature for all treatments, 2.) two levels of drought stress, *i.e.*, without drought stress (plant available water (PAW) > 60% plant available water capacity (PAWC)) and with drought stress (PAW < 20% PAWC), 3.) two levels of treatment timing, *i.e.*, flowering stage (BBCH 61) and seed filling stage (BBCH 75), and 4.) two levels of treatment duration, 6 days and 12 days. We evaluated the effects separately on the main branch, first and second side branches, and remaining branches.

For the germination test, we placed the harvested seeds of each treatment × branch-level combination on wetted filter paper in 10 cm2 petri dishes in a climate chamber at 22°C. We ran the experiment in three replications, counting germinated seeds 12, 14, 16, 18, 20, 22, and 36 hours after wetting. Using the germination-metrics package in R studio, we computed various germination indices, including the time until 50% and 100% of seeds germinated, median germination time, mean germination rate, and germination speed. We used mixed linear models for further statistical analysis using the lme package in R.

3. Results and Discussion

The experiments showed significant effects on grain yield, with heat and drought stress, coupled with longer duration, resulting in decreased yields (Figure 1). Stress during flowering had a greater impact on yield compared to the seed filling stage. Interestingly, severe heat stress during flowering, which obstructed fertilization and seed set on the main branch, was fully compensated by additional siliques and seeds on the lower branches, while severe drought stress during flowering could not be compensated. Analysis of seed size and fatty acid composition provided insights into combined heat and drought stress effects. Regarding germination indices, heat, and drought stress together had a pronounced impact compared to individual stressors. Stress during flowering reduced germination percentage and time, especially with both stressors present. Drought stress lowered germination across all branches, while combined stress reduced it in the first two branches only. We explain this by the compensation of destroyed main branch flowers *via* additional new flowers and seeds on the lower branches after stress ceased. These findings highlight the compensation capacity of OSR against severe heat but not drought stress during flowering supporting the design of more resilient OSR cultivation systems under climate change.

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Rethinking flowering times of winter cereals for future climates (Oral #120)

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Keywords: phenology; optimal flowering period; wheat; barley; yield

1. Introduction

The adaptation of wheat and barley to different growing environments is underpinned by an understanding of crop phenology. The importance of an optimal flowering period (OFP) to ensure the critical period for yield development coincides with favourable seasonal conditions has been demonstrated, whereby the combined risk of frost, heat and drought is minimised, and grain yield potential is maximised (Flohr *et al.*, 2017). Whilst this concept provides useful targets for growers to mitigate risk of abiotic stresses, they remain a major limitation to yields of wheat and barley in Australian rainfed cropping systems (Hochman and Horan, 2018). Future climate predictions increase the complexity of cultivar selection and sowing decisions and present a challenge for breeders, to release new cultivars that combine improved adaptation and stress tolerance, and for growers, to improve farming systems and agronomic practices to capture genetic gains. We consider an integration of genotype (G), environment (E) and management (M) to rethink flowering time in wheat and barley to better enable growers to adapt to climate variability and attain new yield frontiers.

2. Methods

A comparative analysis was conducted in a series of field experiments across 31 locations in the Australian cropping region from 2010–2022, whereby annual rainfall ranged from 117–978 mm. Grain yield was recorded with respect to flowering time (phenology) to enable us to investigate yield-flowering date relationships in locations where frost, heat and drought are major sources of variation in crop yield, and a significant concern for growers. We applied the field data to test the wheat and barley models in APSIM Next Generation, and conducted long-term simulations of genotype, environment, and management to identify differences in flowering and yield responses.

3. Results

Grain yield ranged from 0.5–11.8 t/ha, with barley maintaining higher yields than wheat across all yield levels. However, there is evidence to suggest that current genetics is limiting the yield potential of barley in high yielding environments. The OFP for barley was earlier and broader than for wheat, with genotype × sowing time responses observed to be less apparent in barley than for wheat.

4. Discussion

Our comparative analysis indicates differences in flowering and yield in response to sowing date for wheat and barley. The ability of barley to achieve grain yields greater than wheat at comparative flowering dates suggests wider adaptation of barley in Australian rainfed cropping systems. This may be in part due to the narrow range in phenology responses of current commercial barley cultivars than for wheat, differences in accumulation of biomass and partitioning, or differences in tolerance to frost, drought and/or heat stress. An improved understanding of these species-specific differences will improve future crop model predictions and provide information to growers to refine crop management and reduce the risk associated with sowing time decisions.

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Assessment of the complementarity between field observations and multispectral UAV imaging for optimized cover crop management in viticulture: towards a comprehensive approach to the functioning of agroecological practices (Oral #187)

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Keywords: UAV; image analysis; cover crop management; sustainable viticulture; on-farm experiment

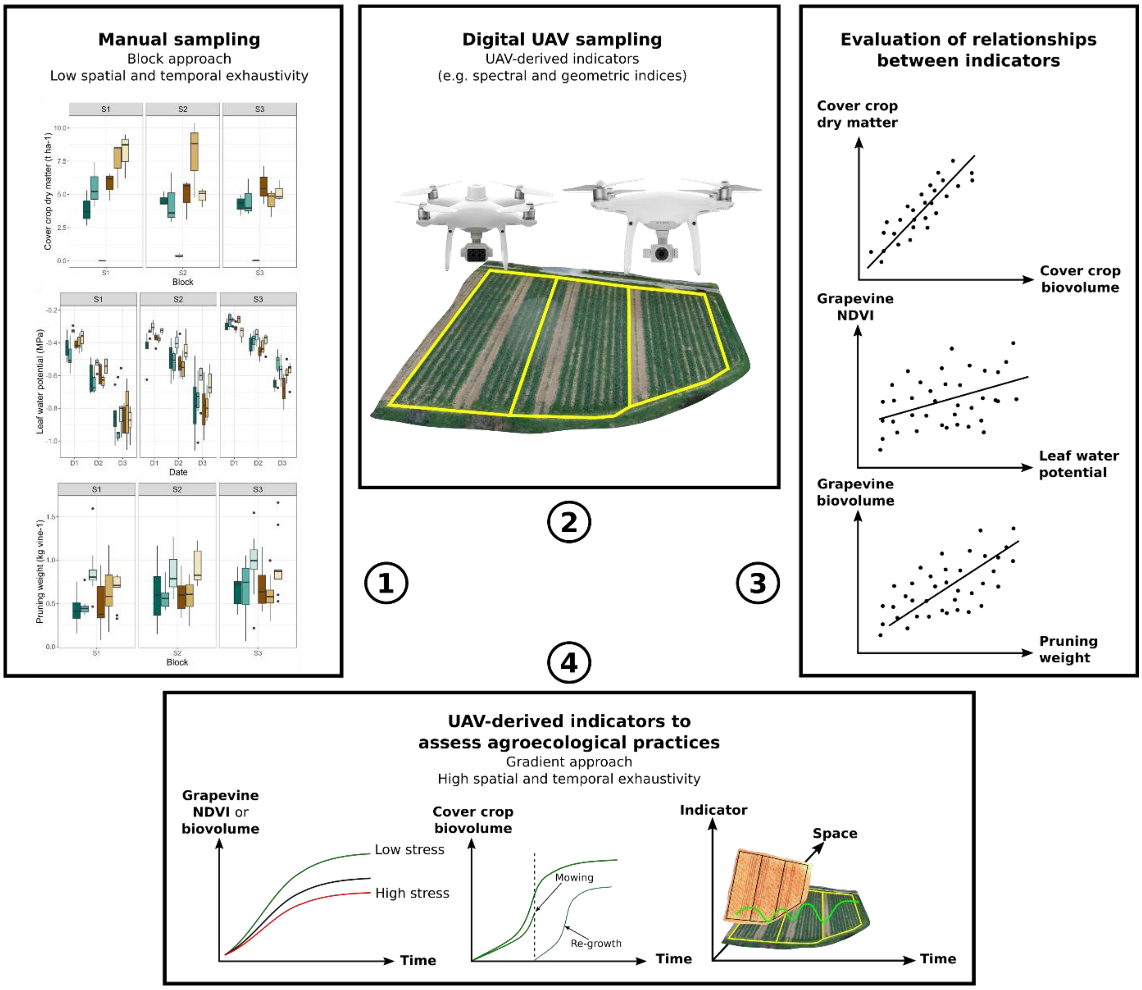

Figure 1. A four-step framework to combine field observations and UAV-derived data to assess cover cropping practices in agroecological viticulture

1. Introduction

The evolution of agroecological systems introduces greater complexity in cultivated fields, challenging both traditional and modern observational networks and methods. These include remote observations, *e.g.* aerial data collection, proxidetection, *e.g.* crowdsourcing, and direct in situ measurements. The digital transition is continually producing vast amounts of data, enhancing our understanding of agroecosystems when used effectively (Ingram and Maye, 2020), both within and surrounding agricultural plots. As a result, the increasing availability of digital tools is transforming the role of on-farm experimentation (OFE) in contemporary agriculture (Lacoste *et al.*, 2021). With this backdrop, this study aims to assess whether there is redundancy or complementarity between field measurements and UAV imaging throughout the growing season, and to determine the efficacy of UAV imaging in the management of service crops in viticulture.

2. Materials and Methods

An experiment was conducted over three years (2019-2022) at the Domaine du Chapitre (France) on a vineyard plot (*Vitis vinifera* Syrah), divided into three blocks. The experiment aimed at comparing 6 service crops termination strategies, combining two termination periods (early and at grapevine budbreak) and three termination methods (mowing, roller-crimper, mowing + tillage). Several indicators were assessed to evaluate the water stress (predawn leaf water potential), vigor (pruning weight) of the grapevine, as well as to monitor service crops development through biomass and LAI measurements. In 2021-2022, alongside field measurements, auxiliary data were collected on 10 dates, from service crops emergence to grapevine flowering, using multispectral sensors mounted on a UAV. All the aerial imagery were processed using Agisoft Metashape software. The same products were obtained in the pre-processing step: orthoimage, digital elevation model, digital surface model, normalized digital surface model (nDSM). A series of indicators were calculated, including the geometric characteristics of the vines canopy, the biovolume of inter-row vegetation cover and spectral indices. To assess the quality of UAV-derived indicator estimates, correlation analyses were used to explore the precision and robustness of the relationship between manual measurements and indicators from multispectral imagery. A spatio-temporal complementarity table is used to provide a detailed assessment of data complementarity at different growth stages and to highlight potential correlations and divergences between UAV and direct field indicators.

3. Results and Discussion

Analysis of the data collected over the three-year experiment revealed a significant complementarity between field measurements and multispectral UAV imagery (Figure 1). We looked at the relationship between field measurements indicators and UAV-derived indicators. For instance, we assumed a strong indicator relating to water stress in vines (predawn leaf water potential *vs* NDVI or tree row volume). The results showed promising correlations between variations of both manual and UAV-derived indicators. In addition, it was observed that estimates of inter-row vegetation cover biovolume, obtained from the nDSM, closely matched field measurements, thus confirming the accuracy of UAV imagery in estimating vegetation cover crop biomass. To extend this analysis, a spatio-temporal complementarity table was drawn up, enabling a detailed assessment of the interaction between field measurements and data acquired by UAV, depending on the vine block and phenological stage under consideration. The results confirmed the complementary nature of the measurements obtained by different methodologies, but also highlighted the importance of combining these data for accurate and informed farm monitoring and management.

4. Conclusion

This study illustrated the role of multispectral UAV imagery in refining cover crop assessment and opening new perspectives for cover crop adaptive management in viticulture. As a result, the growing availability of digital tools offers unprecedented prospects for designing new experimental models in agroecology, making it possible to reimagine the role of the OFE and bring out innovative practices for optimized management of cover crops in viticulture. In this perspective, exploring the synergy between advanced digital tools and the Ecosystem

Services functional Spatial Unit offers promising horizons for redesigning on-farm spatial experiments.

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From NDVI to variable nitrogen application map – Precision agriculture (Oral #54)

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Keywords: precision agriculture; NDVI index; N application maps

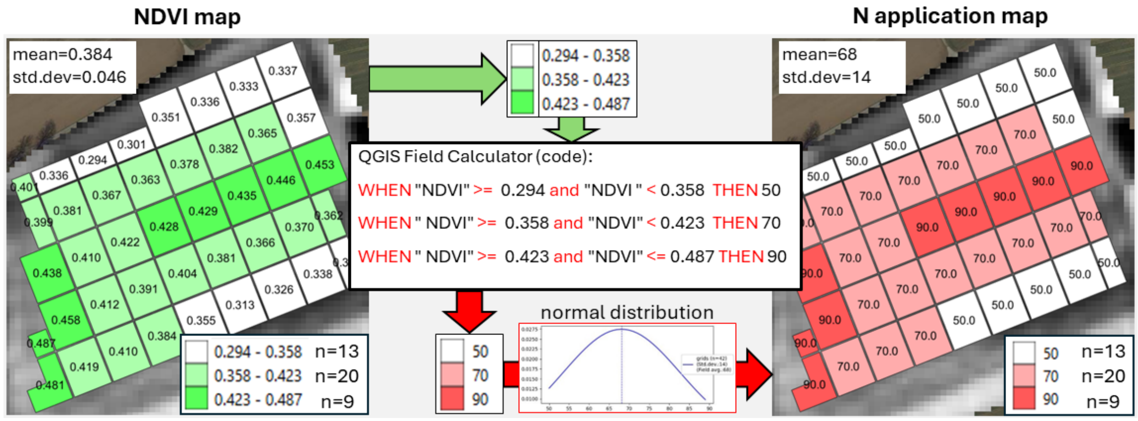

Figure 1. Spatial NDVI index distribution according to three NDVI index categories used to determine N application rates at an early growth state (BBCH 22-25) of winter wheat

1. Introduction

In Baden-Württemberg (B-W, Germany) N application for high protein quality winter wheat (E) is commonly split into three application dates: tillering, stem elongation and late booting. Total possible N application amount of a field is defined by B-W N-Düngebedarfsermittlung (N-requirement determination). Farmers in B-W commonly apply homogeneously at first N application date about 30-35%, about 40-45% on second application and the rest at third N application date (of N-Düngebedarfsermittlung total). However, this approach does not take in-field variability into account.

Identification of in-field variability can be conducted based on normalized difference vegetation index (NDVI) in the form of satellite image-based remote sensing vegetation monitoring. It is expected that "healthy" biomass causes higher reflectance rates in the near infra-red (B08) and high absorption in red (B04) enabling "detection" of biomass with higher chlorophyll content. It is hypothesized that higher N application rates are needed where the index is higher, as it "indicates" good conditions for plant growth.

For demonstrating a conceptual framework that uses NDVI for developing variable N application maps, free of charge satellite images downloaded with Copernicus Browser (CDSE 2024) were used. NDVI of a specific field was calculated, potential site-specific zones were delineated and the degree of in-field variability, in relative terms depending on NDVI value was quantified. Detailed instructions on downloading satellite images and using QGIS for identifying in-field variability and producing site-specific N application maps can be found in the GitHub repository (https://github.com/memicemir/ndvi_to_variable_N_application).

2. Materials and Methods

In the case of variable N application rates, farmers have to delineate site-specific zones with different yield potential. For this short study only the first N application (at tillering) was tested, where approximately 70 kg N ha^{-1} can be spread in the field. In the case of site-specific applications, farmers reduce N application amounts in certain site-specific units (with lower yield potential) and apply higher N amounts in areas with higher yield potential without exceeding 70 kg N ha^{-1} in total. In this study NDVI (Eq.1) was calculated for each site-specific unit (average value of all pixels in one site-specific unit) and used as an indicator of biomass development on 28 February 2021.

$$NDVI = (B08-B04)/(B08+B04) \quad (1)$$

Because site-specific NDVI was normally distributed in the field, all index values were classified as either low, medium, or high. The NDVI classes were formed by arbitrary splitting min/max range of field NDVI values into three groups with equal intervals.

3. Results

Figure 1 shows the NDVI index across different site-specific units with three NDVI range categories: low (white), medium (light green), and high (dark green), representing different plant growth potential. Based on the normal distribution of the index, medium category ($0.358 \leq NDVI < 0.423$, Figure 1) was set to 70 kg N ha^{-1} while low and high corresponded to ±20 kg N ha^{-1}, respectively. The ±20 step was used in order to avoid too large differences between min and max N application rates. After translating NDVI index variability into site-specific N applications, the average N amount applied in the field was 68 kg N ha^{-1}.

4. Discussion and Conclusion

Depending on the distribution of low, medium, and high NDVI zones, farmers have to be aware of maximum N kg ha^{-1} allowance. If there are more high-NDVI zones in the field than low (with medium 70), the farmer might end up exceeding the total N allowance limit. It has to be kept in mind that even if the plants are not growing in specific parts of the field, it does not automatically mean that there is no N in the soil or that N is the growth limiting factor.

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Acknowledgment

https://diwenkla.uni-hohenheim.de/

Assessing the sustainability of precision nitrogen fertilization strategies for durum wheat: a comparative study of NNI and NDVI map-based approaches (Oral #22)

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Keywords: variable-rate fertilization; life cycle assessment; N fertilizer use efficiency; social cost; dough technical properties

1. Introduction

Durum wheat, a crucial staple crop, is confronted with escalating fertilizer usage, particularly nitrogen, to meet the surging demands of a growing population. However, the mismanagement of nitrogen to fulfill crop requirements can inflict harm on ecosystems, spark conflicts, and disrupt supply chains. In response to this challenge, precision fertilization technologies, specifically variable-rate fertilization based on satellite imagery, are being explored to optimize nitrogen (N) fertilizer efficiency in no-till durum wheat cultivation.

2. Materials and Methods

Conducted over four consecutive growing seasons, from October 2018 to July 2022, the experiment took place in Asciano, Siena, Italy, on soil maintained under no-till conditions. Sowing was executed using a "disc-type furrow opener Vella VSD3200A No-till seeder". Four N fertilization approaches were assessed: a uniform N rate conventionally calculated, and three variable rates based on Sentinel-2 L2A spectral bands. These variable-rate approaches encompass one utilizing the Nitrogen Nutrition Index (NNI) (Fabbri *et al.*, 2020), a proportional NDVI-based estimate (NDVIH), and a compensative NDVI-based estimate (NDVIL). The treatments were applied according to a strip-plot design in three block. The surface area of the experimental units ranged from 0.27 to 0.4 hectares over the four growing seasons. Analyzed parameters related to grain yield and kernel quality, protein partitioning, and dough rheology (Guerrini *et al.*, 2020). For the four N fertilization strategies, economic analysis was conducted following the methodology outlined in Fabbri *et al.* (2023). Further, the carbon footprint was assessed in accordance with the ISO 14044:2006 guidelines.

3. Results and Discussion

The study findings indicate that the NDVIL strategy, while enhancing protein and gluten levels, does incur at cost of yield compared to the uniform N rate. Indeed, the application of High-N fertilizer resulted in noteworthy increases in protein, specifically glutenin (Guerrini *et al.*, 2020; Mancini *et al.*, 2024). Conversely, the NDVIL strategy proves advantageous, increasing both grain yield and protein composition compared to the uniform N rate. In contrast, the NNI strategy, based on satellite imagery, demonstrates promising results by significantly reducing nitrogen usage without compromising grain yield or quality. Moreover, the NNI approach optimizes protein partitioning and dough technical properties, essential factors for various end-use applications. Regarding nitrogen fertilizer use efficiency (NfUE), the NNI strategy consistently outperforms other approaches. Notably, among the tested strategies, only the NNI significantly reduces the carbon footprint of cultivation, exhibiting a decrease of approximately 20 gCO_2eq per kg of grain produced (-7.6%) compared to the uniform N rate. Furthermore, the economic analysis underscores the advantages of the NNI approach, showcasing lower social costs and higher rates of return compared to alternative nitrogen treatments. This underscores the economic and environmental sustainability of precision fertilization techniques, particularly the NNI strategy, in durum wheat cultivation.

4. Conclusion

This research not only advances our understanding of how various N treatments impact durum wheat production but also provides valuable insights across multiple dimensions of this intricate relationship. These dimensions encompass not only yield and protein composition but also extend to dough properties and economic considerations. The findings collectively provide valuable insights for the practical implementation of satellite-based N fertilization strategies, emphasizing the potential long-term benefits and sustainability of the NNI approach in promoting precision agriculture for durum wheat cultivation.

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Site-specific mechanical weeding in North-West-Germany (Oral #231)

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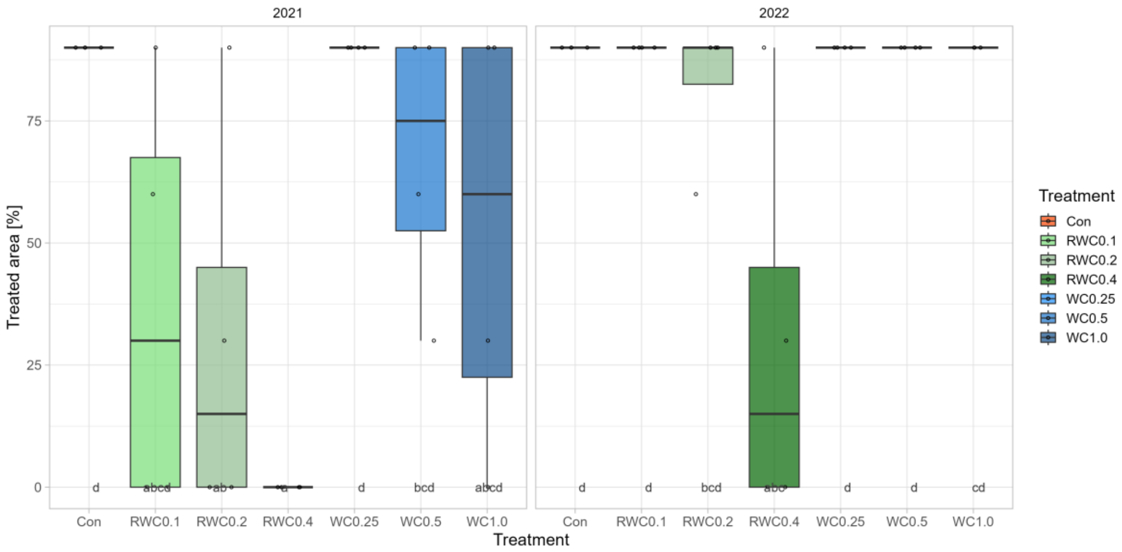
Keywords: biodiversity; precision farming; precision weed control; sustainable weed management; weed detection



1. Introduction

Weeds compete with crops for resources such as water, nutrients and light, causing an average yield reduction of 34 % globally (Oerke, 2006). However, weeds also have positive effects, such as providing food and shelter for arthropods (Selfors *et al.*, 2018) and preventing soil erosion (Seitz *et al.*, 2019). Weeds are not evenly distributed in the field, but form patches, so uniform weed management is often unnecessary (Castaldi *et al.*, 2017). Mechanical weeding offers the possibility to reduce herbicides and is commonly used in organic farming. But it has drawbacks, such as damaging or killing crops by hoeing and increasing soil erosion and weed seed emergence after soil disturbance (Seitz *et al.*, 2019). Site-specific weed management (SSWM) is the concept of adjusting management intensity according to the weed species and density distribution within a field. This technique can reduce the negative impacts of weed control. This work analyses approaches of site-specific mechanical weeding in maize in North-West-Germany.

2. Materials and Methods

A field trial was conducted at the research station “Waldhof” of University of Applied Science Osnabrück, in the North-West-Germany, in 2021 and 2022. Two types of decision support were compared with uniform weeding. One is based on the weed cover (WC), and the other on the relative weed cover (RWC). The RWC is the ratio of weed cover to crop cover. For both treatments, three factor levels were tested: WC0.25; WC0.5; WC1.0; RWC0.1; RWC0.2; RWC0.4. Each treatment was repeated four times in randomised order. UAV-based multispectral cameras were used to distinguish between maize, weeds and soil. Different camera systems and algorithms were tested to optimise the workflow. Weed management was applied when the threshold of the treatment was exceeded. A uniform weeding was carried out with torsion harrow, followed by two site-specific hoeing applications. ANOVA with subsequent Tukey test (α = 0.05) was used to identify significant differences.

3. Results and Discussion

In 2021, higher maize yields and lower weed biomass were observed due to 106 mm more precipitation than in 2022. In both years, there was no difference in maize yield or weed biomass among the treatments. The thresholds of the first site-specific hoeing application were reached by all treatments. With the second site-specific hoeing, only 58 % of the area was hoed on average in 2021, while in 2022, 89 % of the area was hoed. These savings are similar to those reported by other studies (Castaldi *et al.*, 2017; Niemeyer *et al.*, 2024). In 2022, the smaller plants competed less with the weeds, resulting in higher weed growth in the early stage and more thresholds being exceeded. The non-conservative RWC0.4 treatment spared significantly less area, with -100 % and -66.6 % treated area in 2021 and 2022, respectively. For several of the treatments with low thresholds no significant differences to a uniform weeding were observed. The RWC treatments also considered maize growth. With better crop development more weeds could be tolerated and less area needed to be hoed. This study demonstrates the potential of SSWM and the RWC as weed control thresholds to enhance biodiversity and mitigate the negative effects of weeding.

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From genotypes to cropping system improving soybean yield in relay-cropping under water stress enhanced by cereal competition (Oral #145)

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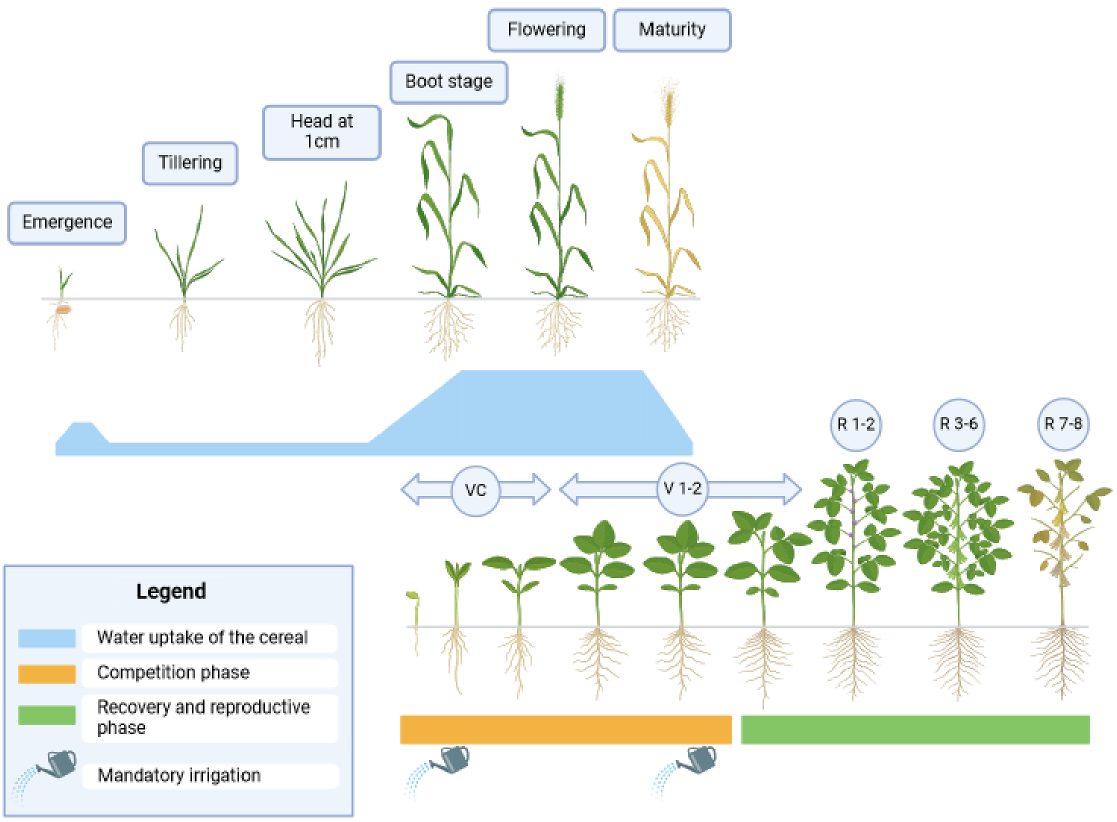
Keywords: competition; crop association; hydraulic traits; water stress; root plasticity



1. Introduction

Relay-cropping is a crop association where the implementation and harvest of the crops is delayed, leading to an asynchronous cycle of development. It enhances land productivity with two separate harvests in a year (Lamichhane *et al.* 2023). The main constraint of relay-cropping is the competition endured by the second crop (*i.e.*, soybean) from the winter cereal, leading to yield losses that can range from insignificant to over -90 % (Wallace *et al.* 1996; Sandler *et al.* 2015) depending on climatic conditions. Soybean's sensitivity to water stress necessitates the development of more resistant genotypes, particularly in the context of increasing drought events and intercropping systems. To advance knowledge in this area, we conducted in situ experiments exploring soybean functional traits responses to relay-cropping and water stress under low irrigation as well as controlled conditions experiments to quantify their hydraulic resistance to water stress.

2. Materials and Methods

Five years of preliminary trials were conducted in southwestern France, on a farm experienced in soybean cultivation under irrigated conditions. Yields of pure and relay crops and land equivalent ratio (LER) were assessed every year. Two years of field experiments under non-irrigated conditions were performed in northern France of barley/soybean relay-cropping with four soybean contrasted genotypes. Root functional traits (mass ratio, specific length, length density, angle and nodules) were measured at barley harvest and one month after to assess the plasticity of the genotypes to relay-cropping and water stress. In controlled conditions hydraulic traits including vulnerability to embolism and residual transpiration were measured on ten contrasted soybean genotypes to quantify their resistance to drought compared to other crops and the variability among genotypes.

3. Results

The irrigated trials in southern France demonstrated the productivity potential of relay-cropping with a mean LER of 1.62. The cereal is not impacted by the relay-cropping, while soybean present a mean yield loss of 25 % compared to pure soybean. In northern France field trials, we demonstrated that relay-cropping can exacerbate drought stress and, consequently, competition for water between crops, leading to phenological delay and growth abortion. However, root functional traits like lateral root mean angle and specific root length were higher in relay-cropping. The experiments in controlled conditions showed that the soybean is sensitive to embolism, but the genotypes presented wide variations of resistance to embolism of 1 MPa between the most resistant genotype and the less resistant. Hydraulic segmentation was observed in soybean and petiole was highlighted as a hydraulic fuse, being more vulnerable to embolism.

4. Discussion

Relay-cropping increases competition for water between both species and impact the performances of the soybean. Irrigation appears as mandatory to allow soybean to sustain the competition with the cereal, specifically during the emergence and vegetative growth as they are critical stages of soybean development in relay-cropping. The soybean genotypes in relay-cropping treatments presented higher root mass ratio from 10 to 32 %. Higher specific roots length and lateral root angle indicated longer, thinner, and vertically oriented roots to favour water acquisition. The highlight of root traits plasticity brings new perspectives to identify and select appropriate genotypes for relay-cropping (Schneider and Lynch 2020). Characterisation of adapted genotypes to relay-cropping requires also to quantify the genetic variability of soybean to drought resistance notably by focusing hydraulic traits. Whereas soybean is sensitive to water stress compared to other crops, the genetic variability allows to select more resistant genotypes. Correlation between embolism resistance and the relative performances of soybean (data from Terre Inovia 2020 to 2022) genotypes shows that this trait offers prospects for improving genotypes.

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Use of past advisory bulletins to rebuild pest and disease historical annual pressures in French vineyards (Oral #199)

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Keywords: grapevine; advisory bulletins; pests and diseases; historical rebuilding

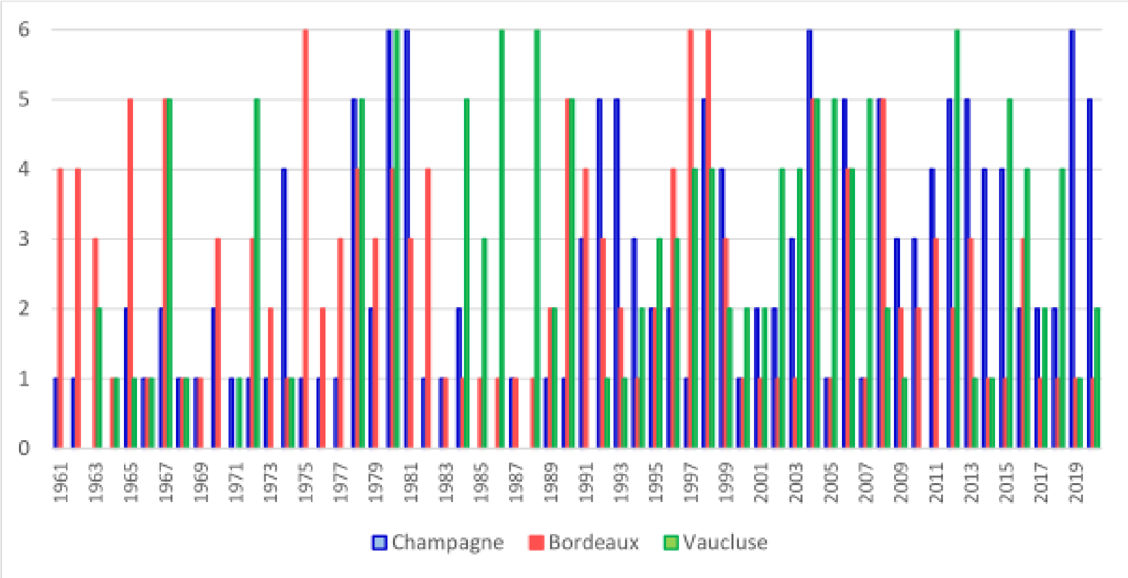

Figure 1. Time series of powdery mildew pressures over three French wine growing regions recovered from advisory bulletins

1. Introduction

As a perennial crop, grapevine life history covers many decades, and the vines are exposed year after year to several biotic and abiotic hazards. The cumulative effect of such exposures influences the present health and productive potential of the vines. It is there important to understand the vine past in order to manage them properly.

The protection of crops against pests and diseases have always been a major concern for growers. To help them, advisory bulletins have been provided to growers under different forms for almost one century by the French service of Plant Protection, part of the Ministry of Agriculture. They constitute an important source of information on the history of biotic threats and crop protection.

The aim of this work was to reconstruct the vines' past exposure to diseases and pests. We build time series of annual indicators of grapevine pests, using agricultural warning bulletins from several French wine-growing regions.

2. Materials and Methods

2.1. Material used

The publication in France of warning bulletins, called “Avertissements Agricoles” (AA), began in the 1940s, although some other forms of advisory bulletins existed previously. The AAs were edited in each region for each crop. In 2009, they were replaced by the “Bulletin de Santé du Végétal” (BSV), that came in a uniformed format in all regions.

To rebuild the past exposure to pests and diseases, we collected long time series of these documents (at least 60 years) in three different wine-growing regions covering the whole range of climate variations in France. We collected periodical bulletins published along the seasons, and, as soon as possible, annual syntheses.

2.2. Document analyses

In each studied region, we selected the main grapevine pests and diseases and analyzed the information for each of them. We collected, in the yearly synthesis or periodic bulletins, all the words or parts of sentences describing the observed prevalence, on one hand, and the severity, on the other hand, of the pest. We then translated these textual elements into a severity and a prevalence score, and constructed an aggregated scale of these two scores to obtain a final annual score. Repeating these steps for each year allowed us to build time series of pest or disease level over the studied winegrowing region.

3. Results

We collected and analyzed advisory documents from the three French wine growing regions of Bordeaux, Champagne and South Rhône Valley / Vaucluse. The timespan covered by these corpus differs between regions: in Bordeaux, we succeeded in and calculating pests and diseases indicators from 1940, in Champagne from 1944 and in Vaucluse from 1954, with fewer gasps in time series after 1960.

The result of this work consisted in time series of annual pest levels. The level was expressed in a semi quantitative score ranging from 0 (absence) to 6 (pest or disease generally present over the region and with high severity). Grades 1 to 3 indicate local attacks, grades 4 to 6 indicate generalized presence of the pest over the region. The figure shows the calculated levels of powdery mildew in the three regions from 1961 on.

4. Discussion

This work allowed us to build and validate a method for translating textual information on past pest and disease levels into semi-quantitative scores, and to validate it in different regions. However we had to develop region-specific decision rules, mainly to account for the prevalence. We will now relate the obtained time series to climatic time series and have engaged collaborations with historians to rebuild the past socio-technical context of grapevine protection against pests and diseases. Apart from the need of local adaptation, the method for analyzing advisory documents can easily be transferred to other cultivated species and other pests and diseases mentioned in these documents.

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Combining grapevine yield, soil quality and service crops: results from a three-year on-farm experimentation in the Mediterranean region (Oral #195)

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Keywords: viticulture; soil organic matter; water constraints; agroecology; management

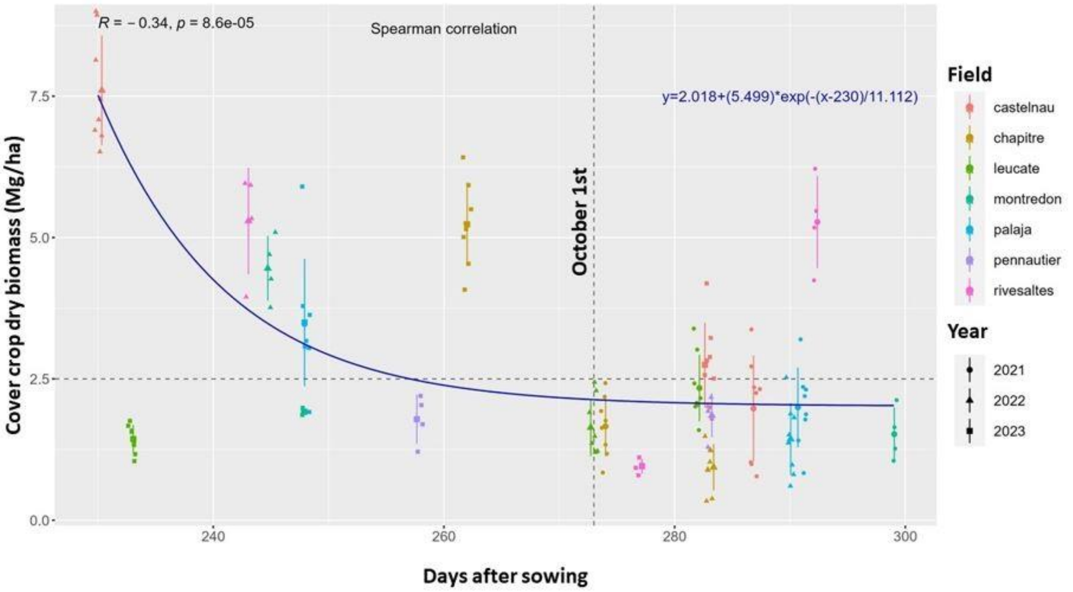

Figure 1. The sooner, the better. Effect of sowing date on biomass production analyzed on the total dataset of the RESAMOVITI project

1. Introduction

Enhancing soil organic matter is key to sustainable viticulture. This study evaluates strategies to improve soil quality and viticultural performance in the Mediterranean. Winegrowers, acknowledging the impact of soil health on yield and resilience, are adapting to evolving policies like the anticipated glyphosate ban by turning to alternatives like cover crops for effective weed management (Cataldo *et al.*, 2021; Jacquet *et al.*, 2021). Cover cropping is increasingly adopted for its benefits in reducing herbicides, boosting soil quality, and water resource management (Garcia *et al.*, 2018). Organic amendments are also used to enrich soil and recycle nutrients (Mondini *et al.*, 2018). Challenges in cover cropping and organic amendment implementation prompt research into resource management and soil property changes (Crystal-Ornelas *et al.*, 2021). At the farm level, the diversity of viticultural practices reveal continuous uncertainties among winegrowers about the effectiveness of ecosystem services and the long-term viability of cover crop management strategies. The Occitanie-funded RESAMOVITI project, involving the ABSys research unit, the French Institute for Vine and Wine (IFV), agri-suppliers (Frayssinnet Club Authentis), and winegrowers, focuses on sustainable soil management, assessing cover crop and organic amendment interaction to improve soil health and yield in diverse Mediterranean conditions.

2. Materials and Methods

Seven vineyards across the Mediterranean region participated in the project, with winegrowers actively involved. Soil characteristics were analyzed in 2019 and 2023, while grapevine and cover crop indicators were monitored during the years 2020-2022. Four modalities combining or not amendment and cover crop in comparison with a bare soil control were tested in the inter-rows of each experimental field.

3. Results

Results indicated that cover crop development was strongly influenced by sowing (Figure 1) and termination dates, initial rainfall and cumulative degree days. Cover crop biomass varied across plots and years, with no discernible impact of organic amendments (from less than 1 Mg ha^{-1} to more than 7). Potential carbon and nitrogen returns from cover crops depended on their development and management, including modulation of the C/N ratio based on the destruction date. Moreover, the presence of cover crops notably enriched soil labile and stable organic carbon content even after three years only. Results about nitrogen balance varied a lot from one field to another, depending on the initial soil content; at the network level, the study demonstrates that cover crops in Mediterranean conditions did not affect vine nitrogen status at flowering or veraison compared to a tilled control. A decrease in yields and vigor due to cover crops was observed in some fields. Nevertheless, this competition appears to decrease in the presence of amendments. Additionally, other factors might influence resource competition between vines and cover crops, thereby affecting yield and vigor. For example, the method of destruction notably influences soil nitrogen availability and could therefore impact vine performance (Garcia *et al.*, 2024).

4. Conclusion

The RESAMOVITI project provides valuable insights into cover crop dynamics and their impact on Mediterranean soil-vineyard systems highlighting that covercropping improves soil quality, and is compatible with grapevine yield if well managed. These findings inform optimized management strategies and support sustainable viticulture practices.

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Planning in uncertainty: vegetable producers and middlemen management of disturbances affecting production (Oral #144)

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Keywords: risk; adaptation; long value chain; market gardening; drought

In vegetable long value chains, products' perishability requires to precisely plan production. Such planning has to respect middlemen (*e.g.*, cooperatives or wholesalers) expectations: quantity and timing of supply. Besides farmers have constraints and objective including farm land, crop rotation, workload, and viable income. Middlemen agree with regular suppliers on a planned supply calendar, which is defined as coordinated and anticipated establishment of expected production (characterised by a crop, a volume and a timing). Planned supply calendar are defined several months in advance, before plantation, and are then usually adjusted depending on unexpected events (technical or commercial). However, in a context where disturbances become more frequent and intense, such routine adjustment may not be suited anymore. Our objective was to understand i) how farmers and middlemen usually adjust planned supply calendar to manage unexpected events, and ii) taking the example of drought, how major disturbances may challenge these routine adjustments. We then discuss how such short-term management leads to potential trade-offs with long-term goals.

Our method is inspired by the "diagnosis of uses", which aims at understanding the diversity of ways to address an issue in a concrete situation of use (Cerf *et al.*, 2012). We implemented a diagnosis of crop planning to understand how farmers and middlemen plan production, what disturbances they face and how they manage it (or not).

Our case study is located in the Roussillon plain (Pyrénées-Orientales, Southern France), a vegetable production basin mainly oriented towards long value chains, which underwent drought for the last two years. We conducted semi-structured interviews with 18 farmers, 6 middlemen and 2 advisors, following an iterative snowball sampling method. Quotes were inductively analysed to specify their topics.

One key step in planning process is seedlings ordering, as it implies to make non-reversible choice involving a significant amount of money (several thousand €/ha). Crop development is then monitored by middlemen in order to anticipate changes in planned supply calendar. During harvest, middlemen can manage overproduction at a given period by finding backup outlets (rather selling, even at low price than not selling). In case of shortage in planned supply, middlemen can solicit unplanned suppliers.

In a context of drought, interviewed farmers took different decisions, depending on farm resources, crops produced, and available information on water resource. Decisions taken included i) proceed regardless of risk, ii) cancel plantation or decrease planted area, iii) postpone plantation with hope that water will get available later, iv) prioritize crops already planted, and limit water use for non-productive soil management operations. Due to drought, middlemen face a risk of major supply shortage, which was managed by: i) buying a more important share of supply to unplanned suppliers located in another region not affected by drought, ii) one middleman committed to refund bought seedlings in case of a harvest loss, in order to encourage producers to take risk. The first strategy is a short-term disturbance management, and the second strategy seems to be emerging as a last resort measure, for cases where a crop central for middlemen cannot be sourced from other suppliers.

Farmers adaptations to disturbances such as drought aim to reduce economic impact, but in case all regular suppliers cancel or decrease production, this would lead to significantly reduced supply for middlemen. Thus, middlemen seek to secure their supply by broadening their supply basin or sharing risks taken by farmers. The short-term coping strategies we identified may however be implemented at the expense of longer-term goals in three ways. First, reduced production leads to reduced gross margin, for both farmers and middlemen, which may not be viable, particularly if drought is to last more than one or two years. Second, when farmers limit water uses for non-productive operations, this preserves gross margin on the short term, at the expense of longer-term production since such operations are important for soil quality management. Third, mutual trust built on long term between middlemen and regular suppliers cannot be built with unplanned suppliers solicited by middlemen for short-term disturbance management. Recurring solicitation of unplanned suppliers can also affect regular suppliers' trust. Our results thus call for a broadening of perspective on long term, to anticipate potential intense and long-lasting disturbances.

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Yield and quality of food and feed in organic farming systems with and without livestock (Oral #273)

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Keywords: crop yield; organic farming; livestock based; stockless; long-term experiment

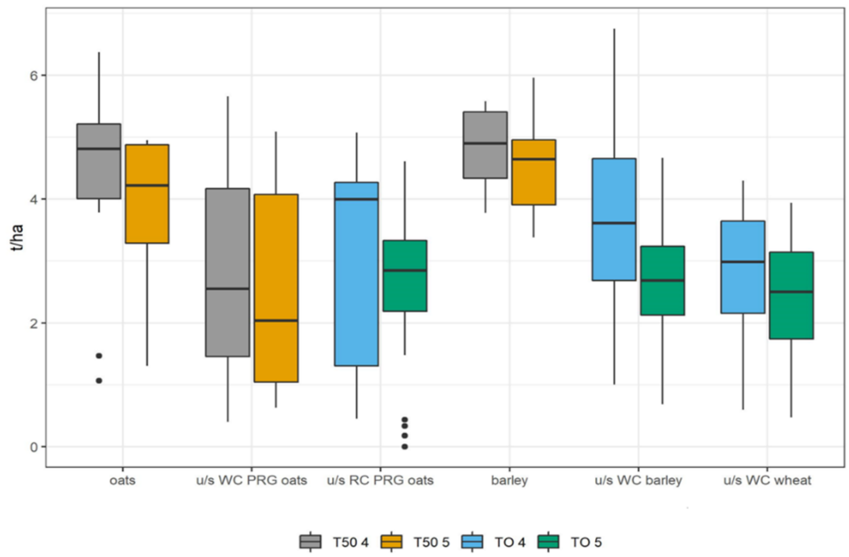

Figure 1. Yields (85% dry matter) of spring oats and spring barley with and without undersowing (u/s) of red clover (RC) or white clover (WC) in a stocked rotation with 3 years of grass/clover ley (T50) or a stockless rotation (T0) in the 4th (2008-2013) and 5th cycle (2014-2019) of the experiment

1. Introduction

Organic farming restricts the import of fertilisers to support crop and grassland production because it aims to rely on supplying nutrients to crops through managing soil fertility *via* rotations and the use of on-farm manures and crop residues rather than direct intervention. Designing rotations that effectively use nitrogen fixed by legumes is challenging, as the release of fixed nitrogen through mineralisation is difficult to predict. Some import of nutrients from outside the farm is allowed but restricted *via* certification rules. This paper explores yield, nutrient uptake and soil fertility in contrasting stocked and stockless organic farming rotations in a long-term experiment in Scotland.

2. Materials and Methods

A replicated experiment comparing two 6 course crop rotations with different ratios of ley to arable cropping was established at Tulloch, Aberdeen (02°15'W, 57°11'N), UK in 1991. From 1991–2006, the experiment compared two rotations, the first with 3 years of grass/white clover ley and 3 years of arable cropping (T50) and the second with 4 years of grass/white clover ley and 2 years of arable crops (T67). These rotations are described in detail in Watson *et al.* (2011). In 2007, T67 was changed to a stockless or "plant based" rotation (T0), with a one-year grass/red clover green manure followed by 5 years of arable cropping. The stockless rotation is described in Ball *et al.* (2014). Crop yield and quality, soil nutrient contents and soil organic matter have been measured over 32 years. Nutrient budgets have been calculated on a rotational basis to address relationships between yield and nutrient inputs in stocked and stockless systems. Yields have been analysed over rotational cycles.

3. Results

The median yields of spring barley and spring oats declined between the 4th and 5th rotational cycle of the experiment (Figure 1) in all rotations. The decline in yield was larger in the stockless system. The median yields of organic grass/white clover year 2 in T50 and T67 declined over time. Silage yields of the 4th and 5th cycles for T50 were lower than the median yields for cycles 1–3 (data not shown). Maximum yields for the organic grass/white clover leys were 15.8, 13.3 and 10.1 t DM/ha in swards aged 2, 3 and 4 years respectively. Extractable P and K in soil has declined over time in all the rotations. Soil organic matter declined in the stockless (T0) system but did not show a clear trend in the stocked rotation (T50) (data not shown).

4. Discussion

The decline in cereal yields over time reflects declining levels of soil P and K. Maintaining soil P and K levels from acceptable sources is widely accepted as a challenge in systems reliant on biological N fixation. The decline in soil organic matter in the stockless (T0) system reflects the difficulties of maintaining soil organic matter in systems without grazing livestock or manure additions and is a major consideration for future production systems. Nutrient budgets provide helpful information for decision making on suitable inputs for organic systems.

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Trajectories of technical changes in pesticide reduction across French vineyards (Oral #173)

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Keywords: change of practices; trajectory; transitional pathway; pesticide use; vineyard; ESR

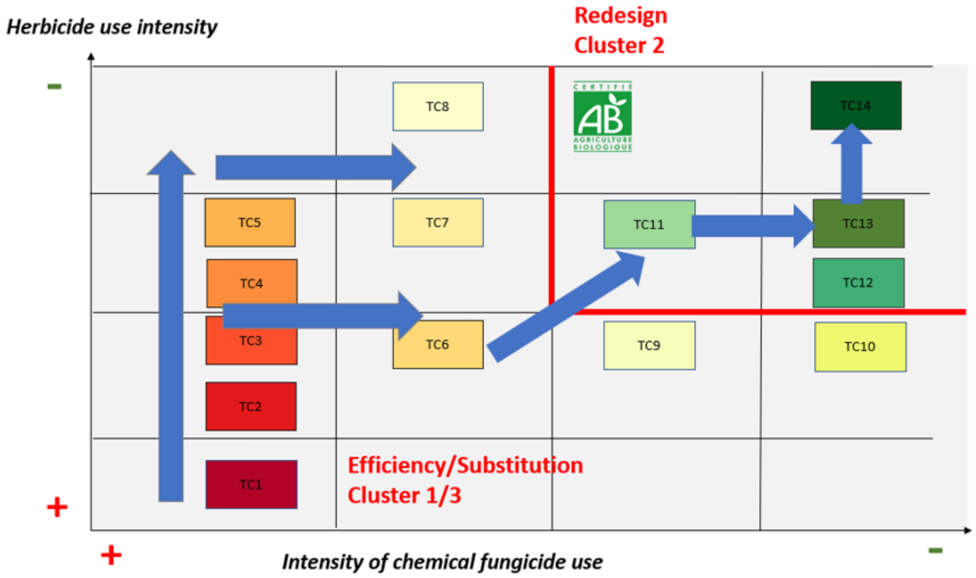

Figure 1. Trajectory of changes followed by surveyed winegrowers. The TC boxes correspond to identified Technical Combinations encompassing both the strategy of fungicide use and the management of row and inter-row strategy (from chemical management to grass cover). Technical combinations corresponding to organic farming practices are represented in green. The trajectories-type of observed changes according to the survey are represented by the blue arrows

High quantities of pesticides are applied in vineyards. A shift towards pesticide-free cropping systems, grounded in agroecological principles, is imperative for enhancing the sustainability of agriculture. To achieve this objective, farmers need to change their practices (Tittonell 2014). At the farm level, numerous agroecological practices, more or less effective, already exist but they must be combined (Wezel *et al.*, 2014). The implementation of practices is often done step-by-step following a long process (Sutherland *et al.* 2012). However, winegrowers are facing several lock-ins toward pesticide use reduction. It is important to explore their trajectories to understand how farmers bypassed these lock-ins. This study aims to analyse the diversity of trajectories of technical changes during the pesticide use reduction transition.

Our study is based on the DEPHY-Network, a French farm network created to demonstrate the capacity of farms to reduce their pesticide use. We focused on farms that joined the network between 2010 and 2012, analysing a minimum 10-year trajectory and selecting 37 farms from the network using a three-criteria sampling grid for the survey. The criteria included the wine-growing area (Mediterranean, Atlantic, or Northern climate), production mode (conventional or organic farming), and pesticide use trajectory type defined by Fouillet *et al.* (2023). Cluster 1 corresponds to farms that entered the network with a low TFI and that experienced a low TFI decrease (-16.4%). Cluster 2 corresponds to farms that started with a low TFI and that managed to reduce significantly their TFI (-48.7%). Cluster 3 represents farms with a high initial TFI and a high TFI reduction (-63%).

All technical changes related to pesticide use since entering the network were identified and characterized using the “Efficiency (E), Substitution (S), Redesign (R)” (ESR) framework (Hill & MacRae, 1996). Each change was assigned an E, S, R level based on its nature and intensity, and an integrated ESR score of change was calculated each year for each vineyard following Merot *et al.*'s (2019) methods. We studied each individual trajectory of ESR scores by using Moulin *et al.* (2008) method, splitting trajectory into agronomic coherence phases. We considered that an integrated ESR score R affected this coherence. After delimiting the coherence phases, the next step consisted of qualifying each coherence phase according to the practices performed into technical combination.

From the surveys, we recorded 64 changes implemented by the winegrowers. Major levers included dose reduction, replacement of chemical products with biocontrol and cessation of herbicides under the row. Cluster 2 experienced a higher change in the coherence phase by predominantly redesigning their cropping systems (*e.g.* conversion to organic farming,), while Cluster 3 and Cluster 1 Farms primarily implemented levers focused on gaining efficiency (*e.g.* progressive dose reduction).

Our study underscores that the diversity of identified pathways is associated with different implemented levers and the evolution of pesticide reduction. Further analyses are essential to identify the trade-offs between pesticide reduction and other performance indicators (yield evolution) and to characterize the risks undertaken by farmers during the agroecological transition.

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A multi-criteria tool for jointly assessing the sustainability and resilience of dairy farms
(Oral #311)

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Keywords: multi-criteria assessment; DEXi tool; dairy farms; sustainability; resilience

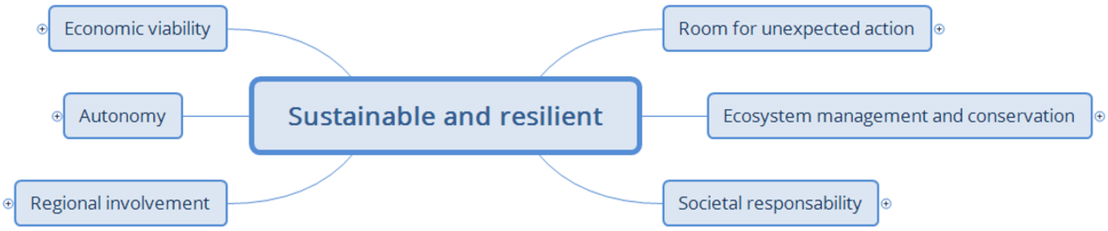

Figure 1. Properties used to jointly assess sustainability and resilience

1. Introduction

Livestock farms are a major contributor to environmental impacts [1]. For dairy farms, one strategy for reducing these impacts is to increase the share of grass in the animals' diet [2]. However, this increases their dependence on grass growth, and therefore on the climate, in the context of climate change. This raises questions about the possibility of reconciling sustainability and resilience for these farms.

The aim of this study was to create and apply a tool for jointly assessing the sustainability and resilience of dairy farms.

2. Materials and Methods

The study was conducted in collaboration with a group of farmers and advisers promoting the use of grass in dairy farms (CEDAPA). A literature review and participatory workshops involving scientists and farmers were employed to create a conceptual framework on sustainability and resilience concepts. This framework was then transformed into a tool comprising criteria and indicators, validated by the stakeholders; the tool was implemented using the DEX method [3].

The tool was then applied to 23 CEDAPA dairy farms. The determinants of sustainability and resilience were analysed by principal component analysis and hierarchical clustering using the tool's indicators as input variables (R software, version 4.2.2). The resulting determinants were associated with technical and economic descriptors of the farms.

3. Results

Creation of the tool

During workshops, tensions were identified between the two concepts, *e.g.* in terms of context and hypothesis: sustainability is assessed when the farm is in steady state whereas resilience is assessed when the farm faces changes. However, each concept was well-associated with a set of system properties, *e.g.* productivity or autonomy for sustainability and buffer capacity for resilience, represented in the conceptual framework. It allowed the creation of a tool that assesses whether dairy farms achieve the sustainability objectives and to what extent they can be maintained when facing disturbances. The tool was organised on six properties of sustainable and resilient farms (Figure 1), described by 37 indicators. The tool enables the classification of farms into five classes, ranging from those exhibiting very low resilience and sustainability to those demonstrating high resilience and sustainability.

Assessment of dairy farms with the tool

Fifteen farms were sorted in the two most sustainable and resilient classes, five farms in the intermediate class, three farms in the two least sustainable and resilient classes. An analysis of the determinants of the sustainability and resilience three clusters. Cluster 1 (eight farms) gathered organic, economically and environmentally efficient farms, all specialised in dairy production, with grass-based forage system. Ten of the eleven farms in cluster 2 were conventional, economically efficient, but not particularly environmentally effective. They were the most productive of the total set, used more maize and had a greater degree of diversification in sales than cluster 1. Cluster 3 comprised four organic farms, with moderate economic efficiency but good environmental performances. Their production strategy was grass-fed milk production and diversified sales.

In each cluster, at least two farms were in the most favourable class and the other were spread across two or four classes. This indicates that the three identified production strategies were capable of achieving satisfactory levels of sustainability and resilience.

4. Discussion

The farms assessed demonstrated good performances in terms of sustainability and resilience. To be sure that the tool does not sort farms too easily into the most favourable classes, a Monte Carlo analysis was performed and showed that the most likely class is the least sustainable and resilient one.

However, it is possible that the tool, constructed with CEDAPA criteria, favours their farming practices. To validate the tool, it is necessary to test it on a second set of farms. This will enable the tool to be evaluated in terms of its ability to discriminate between farms and farming systems.

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Conceptual framework of a Decision Support Tool aimed at enhancing fertilization advice for agroecological banana cropping systems (Oral #163)

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Keywords: *Musa* sp.; French West Indies; plant nutrition; fertilization issues; soil fertility

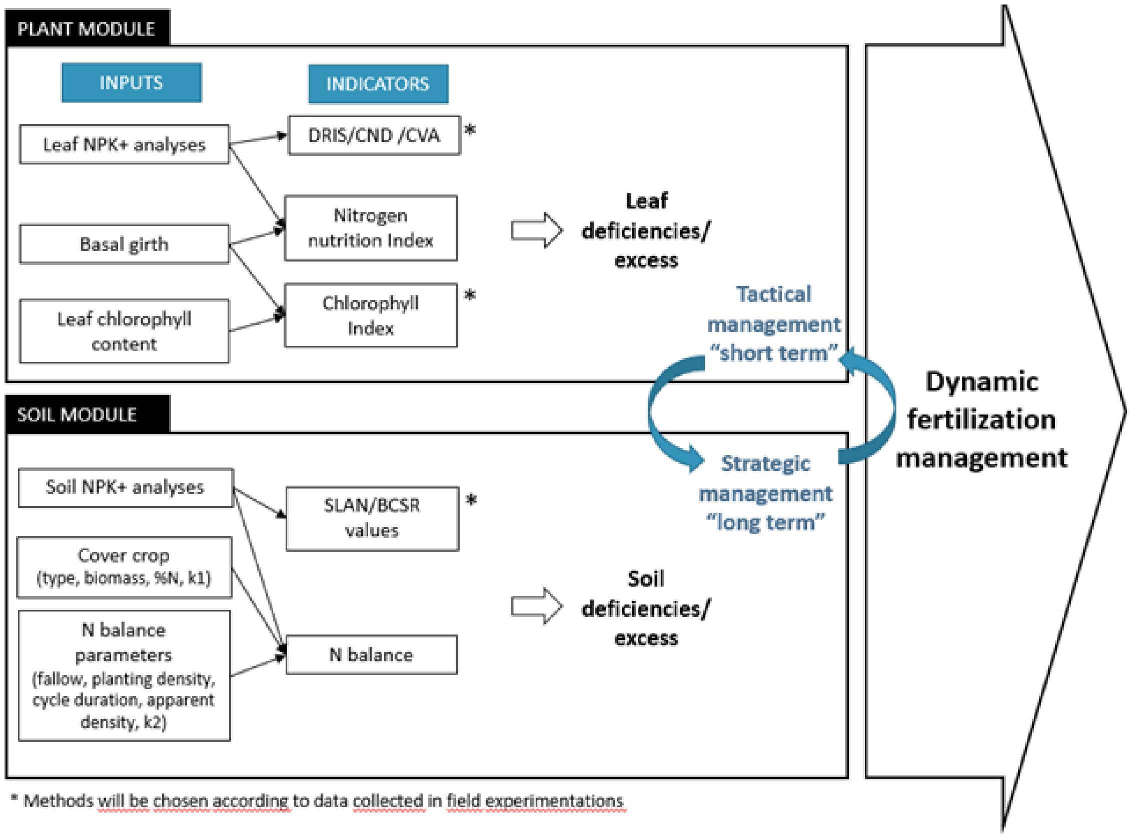

Figure 1. Conceptual framework of a Decision Support Tool for fertilization management in banana cropping system

1. Introduction

In conventional intensive banana monoculture systems, fertilization, mainly mineral-based, is managed to keep high levels of mineral elements in soil, in order to ensure maximal crop nutrition and compensate for leaching losses. It actually results in excessive applications of fertilizers, far surpassing plant's uptake and soil absorption capacity (Godefroy & Dormoy, 1983).

With the development of agroecological banana cropping systems in French West Indies (FWI), adjusting fertilization to plant's requirements in order to reduce nutriment losses by leaching became a priority. But these new banana cropping systems, based on increasing use of organic fertilizers and cover crops in association with bananas could show nutritional stresses for crop. To prevent them, the nutritional status of crop is typically assessed through chemical leaf analysis, it allows a prompt correction of deficiencies. However, this method is not easy to use because it doesn't take into account N dilution with biomass growth (Lemaire *et al.*, 1984). Furthermore, long-term management by soil nutrition is crucial to ensure fertility, although soil diversity in the French West Indies with different exchanges capacity complicates even more this management.

The management of fertilization in the new banana cropping systems, more complex, requires the design of new decision support tools in order to adjust the inputs of fertilizers dynamically based on plant nutritional status and soil resources availability. Here, we present a conceptual framework of a Decision Support Tool designed to assist agricultural advisory in fertilization management of banana cropping systems in the French West Indies.

2. Materials and Methods

The conceptual framework of the decision support tool has been realized in three steps:

1. A literature review of plant and soil nutritional status diagnostic methods.

2. A detailed analysis of recommendations for fertilization of banana cropping systems through interviews between farmers and private agricultural advisor during three days. This step enabled the identification of limits on actual method and expectations for the new tool.

3. Designing conceptual framework of the decision support tool for fertilization management and identification of needs of data for parameterization.

3. Results

Three methods are used for analyze nutrient soil availability: Sufficiency Level of Available Nutrients (SLAN), also called "Critical Tresholds Method", Basic Cation Saturation Ratio (BCSR) or "ideal soil" suggested a balanced soil cation ratios for optimal plant growth and Nitrogen Balance method.

Concerning foliar diagnostic, three methods are used: Critical Values Approach (CVA) that compared nutrient levels to individual thresholds, Diagnostic and Recommendation Integrated System (DRIS norm) that used ratios of two nutrients and Compositional Nutrient Diagnosis (CND) that allows to compare ratios of one nutrient to the levels of all other nutrients.

Current fertilization strategy was reviewed, and leaf and soil analysis were analyzed using CVA method for foliar diagnostic and SLAN method for nutrient soil availability. References of norms used and threshold associated are sometimes unknown or seems very old (1990's). The introduction of cover crop in system was never considered.

Figure 1 illustrates that fertilization management for agroecological banana cropping systems should carried out on two distinct compartments (soil and plant) for taken into account the both tactical – short term and strategic – long term management.

4. Discussion

The conceptual framework realized in this study presents an innovative Decision Support Tool, able to assist farmers for fertilization management by combining tactical and strategical management. This dual approach, taking into account both long-term requirements linked to soil fertility and immediate adjustments to correct deficiencies will allow dynamic and sustainable management of soil fertility of agroecological banana cropping systems in FWI.

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The impact of pH and climate on the yield of cereals (Oral #323)

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Keywords: oats; wheat; pH; climate

1. Introduction

It is well known that the pH of soils will impact on the yield of the crop, and the optimum pH for grasslands is around 6.0 while for arable crops the optimum pH is 6.5. Soil pH is usually tested and modified periodically with lime application to raise the pH as crop growth and associated management practices generally tend to reduce the pH over time. To demonstrate the value of liming, a pH experiment was established at SRUC Craibstone, Aberdeen (02°15'W, 57°11'N) in 1961. The trial was established as a demonstration with a gradient from 4.5 to 7.5. The aim of this study was to assess the yield sensitivity of spring oats and winter wheat to meteorological variables.

2. Methodology

The rotation established in 1961 was an 8-course ley-arable system. The pH of the plots was tested annually and amended as appropriate in order to maintain the target pH. The rotation included three years of grass/white clover, winter wheat, potatoes, spring barley, swedes and undersown spring oats. Although every course of the rotation is present in every year, there are no within year replicates. The fertiliser applications have not changed since the establishment of the trial, and crop protections products were applied when required.

The yield data is reliable from 1969, and by that time the soils had settled at or close to the target pH. Currently, we have focused on exploring the effect of the pH on the yield of the oats and the wheat over the last 50 years. This has been carried out as a two-stage process. The first stage was to fit separately for each year a gaussian non-linear curve (Archontoulis & Miguez, 2015) to the yield data. Thus the equation fitted was:

yield = (w.max * exp(-0.5*((pH-pHm)/b)* * 2)

w.max is the maximum yield, pHm represents the pH at this maximum yield, and b controls the width of the bell. The initial value for w.max was set at the average maximum yield over the course of the trial, and the pHm was set at the pH at which that yield occurred. The initial value of b was set at 1. The next stage was to explain the estimated w.max values by the weather parameters. The weather variables selected to include in the regression analysis were based on total precipitation and average daily temperature during both the previous winter, and the current growing season. In addition, variables based on rainfall and temperature were calculated to assess whether extreme weather conditions during the growing season were impacting on yield. These included the mean maximum temperature (TDD), the maximum number of dry days (rainfall < 0.2 mm (CDD), the maximum number of days where the rainfall was greater than 0.2 mm (CRD) and the maximum number of days where then rainfall was greater than 1mm (CHD). All the weather parameters were also squared to include any non-linear effects. A stepwise regression was performed to determine which of the climatic variables were impacting the w.max parameter.

3. Results

The peak maximum yield for the spring oats and winter wheat occurred at a pH5 and 5.5, respectively. The results indicate that for oats w.max was explained by average daily temperature (T), winter rainfall (WP), and the extreme conditions of the maximum average daily temperature (TDD), and the maximum number of dry days (CDD). A wider range of weather parameters has a significant impact on the w.max for winter wheat. In this case, average daily temperature (T, T2), and total rainfall during the winter and the growing season (P, P2) were significant. The extreme conditions of the maximum average daily temperature (TDD, TDD2), the maximum number of rain days (CHD, CRD).

4. Discussion

This long-term pH experiment has enabled us to explore the effect of pH on yield over an extended period. Temperature, rainfall and extremes of temperature and rainfall are important in determining the maximum yield of the spring oats and winter wheat. However, the maximum for winter wheat was affected by the number of rainy days whereas spring oats was affected by the number of dry days.

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Syppre, a unique experimental network to meet the sustainability objectives of agricultural systems (Oral #184)

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Keywords: diversification; multiperformance; system experiment

	From 2017-2022	PIC	CHA	BER	LAU	BEA- T3	BEA- I1
Technical and Environmental	↘ 20 % Mineral N	-27%	-28%	-34%	-23%	-47%	-10%
	↘ 50 % Treatment frequency index	-25%	-10%	-28%	+18%	-33%	+7%
	↘20 % GHG	-16%	-22%	-28%	-17%	-27%	-4%
	≥ Soil organic matter content	+2.2%	-0.2%	-5.2%	+10.8%	+1.5%	+1.4%
	↘ 20% Energy consumption	-20%	-13%	-21%	-1%	-23%	-7%
Profitability	≥ Direct margin	-36%	-29%	-12%	-38%	+28%	-40%
	≥ EBE / UTH	-39%	-30%	-11%	-39%	+40%	-45%
Productivity	≥ Gross energy production	-25%	-7%	-20%	-8%	+2%	-14%
	≥ Energy efficiency	-6%	+9.0%	+0%	-8%	+32.1%	-8.3%

Table 1. The results of the multi criteria analysis made with Systerre tool from 2017 to 2022. The results are the performance of the innovative system compared to the reference one

Agriculture must reconcile food production, energy production and conservation of the environment, while ensuring a fair income to farmers. This requires a shift towards new production systems, based on both ecological intensification and technical innovations, adapted to local conditions and usable by farmers. To address this issue, the French technical institutes on arable crops ARVALIS, Terres Inovia and Institut Technique de la Betterave (ITB), launched a collaborative project called Syppre in 2014 (Toqué *et al.*, 2015). It consists of an experimental network of diversified cropping systems implemented in five locations that are representative of France's major regions for arable crop production: the deap loamy soils of Picardie, the chalk soils of Champagne, the shallow clay-limestone soils of Berry, the clay-limestone hillsides of Lauragais and the humus-rich soils of Béarn. For each site, we have verified that the reference system is the dominant system of the representativeness area (Galano *et al.* 2024). On each experimental platform we experiment this reference cropping system and one or several innovative systems. The latter have been co-designed with local stakeholders to meet a multi-performance objective defined as follow: profitability and productivity higher than or equal to the reference, and improved environmental performance compared with the reference. They also aim to meet local challenges such as controlling certain weeds or reducing erosion. Environmental and input use performance is measured by indicators such as treatment frequency index (TFI), mineral nitrogen application, greenhouse gases emissions (GHG) emissions and soil organic matter content. Target thresholds have been set to be consistent with public policies: -50 % compared to regional reference for TFI, -20 % for GHG emission (SNBC, 2020).

The multi-criteria evaluation is carried out using the SYSTERRE tool (Casal *et al.* 2022). To meet the objectives, the innovative systems mobilize and combine several technical solutions based on a systemic approach, such as more diverse rotations including legumes, cover crops and reduced tillage wherever possible.

At the system level, environmental and input use performances reach the expected goal in average for the 7 years of trial, with a reduction in GHG emissions of over 20% compared to the reference system, less mineral nitrogen used, lower TFI on 4 of the 5 platforms, and a positive carbon balance. However, this has been achieved at the expense of economic performance: the profitability of innovative systems is lower than that of reference systems, due to the weight of diversification crops in rotations and their lower productivity (Longis *et al.* 2024) (Table 1).

The presentation will detail the results of the innovative Syppre systems and question the cost of implementing agroecological levers for farmers at the exploitation scale. It will illustrate the difficulties encounter by experimentators to answer short term and long-term objectives, and the compromises they have to make each year.

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How can models contribute to the design of cropping systems that meet both farmers' short-term problems and long-term objectives for sustainable weed management? (Oral #310)

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Keywords: weed management; model; cropping system design; combination of practices

	Cropping system	Current		Innovative (1st version)		Innovative (2nd version)	
Weed harmfulness for crop production	Yield loss due to weeds	1.00	a	0.94	c	0.96	b
	Lack of resilience against peaks of weed pressure	0.98	a	0.91	b	0.90	b
	Harvest pollution	0.91	a	0.81	b	0.75	c
	Field infestation (average weed aerial biomass)	0.97	a	0.77	b	0.67	c
Weed contribution to biodiversity	Flora specific richness	0.41	a	0.50	b	0.58	c
	Flora evenness	0.39	b	0.41	b	0.31	a
	Food offer for birds	0.26	a	0.38	b	0.44	c
	Food offer for carabids	0.30	a	0.40	b	0.41	b

Table 1. Performances of the current and innovative systems of a farmer in terms of weed management. There is no use of herbicides in the innovative systems (organic farming). Indicators are an average over total length of simulation (30 years) and are normalized: 1 is the best performance (green), 0 the worst one (red)

1. Introduction

Weeds are the most harmful pest among those targeted by pesticides for arable crops but they are also are beneficial (*e.g.* feeding wild fauna). If herbicides are the most effective to control them, their consequences on health and environment compel to reduce their use. To achieve this goal, farmers need to combine several partially effective techniques. While the effects of each technique are known, it is much more difficult (if not impossible) to predict short-term and long-term effects of their combination. During the COPRAA project, we demonstrated in different farmer groups that providing them with specific knowledge inputs and model results, is an effective way of motivating them and helping them in the design process, as it enables them to take both time scales into account.

2. Materials and Methods

Three workshops were held in each group of farmers, over a period of a few months: presentation of our method and definition of weed issues for at least one farmer; design of an innovative cropping system by the other members; discussion about the results of our assessment. The performances of each cropping system for weed management were assessed with the virtual field FLORSYS (Colbach *et al.*, 2021), a mechanistic model simulating crop and weeds development and competition for light and nitrogen. DEXiPM (Pelzer *et al.*, 2012) was used to assess the sustainability of the designed cropping systems.

3. Results

Evaluation results for co-designed systems

The assessment of several innovative cropping systems with FLORSYS has pointed out three main trends (see one example in Table 1):

1. Although weed harmfulness for crop production increased a little in most of innovative systems, it remained low.

2. These performances are achieved while reducing significantly or even stopping herbicide use.

3. Mixed effects are observed on weed contribution to biodiversity: increase in food offer for wild fauna, but a decrease in weed species richness and/or evenness.

Results of discussions with farmers

Reducing or stopping the use of herbicides without increasing weed harmfulness implies multiple and significant changes in the cropping system, which may have consequences for its sustainability. We have submitted to the farmers the results of the multicriteria assessment (economic, social and environmental sustainability) performed with DEXiPM. These results have raised discussion on important subjects for farmers, such as the effect of tillage (especially ploughing) on soil fertility, the need to purchase new machinery, the technical know-how and outlets for new crops. The workshops with the farmer groups were also an opportunity to discuss about their perception of weed infestation in their fields and its long-term impact for the cropping system management. In our example, these discussions led to modifications of the succession of crops in the innovative system (column “Innovative system (2nd version)” in Table 1).

4. Conclusion

Mechanistic models, such as FLORSYS, are useful to answer questions of farmers or advisors when they design cropping systems in order to solve weed management issues. However, such models are complex to use, require a lot of input data and the length of simulations is not compatible with the duration of a workshop with farmers. That is why a simpler tool, DECIFLORSYS based on meta-modelisation, has been designed and completed during the project. It will allow advisors to compute results for a cropping systems assessment in a few minutes.

Moreover, we carried out similar approaches in other groups with different production contexts and group composition (with or without advisors). The diversity of situations will make it possible to create a guide for the design of innovative systems aimed at sustainable weed management, specifying how the models can be used in the process.

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Soil phosphorus budgets differ according to plot managements and farm types: a French observatory (Oral #50)

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Keywords: phosphorus management; organic farming; soil fertility

1. Introduction

Soil fertility management differs significantly in organic *vs.* conventional farming systems, as it ideally relies on closing nutrient cycles rather than on the use of external mineral fertilisers' inputs. While nitrogen (N) fertility is relatively easy to manage through BNF, phosphorus (P) management is more challenging (Möller *et al.*, 2018). Therefore, investigating soil P nutrient flows and status is key to assessing the sustainability of fertilisation practices on organic farms. A number of studies have already attempted to investigate the relationship between farm-gate P budgets and farm types or management practices, with contrasting results (Reimer *et al.* 2020). However, there is still a knowledge gap in the factors that drive the soil P budgets of organic fields across management practices and farm types.

2. Methods

We analyse 5-year P budgets for 179 certified organic plots distributed over a wide range of geographical zones in France. The plots were selected to cover a range of farm types, conversion dates, pedoclimatic conditions, as well as cropping practices, in order to identify possible relationships between territorial socio-economic characteristics of farms, P management practices and soil P budgets. Semi-directive interviews were conducted to collect data for the calculation of soil P budgets. Soil budgets (Watson *et al.*, 2002) were calculated for each surveyed plot. Soil P availability was estimated using the Olsen method. The data were analysed using a Linear Mixed Model. As few relationships were identified in the whole dataset, a Factor Analysis of Mixed Data was performed in order to identify associations between management, socio-economic and territorial variables and to analyse the similarity between the plots studied. Subsequently, Hierarchical Clustering on Principal Components was used to identify clusters of similar plots.

3. Results and Discussion

The data showed a wide range of socio-economic contexts, farm production types and P management strategies. Mean annual soil P budgets ranged from -32.3 to 50.3 kg.P ha^{-1} y^{-1}. Over the study period, only 7% of the plots had a consistently positive soil P budget, while 30% of plots repeatedly had a negative soil P budget and the remaining 64% had either positive or negative budgets. Soil P budget were mostly explained by the cumulative P inputs, followed by P management, the frequency of N-fixing crops, and frequency of fertilisation. If the plot management was characterized by high P inputs, a high proportion of exogenous P and a low frequency of N-fixing crops, the average P budget tended to be positive. On the contrary, we found a significant negative relationship between the frequency of N-fixing crops in rotations and the P budgets, thus raising concerns about the long-term P fertility of organic farms that rely heavily on BNF. The cluster analyses revealed contrasting situations regarding P management practices and thus soil P budgets. Interestingly, the absence of livestock on the farms led to divergent situations with, on the one hand, cropland plots that were not fertilized at all and, on the other hand, plots that received important quantities of exogenous P inputs. Conversely, plots located on livestock farms tended to have more balanced soil P budgets. In conclusion, a strategic management of P resources and fertilisation is necessary to avoid soil P imbalances that may be difficult to reverse in the medium to long term. Our analysis also shows that the presence of livestock is often, although not always, correlated with a balanced management of soil P status. Thus, the reintegration of crops and livestock in organic systems has a strategic importance also for the P management, in addition to other agronomic benefits.

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Sowing date and sowing rate affect yield and yield components of winter poppy (Oral #338)

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Keywords: *Papaver somniferum* L.; plant density; capsule density; thousand seed weight

	Seed yield		Plant density	Capsule denstiy	Capsules plant^{-1}	Seeds capsule^{-1}	TKW
	(g m^{-2})		(m^{-2})	(m^{-2})			(mg)
Sowing date							
1	185^{b}		42.4^{ab}	71.8^{a}	1.83^{b}	6391^{b}	415^{bc}
2	203^{b}		46.2^{a}	75.8^{a}	1.85^{b}	6290^{b}	432^{a}
3	254^{a}		36.7^{b}	77.5^{a}	2.29^{a}	7774^{a}	424^{ab}
4	181^{b}		46.2^{a}	60.8^{b}	1.37^{c}	7389^{a}	408^{c}
Sowing rate (mg seeds m^{-2})							
50	223^{a}		38.6^{b}	73.4^{a}	2.08^{a}	7230^{a}	425^{a}
100	189^{b}		47.1^{a}	69.6^{a}	1.59^{b}	6692^{b}	414^{b}

Values are means over two experimental years. Different letters show statistically significantly different means.

Table 1. Seed yield and yield components of winter poppy as affected by sowing date and sowing rate

1. Introduction

Growing spring poppy for bakery products has a long tradition in Central Europe. Mean spring poppy seed yields in Austria are with 75.0 g m^{-2} (2008–2017) quite low as spring poppy starts to flower late and drought during the transition from the vegetative to the generative phase can lead to significant yield reductions. Growing winter poppy instead of spring poppy might get more favorable under conditions of climate change. The recommended sowing rate for spring poppy is 100 to 150 mg m^{-2}. The sowing rate for winter poppy might be lower as it develops larger plants. However, the knowledge on optimum sowing date and optimum sowing rate for winter poppy under Pannonian climate conditions in Central Europe is missing.

2. Materials and Methods

A two-year field experiment was performed in 2014/15 and 2015/16 in Eastern Austria in Groß-Enzersdorf, located in Marchfeld plain which belongs to the Pannonian Basin. The mean annual temperature is 10.7 °C and the mean annual precipitation is 568 mm. Four sowing dates ranged from early September to mid/end of October: SD 1 = 8 September 2014 or 8 September 2015, SD 2 = 22 September 2014 or 22 September 2015, SD 3 = 2 October 2014 or 6 October 2015, SD 4 = 13 October 2014 or 27 October 2015. The two sowing rates were 50 or 100 mg seeds m^{-2}. Main effects for factors are shown. For interactions of factors and details for the experimental design and setup see Neugschwandtner *et al.* (2023).

3. Results

The seed yield was highest by sowing in early October (Table 1). With this sowing date (SD 3), a higher number of capsules plant^{-1} and seeds plant^{-1} could be obtained although the plant density was lowest.

The latest sowing date (SD 4) resulted in at the lowest number of capsules plant^{-1} and seeds plant^{-1}. The number of seeds capsules^{-1} was higher in SD 3 and 4 than in SD 1 and 2. The TKW was ranked as followed among SD: 2 ≥ 3 ≥ 1 ≥ 4.

The lower sowing rate resulted in a higher seed yield as the capsule density, number of capsules plant^{-1}, seeds plant^{-1} and the TKW were higher than with the higher seeding rate. The higher seeding rate just resulted in a higher plant density.

4. Discussion

The optimum sowing date for winter poppy under Pannonian climate conditions in Central Europe is early October but sowing can be performed over a wider range of dates. A much lower sowing rate than the recommended one for spring poppy can be used.

5. Reference

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Improving soil quality while preserving farmers' income: an ecosystem services-centered conceptual framework (Oral #86)

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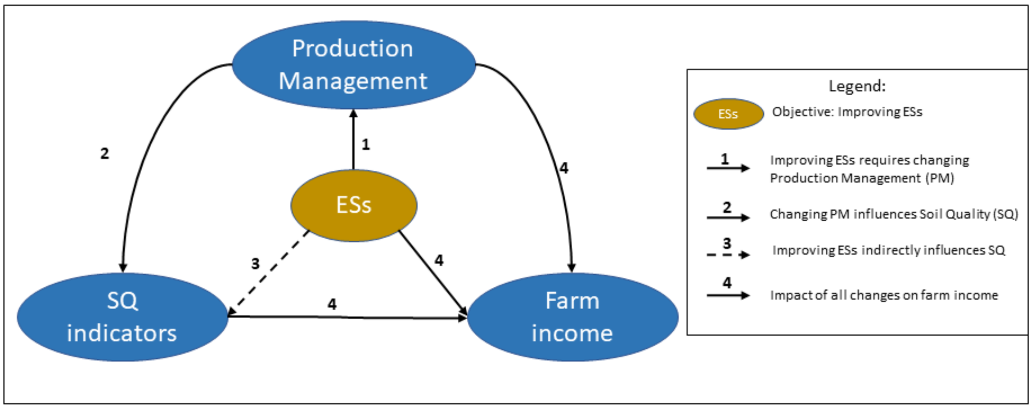
Keywords: ecosystem services; farming practices; soil quality; farm income; crop production



1. Introduction

There is an increasing need to improve soil quality (SQ) to preserve agricultural productivity and environmental benefits. While farmers can improve SQ by changing their production management (PM: set of farming practices), this can affect their farm income and therefore constitutes a challenge that can restrain them from improving SQ. To overcome this challenge, focusing on improving ecosystem services (ESs) rather than SQ itself offers both the potential to improve SQ and generate additional income as ESs can be marketed (*e.g.*, payment for ESs). In this context, it is fundamental to clearly understand the consequences for farmers' income and SQ if farmers attempt to improve their ESs supply through PM. Several studies have approached part of the problem, and the most complete conceptual frameworks addressed the linkage between SQ, PM, and farm economics [1,2]. However, studies that consider ESs at the center of the decision-making process are lacking, and/or poorly address the problem as a whole by considering each concept's complexity, and in particular the large diversity of ESs, SQ indicators, and farming practices. To fill this gap, we developed an ESs-centered conceptual framework that aims at providing a clear holistic qualitative understanding of the problem and a blueprint for further modeling/quantitative analysis. This framework was built with a focus on crop production systems and using an iterative process based on an extensive literature review and expert solicitation.

2. Conceptual framework

In Figure 1, the conceptual framework approach is presented and consists of setting the objective as “Improving ESs” while considering SQ, PM, and farm income as being directly and/or indirectly influenced by this objective. From this approach, it appears that “Improving ESs” results in a sequence of choices/requirements and consequences that create a combined effect on farm income. This sequence can be described with the following four relations: (1) “Improving ESs” requires changing PM, (2) changing PM directly influences SQ, (3) “Improving ESs” indirectly influences SQ through PM, (4) and finally “Improving ESs” (yield, and payments for ESs), PM (costs), and SQ (long term productivity) have a combined effect on farm income. Each relation was explored and described qualitatively (mostly in the form of tables and in terms of “positive”, “negative”, and “unclear/neutral” relations) using the most recent literature (mainly meta-analysis, and reviews). For this purpose, we used 19 ESs (food provisioning/yield, water quality, carbon sequestration, *etc.*), 50 farming practices (no-tillage, manure, cover crops, *etc.*), and 19 SQ indicators (incl. bulk density, pH, earthworm abundance, *etc.*) selected based on literature and expert solicitation. Finally, using this conceptual framework, the paper presents a blueprint for modeling and a semi-quantitative illustration.

3. Discussion and Conclusion

Despite limitations including the lack of precise quantification, four major findings could already be drawn using this conceptual framework. First, it becomes obvious that decisions on ESs result in a sequence of choices and consequences that affect together farm income. Second, improving ESs leads to different trade-offs and synergies with SQ, depending on changes in PM required to improve ESs. For instance, while carbon sequestration can be improved by no-tillage and organic amendment, no-tillage tends to increase bulk density (at least in the short term) while organic amendment tends to decrease it. Third, synergies between ESs and SQ offer the potential to reduce the marginal costs of further improving SQ. Fourth, not only soil-related ESs but also non-soil-related ESs offer the potential to increase SQ while preserving income. For instance, pollination (a non-soil-related ES) could provide an additional income to enhance SQ, as pollination can be improved *via* agroforestry which can also positively influence several SQ indicators (*e.g.*, water infiltration). In conclusion, the conceptual framework provides valuable qualitative insights and a blueprint for quantitative analysis, which will together contribute to the development of sustainable (people: ESs, planet: SQ, profit: farm income) farm business models.

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Soil N dynamics and soil moisture after mechanical weed control in organic maize cultivation (Oral #259)

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Keywords: harrowing; hoeing; N mineralization; organic farming

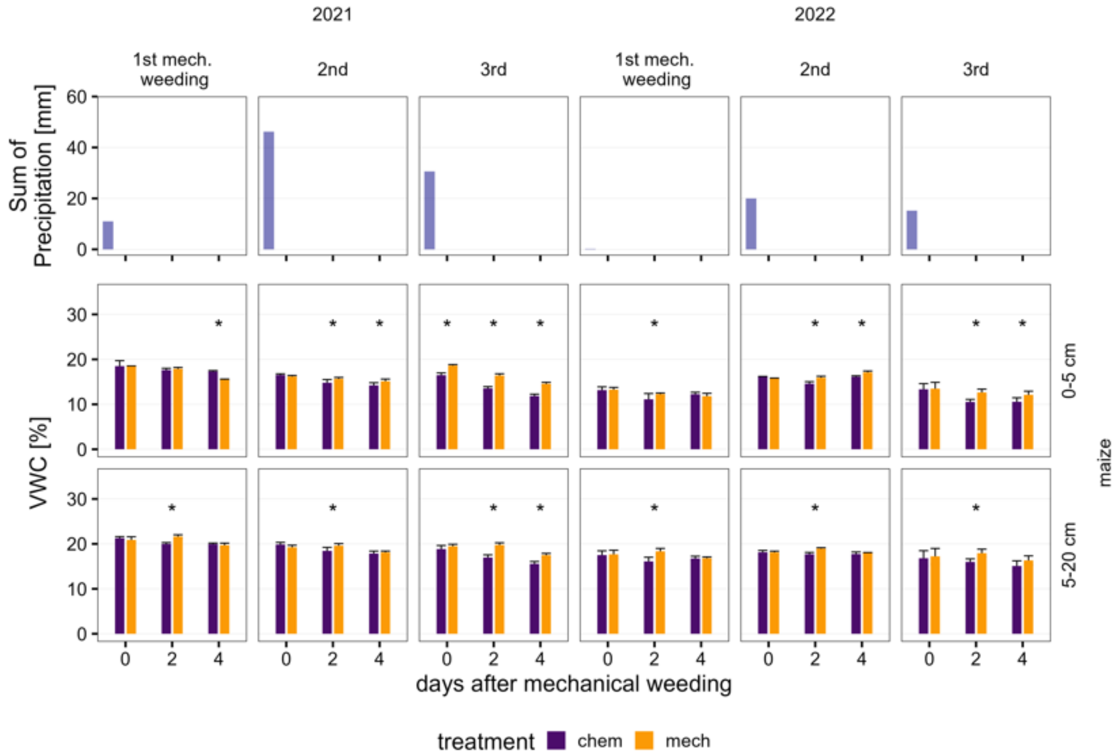

Figure 1. Mean volumetric water content (VWC; bars) with standard deviation (errorbars) in 0-5 and 5-20 cm soil depth with precipitation sums between the treatments for both years and treatments (mech: mechanical; chem: chemical) in maize. * indicates a significant difference between the means of the two treatments ($p \leq 0.05$)

1. Introduction

Mechanical weed control is a major element of weed suppression in organic farming systems. In addition to the direct effect on weed growth, mechanical weeding, such as harrowing or hoeing, is known to induce side effects on several soil- and crop-related properties. There is a lack of knowledge regarding the effect of mechanical weeding on soil N dynamics and soil moisture in organic maize cultivation after a legume-rich ley (Gilbert *et al.* 2009). In the context of efficient use of resources and increasing occurrence of extreme weather events (*e.g.*, drought, heavy rainfall), the impact of mechanical weeding needs to be further examined and reconsidered.

2. Materials and Methods

A field trial was conducted in two consecutive years (2021, 2022) on a sandy loam in North-West Germany to investigate the impact of mechanical weeding on soil mineral nitrogen (SMN), soil moisture and crop yield in silage maize (*Zea mays* L). The previous crop in both trial years was grass-clover (*Lolium multiflorum* LAM., *Trifolium pratense* L.). Mechanical weed control was performed by harrowing or hoeing three times per growing season and compared to a control treatment without soil disturbance. The two treatments (mechanical weeding (mech): harrowing or hoeing; chemical weeding (chem): herbicide) were arranged in a randomised block design with four replications. For investigating SMN, disturbed soil material was taken from 0-5 and 5-20 cm soil depth directly before harrowing or hoeing and two and four days afterwards, respectively. Additionally, soil samples were taken at greater depths (0-30, 30-60, and 60-90 cm) before sowing and after harvest to calculate net N mineralization according to Kühling *et al.* (2023). Soil water content was first determined gravimetrically by drying a subsample of each soil sample and then volumetrically using the bulk density determined in field. Maize was harvested manually as whole plants. Weed coverage was determined directly before each mechanical weed control and at harvest using a Goettinger Schaetzrahmen (0.1 m^2).

3. Results

In 2021, several events were observed where SMN was up to 47 % lower after mechanical weeding in 0-5 cm soil depth compared to the chemical treatment (32.59 kg ha^{-1}), while in 2022, SMN in 0-5 cm was significantly different between treatments in only one event (12.60/16.05 kg ha^{-1}; mech/chem). Mechanical weeding did not affect SMN in 5-20 cm soil depth but led to higher volumetric water content (VWC) in both soil depths, with differences between years and days of measurement (Figure 1). Both treatments (mechanical and chemical) did not completely suppress weed growth. Weed cover was significantly higher for the mechanical treatment at the third measure (12.67 %) and at harvest (10.07 %) in 2021 than for the chemical treatment (1.42/1.18 %), while no significant effect of the different treatments on weed cover was observed in 2022 (2.88/3.6 %; chem/mech). Net N mineralization and biomass yield were not affected by the different weed control treatments.

4. Discussion

The incorporation of grass-clover residues before sowing enhanced N mineralization, which was indicated by a high net N mineralization and high SMN content in both soil layers and years. Furthermore, compared with those of the chemical control, significantly higher weed coverage was observed for mechanical weeding in 2021 after the third treatment and at harvest. Low temperatures at the time of sowing could have delayed maize development and benefitted weed growth. These results indicate that the difference in SMN content between mechanical and chemical weeding around the third treatment (hoeing) may have occurred due to higher N uptake by weeds in the mechanically weeded plots. In 2022, no difference in weed growth was observed between the treatments, which was also reflected in similar SMN contents. In our study, higher VWC after mechanical weeding was attributed to improved water infiltration. Superficial soil disturbance by mechanical weeding following conventional tillage could have been beneficial due to disrupting the soil crust after rainfall.

5. References

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Intercropping chickpea with a mechanically controlled service plant: a promising way to manage weeds while mitigating interspecific competition (Oral #90)

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Keywords: chickpea; intercropping; weed control; interspecific competition; mechanical control

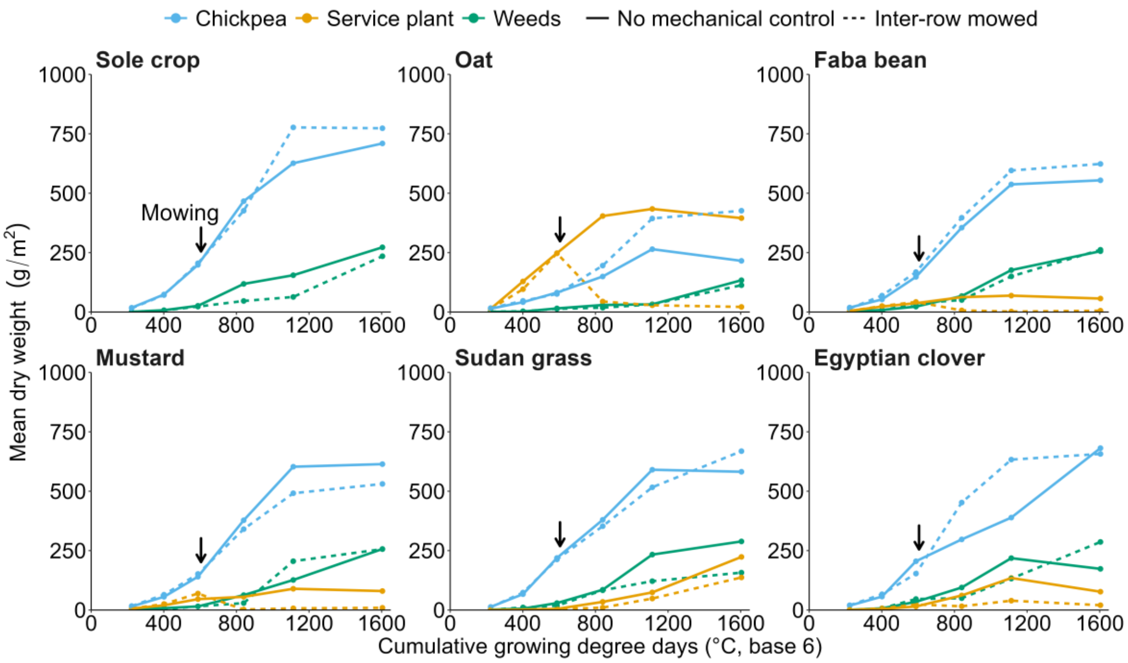

Figure 1. Mean dry weight accumulation of chickpea, service plants and weeds in sole crop and intercrops with or without mechanical control of the inter-row

1. Introduction

Grain legumes are key species for the agroecological and dietary transitions due to the numerous services they can provide. However, they are known to be weak competitors against weeds leading to unstable yields. For instance, chickpea (*Cicer arietinum*) is one of the most commonly grown grain legumes worldwide but suffers from major yield losses because of its poor competitive ability against weeds. Besides, few references are available under European pedoclimatic conditions since chickpea is a marginal crop in Europe. Intercropping has been proved to be a relevant lever to control weeds but can cause yield losses in the main crop (Cheriere *et al.*, 2020). Mechanically controlling the associated species could limit its negative impact on the main crop. This study investigates whether intercropping chickpea with a mechanically controlled service plant allows to facilitate its production by improving the competitive ability against weeds while mitigating interspecific competition.

2. Materials and Methods

A field experiment (2023, 2024) was conducted in western France on chickpea-based intercrops. We selected five species of service plants varying in their morphological, physiological and phenological traits: spring oat (*Avena sativa*), faba bean (*Vicia faba*), white mustard (*Sinapis alba*), Sudan grass (*Sorghum x drummondii*) and Egyptian clover (*Trifolium alexandrinum*). Chickpea was sown at the recommended density in rows spaced 33 cm apart. In the intercrops, the service plant was sown in chickpea's inter-row at 50% of the recommended density. Chickpea's inter-row (service plant, weeds) was either mowed at the beginning of chickpea flowering or left without mechanical control. The selected service plants were contrasted in their response to mowing depending on their ability to regrow (oat, Sudan grass, clover) or not (faba bean, mustard) after being mowed. The experiment was arranged in four randomized complete blocks. Ground cover, accumulation of dry matter (chickpea, service plant, weeds) at 6 sampling dates (5 and 10 leaves, beginning and end of flowering, grain filling, harvest) and N content were measured. Grain yield and thousand grain weight (TGW) were also determined.

3. Results

Our results showed that weed control was the highest when chickpea was intercropped with oat reaching a weed biomass (14 g/m^2) lower than the sole crop (82 g/m^2) and three other mixtures (59 - 84 g/m^2) at the end of flowering. Mowing the inter-row induced a lower weed biomass but only at the sampling date two weeks after the operation. Oat is the only service plant that affected chickpea's yield dropping from 4 t/ha (sole crop) to 1.5 t/ha with fewer grains and a higher TGW. Mowing the inter-row had no effect on total grain yield and number of grains produced but did induce a higher TGW.

During crop establishment, oat accumulated more biomass (Figure 1) and nitrogen than the other service plants. At the beginning of flowering, chickpea had a lower biomass and N content in the intercrop with oat than the other treatments. When the inter-row was mowed, chickpea biomass and N content measured at grain filling stage tended to be higher in the mixtures with oat and clover. The chickpea/oat intercrop covered the soil faster but reached a lower final ground cover than the other treatments.

4. Discussion

The intercrops that included a service plant with a delayed biomass production, ground cover and N acquisition compared to oat reached the same level of weed control than the sole crop despite having a higher final ground cover. An early competitive ability against weeds is therefore necessary to guarantee an effective weed control later on in the cycle. In our study, mowing the inter-row did not have a lasting effect on weed biomass.

Oat's interspecific competition affected not only weeds but also chickpea. It led to a low yield with fewer grains and a higher TGW. The higher TGW observed when the inter-row was mowed without affecting the number of grains shows that we managed to mitigate the competition exerted on chickpea regardless of the associated species. The increasing trends in chickpea biomass and N content in presence of mechanical control support this observation. Overall, this study provides further knowledge on mechanical control as a lever to manage trade-offs between services in intercrops.

5. Reference

Cheriere *et al.*, 2020. Field Crops Res., 256.

Which pea traits for agroecological weed management in pea-wheat intercrops (Oral #34)

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Keywords: legume-cereal intercrops; weeds; ideotype; biological regulation; simulation model

	Maximise…	Pea yield						Intercrop yield				Weed suppression	Intercrop yield		
	Weed presence	No		Yes						No		Yes			
	Cropping systems	All				Herbicides and tillage							No herbi[cides]	No tillage (with herbicides)	
Beneficial pea characteristic	**Ideotype**	**gp1**	**gp2**	**gy1**	**gy2**	**y12**	**y3**	**Y1**	**Y23**	**P12**	**P3**	**F2**	**NH123**	**NT1**	**NT2**
Germination and emergence															
Germination onset									Similar					**Earlier**	Similar
Germinate in darkness							Similar		Similar			Similar		**Worse**	Similar
Seedling loss in buried seeds							Similar		Similar					**Worse**	Similar
Seedling loss in compacted soil									Similar			Similar		**Worse**	Similar
A. Above-ground plant morphology: all aim to increase light interception & shading of neighbours (except if otherwise indicated)															
Post-emergent gound cover				Similar	**Smaller**				Smaller			**Larger**			Smaller
Maximum plant height			Similar	Smaller	Taller				Similar			Taller		**Smaller**	Similar
Plant height homogeneity	emergence	**Better**	Worse	Better	Worse		Better			Better	Worse				
	vegetative	Better	Worse	Better	Worse		Better			Better	Worse				
	reproduction	Better	Similar				Better			Better	Worse	Better			
Plant width per biomass	vegetative	Narrower	Wider				Narrower			Narrower	Wider	Narrower			
Plant width homogeneity	vegetative	Better	Similar				Better			Better	Worse	Better			
% biomass allocated to leaves	emergence			Similar	**Less**				Similar						
	reproduction	**More**	**More**	Similar	**More**			**More**	**More**					**More**	Similar
Leaf area distribution along plant height	emergence		Similar	Lower	Higher		Lower			Lower	Higher	Higher			
	reproduction			Higher	Lower				Similar						
B. Shading response															
Timing		**Earlier**	Similar				Earlier		Earlier	Earlier	Later	Earlier			Earlier
Plant height per biomass	emergence	Smaller	Taller	Smaller	Taller		Smaller					Smaller			
	reproduction			Smaller	Taller				Taller	Smaller	Taller	Smaller			
Plant width per biomass	reproduction			Wider	**Narrower**	Narrower	Wider			Wider	Narrower	Wider	Narrower		Narrower
% biomass allocated to leaves	emergence														
	vegetative	More	Less				More			More	Less	Less			More
	reproduction	More	Less	More	Less		More			More	Less	Less			
Leaf area distribution along plant height	emergence											Lower			
	vegetative	**Higher**	Similar	Higher	Lower		Higher			Higher	Lower	Lower			
	reproduction			Similar	**Lower**										
Leaf area per leaf biomass	emergence			Smaller	Larger				Similar			Smaller		**Smaller**	Similar
	reproduction	Smaller	Larger				Smaller		Similar	Smaller	Larger			**Larger**	Similar
B. Root system															
% biomass allocated to roots		**Less**	Similar				**Less**		Similar	**Less**	Similar				Similar
Root system width		Narrower	Similar				Narrower		Similar	Narrower	Wider	Similar		**Wider**	Similar
Root-system depth growth				Slower	Faster							Faster			
Root-system width growth				Slower	Faster							Similar			Similar
Root biomass distribution		**Shallow**	Similar	Shallow	Deeper		Shallow			Shallow	Deeper				
Root growth in compacted soil		Better	Worse	Better	Worse		Better			Better	Worse				
C. Temperature sensitivities															
Frost tolerance	vegetative		Similar	Better	Worse		Better	Better	Better	Better	Worse				Better
	reproduction											Similar		**Better**	Similar
Photosynthesis efficiency in hot conditions		**Worse**	Similar	Worse	Better		**Worse**			**Worse**	Similar	Worse			
D. Pea varieties answering to the rules															
		Isard	DCG0449 Virtual4 Virtual8	Isard Virtual4	DCG0449	Dcg0449 Isard Virtual4	Isard	China Dcg0449 Isard Vi4	China Dcg0449 Isard	Isard	Dcg0449 Virtual4	Enduro	Dcg0449 Isard Virtual4	Virtual4	Dcg0449 Isard
E. Contraints on wheat varieties and crop management (number of parameters or management rules) Cells coloured from white (0) to purple (largest number of rules in line)															
Wheat varieties		0	0	0	0	3	28	0	31	2	8	1	10	0	0
Intercrop management		0	0	0	0	6	38	7	14	0	0	11	5	2	11
Management of other crops		0	0	0	0	3	46	2	12	0	0	20	9	0	33
F. Intercrop performance		gardless of wheat variety and crop managem				With adapted wheat varieties and crop management									
Pea yield		1.1	1.0	1.3	1.1	5.8	3.2	2.6	4.6	1.6	1.7	0.2	3.8	2.9	1.8
Potential pea yield		2.4	1.9	2.4	2.1	6.9	3.3	2.6	5.3	3.6	3.3	0.2	4.0	3.0	2.7
Wheat yield		1.7	1.6	1.6	1.9	0.4	2.7	5.1	2.1	2.1	1.2	2.4	2.0	0.9	5.4
Potential wheat yield		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Figure 1. The pea ideotypes and pea varieties aiming to maximize yields and weed competitivity in pea-wheat intercrops in different cropping system types, identified with classification and regression trees. Rules in sections A-D in green improve yield and weed suppression compared to some (standard) or all (bold) existing varieties used here, those in red show trade-offs, *i.e.*, rules that potentially decrease performance and result from correlations with beneficial characteristics and/or have no influence in the given cropping system type; white cells show rules respected by current varieties. Empty cells show non-significant variety parameters. Constraints in section E are coloured from white (0) to purple (highest number of constraints). Cells in section F are coloured from red (lowest pea or wheat yield, highest infestation) through yellow to green (vice-versa)

1. Introduction

Pea (*Pisum sativum* L.) is a key diversification crop but current pea varieties are not very competitive against weeds. Intercropping pea with cereals is a promising lever to reduce weed infestation and damages. However, past pea varieties were bred for sole crops usually in herbicide-protected fields. They may not be optimal for growing in intercrops with wheat and in the presence of weeds. The objective of this study was to identify, depending on the type of cropping system and weed flora, (1) the key pea parameters that drive crop production and weed control in pea when intercropped with wheat (*Triticum aestivum* L.), (2) optimal combinations of pea and wheat parameter values as well as intercrop management techniques (tillage, sowing date and density, interrow width…), to maximise these goals.

2. Materials and Methods

Virtual experiments were run, using FLORSYS (Colbach *et al.*, 2021). This mechanistic individual-based 3D model simulates daily crop-weed seed and plant dynamics over the years, from the cropping system and pedoclimate, focusing on plant-plant competition for light. The model includes five winter pea and three winter wheat varieties. Virtual varieties (5 pea and 10 wheat) were created by randomly combining variety-parameter values according to a Latin Hypercube Sampling (LHS) plan, respecting parameter ranges and correlations observed in the actual varieties. A global sensitivity analysis was run, using another LHS plan to combine pea and wheat varieties, crop rotations and management techniques in nine contrasting situations (*e.g.*, conventional *vs* organic, no-till, type of weed flora). Simulated data were analysed with classification and regression trees (CART). Additional simulated data with sole-crop winter pea instead of pea-wheat intercrops were taken from Colbach *et al.* (2022).

3. Results

Intercropping reduced pea yield loss due to weeds (by 30% for the least weed-tolerant varieties, *e.g.* Enduro) and field infestation (by 14% for the least weed-suppressive varieties, *e.g.*, 886-1). In wheat-pea intercrops, intercrop management and the pea variety were more influential than the wheat variety for yields. Yield loss due to weeds and field infestation depended mostly on the management of intercrops and other crops of the rotation, with little effect of variety parameters.

We highlighted (1) key pea parameters that drive potential (weed-free) yield and competitivity against weeds (*e.g.*, biomass allocation to leaves until full maturity, increased plant width per unit biomass when shaded, frost tolerance). These are pointers for breeding varieties that regulate weeds in intercrops by better competing for light; (2) Rules to guide farmers to choose the best pea variety, depending on the production goal, the intercropped wheat variety and the cropping system (Figure 1). Pea and/or intercrop yields as well as weed suppression improved when pea ideotypes were tailored to cropping system types (*e.g.*, always tilled *vs* never tilled), and combined with optimal wheat varieties and crop management (*e.g.*, ideotypes y12 and y3 *vs* gy1-gy3). The best pea ideotypes had a small root system and prioritised above-ground plant growth and light interception, except in no-till where a large superficial root system left less soil moisture for superficial weed seeds (NT1 and NT2). Pea ideotypes based on CARTs searching for the best weed-infested pea or intercrop yield also produced the best weed-free yields and weed suppression (*e.g.*, gy1-gy3 *vs* gp1-gp2, Y1 and Y23 *vs* P12 and P3 or F2). Contrasting pea ideotypes could achieve similar performances, if the associated wheat varieties and/or crop management rules were optimised (*e.g.*, P12 *vs* P3). In summary, a high pea yield in weedy intercrops required a pea variety with a high yield potential combined with a weed-suppressive wheat variety and weed-preventive management.

4. Perspectives

The present pea-parameter rules provide guidelines for farmers to choose their pea varieties in cereal-legume intercrops and for breeders to screen existing germplasm collections and to identify traits for which the select during breeding.

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Colbach *et al.* (2022) Frontiers in Plant Science doi.org\10.3389/fpls.2022.809056

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Effect of sowing patterns and species proportions of cereal–legume intercrops on weed control (Oral #35)

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Keywords: intercropping; weeds; simulation model; sowing pattern; sowing density

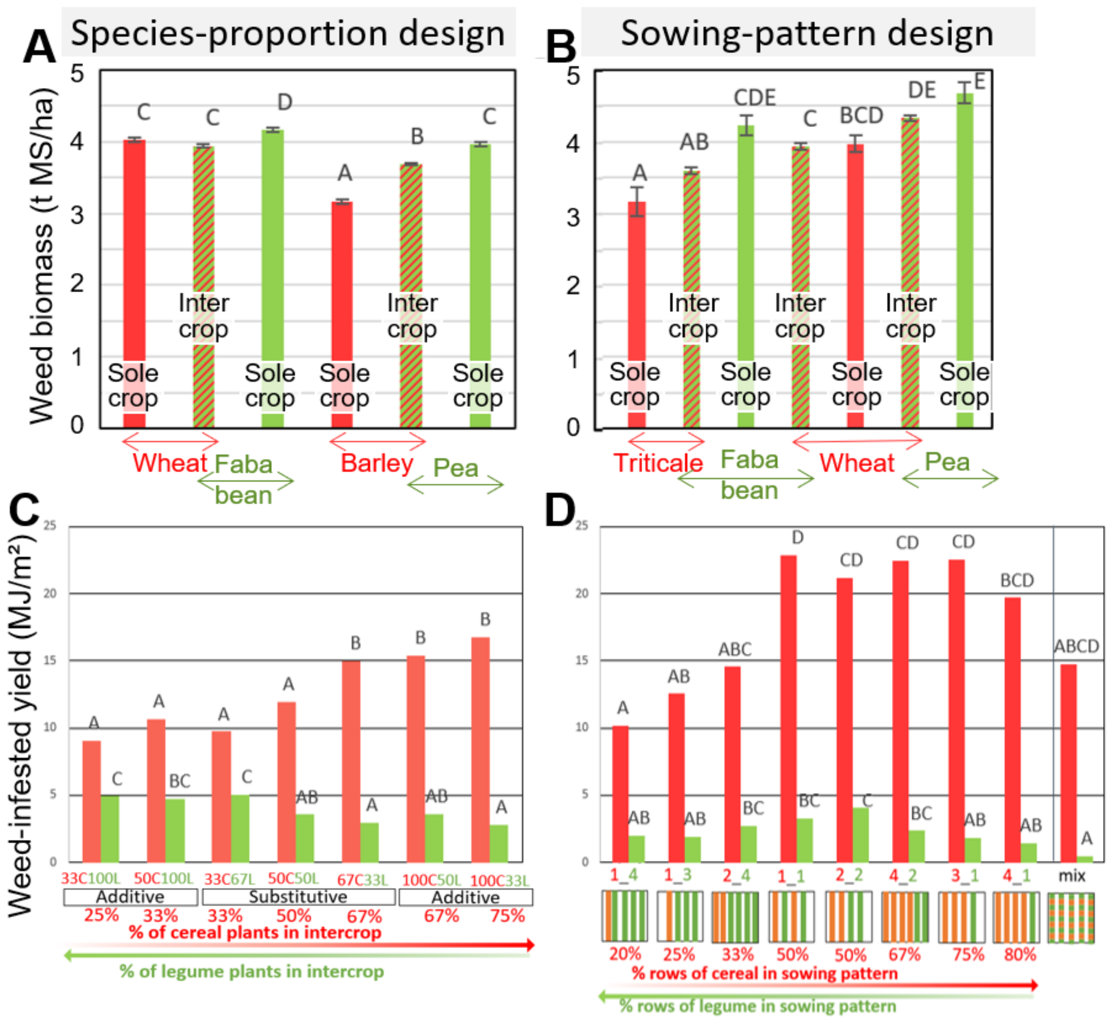

Figure 1. Effect of species proportions (A, C) and sowing patterns (B, D) of cereal–legume intercropping on weed biomass (A, B) in intercrops (hatched) and in the corresponding sole crops with legumes in green and cereals in red, as well as on intercrop yields in the presence of weeds (C, D). Cereal (in red) or legume yields (in green) with the same letter are not significantly different at p=0.05 (Tukey test after analysis of variance)

1. Introduction

Intercropping – several species cultivated in the same field for a significant part of their growing periods – is a key lever for weed control. The aim of this study was to evaluate, by simulations with the FLORSYS model, the effects of bispecific legume–cereal intercrops on weed dynamics and their impact on crop production, tested in the absence of nitrogen or water stress.

2. Materials and Methods

This study simulated: (1) seven species proportions for wheat (*Triticum aestivum* L.)–faba bean (*Vicia faba* L.) and barley (*Hordeum vulgare* L.)–pea (*Pisum sativum* L.) mixtures (hence "species-proportion design"), and (2) nine spatial sowing patterns for triticale (*Triticosecale*)–faba bean, durum wheat (*Triticum durum* Desf.)–faba bean and wheat–pea mixtures (hence "sowing-pattern design"). In both cases, mixtures were compared to their corresponding sole crops (controls). Intercrops and controls were inserted into rotations and simulated over 30 years and repeated with 10 climate scenarios from Toulouse (South-Western France), either without weeds or with a high-density weed flora typical of the region. Weed management was organic-based or with reduced herbicide use. Simulations were run with FLORSYS, a mechanistic individual-based 3D model which simulates daily crop-weed seed and plant dynamics over years, from the cropping system and pedoclimate, focusing on plant-plant competition for light (Colbach *et al.*, 2021).

3. Results

Simulations showed that, in the absence of weeds, the yield per plant in intercrops varied from 13% of the sole-crop yield (pea–wheat mixture in the species-proportion design) to 173% (triticale–faba bean mixture in the sowing-pattern design). In average, intercropping reduced weed-free yield per plant by 42% for legumes and had no effect for cereals. When weeds were included in the simulations, the average legume yield per plant decreased by only 24% compared to sole legumes, whereas the average cereal yield per plant decreased by 18%. In other words, the more competitive cereals protected legumes against weeds in intercrops but suffered more from weed competition than in sole cereals. Indeed, the weed biomass in intercrops was greater than or equal to that of the sole cereals, and less than that of the sole legumes (Figure 1. A and B). The intercrops that best controlled weeds were barley–pea and triticale–faba bean.

In presence of weeds, the spatial pattern alternating one cereal row with one legume row (50% cereal–50% legume) as well as the 67% cereal–33% legume and the 100% cereal–50% legume in the species-proportion design were those that both maximised yields of both legumes and cereals and minimised losses due to weeds (Figure 1. C and D). Additive designs were not more weed-suppressive than substitutive designs.

4. Conclusion and Perspectives

The present study highlighted the value of intercropping for weed management, and identified sowing proportions and sowing patterns depending on the objectives being pursued. In the presence of weeds, legumes benefitted more from intercropping than cereals because legumes are less competitive against weeds. This work will be extended to other species mixtures and management methods in order to better integrate farmers' practices and in contexts where water and nitrogen may be limiting. This work will thus contribute to help designing innovative cropping systems by integrating, among other things, the resilience of the systems designed in the face of climate change, using an agro-ecological approach to weed management.

5. Reference

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Which tillage to limit regrowth of perennial weeds from storage-organ fragments? From field experiment to modelling (Oral #47)

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Keywords: perennial-weed regeneration; tillage tool; storage-organ fragmentation; predictive modelling; *Cirsium arvense*; creeping-root fragments

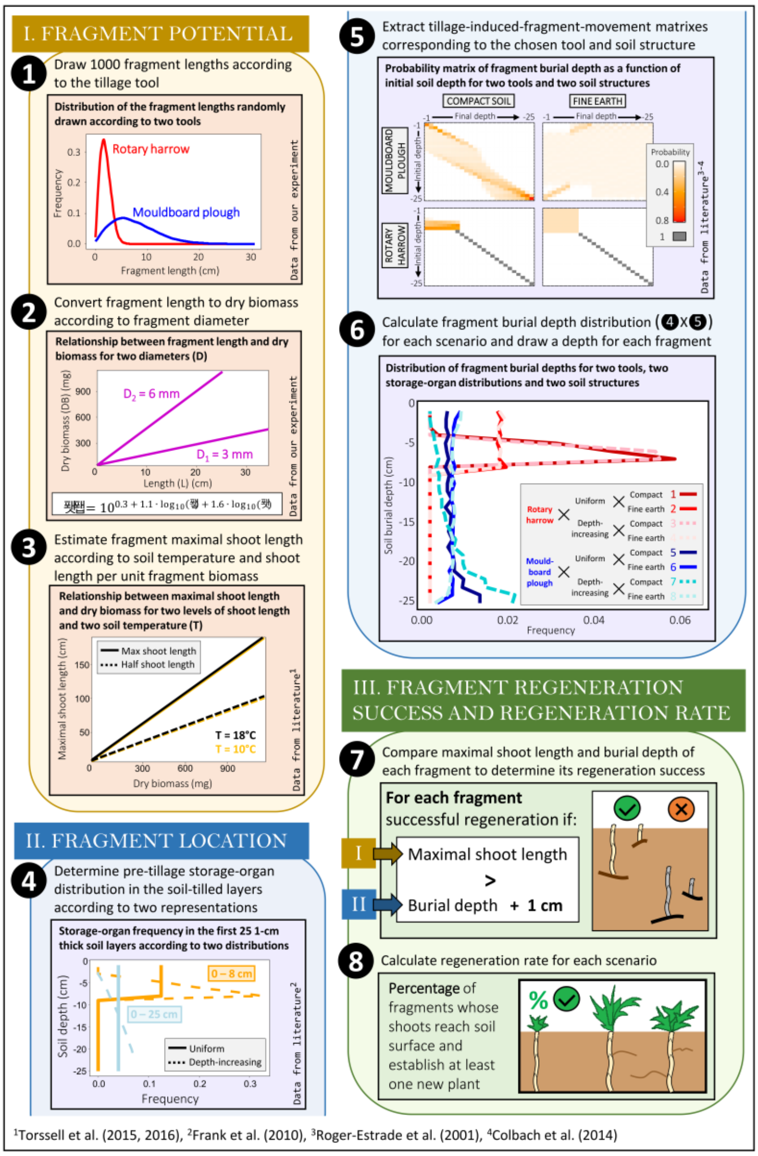

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Figure 1. Model for the prediction of perennial-weeds regeneration rate from storage-organ fragments after a single tillage operation. Illustration for a mouldboard plough and a rotary harrow

1. Introduction

Management of perennial weeds has become increasingly difficult with the reduction of herbicide use. Perennials accumulate reserves in belowground storage organs from which they can regenerate new plants after a disturbance. Tillage is a key lever to control perennial weeds because it destroys the aboveground part and fragments the belowground storage organs, stimulating the regrowth of new shoots that use and thus reduce the reserves. Field studies suggest that the tillage tool's features influence perennial-weed control. However, the underlying mechanisms of these effects need to be further investigated, especially the fragmentation of perennial storage organs by tillage tools. The objectives of this study were to 1) analyse how different tools fragment the creeping roots of *Cirsium arvense* (L.) Scop, one of the most problematic perennial species in arable crops, 2) combine existing knowledge in a predictive model to identify and rank the most important factors driving post-tillage regeneration of perennial weeds from fragments of their storage organs.

2. Materials and Methods

A field trial was conducted in Dijon in 2022-2023 to sample C. arvense root fragments left in the soil after single passages by five contrasting tillage tools (mouldboard plough, rotary harrow, chisel plough, horizontal cultivator and disc harrow). The fragments were measured and the distribution of root-fragment lengths was analysed for each tool with regard to their features (blade type, power take-off drive and working depth). By combining the results of this experiment and data from literature on the other processes involved, a model for predicting the regeneration rate of perennial weeds after tillage from fragments of their storage organs was built. Regeneration was successful when the belowground shoot produced by a fragment was long enough to emerge. The model was applied for different scenarios combining two tillage tools, two soil structures, two storage-organ distributions in the soil, two soil temperatures, two fragment diameters and two levels of maximal shoot length per unit fragment biomass (Figure 1).

3. Results

In the experiment, the distribution of fragment lengths varied with tillage tool: rotary harrow left the smallest and least variable fragment lengths (3.7 cm on average), mouldboard ploughing the largest and most variable ones (12.7 cm on average and up to 30 cm). The three other tools produced intermediate-sized fragments (8-10 cm on average).

According to the model, fragment diameter and maximal shoot length per unit fragment biomass were the main determinant of regeneration rate: fragments were 32% (respectively, 29%) more likely to regenerate when their diameter (respectively, their maximal shoot length) doubled. The choice of the tool also had a significant impact: there were 13% less regenerated fragments after a rotary harrow than after a mouldboard plough. Soil structure and storage-organ distribution in the soil had a minor impact while soil temperature had no impact.

4. Discussion

The length distributions of C. arvense root fragments depending on the tools were consistent with the scarce previous work (Leblanc & Lefebvre, 2018). The important role in the model of fragment weight and maximal shoot length in regeneration was in line with previous work on emergence (Torssell *et al.*, 2015) and highlighted that the regrowth potential of perennial species are key drivers which need to be investigated further. Finally, the model showed differences between the tools: rotary harrow induced a lower regeneration rate from fragments than mouldboard plough, which was probably linked to a higher fragmentation rate (Bergkvist *et al.*, 2017). However, to compare the overall effect of different tillage tools on perennial-weed control, the present model needs to be supplemented with formalisms predicting the regeneration rate of the unfragmented storage organs, located below the tillage depth.

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Design and integrated assessment of anaerobic digestion and cropping systems at a territorial scale (Poster #182)

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Keywords: anaerobic digestion; soil; nitrogen supply and leaching; carbon storage; modeling

The development of anaerobic digestion plants in agricultural farming systems and landscape can offer the opportunity to redesign cropping systems, with the aim of maximizing both biogas production, nitrogen cycle and ecosystem services provision (*e.g.* water quality regulation, organic carbon sequestration). This transition has already been initiated by a few pioneers, but for its implementation in most farming systems linked to a biogas plants it would require:

• Identification of potential innovative cropping systems meeting sustainability issues.

• Assessment of their effects on nitrogen losses, ecosystem services and energy production.

The Métha3G research project (2023-2025) aims at identifying, designing and assessing innovative territorial organizations of cropping systems linked to biogas plants improving sustainability of both biogas productions and cropping systems.

In this study, we used participatory workshops and the integrated assessment and modelling (IAM) platform MAELIA (Therond *et al.* 2014) to design and assess effects of innovative cropping systems on ecosystem services, environmental impacts and biogas production at the territory level. For this, we used two contrasted study areas:

• The permanent environmental observatory (OPE) around Bure (Eastern France) is characterized as a predominantly cereal-growing region.

• Le Coglais (Western France) is characterized as a livestock farming area.

Two workshops, one for each territory, to design cropping systems (crop rotations and managements) that optimize the ecosystem services were held with farmers, representatives of chambers of agriculture and researchers.

MAELIA is a multi-agent platform for IAM of agricultural territories (landscape) and territorial bioeconomy systems. It enables to assess the environmental, economic and social impacts of the combined changes in agricultural activities, biomass processing (*e.g.* anaerobic digestion) and recycling (*e.g.* digestats management), natural resource management strategies (*e.g.* water) and global changes.

Data required by MAELIA were collected and integrated to represent the current situation of each territory : climatic data for the last 30 years (Météo France), soil types, spatial boundaries of fields and their observed crop rotations (Land Parcel Identification System). The crop management (crops, sowing/harvesting periods, tillage, fertilization) of the main production situations were collected through dedicated surveys with farmer and agricultural advisors. In MAELIA crop management are presented through IF-THEN rules in order to be able to simulate a consistent spatio-temporal triggering of technical operations in face of climate variability. First simulations of MAELIA were used to provide an initial diagnostic of biogeochemical cycles (water, nitrogen, carbon) and biogas production in each territory. Then, cropping systems design during the two workshops were translated into MAELIA inputs. In parallel, expert knowledge were used to define characteristics of biogas plants adapted to each territory and translated into adapted inputs for the SYS-Metha model used in MAELIA to simulate biogas and digestat productions. A second set of simulation was then performed to assess these scenarios (including the new cropping systems and biogas plants).

During the workshops, experts identified for each territory a number of possible crop rotations with an expected nitrogen losses (ammonia and nitrates) and ecosystem services like erosion control, carbon storage, nitrogen self-provision. For this, starting from the main current rotations of cases studies they integrated legumes, multi-species energy crops and multi-services catch crops. For example, starting from the rotation wheat-barley-rapeseed, one of the proposed new rotations is:

wheat-rye+clover (energy crop)-sorghum-wheat/barley-rapeseed+sunflower-rye+clover (energy crop)-Sorghum.

Currently scenarios are being formalized and will be simulated. During the ESA meeting we will present the main results regarding the effects of these scenarios on water, nitrogen and carbon cycles at field, farm and territory levels. We will also present the main outcomes of the transversal analysis of the simulations performed on the two cases studies using machine learning methods to identify relationships between biophysical and socio-technical characteristics of production situations and environmental performances of cropping systems and biogas plants.

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Intercropping chickpea and lentil with buckwheat: effect on weed suppression and legume yield (Poster #10)

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Keywords: intercropping; agroecology; legumes

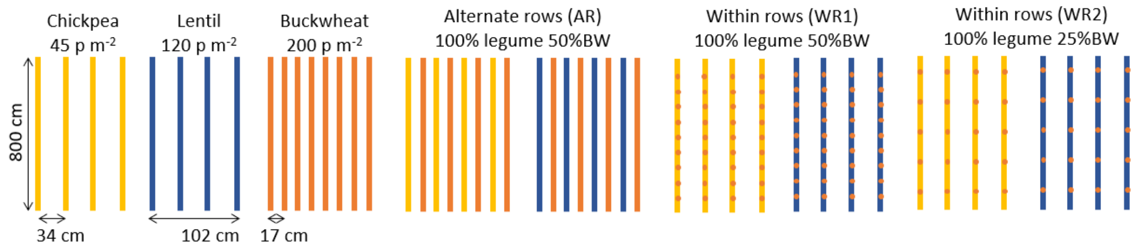

Figure 1. Spatial arrangements and plant densities of the three crops in pure stands and in intercropping

Intercropping provides benefits in terms of production gains and other ecosystem services. Although legume-cereal intercrops have received the most attention in literature, other species should be explored to increase the diversity of intercropping systems (Cheriere *et al.*, 2020). Including pseudo-cereals in cropping systems enriches biodiversity and lowers the environmental impact of arable crops as they are often adapted to grow in nutrient-poor soils (Manners *et al.* 2020). In a policy context of protein and agro-ecological transitions, it is necessary to increase legume production and consumption. Since legumes are known to be poor competitors towards weeds agroecological practices may help decrease weed pressure. Our objective is to study the effect of different intercropping arrangements of lentil (*Lens culinaris*, Medikus) and chickpea (*Cicer arietinum*, L.) with buckwheat (*Fagopyrum esculentum*, Moench) on weed suppression and potential legume yield improvement.

The field experiments were conducted at the experimental farm of the University of Udine (NE Italy) in 2023 and will be repeated in 2024 (expected harvest July 2024). Lentil (LN) and chickpea (CH) were intercropped with buckwheat (BW) in two spatial arrangements (Figure 1). Trials followed a completely randomized design with four replicates per treatment. Weeding was performed once by manual hoeing at the 5th leaf stage of the legumes (only in pure legumes, WR1 and WR2). A vegetation survey was performed before and after hoeing. In two quadrats (0.50m x 0.7m), randomly placed in each plot, we identified weed species and estimated plant cover of weeds and crops. At crop flowering and harvest, plant height of the legumes and BW was measured on five plants per plot. Aboveground biomass of LN, CH, BW and weeds was collected in one quadrat of 0.35m^2, then oven-dried at 70°C for 72h. Crop grain yield was measured from a larger area (0.70m x 2m). Response variables were analyzed with a one-way anova. When treatment resulted significant, differences between means were assessed with a Tukey HSD test.

In both the CP and LN trials, weed biomass was significantly higher in the pure BW plots. No differences in weed biomass were found between the pure legume plots, AR and the WR plots in both trials. CH yield was lowest in AR (0.44 ± 0.12 t ha^{-1}) and highest (1.24 ± 0.18 t ha^{-1}) in the pure crop. LN yield was not affected by intercropping with BW.

Our results indicate that BW significantly affected CH yield only in the AR arrangement. Zhou *et al.* (2023) found similar results in CH intercropped in AR with flax. LN yield was not affected by the presence of BW. This is in contrast with the results of Wang *et al.* (2012), who recorded significant LN yield losses in a 3:1 ratio with BW. We expected good weed suppression by BW (Farooq *et al.*, 2016), but higher weed biomass was recorded in sole BW plots compared to others. BW stand density was affected by three light frosts within a few days of sowing. Perhaps a higher density of BW in the ongoing 2024 experiments could confirm findings from other intercropping studies, where a competitive effect of BW on weed species was documented (Cheriere *et al.*, 2020).

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Morphological indicators of young tree health and recovery in agroforestry systems (Poster #364)

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Keywords: agroforestry; tree recovery; root-shoot ratio; morphological indicators; young tree establishment

Agroforestry, which combines crops and trees, promotes biodiversity and ecosystem services. Despite its potential, the successful establishment of young trees within the agroforestry system remains a major challenge for farmers, who may be faced with heterogeneous recovery after planting. This research aims to identify indicators to assess tree recovery and root health after planting, while also providing a better understanding of the factors influencing the establishment of young trees.

Our study analysed the recovery of 600 young Mediterranean hackberry trees (*Celtis australis* L.) planted with bare roots across four micro-plots with varying soil types. Different pruning protocols before planting enabled us to establish various root/shoot ratio categories and to assess their impact on recovery quality. Over the two years following planting, we monitored the trees' establishment phase, which included bud burst, shoot elongation, and trunk growth. Through 125 targeted excavations, we investigated the correlation between aerial growth dynamics and the recovery and health status of root systems. Additionally, we analysed spatial growth patterns to better understand the influence of soil on tree recovery.

After planting, significant heterogeneity in tree recovery was observed. A higher root/shoot ratio at planting correlated with improved survival and recovery. Analysis of the aerial system's growth identified four primary categories of growth dynamics, associated with the traits of annual shoots (number of elongation cycles, length of elongation units, leaf area, and type of buds mobilised). Excavation data indicated that each category of aerial growth dynamics was linked to distinct root system behaviours regarding root regeneration and health. A relationship was found between the number and size of annual shoots, the total leaf area, and the number and size of new roots developed on the root system. This implies that visible annual shoots on the aerial system can serve as indicators to infer the less observable root production in the soil. Spatial analysis uncovered non-random patterns of growth, suggesting that soil characteristics significantly influence recovery.

Findings underscore the importance of meticulous selection of young trees for planting and demonstrate that morphological indicators on the aerial system can serve as effective proxies to monitor successful recovery and root health during the establishment phase. The spatial distribution of tree growth enhances our understanding of soil characteristics and functionality, thus aiding decision-making for soil management in agroforestry systems. Overall, our results provide deeper insights into the critical phase of young tree establishment, essential for achieving the long-term goals of agroforestry.

How to account ecosystem services into energy assessment of agroecosystems and bioeconomy? (Poster #203)

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Keywords: integrated assessment; multi-criteria assessment; cropping systems; biogas

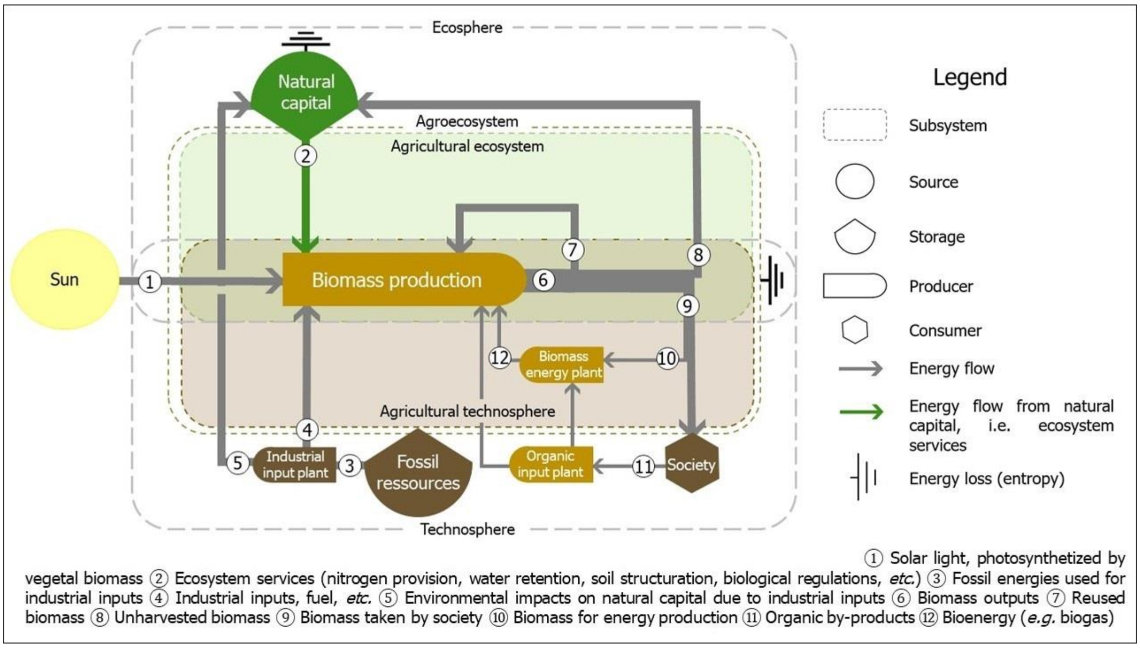

Figure 1. Diagram of agroecosystem energy flows. The grey arrows' widths are proportional to the energy flow

Current economy heavily relies on fossil resources to satisfy energy demands of human societies. Reaching climate change mitigation objectives requires to shift to carbon neutrality through the development of a bioeconomy. Notably, such transition requires the substitution of fossil-based energies into biomass-based energies (*e.g.* biogas). However, reducing dependency on fossil energies through production and use of biomass energies can lead to undesirable pressures and impacts on the environment if biomass production relies on intensive agriculture. The latter depends on external fossil-based inputs to produce biomass and would be energy deficient if fossil energy use were replaced by energy produced with biomass [1]. Another way of biomass production is possible by switching to agroecological systems [2]. Such agriculture models rely on ecosystem services rather than industrial inputs and thus, would reduce dependency on fossil energies and improve efficiency of input used and energy production. Integrated assessment of agriculture models and associated biomass energy plants have to be performed to clarify the potential of agroecology to develop a sustainable and efficient bioeconomy. Clarifying the role and effects of developing ecosystem services on energy flows and efficiency in agriculture and bioeconomy remains poorly investigated.

Classical energy assessments are based on ratios between inputs and outputs like EROI (Energy Return On Investment). Some recent studies aimed to develop new assessment approaches accounting for internal and external energy flows in agroecosystems, but strong disagreements [3] exist on the way to represent and assess internal flows and poorly deal with the concept of ecosystem services. In this study, we present a new conceptual and operational framework for energy flows and efficiency analysis, accounting for internal energy flows, ecosystem services in particular. A first sketch of this conceptual framework is depicted in Figure 1, considering, like in Life Cycle Analysis, both a natural (ecosphere) and a technical (technosphere) subsystem. Furthermore, natural capital and ecosystem services are considered as energy carriers and flows respectively in the same way as fossil resources and industrial inputs [4]. Then based on previous pioneering studies [5,6], we aim to develop original energy assessment indicators enabling to account for the part of energy provided by nature through ecosystem services *vs.* the ones provided by the technosphere through industrial inputs. For example, as already shown [6], assessment of the mineralisation rate of soil organic matter can be used to assess energy provided by some ecosystem services linked to the soil functioning.

Our framework will provide the researchers and stakeholders with an operational approach for the assessment and design of energy efficient agroecological systems connected to biomass energy plants. We will illustrate our approach by applying it to farms-biogas plant systems considering different agriculture models of biomass production: from conventional to agroecological ones.

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Maize-soybean strip intercropping in organic farming, in Austria (Poster #270)

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Keywords: cropping systems; fertilization; productivity; organic management

Fertilization	**Cropping system**	**Yield (t/ha)**
Fertilized	Sole maize	11.56 ± 1.94
	Intercropped maize	7.10 ± 0.45
	Relative yield	0.71 ± 0.19
Unfertilized	Sole maize	9.74 ± 1.20
	Intercropped maize	6.53 ± 0.64
	Relative yield	0.71 ± 0.12

Table 1. Impact of fertilization and intercropping with soybean on the yield of maize in organic farming

1. Introduction

The side effects of chemical inputs in agriculture raise concerns and necessitate the exploration of options for a transformation in cropping systems for enhanced efficiency and sustainability. Intercropping is the cultivation of multiple crop species in the same field at the same time and has multiple ecological advantages, e.g related to nutrient capture and disease control (Weih *et al.*, 2022). Nitrogen (N) plays a vital role in maize growth, significantly influencing crop yield, but intercropping with a legume can mitigate the requirement for N input. There is little experience in Europe with intercropping maize with legumes (but see Wang *et al.*, 2023). This study aims to examine maize yield in an intercropping system with soybean, comparing it to monocropping within an organic farming framework with low or no fertilizer input.

2. Materials and Methods

We conducted a field experiment on organically managed fields of the University of Natural Resources and Life Sciences, Vienna. The experimental site is located in the Marchfeld region, about 5 km east of Vienna in Raasdorf (48° 14' N, 16° 35' E). The Marchfeld climate is characterized by hot, dry summers with little dew and cold winters with little snow. The long-term average (2000-2020) annual precipitation is 524 mm; and the average annual temperature is 10.9 °C. The soil is classified as Calcaric Phaeozem. The maize-soybean strip intercropping experiment was designed as a randomized complete block design with four replicates, and the plot size was 60 m^2 (6 m x 10 m). Soybean and maize were sown simultaneously by machine on 20 June 2023, with a uniform row spacing of 50 cm across all plots. The experimental treatments compared two cropping systems: monocrops of maize or soybean, and strip intercropping with a pattern of three rows of maize and three rows of soybean (a total of 12 rows of 1.5 m each), crossed with two fertilization levels: fertilizer and unfertilized. The organic fertilizer used in the experiment was "Sedumin hair meal pellets

N 14%" at a rate of 190 kg N/ha in the fertilized treatment. Maize plants were harvested in October 2023 and seed yield and relative yield were calculated after drying.

3. Results and Discussion

Maize yield was significantly higher in the monocrop than in the intercrop with soybean in both the fertilized and unfertilized treatments ($P<0.05$), and in both cases, the maize yield in intercropping was 71% of the yield in the sole crop (Table 1). Observed yields were lower at zero fertilizer input than with fertilization, but the fertilization effect was not significant in an analysis of variance with cropping system and fertilization as factors ($P>0.05$). Thus, fertilization did not significantly increase yield under the conditions of the study. The relative maize yield in intercropping was substantially higher (71%) than would have been expected on the basis of its proportion in the mixture (50%) indicating that intercropping favoured the growth of maize plants. The results highlight the potential of intercropping within organic farming as effective models for reducing input requirements.

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SATDOS: a decision support system for evaluating the sustainability of olive orchards (Poster #79)

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Keywords: carbon exchange; FertiliCalc; *Olea europaea* L.; olivecan; water footprint

1. Introduction

Olive orchards have been a very important part of Mediterranean agriculture since ancient times. Historically a low input crop grown on rolling landscapes with shallow soils, olive growing is experiencing an intensification process that carries along some radical changes in its thousands-year-old agronomic practices: olive orchards are moving from low-input traditional to highly mechanized and input-demanding plantations. The rapid expansion of these new olive cropping systems raises concerns over the environmental impacts associated with an excessive use of water, fertilizers, and energy, the later potentially leading to increased CO_2 emissions that contribute to global warming. Unfortunately, scientific reports providing quantitative assessments of the different environmental impacts of olive growing are still scarce and scattered. This challenges the comparison among farming alternatives and the identification of best management practices (BMPs) to meet sustainability objectives. This work introduces ‘SATDOS’, a decision support system for assessing the productive and environmental performances of different olive cropping systems and management schemes.

2. Model description

SATDOS integrates a well-established process-based simulation model of olive orchards (OliveCan, López-Bernal *et al.*, 2018), an improved model for calculating nutrient balances and fertilizer requirements (FertiliCalc, Villalobos *et al.*, 2020) and a new tool (CCO2E) for accounting for CO_2 emissions resulting from cultural practices. The systems runs OliveCan for estimating crop evapotranspiration (ETc), net ecosystem productivity (NEP) and potential yield. The latter is used for estimating the yield gap. The water footprint is subsequently determined using a corrected procedure overcoming some of the limitations of the original formulation (Fereres *et al.*, 2017). In short, the evapotranspiration of natural vegetation (ETnv), calculated by a simple routine, is considered as the baseline for nil footprint. On the other hand, CCO2E calculates anthropogenic CO_2 emissions by quantifying direct and indirect energy requirements for inputs and operations in the farm, including all those related to tillage, fertilization, application of plant protection products, irrigation, harvest, transport of inputs and outputs and labour. By comparing NEP and CO_2 emissions, the system provides an estimate of the net carbon balance of the orchard. Finally, FertiliCalc quantifies the excess or deficit of nutrients (N, P and K) and nitrogen losses associated to the fertilization plan.

3. Data requirements

Input requirements include basic information on the location of the orchard, soil characteristics, actual yield and details on the management operations and materials used by the farmer. Weather data required for running the system are gathered automatically from public Spanish databases.

4. Model applicability

SATDOS has been conceived as a tool that enables users to identify BMPs for any kind of olive orchard with a holistic perspective. This may contribute to the digital transition of the olive industry, supporting decision-making. Furthermore, the software may provide relevant information to guide policies in the context of climate change mitigation, the sustainable use of resources, and pollution prevention and control.

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Climate change impacts on canola growth and yield characteristics: challenges and opportunities (Poster #148)

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Keywords: heat stress; drought stress; vegetative; reproductive; CO_2 fertilisation

1. Introduction

Climate change is caused by the increase in atmospheric greenhouse gases, which leads to rising temperatures. This, in turn, alters rainfall amounts and distribution patterns, which will affect canola growth and yield characteristics. A systematic literature review was conducted to investigate the influence of changing climatic factors on canola growth during its vegetative stage and canola yield development through its reproductive stage.

2. Materials and Methods

Twenty-two peer-reviewed journal papers were selected following the screening of 2055 papers according to the climatic factor's effects on canola growth and canola yield characteristics. All factors were compared to the control within the study and expressed in a percentage.

3. Results

During its vegetative growth stage, canola growth responded positively to an increase in CO_2 concentration by improving the carbon assimilation rate by, on average, 40%, which resulted in plants producing 58% more biomass. If temperatures were closer to the optimum (*i.e.*, 20-25 °C), biomass production improved, with colder temperatures (5 °C) having a greater impact on the biomass (34% reduction) (Rahman *et al.*, 2020) than extreme hot conditions (34 °C) (9% reduction) (Pokharel *et al.*, 2021). Moderate soil moisture stress caused an average reduction in leaf area of 41% (Uddin *et al.*, 2018), a 44% reduction in stomatal conductance, and a decrease of 17% in evapotranspiration. Climatic factors mostly affected canola seed yield during its reproductive growth stage. Elevated CO_2 improved the seed yield by on average 38% (Uddin *et al.*, 2018). Daytime temperatures above 28 °C (heat stress) caused canola flower abortion and resulted in a 16% reduction in pollen viability (Wu *et al.*, 2020), which ultimately led to an 84% decrease in seed yield (Elferjani *et al.*, 2018). Heat stress also reduced the oil extraction by 50% (Elferjani *et al.*, 2018). Soil moisture stress during the flowering stage resulted in a 43% reduction in seed yield, on average, and an oil extraction reduction of 36%. Soil moisture stress during the seed fill stage had the same effect, but to a lesser extent; a 22% reduction in seed yield and an oil extraction reduction of 27% were observed.

4. Discussion

This literature-based study illustrates that: i) the effect of rising atmospheric CO_2 concentration has a fertilising effect on canola growth and production; ii) increased heat stress occurrence during the reproductive growth stage has a greater effect on production than heat stress during the vegetative growth stage; iii) the effect of drought stress during the reproductive stage is detrimental to canola production; iv) elevated atmospheric CO_2 concentration may offset the yield limiting effects of heat and drought stress during the vegetative and reproductive growth stages.

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Contribution of plant to the DOC pool in a soil-plant-digestate system: a 13C-labelling experiment (Poster #312)

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Keywords: digestate; DOC; plant; contribution; 13C labelling

The application of organic waste products (OWP) and the sowing of winter cover crops are agronomic levers to improve soil health. Anaerobic digestion of OWP is now a common practice and, as biogas is considered a renewable energy source, its development is encouraged by the European Union. Biogas digestate, a by-product of this process, is increasingly produced and recycled on agricultural land.

Studies on the transfer of dissolved organic carbon (DOC) in the soil after digestate application are scarce, despite the potential interest in carbon sequestration through the transfer of DOC to the subsoil and stabilization on the mineral phase (Rumpel and Kögel-Knabner, 2011) or the risk of co-transport of contaminants to groundwater, which poses a threat to the health of aquatic ecosystems (Dunnivant *et al.*, 1992). In a previous lysimeter study conducted over 9 years (Didelot *et al.*, submitted 2024), the effect of digestate application was compared to its original pig slurry in association with different winter crops (wheat, mustard, multispecies) on DOC concentrations and fluxes. Higher topsoil DOC concentrations were observed each year for the digestate modality, possibly related to crop root development. Crops can provide organic matter through the decomposition of residues (roots, leaves, stems) and root exudates (Kalbitz *et al.*, 2000). Root exudates are low molecular weight compounds (Nguyen, 2009) and can contribute to the DOC pool. In annual plants, 30-60% of the carbon fixed by photosynthesis is translocated to the roots and up to 70% of this carbon can be released to the soil (Neumann and Römheld, 2000). Scaglia *et al.* (2015) highlighted an auxin-like effect in pig slurry digestate, which could potentially lead to biostimulation of root growth. Thus, the additional DOC measured after digestate application could be due to an increased production of root exudates through a potential auxin-like effect of digestate.

A 13C-labelling experiment was set up in soil columns mixed with digestate, pig slurry and a mineral treatment, and containing mustard plants. The plants were grown under greenhouse conditions and twice a week, for 3 h, they were placed in airtight chambers into which 13C-CO_2 was injected. After a total duration of 2.5 months of multipulse labelling, drainage was induced. Samples of drained water, soil, shoot (leaves, flowers, stems) and roots were dried or freeze-dried and then finely ground before isotopic analysis of the 13C content using cavity ring-down spectroscopy. The amount of rhizodeposition will be calculated using a model for 13C in the soil solution. The aim of this experiment is to accurately assess the contribution of rhizodeposition from the plant to the DOC pool in the soil-plant-digestate system.

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Towards stopping pesticides use in vineyard: characterization of on-farm solutions (Poster #60)

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Keywords: grapevine; innovation; pesticide reduction; agroecology; plot network; systemic approach

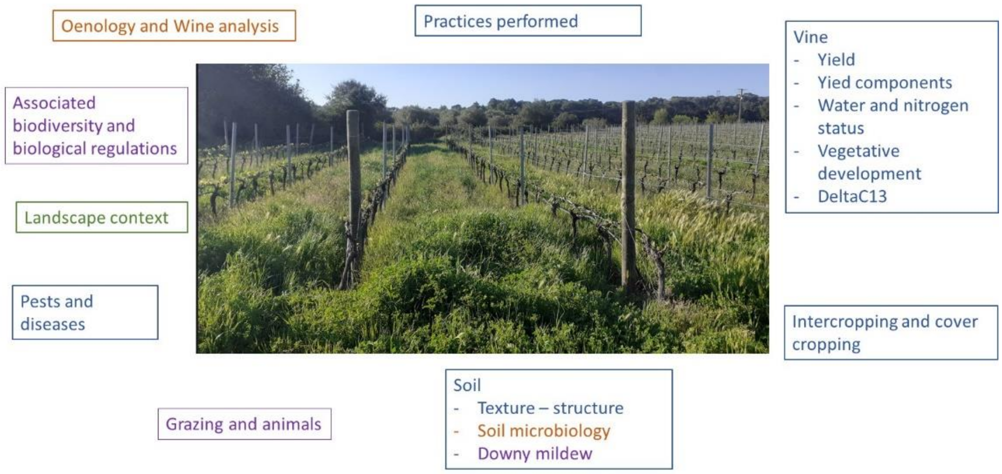

Figure 1. Systemic approach of low input vineyard and list of observations performed in boxes

1. Context and Purpose of the study

The winegrowing sector consumes large amounts of pesticides. Changes in vineyard are necessary in order to reduce or even stop using pesticides, and thus limit their harmful impacts on health and on environment. To address these issues, the VITAE project (2021-2026) aims at assessing and designing pesticide free viticulture in France. For that, we searched for commercial vineyards that have already adopted strategies strongly reducing chemical pesticide but also biopesticides. We assume that such vineyards are implementing solutions that could inspire the design of pesticide-free systems. Thus, the objective of this study was to characterize the solutions implemented in these commercial plots that allow winegrowers reduce pesticides and then to assess associated performances.

2. Materials and Methods

A network grouped 14 commercial plots among the six main French wine-regions. Plots were selected on their environmental performance only (60% pesticide reduction compared to regional reference), not on their localization or production modes so that they covered a wide diversity of production contexts (biotic, abiotic and socio-economic contexts). The three-year observations consist in the characterization of all the compartments of the agrosystem that influences the systemic pest and disease management: vine, cultivated associated vegetation in the plots -mainly in the inter-row and under the row, natural associated vegetation in the plot and in the surroundings, pests and diseases, soil (Figure 1). We also monitored vineyard performances in quantity (yield) and in quality (grape quality) and collected information on practices during one growing season of vine (2023). All the commercial plots are positioned along a gradient of pesticide use intensity and the corresponding farm is characterized by its position along an agroecological gradient.

3. Results

The results from the 2023 vintage showed an important diversity among the plots on most of the indicators monitored. In 2023, vineyards faced high downy mildew pressure with important yield loss reported in half of the wine-growing regions. This particular context affected the strategy of disease control in the network. The agronomic performance was reached for 9/14 plots when compared to grower's objective. Important yields loss was reported in 4 plots (more than 50%). In 8/14 plots, the pesticide use was lower than the regional average and the yield acceptable. In these plots, the severities and incidences for downy and powdery mildew were limited and acceptable according to the winegrowers' objectives. We observed an important heterogeneity in the yield components and vegetative development within each plot. The vines did not suffer from lack of nitrogen in the majority of the plots followed but we showed a water stress, notably under Mediterranean climate in absence of irrigation. Eleven over the 14 plots presented a voluminous vegetation in the inter-row Soil structure, represented by aggregate stability, complied with standard.

4. Perspectives

2023 constituted the first year of monitoring. Two additional years of measurement are planned to cover a diversity of weather and biotic pressure conditions. Understanding these very low pesticide commercial plots require a pluri-annual assessment. At the same time, soil microbiological quality, oenological quality and biodiversity indicators will also be measured and will be used in a multicriteria assessment of these innovative systems toward stopping pesticide use. Year 2023 showed that some of the cropping systems followed were promising systems to inspire changes in other vineyards.

Sugarcane x Jack bean competition in intercropping system under contrasted nitrogen and water availability (Poster #127)

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Presenter: Antoine Couëdel (antoine.couedel@cirad.fr)

Keywords: *Saccharum officinarum*; cover crops; Fabaceae; crop association; competition

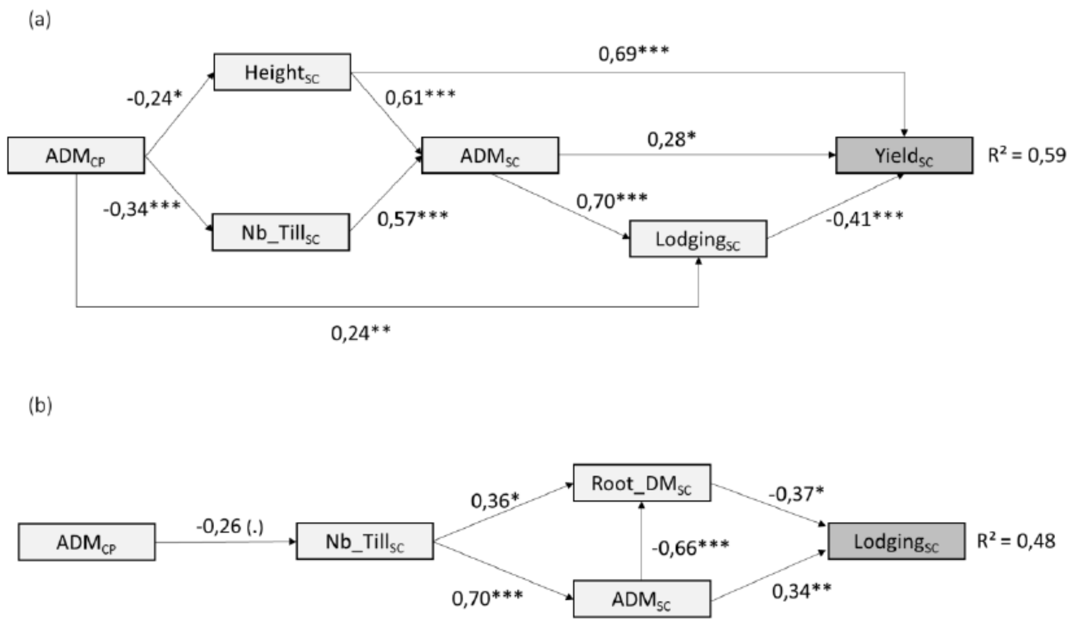

Figure 1. Structural equation model (SEM) showing direct and indirect effects of legume companion plant (CP) biomass and sugarcane (SC) parameters on (a) sugarcane yield (YieldSC) and (b) lodging (LodgingSC). The explanatory variables were the companion plant biomass (ADMCP), sugarcane aboveground dry mass (ADMSC) and root biomass (Root_DMSC), height (HeightSC), numbers of tillers (Nb_TillSC), and lodging (LodgingSC for (a)). All the explanatory variables were measured at 5 month after harvest (MAH) during the companion plant's peak biomass, except for lodging (7 MAH). The black arrows represent the result of the analysis. The P values are indicated by ***, **, *, and (.) when lower than 0.001, 0.01, 0.05, and 0.1, respectively. R^2 are given for the predicted variables. The standardized model estimates were given to compare the relative strengths of predictors for continuous variables

1. Introduction

Sugarcane-legume intercropping systems have attracted much attention worldwide to improve soil fertility (Tang *et al.*, 2021) and to reduce herbicide application (Soulé *et al.*, 2024). Nonetheless, a recent meta-analysis highlighted how introducing companion plants with sugarcane leads to highly variable yield response (Viaud *et al.*, 2023), and the processes and resources involved in competition between sugarcane and companion plants are still poorly understood. The aim of this study, based on Viaud's (2023) thesis work, was to evaluate the competition mechanisms between a legume (Jack bean, *Canavalia ensiformis*) and sugarcane depending on environmental conditions (water and nitrogen availability) in the tropical island of La Réunion.

2. Materials and Methods

A three-year experiment has been set up to test the interactions between irrigation, nitrogen fertilization, and sugarcane-legume intercropping through a factorial trial with three crossed treatments and four repetitions in the experimental station of La Mare (Reunion Island). Above and belowground sugarcane traits were measured overgrowth to assess the impact of legume presence on sugarcane traits, and their temporal relation was assessed through structural equation modeling. The competition for soil N and N from fertilizer was distinguished through 15N-labelled fertilizer, and the competition for water was assessed through soil water content measurements.

3. Results

The presence of a legume reduced sugarcane yield by 9% on average through an overall decrease in both above- and below-ground biomass. At the beginning of growth, the decrease in biomass was linked to a reduction in the number of tillers (-8%), adding the effect of lodging amplified by the presence of legumes at the end of growth (+25% in the irrigated conditions, Figure 1). While legume intercropping did not impact nitrogen fertilization uptake by sugarcane, soil N competition occurred under low water availability conditions and impacted the sugarcane N nutrition index (-23%). On the contrary, no evidence of water competition was found. The sugarcane root response was determinant in the sugarcane-legume interaction. The presence of legume decreased sugarcane root colonization around six months after the beginning of growth, which was correlated with the higher lodging at the end of the growth (twelve months). The lower root colonization could also explain the lower nitrogen nutrition index during the first six months of growth. Despite the absence of Nitrogen fertilization uptake by legumes, the fertilization did not give sugarcane a competitive advantage. However, irrigation ensured better sugarcane growth at the beginning of the cycle, making it more competitive with the legume, although increasing the risk of lodging at the end of the growing year.

4. Discussion

Our results illustrate the complexity of sugarcane response to intercropping as a function of resource availability. Despite a significant competitive advantage of high-biomass sugarcane over the legume, sugarcane's root-avoidance strategy highlighted in previous studies (Christina *et al.*, 2023) makes it sensitive to inter-specific competition. Adequate irrigation management at the beginning of sugarcane growth is essential to limit sugarcane yield loss. Finally, the interest of this legume in sugarcane intercropping systems in terms of symbiotic fixation, N return to the soil, and sugarcane nutrition was explored in Viaud's (2023) subsequent thesis work.

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A comparative assessment of the productive and environmental performance of contrasting olive cropping systems using SATDOS (Poster #80)

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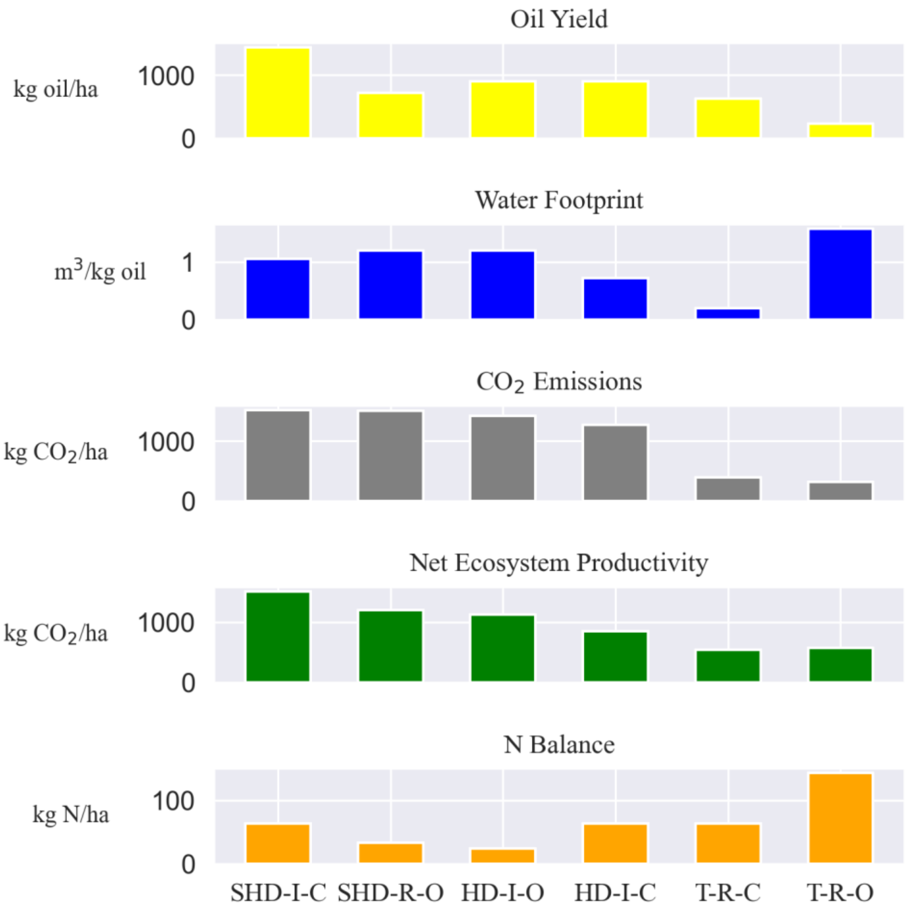
Keywords: carbon exchange; decision support system; *Olea europaea* L.; sustainability; water footprint



1. Introduction

Olive orchards represent a major component of agricultural systems in the Mediterranean basin. In recent decades, modern high-yielding intensive cropping systems are expanding fast, often replacing low-yielding traditional orchards. These changes in olive farming may result in higher environmental impacts as new orchards are highly mechanized and require a higher use of inputs (water, fertilizer, energy, pesticides), but quantitative reports in this regard are scarce in the literature. This work provides a comparative assessment of the productive and environmental performances of real orchards with contrasting characteristics and management schemes using the decision support system 'SATDOS'.

2. Materials and Methods

SATDOS integrates a well-established process-based simulation model of olive orchards (OliveCan, López-Bernal *et al.*, 2018), an improved model for calculating nutrient balances and fertilizer requirements (FertiliCalc, Villalobos *et al.*, 2020) and a new tool (CCO2E) for accounting for CO_2 emissions resulting from cultural practices. The water footprint is also computed using a corrected procedure that considers the evapotranspiration of natural vegetation as the baseline for nil footprint (Fereres *et al.*, 2017). With these elements, the system aims to provide simultaneous information on different sustainability indicators related to the water, carbon and nutrient balances of the orchard.

Six olive orchards located in the province of Córdoba, Spain, were selected for the study. We aimed to include representative examples of contrasting olive cropping systems. The sample included the following orchards:

- ‘SHD-I-C’: irrigated hedgerow orchard (1852 trees/ha) under conventional management
- ‘SHD-R-O’: rainfed hedgerow orchard (1143 trees/ha) under organic management
- ‘HD-I-O’: medium-density irrigated orchard (521 trees/ha) under organic management
- ‘HD-I-C’: medium-density irrigated orchard (204 trees/ha) under conventional management
- ‘T-R-C’: traditional rainfed orchard (83 trees/ha) under conventional management
- ‘T-R-O’: traditional rainfed orchard (83 trees/ha) under organic management

Data required to run SATDOS was collected from different sources, including interviews with farm managers for delineating the operations and materials used in 2023. Weather data were gathered automatically from public Spanish databases.

3. Results

Actual yields of the farms ranged from 1500 (SHD-I-C) to 225 kg oil/ha (T-R-O), with the highest values in the irrigated plantations and the low yield of T-R-O. Productivity was positively correlated with net ecosystem productivity (NEP) (r^2=0.69). CO_2 emissions ranged from 1500 (SHD-I-C) to 320 kg CO_2/ha (T-R-O), being higher with higher level of mechanisation and input use. The extreme values of water footprint were estimated for the traditional farms, with the rest exhibiting values between 0.70 and 1.20 m^3/kg oil. Regarding fertilisation plans, N was supplied in excess as compared to the requirements estimated by SATDOS in all cases (the excess ranged from 24 to 143 kg N/ha).

4. Discussion

Substantial differences in the productive and environmental performances of the studied farms were found. Our results suggest that CO_2 emissions increase as the farm intensifies and irrigation is applied, just as NEP and oil yield increase, revealing a trade-off between some negative environmental impacts and farm productivity.

This work shows the potential of SATDOS as a decision support system for evaluating the cost/benefit of specific management schemes from the economic and environmental perspectives. This may be helpful for preventing unnecessary environmental impacts associated to specific strategies. As an example, an excess of N supply was found for all the orchards, which may contribute to diffuse pollution and indirectly lead to increased CO_2 emissions.

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Future change in soil organic carbon and wheat yield under different climate change projections and agricultural managements in semi-arid Iran (Poster #20)

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Keywords: climate change impacts; soil organic carbon sequestration; crop yield; crop residues

Arable land plays a key role in the sequestration of soil organic carbon (SOC). SOC is an important contributor in soil quality and hence crop productivity. In southwestern Iran, SOC levels are low due to climatic conditions and agricultural practices, and are likely to be affected by climate change. In this study we used the calibrated and validated model called MONICA to assess the impacts of two Shared Socio-economic Pathways SSP245 (480 ppm) and SSP585 (600 ppm) on future (2030 to 2060) changes in yield, ABG, crop cycle length and SOC for a maize-wheat rotation as the most common cropping system in the region under three agricultural strategies: Conventional (CON), where all inputs were inorganic and all crop residues were removed after harvest; Organic (ORG), where only organic fertilizer was applied and 30% of crop residues were returned to the soil; Integrated (INT), where a combination of inorganic and organic fertilizer was applied and 15% of crop residues were returned to the soil. The model was run for the regions of Ahvaz in the south-west and Torbat-Heydareye in the north-east of Iran. The results indicated that projected grain yield and AGB of wheat and projected SOC were affected by elevated CO_2 and increased temperature. Future wheat yield and AGB were significantly reduced in Ahvaz and partially increased in Torbat-Heydareye under SSP245 and SSP585 compared to the baseline. Although future SOC tend to improve in Torbat-Heydareye for the organic-based agricultural strategies (ORG and INT), it tends to decrease in Ahvaz in the climate change scenarios. The conventional (CON) strategy was more sensitive to climate change than the organic-based strategies in terms of future SOC and yield in Ahvaz and AGB and SOC in Torbat-Heydareye. This study emphasizes the importance of assessing the impact of climate change on different agricultural strategies on a regional scale in order to define climate change adaptation measures in semi-arid regions in Asia.

Assessing the potential of legume crops to meet protein demand in the context of climate change in Southern Belgium (Wallonia) (Poster #217)

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Keywords: protein; legumes; climate change; yield components

Over the past decades, the demand for plant-based proteins has steadily increased, especially to support animal-based proteins, leading to a strong dependence of European countries towards foreign producers. In a context of transitioning food system through more reliance on food security, reduction of meat consumption or more plant-based diet, legume crops appear as a promising solution. These kinds of crops have the remarkable ability to fix atmospheric nitrogen, thus reducing reliance on fossil-based fertilizers, promoting soil health and fertility, mitigating risks associated with intensive monocultures, and preserving biodiversity. Faba beans and peas are the two most cultivated legumes in Europe (Falconnier *et al.*, 2020), and in Belgium. However, these crops are strongly impacted by climatic hazards such as heat and water stress, leading to the necessity of exploring their potential under the effects of global warming.

Using statistical and process-based models, historic Belgian data regarding faba beans and peas yields and climatic conditions were used to study the potential of those crops and project yields under different climate scenarios in the near and distant future, with moderate (RCP 4.5) and high (RCP 8.5) warming scenarios (Calvin *et al.*, 2023). To approach the crop ecophysiology, yield estimates were calculated from yield components (*i.e.*, grain number and thousand kernel weight) derived from predictive models using climatic indicators such as temperature variables (*e.g.*, averages, maximums or number of frost and hot days), water-related variables (*e.g.*, cumulative rainfall, number of rainy days, evapotranspiration or water deficit) or even solar radiations. Key development periods based on species-specific cumulative degree-days were calculated, with the aim of determining each yield component. Grain number was defined using climatic indicators calculated between emergence to early flowering and between early to late flowering and thousand kernel weight between late flowering to maturity (Lake *et al.*, 2019).

The results highlighted the significant influence of climatic indicators on yield components. Moreover, our study emphasized the potential of exploiting differences between species able to adapt to such climatic conditions. For example, according to various statistical models, spring pea yield predictions tend to decrease by the year 2100 under both moderate and high warming scenarios. Furthermore, most simulations carried out in various studies on the impact of climate change on yields generally indicate yield increases for legumes in northern countries, particularly for winter crops (Manners *et al.*, 2020; Marteau-Bazouni *et al.*, 2024).

However, with such models, it is important to note that gaps persist in our understanding of the effects of climate change, such as the impact of increased in CO_2 on photosynthesis, as well as the influence of climate change on disease, pest, and weeds, and consequently on achievable yield (Marteau-Bazouni *et al.*, 2024). Additionally, it is essential to recognize that yield potential also depends on the choice of cultivars adapted to climate change, as well as on soil type, which is not yet accounted for in our models. Not to mention the limitations of statistical models such as projections formulation that do not go beyond the data used for training (Guilpart *et al.*, 2022). While our models already account for the CO_2 effect on evapotranspiration (M. G. Jadhav *et al.*, 2021), our approach would benefit to be completed with a process-based modelling approach that would simulate the impact of CO_2, heat, and drought on yield and nitrogen fixation of these seed legumes (Falconnier *et al.*, 2020).

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Spatial and temporal variability of pH, P, K and Mg content in topsoil across mainland France (Poster #330)

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Keywords: soil test; spatio-temporal trends; phosphorus; pH; magnesium

1. Introduction

In France, phosphorus (P) and potassium (K) fertilizer deliveries have declined since 1990, and stabilized at a relatively low level since 2010. This current situation is the consequence of, on the one hand, the continuing rise in energy prices which is affecting fertilizer prices and, on the other hand, a general reduction in phospho-potassium fertilization of agricultural plots nationwide following fertilization optimization. The aim of this study was to estimate the spatial variability of pH and P, K and Mg content in topsoil of cultivated soils on a national scale, and to identify trends over the period 1990-2020.

2. Materials and Methods

In France, since 1990, the National Soil Test database “Base de Données des Analyses de Terre” (BDAT, coordinated by Info&Sols unit, INRAE Orléans) has brought together the results of soil tests of cultivated topsoil carried out throughout mainland France, at the request of farmers in order to manage soil chemical fertility, by laboratories approved by the Ministry of Agriculture. This database contains over 3 million P determinations and an equivalent number of exchangeable K and magnesium (Mg) determinations. Concerning P, three methods of analysis are currently used in France. Thus a pedotransfer function has been used to harmonize the values, which are then expressed in P-Olsen equivalent (Hu *et al.*, 2021). The precise location of the plots remained unknown and only the municipality from where the samples came from was recorded. Statistical parameters (*i.e.* median, quartiles) were derived from the distribution of soil test values by spatial entities of aggregation. These data were then mobilized as part of a spatio-temporal diagnosis to provide information on the trends of these four fertility parameters over the period 1990-2020. Changes in the availability of these elements for crops was estimated following an agronomic diagnosis using the RegiFert approach (Denoroy *et al.*, 2004).

3. Results

General trends in the evolution of agricultural soils in mainland France show an increase in pH and Mg content, and a decrease in K, but especially P, content. The spatial distribution of exchangeable P Olsen, K and Mg contents in soils seems to depend mainly on soil characteristics (texture, mineralogical nature of parent materials). The temporal trends observed for Olsen P and exchangeable K, on the other hand, seem to depend on economic factors (rising energy and fertilizer prices), the presence or absence of livestock farming, and recommendations for lower dose calculations as part of a rational fertilization approach. Changes in available P K and Mg contents has a limited impact of fertility classes (3 classes: low, intermediate and high fertility).

4. Discussion

As change in soil fertility classes is limited, we can argue that changes in cation contents do not have major impact on evolution of recommendations on fertilization in France, until now. However, trend in chemical fertility outlined over the last thirty years are in line with trends in elements contents: decreases in P and K, increases in Mg. This calls for vigilance in the case of P and K, and justify the monitoring of mineral balances on agricultural plots, as well as a policy of regular, reasoned analytical monitoring of soils.

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Comparison of Normalized Green Red Difference Index (NGRDI) with NDVI and NDRE from Sentinel-2 data for the detection of biomass heterogeneity on agricultural fields (Poster #220)

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Keywords: NGRDI; Sentinel 2; aerial photography; biomass heterogeneity

1. Introduction

Spectral indices can determine biomass differences in plant canopies. The indices react differently sensitive to differences in biomass and chlorophyll content in different growth stages (Hunt *et al.* 2005; Voitik *et al.* 2023). This study explores the potential of the NGRDI for vegetation monitoring as an alternative to other well established indices. A focus was set to the sensitivity of the NGRDI at different times during the vegetation of winter grain in two years. Additionally, NGRDI from aerial photos were correlated with satellite data.

According to Choudhary *et al.* (2021) the NGRDI shows a correlation with the Normalized Difference Vegetation Index (NDVI). The Normalized Difference Red-Edge Index (NDRE) shows a correlation with the NDVI with a better vegetation monitoring in later growth stages (Naguib *et al.* 2022; Voitik *et al.* 2023).

2. Materials and Methods

The research was conducted on a field in North-East Germany. Covering the vegetation period of winter wheat 2021/2022 and winter barley 2022/2023, aerial photos of this field were taken with a digital camera at five dates. Corresponding sky clear images from the Sentinel 2-satellite were analysed. A date in mid-October was targeted to capture the pre-winter development. Recordings in April, May and June should capture the vegetation development after winter until harvest. The NGRDI was calculated based on the red and green spectral bands of the aerial photos and satellite images. The combined yield data of winter barley from 2023 were used. For 2022, no yield data was available due to data loss. The information of the calculated indices at different times as well as the yield data were assigned to randomly distributed points covering the field. Regression analyses were performed to evaluate the respective correlations.

3. Results

Emphasis was placed on the NGRDI to achieve a first transferability to the aerial photos. The NGRDI of the satellite images was strongly correlated to the NDVI. In October and April, the NDRE is strongly correlated with the NGRDI. The NDRE showed a reduction in the otherwise strong correlation with the NDVI at the beginning of May. The values of the NGRDI from the sensors satellite image and aerial image correlated moderately with each other in April and June. Until May the satellite and aerial indices correlated moderately with the yield data. In June the satellite indices are strongly correlated to the yield data. The comparison between the index data from 2022 with the index and yield data from 2023 showed moderate to strong correlations at different dates.

4. Discussion

The correlations between NGRDI and NDVI as well as between NDVI and NDRE found in previous studies were retrieved in the comparison of the satellite index data. The loss of correlation between the NDRE and NDVI could be explained by the higher chlorophyll sensitivity of the NDRE. The NDVI is said to get a saturation in increasing growth stages (Naguib *et al.* 2022). The unsteady correlation between the satellite- and aerial-sensor based NGRDI over the vegetation period could be explained by atmospheric influences and the angle of the inclined original image affecting the quality of the aerial image. Nonetheless, the NGRDI aerial images showed useful visual information about different crop development within the field and correlations with the yield data.

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Can biomass from the aquatic weeds water hyacinth (*Eichhornia crassipes*) and hippo grass (*Vossia cuspidata*) supply adequate nitrogen for sorghum on low fertility tropical soil? (Poster #324)

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Keywords: aquatic weed; compost; bokashi; nitrogen mineralization rate; nitrogen uptake

Proliferation of the aquatic weeds water hyacinth and hippo grass in freshwater bodies of tropical and subtropical areas causes serious ecological and socio-economic problems. The weeds have been reported to block waterways, clog hydroelectric power generator turbines and to deplete oxygen for aquatic life. Various efforts to control these weeds have been ineffective. In areas with soils of low fertility, using the aquatic weed biomass as soil amendments for crop production might be an effective way of controlling the weeds. We investigated the potential of using biomass from these two weeds as sources of nitrogen (N) for sorghum on a low fertility tropical soil in a greenhouse study. The objectives were: (i) to determine the N mineralization rates constants (k) of the biomass (ii) to establish the relationship between k and N uptake by sorghum, and (iii) between k and sorghum dry matter (DM) yield. An incubation study was conducted to determine N mineralization from soils amended with weed biomass and a pot study to establish N uptake by sorghum and sorghum DM yield in 44 days. Treatments used were:(i) untreated weed biomass (ii) bokashi from weed biomass (iii) compost from weed biomass (iv) chemical fertilizer (10 % N: 20% P_2O_5: 10 $K_2$0) and (v) soil alone. The weed biomass and chemical fertilizer applied per pot contained 1.13 g N, equivalent to a field application of 90 kg N/ha to a sorghum crop with 80,000 plants per ha. The soil moisture during the study was maintained at 60% of the soil's total pore volume. Nitrogen mineralization from the organic amendments followed the first-order kinetics equation N min 〖(t)〗 =N_o(1-e^(-kt)); where k (day^{-1}) is the N mineralization rate constant; Nmin(t) is the cumulative mineralized N at time t, and N0 is the potential mineralizable N at t0. For water hyacinth, compost had the highest k of 0.0113 day^{-1} followed by untreated biomass with 0.0096 day^{-1}, and bokashi with 0.0083 day^{-1}. For hippo grass, compost had the highest k of 0.0119. day^{-1}, followed by bokashi with 0.0092 day^{-1} and untreated biomass with 0.0054 day^{-1}. Grouped k values were: 0.0116 day^{-1} for compost, 0.0088 day^{-1} for bokashi, and 0.0075 day^{-1} for untreated biomass, showing that compost had the highest N mineralization rate, then bokashi, and lastly untreated biomass. Nitrogen mineralized from water hyacinth biomass, reflected the order of k values of the biomass, with 297 mg N/kg, 333 mg N/kg and 351 mg/kg for untreated weed, bokashi and compost respectively. A similar trend was observed for hippo grass biomass, with 199 mg N/kg, 291 mg N/kg and 285 mg N/kg for untreated biomass, bokashi and compost respectively. The grouped mean sorghum DM yields were: 15g/pot for compost, 12g/pot for bokashi and 7g/pot for untreated biomass. The N uptake by sorghum followed the same pattern as the DM yield. A significant ($p = 0.034$) strong positive linear correlation ($r=0.854$) was found between sorghum DM yield and the biomass k. A similar significant ($p=0.023$) strong positive linear correlation ($r=0.874$) was found between sorghum N uptake and the biomass k. The mean agronomic effectiveness of aquatic weed biomass in producing vegetative sorghum DM compared to chemical fertilizer was 163 % for compost, 97 % for bokashi, and 1.4 % for untreated biomass. We concluded that the two aquatic weeds

can supply adequate N for sorghum on low fertility tropical soils when made into compost or bokashi.

Effect of long-term residue managements and tillage on weeds and its impact on winter wheat in temperate climate loamy soils (Poster #201)

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Keywords: crop residue; reduced tillage; weed flora; winter wheat

Agricultural soil management is a crucial aspect in agriculture. It is known to influence carbon storage, thus potentially aiding in the mitigation of atmospheric CO_2 levels (Martin *et al.*, 2021). The management of crop residues, whether through exportation (*e.g.*, for animal fodder or bioenergy production) or incorporation into the soil, significantly impacts carbon storage (Autret *et al.*, 2016; Hiel *et al.*, 2018). Moreover, soil management practices influence various parameters including soil geochemical dynamics (Hiel *et al.*, 2018), soil microbial communities (Spedding *et al.*, 2004) or weed flora (Nichols *et al.*, 2015).

In Hesbaye region (Belgium) winter wheat is a key component of agricultural rotations. This arable farming region is characterised by a loamy soil and an oceanic temperate climatic condition. In this region, a long-term study of the impact of crop residue management and tillage has been underway since 2008. In 2021-2022, the long-term effect of four soil management on the expressed (in winter wheat) and potential weed flora was examined. Soil management levers were i) the export (OUT) or restitution (IN) of crop residues and ii) the burial of residues by conventional tillage (mouldboard ploughing 25 cm depth, CT) or reduced tillage (cultivator ploughing 10 cm depth, RT). The weed seedbank and expressed flora in winter wheat were characterized. Weed density was monitored during the tillering phases (before weeding) and at wheat flowering. Additionally, at wheat flowering, weed biomass and wheat biomass were collected. Weed diversity was assessed using species richness and the Shannon diversity index. Then, the impact of flora and management on yield were investigated.

The result based on our study (Lacroix *et al.*, 2024) showed that tillage management had little impact on weed diversity with only a slight increase observed in RT. However, RT resulted in a higher weed seedling density in the seedbank compared to CT. A higher weed density was observed in winter wheat crops under RT (+78%) compared to CT. Reduced tillage resulted indirectly to winter wheat yield losses due to the increased of weed pressure. In addition, high density of Alopecurus myosuroides, a very competitive weeds, was present in the trial due to the winter wheat rotation and exacerbated under RT. However, exporting residues had no clear effect on weeds. The lack of effect of maintaining residues could be explained by a dilution of crop residues in the upper soil profile which still occurs in some RT systems (such as the one implemented here), preventing the mulch effect to occur.

In conclusion, within cropping systems based on the cultivation of wheat, reduced tillage practices can pose challenges for the long-term management of the weed flora, necessitating careful attention to management practices.

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Use of intercropping systems to reduce the growth of weeds under Mediterranean pedoclimatic conditions (Poster #252)

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Keywords: biomass; yield; growth; leaf area index; LER

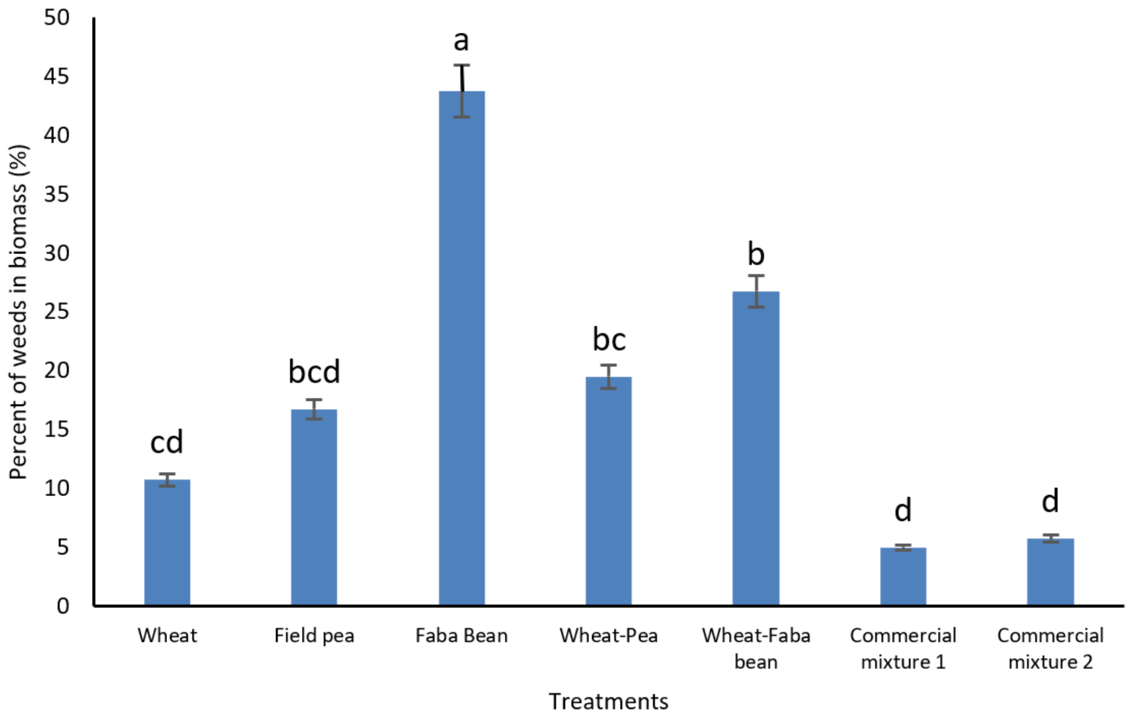

Figure 1. Effect of intercropping and increased in biodiversity on reducing the weed pressure. Means followed by the same letter do not differ significantly between the treatments, according to the LSD0.05 (Least Significant Difference) test (p=0.05)

1. Introduction

Weed management in agriculture largely depends on synthetic herbicides despite the widely accepted environmental & health impacts and the growing herbicide resistance (Liebman *et al.*, 2016). Agroecology seeks to transform food & agriculture systems, providing long-term solutions based on natural processes (Bastiaans *et al.*, 2008). Agroecological practices aim to reduce or even substitute inputs including herbicides, while maintaining or even improving crop productivity (Liebman *et al.*, 2016). The objective of the present study was to determine the effect of intercropping as an agroecological intervention on the growth of weeds.

2. Materials and Methods

The experiment was performed during the 2023-2024 growing season, at the experimental farm of the Aristotle University of Thessaloniki in northern Greece (40°32'07.7"N 22°59'20.5"E) without any application of herbicides. Wheat, faba bean and pea monocultures, their respective cereal-legume intercropping combinations and two commercial intercropping mixtures (Commercial mixture 1) consisting of 20% soft wheat, 10% oat, 35% triticale, 15% field pea and 20% common vetch and the second commercial mixture 2 consisting of 30% soft wheat, 10% oat, 20% triticale, 15% field pea and 25% common vetch (American Genetics, Corporation, Greece) were cultivated to assess weed growth in terms of relevant biomass percentage. Differences in weed biomass percentage between the alternative intercropping schemes were assessed by one way ANOVA and means were compared using the LSD test? within the methodological frame of General Linear Models (SPSS version 27, IBM Corporation, Armonk, New York, United States).

3. Results

Intercropping of wheat in the two commercial mixtures reduced growth of weeds (p=? (Figure 1). Faba bean is a crop species that does not compete with weeds and therefore it showed the lowest ability to control weeds.

4. Discussion

Weed growth is a critical parameter in agriculture as weeds compete with crops for light, water, and nutrients. To effectively control weeds, agrochemicals are extensively used, whereas mechanical weed control is used to a lesser degree when appropriate. Intercropping can potentially reduce weed pressure. However, proper intercropping schemes and sowing density are essential for effectively suppressing weed growth and to improve the sustainability of the cropping systems (Verret *et al.*, 2017; Gu *et al.*, 2021). Although weed control by intercropping alone is a difficult task, on-going experiments indicate that certain mixtures of oat, triticale, field pea, common vetch and bread wheat can suppress weed growth up to 95%.

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Crop phenology assessment with multiscale and multisource time series (Poster #278)

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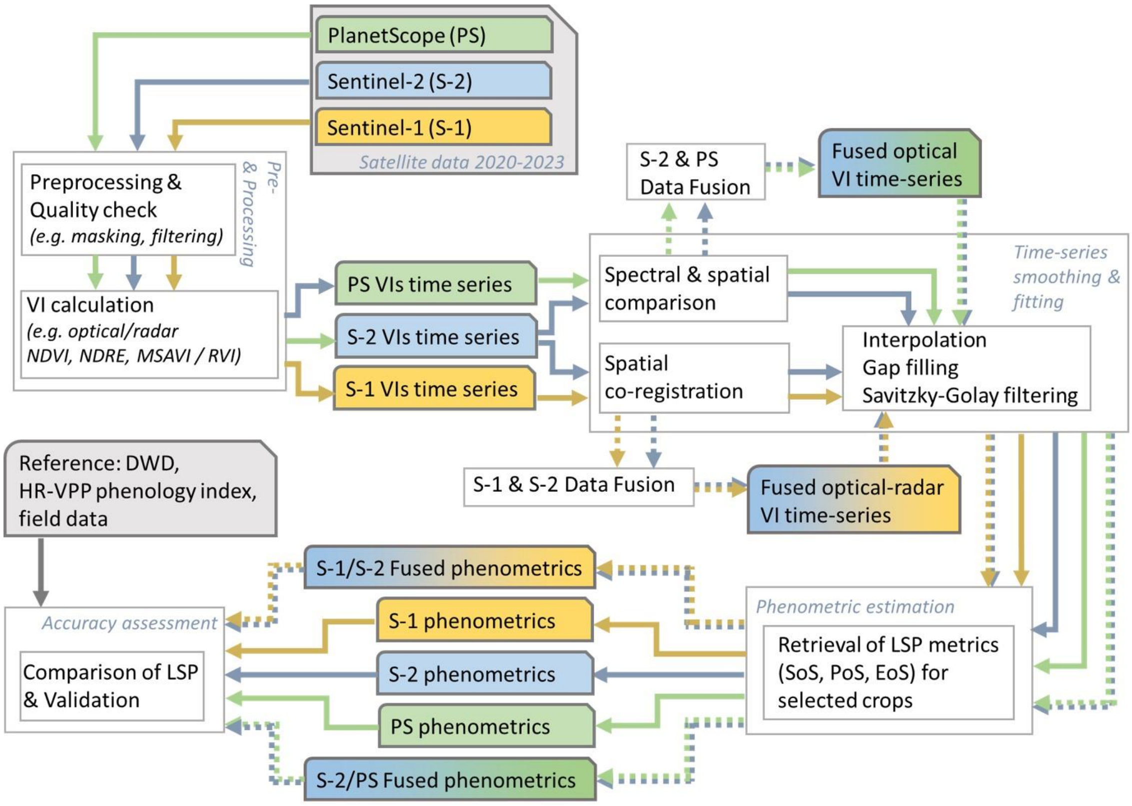
Keywords: time-series; land surface phenology (LSP); fusion; optical; radar



1. Introduction

Monitoring crops, including their phenological stages, plays a crucial role in agronomic applications, providing essential insights into temporal dynamics and crop conditions throughout the growing season. These insights are particularly valuable for informing crop models used in agricultural management and resource allocation, especially in the face of climate change. Remote sensing (RS) data, acquired over large areas, are fundamental in driving process-based simulation models. These models, in turn, generate simulations that are invaluable for informing strategic decision-making in agriculture. While the majority of agricultural studies rely on either optical or radar satellite sensors (Blickensdorfer *et al.* 2022; Meroni *et al.* 2021), there is still a notable gap in the application of fused data products to benefit from both systems (Cheng *et al.* 2023; Chen and Zhang 2023).

In our study, we evaluate the potential of dense time series of multimodal fused data obtained from Sentinel-1 (S1), Sentinel-2 (S2), and PlanetScope (PS) satellites to assess Land Surface Phenology (LSP) metrics at 10m resolution for two crops (maize, winter wheat) in Germany from 2017–2023. The specific objectives are (i) to establish and validate patterns that indicate a phenological stage of Start-, Peak- and End-of-Season (respectively SoS, PoS and EoS) within the time series of both optical and backscatter data, (ii) to prove the added value of particular gap-filling and fusion strategy, and (iii) to obtain regional spatially explicit information of crop phenology.

2. Materials and Methods

The methodology (Figure 1) encompasses radar (S1) and optical (S2, PS) data pre- and processing (filtering, cloud screening, calculation of several vegetation indices *e.g.*, NDVI, RVI), time-series processing (interpolation, gap filling, smoothing and fitting, data fusion), the LSP metrics estimation (threshold-, slope and derivative-based methods), and accuracy assessment (based on phenology from German Weather Service, Copernicus HR-VPP, farmers reports). Analysis and comparison is performed over several federal states of Germany (Brandenburg, Lower Saxony, Bavaria).

3. Results

Generally, the results indicate a strong temporal correlation between dense RS time series obtained from multimodal satellite sources and significant level of agreement between the LSP metrics at a field level for the analyzed crops. The fusion of optical S2 and PS data improves the characterization of phenology variations at a sub-field level across multiple sites and years, and reduce uncertainties related to mixed pixels. Nevertheless, the obvious impact of clouds on optical systems, insufficient data availability and uncertainty related to image co-registration, persist the critical points in accurate LSP retrieval. The S1-derived LSP metrics, such as SoS, PoS and EoS, show high accuracy and reliable results within the expected range compared to other sources like S2 derived metrics, DWD, HR-VPP and farmers reports. Using backscatter and cross-polarization ratio, the temporal patterns of crop phenological development were clearly identified and LPS metrics accurately derived.

4. Discussion

The utilization of multimodal RS time series from combined optical and radar systems significantly broadens the scope of crop phenological monitoring beyond conventional field observations. The fusion of datasets through advanced algorithms and machine learning techniques promises comprehensive insights into crop development stages with denser time series and higher spatiotemporal resolution. This would facilitate timely intervention for crop management, and more effective responses to climate variability as well as can inform process-based crop models, *e.g.* for early-season prediction of yields.

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Combining methods to manage ryegrass with less herbicides in arable crops: key of success of the irrigated on-fam experiment Cap du Futur in the south of the Paris Basin (FR) (Poster #175)

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Keywords: weed management; resistant ryegrass; multi-performance; system approach; reduction of pesticides

One of the major issues of cereal systems in the Paris Basin is the management of ryegrass (*Lolium* spp.). The emergence of herbicide resistance, the increase in winter crops instead of spring crops, and the ban and restrictions on the use of certain chemical molecules tend to exacerbate this problem. Weed management is therefore a short-term but also a long-term issue on which Arvalis, an applied research institute dedicated to arable crops, works on for several years. If the optimization of chemical interventions appears to be an essential lever in the short and medium term, the presence of herbicides in water forces us to find alternative solutions in the long term.

The “CAP du Futur” is an irrigated cropping system set up on the ARVALIS experimental platform in Boigneville (91) in 2016. This experiment at farm scale aims to find sustainable solutions to manage herbicide-resistant ryegrass infestations with less herbicides and without glyphosate while remaining profitable. A combination of levers is tested to achieve this goal with a systemic approach (Metais *et al.*, 2018).

The alternation of winter and summer crops is a major lever for disturbing weeds. It drives to the following crop rotation: sunflower / winter wheat with a very high protein content/ winter wheat / grain maize / grain maize / spring barley / winter wheat. Because of a problem with local outlets, hemp was replaced in 2020 by a clover fallow and then by a sunflower.

Tillage is mobilized through the technic of false sowing and by ploughing. The use of herbicides is limited thanks to the use of mechanical weed control and spot spraying on maize and sunflower crops.

Arvalis has been testing technological innovations related to digital progress for many years (Desbourdes *et al.*, 2020). As soon as these technologies demonstrate their benefits in weed management, they are integrated into CAP practices.

Methods developed by ARVALIS and proven over many years make it possible to extrapolate the technical results obtained on the experimental system with a size of 47 ha, to a farm of 300 ha for two assets. This extrapolation is made possible thanks to the SYSTERRE® tool (Casal *et al.*, 2022).

The results on the period 2017-2023 show that ryegrass management is satisfying: less pressure while a reduction in herbicide use (Bouttet *et al.*, 2023). The herbicide treatment frequency index is relatively low, with an average of 1.61 (local reference: 2.32). This index counts the number of reference doses used per hectare during a growing season. Except for hemp, yields and quality of the different crops are closed to the objectives. The economic sustainability of the system remains profitable. But the three years of hemp and the clover still impact the average margins. There is a difference of 166 €/ha between the net margin of CAP and the local reference (subsidies included).

Moreover, this system remains dependent on the use of certain active substances with uncertain futures. It was supplemented in 2020 by a piloted free-herbicide observatory to explore more disruptive solutions without economic constraint.

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Impact of crop weed competition on yield gap: a field approach in sugarcane in Réunion (Poster #105)

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Keywords: crop-weed interaction; crop model; yield gap; sugarcane; cropping system

In Réunion Island, herbicides are the main pesticides used in sugarcane cropping systems (Antoir *et al.*, 2016; DAAF La Réunion, 2016). Available herbicides registered for use on sugarcane were recently reduced to 8, and should be further restricted to 4 (ANSES, 2023). However, weeds may cause yield losses ranging from 20% to over 50% (Marnotte and Le Bourgeois, 2018), and are considered as a threat by industry stakeholders (Martin *et al.*, 2012; DAAF La Réunion, 2020). In addition, many other factors can contribute to lower yields, like climatic conditions and some management practice (Christina *et al.*, 2021).

To choose and prioritize weed management practices, it is necessary to analyse the crop-weed interaction at stake within the cropping system, even more in tropical context, where there are very few references and studies on this subject.

An agronomic diagnosis using crop modelling may be a useful approach to provide a better understanding of the relative importance of weed competition among the other factors limiting yield (Doré *et al.*, 1997; Affholder *et al.*, 2003).

The objective of the study presented here is to analyse the role of weed-crop interactions on yield in sugarcane cropping systems in Reunion Island. To do this, small plots of 25 m^2 each were identified to minimize intra-plot variability but maximize inter-plot variability within 25 farmers' fields, spread over the five sugarcane production basins of Réunion Island. The main potential local limiting factors were listed according to a literature review and surveys from local stakeholders (growers, technicians and scientists). Based on this, different variables (climate, cropping practices, weed development, crop growth) will be monitored in all farmers' plots over the sugarcane cropping cycle. We will then use this dataset to estimate the respective weight of the different factors in each cropping situation using crop modelling. The comparison between the simulated potential yield and the observed one should allow us to deduce unexplained difference, which we will attempt to explain by the different variables measured during monitoring. In order to reduce parameter-related errors, the MOSICAS model, parameterized and validated for the sugarcane in Réunion Island, was selected and will be used to simulate potential water-limited yield (Martiné,1996; Christina *et al.*, 2019).

If weed-crop competition appears as a major constraint, we will use a functional classification of weed species (Lainé *et al.*, 2023) for an in-depth analysis to determine which species may be the most noxious to sugarcane production. The final aim of this study is to contribute to the understanding of weed-related impacts on sugarcane, and to open a debate on weed control priorities and solutions better suited to each agronomic context.

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Weed community trait composition as an effect of crop competition and mechanical disturbance (Poster #114)

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Keywords: agroecology; biodiversity; ecological weed management

(1) Cropping practices shape the weed species community. Intensive mechanical and chemical weed control measures favour species that can adapt to these conditions while species that cannot adapt disappear, leading to lower species diversity (Albrecht *et al.*, 2016) and potentially making the weed species community more similar to the crop (Fried *et al.*, 2009) and thereby more difficult to control with traditional weed control measures. Moreover, mechanical and chemical weed control also negatively affect organisms in the soil (Torppa and Taylor, 2022) and in water bodies (DeLorenzo *et al.*, 2001), reduce soil structural stability (Montgomery, 2007) and can lead to herbicide resistance (Peterson *et al.*, 2018). Adapting to weed control measures with a weaker selection pressure on the weed community is therefore of interest both for farmers and society at large. Many factors affect the weed species community and over a long time, but annual management methods have a direct impact on which species are favoured and not. We assessed the effects of crop competition and mechanical disturbance on the weed species trait composition over one growing season.

(2) Data on weed species numbers were collected at species level from six field experiments running over three years. RLQ-analysis was used to connect species traits, obtained from two data bases (Bàrberi *et al.*, 2018; Tyler *et al.*, 2021), with the environmental characteristics (biomass of oats and intercropped legume service crop, row-hoeing intensity, and sampling location in relation to the crop row).

(3) The analysis showed that intermediate to high crop competition, mainly from the main crop, reduced the occurrence of tall-growing, perennial, competitive species, according to Grime's life strategies, and additional competition from the service crop in the main crop row reduced the number of tall-growing, shade tolerant, competitive-stress tolerant species. In both cases, a more diverse group of low-growing ruderal species with lower moisture requirements were favoured. Furthermore, with increased disturbance, the weed species community shifted from being associated with competitive-stress tolerant species to ruderal species, except from the most disturbed environments that were more associated with competitive species. Clustering the data according to how commonly the species occur together confirmed the pattern described. The cluster analysis further showed that the cluster with the perennial competitive species scored highest on a set of diversity traits (number of associated species, nectar production and myccorhiza association).

(4) The findings reflected quite well the expected environmental conditions. The most surprising finding was the negative association between high disturbance and the trait of disturbance requirement. However, in the case of this within-season study, it mainly shows that perennials recover better from in-season mechanical disturbance than do annuals, which could be expected due to their under-ground storage organs. Moreover, the effect of management was greater on species level than on trait level, with species being more dispersed over the ordination space than traits. This indicates an already quite homogeneous weed species community, but also that only assessing the weed community based on species composition might indicate larger differences in functions than what is actually present.

(5) High crop competition, especially from contrasting species, as well as intermediate disturbance reduced the in-season occurrence of the most competitive species according to Grime´s life strategies.

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Building eco-resilience of oil palm with omics tools towards a fertilization sustainable plantation system (Poster #67)

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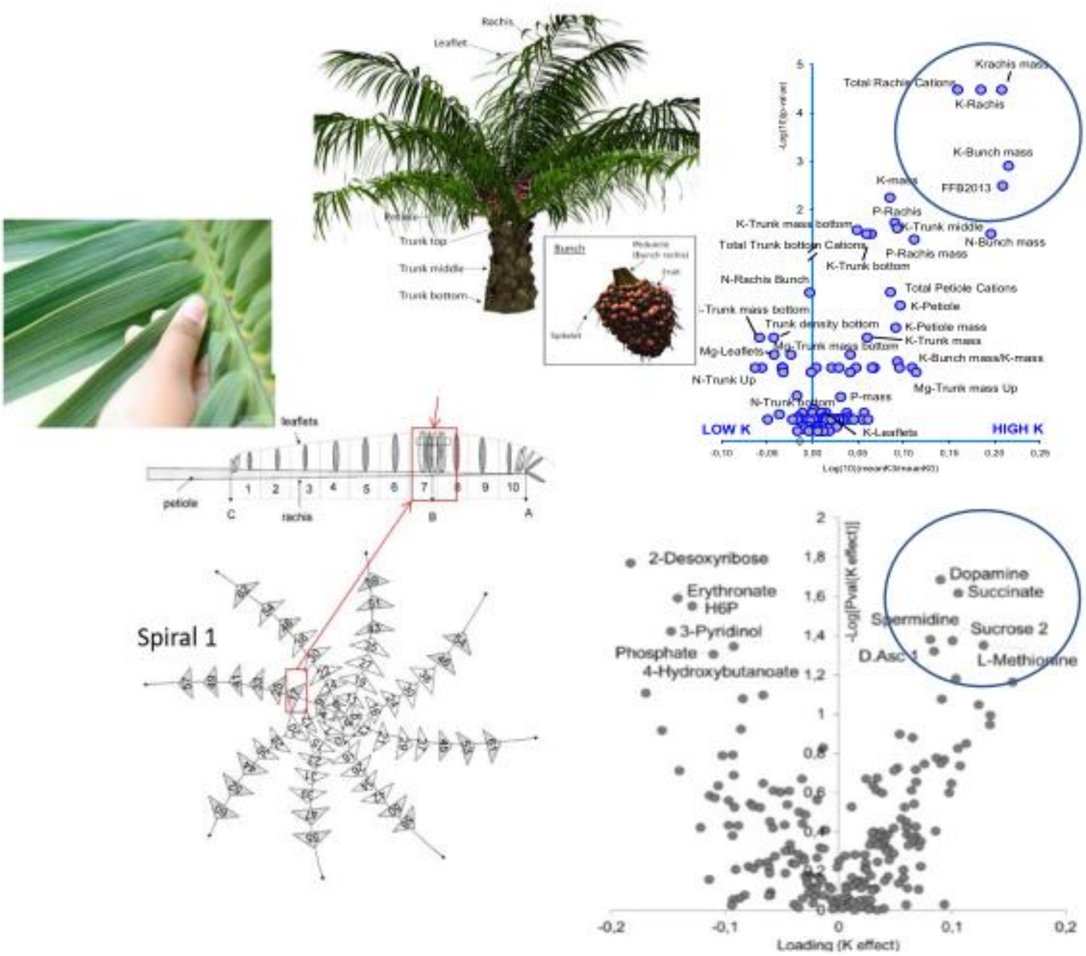
Keywords: oil palm; potassium nutrition; fertilisation; omics tools; mineral diagnosis



1. Introduction

Since 2000, oil palm cultivation has generated considerable controversy, as the >20 million ha of plantations linked with deforestation, burning, a high carbon footprint, biodiversity loss and environmental pollution from the with palm oil industry. The effects of palm oil on human health have also been critiqued, with palm oil used in various fast foods and iconic products like donuts and Nutella. Despite these concerns, the high continuous fruit production (of >35 t FFB/ha) and high oil yield (>28% of extraction rate) of oil palm make it a cheap and high-quality resource for increasing global demand for edible oil. Thus, the oil palm chain, from planters to industry, has sought to improve the environmental impacts of oil palm and engaged the R&D sector to minimize negative impacts of oil palm production. Under pressure of environmental lobbyists, such as WWF, there have been environmental improvements due to the establishment of international obligations for planters to obtain eco-certification (like RSPO Round Table for Palm Oil) and the preference of buyers to purchase “green oil” with certified origin. At the same time, the development of genomics and transcriptomics technologies for oil palm since 2013 has allowed researchers to select varieties with a high yield potential (along with markers for other desirable traits such as drought tolerance, pathogen resistance, and oil composition) and then restrict new planting extension by reducing some local yield gaps. Recently, oil palm agronomists have focused on reducing greenhouse gas emissions from plantations by modifying fertilizer use (decreasing the quantity, choice of some fertilizer type) especially the addition of potassium (KCl: until 300 kg/ha/year) that is commonly used to increase fruit production. Recent metabolomics and proteomics studies have highlighted the potential of using oil palm metabolism data to improve fertilizer efficiency management. A better definition of the nutritional status of individual trees is required to optimize the mineral diagnosis system, which is used to manage fertilizer applications in plantation, and “-omics” tools, in addition with mineral data represent a great potential solution. The iPALMS (Identifying Practicable functionAL biomarkers to Monitor nutritional requirements in oil palm agroSystems [4]) has been elaborate to test the omics solution for fertilizer management.

2. Materials and Methods

Two set of data (one coming from important mineral analyses [1] under KCl gradient) and other (metabolomics [3] coming from same plantation were matched and submitted to multivariate analyses in order to identify best mixed bio-indicators (the excercice have been done for K on K0/K3 trials) and for a futur building K-bio-Index able to integrate K and metabolic palm status precisely.

3. Results

Some evidence shown that high K level might be well correlated to K rachis and K rachis mass and dopamine-leaf as well as sucrose-leaf levels when less evidently low K seems related to phosphate-leaf , N-rachis level and Mg-leaf (see Figure).

4. Discussion

The main point will be to discuss if these kind of bio-mixed indicators might be applicable in the field to manage LD (Leaf Diagnosis) method used in the « French system » to apply fertilizer related to oil palm trees requirements (see Figure)

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Funding

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Exploring machinery management logics for implementing species mixtures (Poster #55)

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Keywords: intercrop; equipment; tracking innovation; tinkering; adaptability

Species mixtures are a key lever for the agroecological transition, mitigating environmental impacts while sustaining yields (Bedoussac *et al.*, 2015). However, farmers encounter diverse lock-ins, including technical and economic challenges, particularly regarding equipment for growing and sorting species mixtures (Bellon Maurel and Huyghe, 2017). To overcome these lock-ins and develop species mixtures, some farmers repurpose, adapt, design or combine machinery to adapt them to their practices and specific situations (Salembier *et al.*, 2020; Guenin, 2006). This study aims to explore farmers' machinery management strategies to grow and sort species mixtures.

The method implemented builds on the tracking on farm innovation approach (Salembier *et al.*, 2021). We surveyed 14 farmers growing species mixtures and adapting their machinery. Relying on concepts from system agronomy, we analysed the data collected on each farm to shed light on: (i) how farmers manage mixtures, from an equipment perspective, (ii) the technical characteristics of their machineries to implement mixtures, including adaptations, repurposes, tinkering, and (iii) their machinery management logic to implement mixtures.

Three main results emerge from our analyses:

1. We characterized the species mixtures through their spatial arrangement and seeding depth which appeared as two characteristics that interfere with the equipment. Therefore, six types of species mixtures were distinguished and defined with dimensions linked to the equipment used. For example, the first type corresponds to species sown in the same row, at the same depth and the second type to species sown in alternate rows at different depths. This equipment-based approach enriches the literature (*e.g.* Gardarin *et al.*, 2022; Verret *et al.*, 2020), which generally characterizes mixtures, among others, by their sowing date, duration of coexistence of species on the field, and intended outcome (cash *vs.* service) without taking into account the machinery used.

2. We identified a diversity of machinery repurposed, adapted, and tinkered for sowing, harvesting and sorting with a majority of identified innovations concerning the sowing. For example, a farmer, using a seed drill with two distribution heads, partitions the hopper to sow a mixture of wheat and faba bean at two different depths.

3. Based on a cross-analysis, we identified different management logic of agricultural machinery to grow and sort species mixtures: (i) minimizing costs in mechanization by repurposing the existing farm equipment, (ii) sowing mixtures based on species characteristics and physiology (*e.g.* seeding depth and alternating row patterns) by adapting equipment, and (iii) the choice of mixtures and equipment is influenced by the available resources in the local area (*e.g.* agricultural services, sorting platforms and cooperatives).

This study provides a new approach to species mixtures, by considering the role of equipment. This original perspective brings results that could support the design of species mixture strategies that integrate equipment design in a variety of situations.

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Water stress detection in sunflower varieties using leaf temperature and leaf water content – Integrating water stress tolerance criteria into varietal study in Switzerland (Poster #240)

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Keywords: sunflower; water stress tolerance; varietal study; leaf temperature; leaf water content

1. Introduction

The sunflower production area in Switzerland is small (6404 hectares; swissgranum, 2023) and increasingly subjected to summer water deficit that may limit sunflower performance. In order to maintain a domestic production, and even support its growth, it is important to determine drought adaptation strategies. The advancement of sowing dates in combination with very early maturing varieties is one option, but under Swiss conditions, the risk of poor establishment due to cold damage will remain high in the coming decade. Drought tolerant varieties with physiological mechanisms conferring drought tolerance at flowering and seed filling constitute the most favorable strategy. Sunflower varieties are currently evaluated on the basis of grain yield, oil content and composition, early ripening, disease resistance and lodging. There are no established indicators to assess water stress tolerance. A protocol to characterise the stress level of sunflower varieties is therefore needed to improve the varietal evaluation criteria and to consider these in the description of varieties.

2. Materials and Methods

A field trial was conducted from April to September 2022 in Nyon, Switzerland. Eight sunflower varieties were sown and replicated four times without and with irrigation (95 mm in total during vegetative and reproductive stages). Crop management followed conventional practices applied by local farmers. Physiological mechanisms of drought tolerance were studied by means of leaf water content and simultaneous leaf and canopy temperature measurements. Five measurement sessions were performed between the end of June and the end of July 2022, covering the inflorescence emergence and ripening phase (BBCH growth stages 51-89). Leaf temperature was acquired for the youngest developed leaf using a handheld infrared thermometer (Extech IRC130) between noon and the early afternoon on days with no or little clouds. The leaf water content (LWC) was determined for the same leaf. Drone surveys using a Micasense Altum multi-spectral camera were performed at one timepoint (around noon) on the same day. Out of the six spectral bands of the Altum camera, the longwave infrared band was extracted to acquire crop temperature.

3. Results and Discussion

Leaf water content was consistently higher under irrigated compared to non-irrigated conditions, with the largest differences on days when air vapor pressure deficit (VPD) was high, *i.e.* above 2.5 kPa, during measurements. Differences between varieties were also detectable on these days.

The difference between leaf and air temperature (dTm) is generally considered a proxy for leaf stomatal conductance (gs) with more negative dTM values indicating higher gs. We found that negative dTm values were only obtained under conditions of high VPD, *i.e.*, when transpiration is more important. An ANOVA including VPD as a covariable showed a significant effect of VPD on dTm. Canopy temperature determined using drone-based image acquisition showed increasingly important differences between irrigated and non-irrigated plots. Crop temperature showed similar differences between varieties as LWC. The correlation with leaf temperature was nevertheless low except for measurements at the end of July when water stress was high.

Our results indicate that conditions of high VPD, and therefore high transpiration rates, are a prerequisite for detecting differences between varieties in response to water deficit based on leaf temperature determined using a handheld infrared thermometer. Measurements of leaf water content were more reliable and sensitive for detecting the presence of drought stress, but also required high VPD conditions for determining differences between varieties. Drone-based thermal image acquisition was less sensitive to measurement conditions and was able to assess varietal differences in drought stress responses at an earlier stage. The work performed confirms the potential of leaf water content and infrared thermography in the evaluation of water stress tolerance of sunflower varieties grown in Switzerland.

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Preliminary results of an experiment of pure and intercopped seeding of cereals and legumes (Poster #298)

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Keywords: intercropping; cereal; legumes

Intercropping, *i.e.* growing two or more crops together on the same land simultaneously is becoming more common in Europe in recent years, especially in organic farming and low-input in production systems. Cultivation of legumes together with cereals in intercropping reduces mineral nitrogen need due to nitrogen biologically fixed by leguminous plants, thus also reducing the expenses on nitrogen fertilizers. Compared to pure seeding of cereals, intercropped seedings are more adaptable and resistant to changing weather conditions, which ensures yield stability and higher protein yield.

In 2022 and 2023 a field experiment with different seed mixtures was established at the experimental field of the Estonian University of Life Sciences, where oat (variety 'Symphony'),spring barley (variety 'Laureate'), field pea (variety 'Casablanca') and spring vetch (variety 'Hanka') were grown. Intercropped treatments included oat + pea and barley + vetch. There were two fertilizer treatments – control (N0) without fertilizer (N0P0K0) and fertilized treatment with complex fertilizer (N1), where the amounts of nitrogen (N), phosphorus (P) and potassium (K) were respectively 23, 30 and 63 kg ha^{-1} (N23P30K63).

The maximum grain yield was obtained from pure seeding of both cereals. The weather of the year had a great influence on the results of the experiment, which caused uneven sprouting of legumes, gaps in the herbage, high weeds and low grain yield of pure seeding of peas and vetch. The assumption that the protein yield of mixed seeding is higher than that of pure seeding of cereals was not proven in this experiment. When preparing seed mixtures, the compatibility, competitiveness and ratio of the seeds in the mixture must be carefully observed. The inappropriate ratio of cereals to legumes in the seed mixtures and the interaction of unfavorable weather conditions caused a very small proportion of legumes in the herbage in this experiment and their extremely low yield in both mixed seeding.

Integral nitrogen fertilization management with CHN-conduite: improving nitrogen use efficiency under climatic constraints and uncertainties (Poster #193)

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Keywords: wheat; management tool; nitrogen use efficiency

1. Introduction

For several decades in France, nitrogen (N) fertilization reasoning has been based on the principle of the "balance sheet" method. This method comes up against strong implementation limitations (Ravier *et al.*, 2016), and a lack of adaptability in the face of climatic hazards. This observation has motivated the emergence of a new concept of "integral" management of N fertilization, which avoids a priori estimates of forecast N rate in favor of reasoning based on instantaneous plant needs. Since 2017, ARVALIS has been developing an integral management tool of N fertilization in wheat, CHN-conduite, which relies on a mechanistic crop model (CHN) to access plant N nutrition levels in real time and forecast canopy N requirements. CHN allows to simulate the development, growth and N nutrition status of a wheat crop on a daily basis in response to its environment using a dynamic approach. The innovative near-real-time coupling of CHN with data from on-board satellite sensors provides a highly accurate diagnosis of wheat's N nutrition status, improving the accuracy of crop N requirement projections. CHN-conduite considers several elements in the reasoning of tactical advice. N requirements are established on the basis of a floor nitrogen nutrition index trajectory. The fractioning of N inputs does not follow an a priori defined strategy, in favor of a multi-criteria reasoning method that is more integrative of annual variability. The aim of this study is to evaluate the agronomic performance of CHN-conduite under field conditions.

2. Materials and Methods

This study relies on a French network of 27 field trials of winter bread wheat (*Triticum aestivum* L.) conducted in 2023. Nitrogen management based on the balance sheet method was compared with that based on the CHN-conduite tool. Measurements of grain yield and grain protein concentration were performed at harvest to compare the two practices. The total N rate applied in each treatment was also recorded. These data were used to calculate a nitrogen net profit margin, incorporating several scenarios for N fertilizer prices (from 1.3 to 2.7 € kgN^{-1}) and grain selling prices (from 230 to 350 € t^{-1}). A remuneration scale for grain protein concentration was also used for this evaluation.

3. Results

Compared with the balance sheet method, integral management of N fertilization using the CHN-conduite tool significantly improved grain yield by 0.25 t ha^{-1} (p-value = 0.03*) without increasing the nitrogen rate applied (-12.1 kgN ha^{-1}, p-value = 0.12NS) and without penalizing grain protein concentration (+0.2%, p-value = 0.23NS). Producing more grain with higher protein concentration using less nitrogen fertilizer mechanically improves the nitrogen net profit margin. Depending on the combination of fertilizer purchase price and grain selling price scenarios, the average gain observed across the network ranges from 77 to 109 € ha^{-1}.

4. Discussion and Conclusion

The main factor in the success of a N fertilization strategy is the ability to integrate the effect of the climatic year on the crop's N requirements. Beyond the direct effect of the total N rate, the tactic of splitting is also very important in maximizing nitrogen use efficiency. While an a priori calculation of the total N rate, as proposed by the balance sheet method, allows only very few adjustments during season, the integral management of N fertilization is extremely reactive to growth conditions. Growth projections, which determine wheat's nitrogen requirements, are regularly updated during the campaign to incorporate the real year's climate. In addition, by coupling CHN with on-board satellite sensors, the impact of non-climate-related accidents can be taken into account when revising N requirements. The tool's decision rules also enable to optimize intervention dates, and adjust the recommended N rates to the dynamics of the wheat's N demand at each application. The combination of these different solutions in the CHN-conduite tool gives it an enhanced ability to propose an optimized fertilization strategy. The results confirm the potential of this new approach. It also opens up prospects for future developments, which will make it possible to optimize fertilization strategies by integrating new optimization constraints, such as reducing the crop's carbon footprint.

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Soil-improving management practices in a dynamic long-term experiment in NE Germany (Poster #162)

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Keywords: biomass; crop rotation; irrigation; long-term experiment; tillage

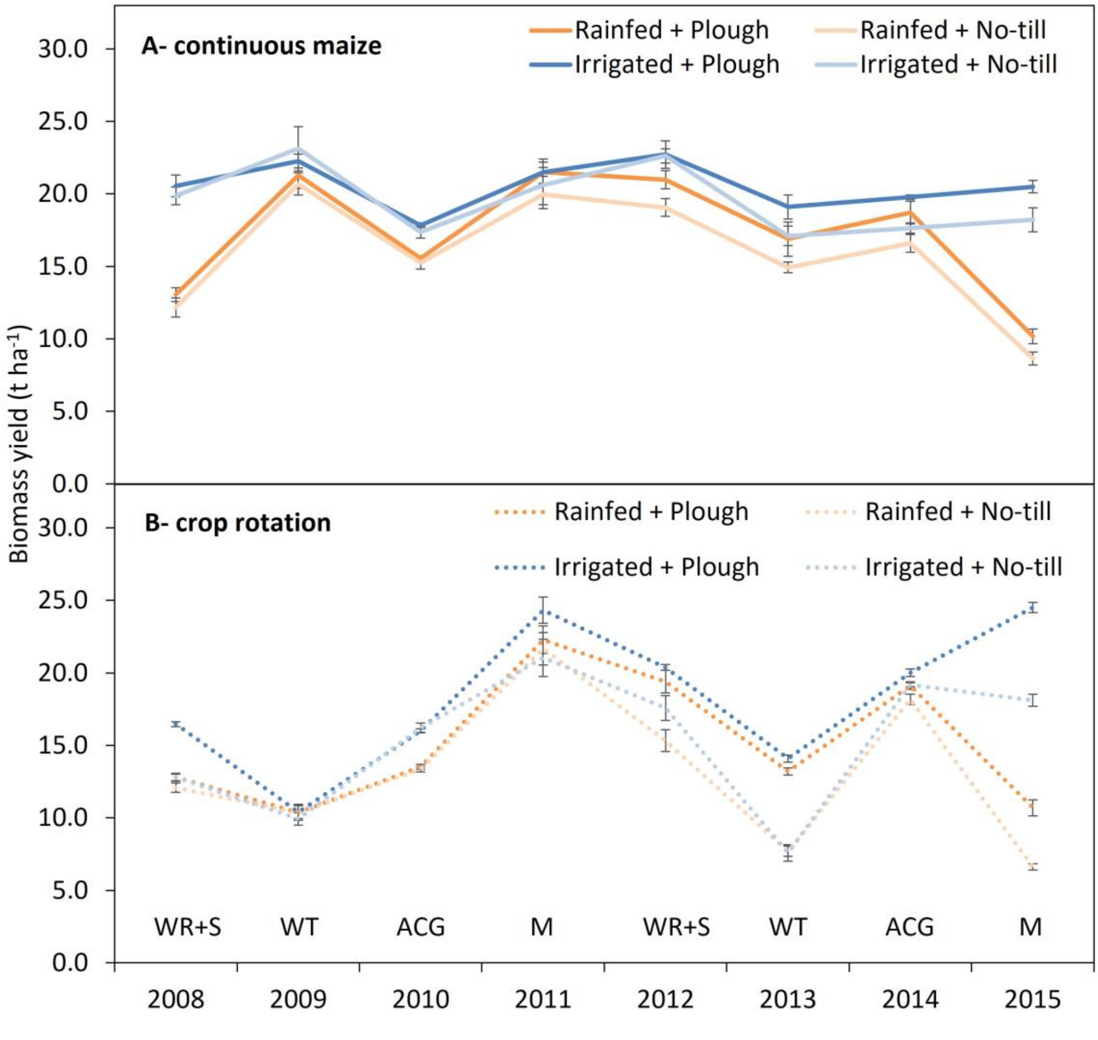

Figure 1. Crops' biomass yield under continuous maize (A) and crop rotation (B). In sub-figure B, abbreviations at the bottom refer to the crop grown each year (WR+S: winter rye + sorghum; WT: winter triticale; ACG: alfalfa-clover-grass mixture; M: maize). Error bars refer to standard error

1. Introduction

Management practices can modify certain aspects of soil quality such as the soil organic C (SOC) content, thus affecting the cropping system performance. While the use of cover crops or perennial forages is associated with increases in SOC stocks (Börjesson *et al.*, 2018;

Poeplau and Don, 2015), the effects of tillage, crop rotations or irrigation are more location-dependent. Climate change will affect the interaction between management practices and crop performance. In this scenario, it is necessary to understand the responses of these factors in the present climate to be able to adapt them in the future (Olesen *et al.*, 2011). Long-term experiments (LTE) provide precious datasets for robust analyses of the effects of different management practices on cropping systems' productivity and sustainability (Cusser *et al.*, 2020). The objective of this work was to explore alternative management practices for increasing crop productivity while maintaining (or improving) soil quality. The hypothesis was that a diversified crop rotation could outperform a continuous maize cropping system and that no-till practices could achieve the same yields as ploughing.

2. Materials and Methods

A long-term field experiment was set up in Müncheberg (NE Germany) in 2000. Within one experimental cycle (2008-2015), the following factors were tested: irrigation (yes/no), tillage (plough/no-till) and crop rotation (continuous maize (*Zea mays* L.)/crop rotation). Irrigation rates ranged from 44 mm (2011) to 400 mm (2015). The crop rotation treatment consisted of a four-year sequence including winter rye (*Secale cereale* (L.)M.Bieb) + sorghum (*Sorghum bicolor* (L.) Moench), winter triticale (× *Triticosecale*), alfalfa (*Medicago sativa* L.)-clover (*Trifolium repens* L.)-grass (*Lolium perenne* L.) mixture and maize (Figure 1B). All crops were harvested for biomass for biogas production. While the use of cropland for biogas production is under debate in Germany, forage production is still a valuable source of livestock feed. Besides productivity, biomass N concentration was analysed, soil mineral nitrogen and water contents were measured five times per year and soil organic carbon concentration was measured every other year.

3. Results

The results refer to two rotation cycles of the experiment (2008-2016). Continuous maize yields averaged 18.3 t ha^{-1} (± 3.6 t ha^{-1}) across years. Instead, the crop rotation system (four phases with five different crops) achieved an average biomass yield of 15.5 t ha^{-1} (± 4.9 t ha^{-1}). Overall, the continuous maize system showed more stable yields across years (Figure 1A). Irrigation increased maize yields by 83 % in two years (2008 and 2015), whereas the increase was below 10% in the rest of them. Regarding the tillage effect, the differences were accentuated towards the later years, with the ploughing treatment achieving higher yields. Under crop rotation, the biomass yields were less stable due to the different crop species involved in the sequence (Figure 1B). Irrigation led to a 151% yield increase in 2015, while the average yield increase in the 2008-2014 period was 8%. Similarly to continuous maize, tillage differences were more patent towards the later experimental years.

4. Discussion

Overall, the diversified cropping system did not outperform the continuous maize in terms of productivity. Nonetheless, the crop rotation system included a perennial mixture, a key element for nutrient loss reduction and SOC accumulation. Irrigation effects on yield were highly variable, thus raising the question of the profitability and amortization times for irrigation infrastructure under the current conditions and cropping systems. While no-tillage slightly reduced crop yields, the reduced costs associated with this management (gas and time, mainly) can potentially offset the yield reduction. Furthermore, no-till benefits can still appear after periods of over 10 years, stressing the importance of such field experiments (Cusser *et al.*, 2020). From the environmental perspective, the evaluation of soil organic carbon concentrations and stock changes over the experimental period will be essential to estimate the carbon sequestration potential of such practices under these pedoclimatic conditions.

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Cover crops and intercropping enable input reduction and maintained yields of subsequent sole crops in an organic arable cropping system (Poster #295)

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Keywords: cereals; crop rotation; diversification; legumes; yield stability

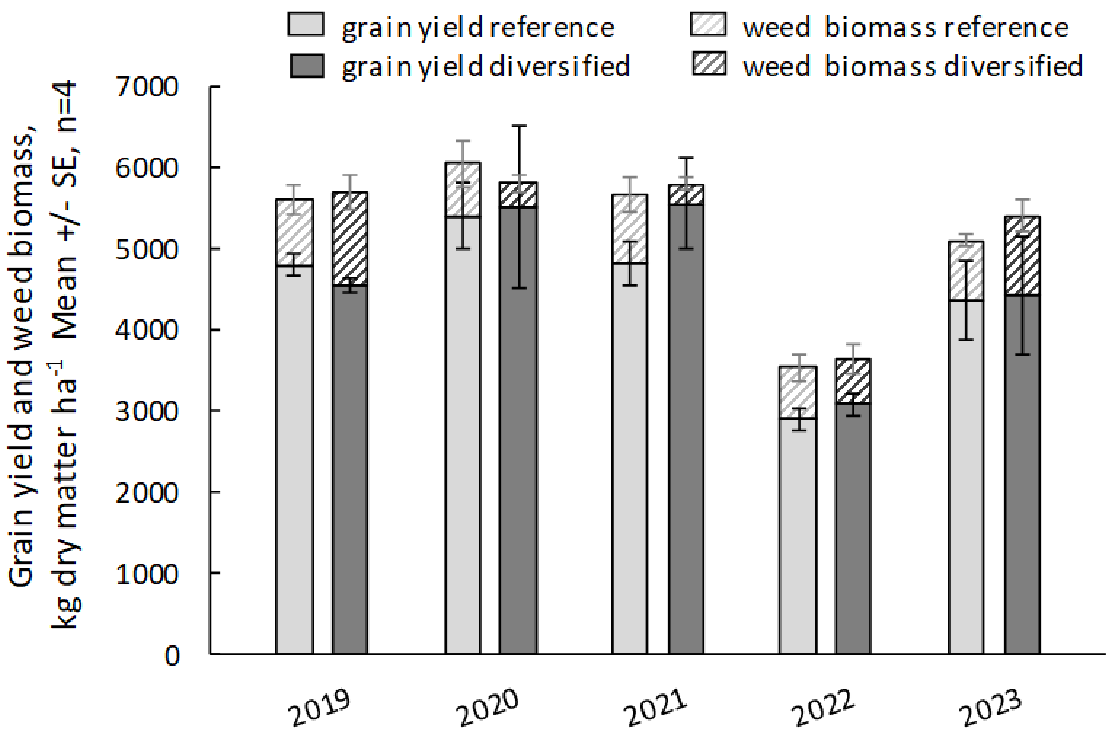

Figure 1. Grain yield (filled bars) and weed biomass (hatched bars) in winter rye in the reference (light grey) and diversified (dark grey) rotations

1. Introduction

Crop diversification in time and space, *e.g.* through crop rotation, intercropping and cover crops, have been shown to promote ecosystem services such as pollination, biological pest control and soil fertility, thereby reducing input dependency and mitigating agriculture's negative environmental impacts (Kremen *et al.* 2012; Tamburini *et al.* 2020). Diversification *via* intercropping and cover crops is typically evaluated based on impacts directly on the studied diversified crops, but less is known about long-term legacy effects of these practices on subsequent crops in the rotation (Rodriguez *et al.* 2021). Little is also known about possible changes in such effects over time. We used a field experiment comprising two organically managed crop rotations to evaluate the effects of cover crops and intercropping in previous crops on grain yields, yield stability and weed abundance in three sole crops that were included in both rotations.

2. Materials and Methods

A crop rotation field experiment was established in 2018 at the Swedish University of Agricultural Sciences (SLU), Alnarp, in southern Sweden (55°39′21″N, 13°03′30″E) on organic land managed by the Swedish Infrastructure for Ecosystem Sciences (SITES) field research station Lönnstorp. The experiment was initiated within the Horizon project DiverIMPACTS (2017-2022; www.diverimpacts.net), and consists of one reference and one diversified crop rotation. Both rotations contain the same six main crops (add-on in the diversified rotation in parentheses): 1. winter oilseed rape (intercropped with frost-sensitive faba bean); 2. winter rye (followed by a buckwheat/lacy phacelia cover crop); 3. oat (intercropped with lupin) undersown with red clover; 4. red clover for seed harvest; 5. winter wheat (followed by a vetch/oilseed radish cover crop); and 6. spring pea (intercropped with spring barley). Each crop was present each year and replicated in four randomized blocks.

In both rotations, all crops except red clover and pea (and the pea/barley intercrop) received organically certified fertilizers, but at lower rates in the diversified rotation where the legumes in intercrops and cover crops were expected to contribute with additional N_2 fixation. In total, crops in the diversified rotation received 33% less N than the reference rotation. To investigate the legacy effects of crop diversification in the crop rotation, we studied differences in grain yields and weed biomass in the three crops that were grown as sole crops in both rotations: winter rye, red clover and winter wheat. We used the coefficient of variation (CV) as an indicator of yield stability over the five years for grain yield of each crop.

3. Results

There were no statistically significant differences in gran yield or weed biomass between the reference and diversified rotations, for any of the studied crops. Although yields differed between years, there was no pattern of increasing or decreasing differences between the two rotations over time (Figure 1 shows the example of rye). The CV was higher in the diversified than in the reference rotation for rye (31 *vs* 23 %) and clover (39 *vs* 29 %) , while the CV differed less in wheat (32 % in diversified *vs* 30 % in reference).

4. Discussion

The lack of differences in grain yields of the sole crops indicates that the crop diversification practices tested here did not create beneficial legacy effects *via* increased soil fertility or reduction of pests and weeds. At the same time, similar yields despite lower fertilization rates (including the studied crop rye, which received less fertilizer in the diversified rotation) confirms the beneficial effects of crop diversification, enabling input reduction without losing yield (Tamburini *et al.* 2021). Yields appeared to vary more in the diversified rotation, indicated by higher CV, which calls for further research to investigate possible causes of increased yield variations in diversified cropping systems.

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Acknowledgement

We acknowledge the SITES Lönnstorp field research station for management of the experiment.

SITES Agroecological Field Experiment – an infrastructure in southern Sweden for cropping systems research in conventional, organic, and perennial agriculture (Poster #354)

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Keywords: agroforestry; intercropping; intermediate wheatgrass; replicated blocks; yield data

Photo: Ryan Davidson, SLU.

Figure 1. Drone image providing an overview of the SAFE plots

1. Introduction

The Swedish Infrastructure for Ecosystem Science (SITES) is a network of nine field research stations across different habitats and climate zones of Sweden (www.fieldsites.se). Lönnstorp field research station at the Swedish University of Agricultural Sciences (SLU) in Alnarp, southern Sweden, is one of two agricultural stations within SITES. Situated in an intensively farmed landscape, this station hosts a unique agricultural research infrastructure: the SITES Agroecological Field Experiment (SAFE), which is available for a wide range of research. The aim of this presentation is to describe SAFE and inspire scientists and stakeholders to consider using this infrastructure.

2. Materials and Methods

SAFE started in 2016, comprising four distinct cropping systems that are replicated in four blocks. It is located at Lönnstorp (Latitude 55.66917, Longitude 13.1027) on land that has been managed conventionally and used for agricultural field experiments since the late 1960s. The soil is described as a sandy loam soil (Barreiro and Albertsson 2022).

1. The reference system – conventional crop production

The reference system contains four common crops in conventional arable crop production in southern Sweden, in the following crop rotation: spring barley, winter oilseed rape, winter wheat, sugar beet. A grass-legume mixture is grown as a cover crop after winter wheat. In each block, all crops are present every year, in four separate plots each measuring 50 x 24 m. The crops are managed with pesticides to control weeds, pests and diseases, and with synthetic fertilizers for optimum yields according to best practices in conventional agriculture in the region.

2. The organic system

This system is based on an eight-year rotation with the following crops: lupin-spring barley intercrop, winter rye, grass-legume ley, sugar beet, pea-spring wheat intercrop, winter oilseed rape, winter wheat, and grass-legume ley. The grass-legume consists of ryegrass, timothy, tall fescue, lucerne, red clover and white clover, and is included twice in the rotation. The system comprises 4 plots per block, which means that each crop is present once every two years, plot size same as in the reference system. The crops are managed according to standards of organic agriculture, with mechanical weed control and applying organic fertilizers to the crops that do not contain any legume.

3. The Agroforestry system – Agroecological intensification

In this system, each block consists of eight 50 x 12 m plots that are separated from each other along their long side by rows (50 x 2 m) of either apple trees (4 rows) or a hedge comprised of a diverse mixture of shrubs and trees (3 rows). In the plots between the apple -or hedgerows, the same crops as in the organic system are grown, and in the same sequence and management, but with the same crop in all plots in a given year.

4. The perennial system

This system is based on a prototype perennial cereal crop – intermediate wheatgrass, also known under its traded name Kernza®. Each block consists of two 50 m x 48 m plots, one with Kernza® sole crop and the other with a Kernza®-lucerne intercrop. The crops are managed with organic practices and harvested once per year. The perennial system is being re-established after termination of all plots in 2023 and sowing a new Kernza® variety as sole and intercrop in the same plots in autumn 2024.

A more detailed description of the four systems is provided in Barreiro and Albertsson (2022).

3. Results and Discussion

Yield data from all crop harvests in all four systems are recorded each year, and made openly available in the SITES data portal. Several studies have made use of the experiment so far (*e.g.* Audu *et al.* 2022; Dimitrova Mårtensson *et al.* 2022; Huddell *et al.* 2023). The presentation will show the yield observations made so far, and outline possibilities to use the experiment for different types of research.

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Diversity of dry manure tea recipes from Tunisian farms and their impact on physicochemical properties (Poster #134)

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Keywords: synthetic fertilizers; plant growth; field survey; statistical analysis; agroecological practices

1. Introduction

Homemade dry manure tea (HMT), a widely used organic fertilizer in North Africa, is considered by local farmers as an affordable alternative to synthetic fertilizers. HMT is used to boost plant growth and health and enhance soil fertility. However, despite its widespread use, HMT remains largely understudied as for its properties and use in North African farming systems. From a survey of agricultural areas in Tunisia, our primary objective was to explore the diversity of HMT recipes utilized by farmers. We aimed to analyze their physicochemical properties and understand the various uses of teas, determining if they are linked to the preparation methods.

2. Methodology

To study this peasant innovation and bridge the existing knowledge gaps, we approached 60 farmers from all regions of Tunisia.

The surveyed farmers have specialized expertise in this technique and have amassed real-production experience over several years. This phase enabled us to delineate various methods of preparing and applying teas, pinpoint technical specifics (like irrigation systems, filtration, container types, *etc.*), and discern their variability based on crop type, soil attributes, available resources, and employed agricultural practices. The data from the interviews on HMT development underwent factorial analysis of mixed data, FAMD, followed by an ascending hierarchical classification (CAH), distinguishing four types of HMT preparation formulas:

• Category 1: Farmers produce HMTs from poultry manure under 2 months old, with a low manure/water ratio.

• Category 2: The employed manure comes from ruminants and is over 12 months old. The tea features a medium manure/water ratio.

• Category 3: The manure comprises a blend of ruminant and poultry manure, aged 2 to 6 months, with a maceration time of 10 to 25 days, and the HMT possesses the highest ratio.

• Category 4: This represents the most intricate recipe relative to the others. It pertains to farmers who engage in aeration and introduce an organic additive to the HMT. The manure's age is 2 to 6 months, maceration is the lengthiest, and the manure/water ratio is elevated.

Following the FAMD, we selected five representative recipes from each category. We evaluated the relevance of each farmer's recipe for our study and the feasibility of future collaboration. Each recipe was replicated thrice in plastic containers, mirroring the conditions utilized by farmers. After 3 days of maceration (T3), specimens were procured and dispatched to the laboratory. This period aligns with the minimum maceration adopted by some farmers for archetype recipes. At this juncture, three evaluations of each subsequent parameter were executed: pH, electrical conductivity, chloride, organic nitrogen, ammonium, nitrates, total phosphorus, orthophosphate, potassium, calcium, magnesium, and sodium. To trace the evolution of macro-elements and secondary nutrients during maceration, identical analyses were reiterated at the end of the maceration duration (Tf), complemented by measurements on suspended matter, Escherichia coli, iron, manganese, and silicon.

3. Results and Implications

The chemical properties of HMT were strongly influenced by various factors such as the source of manure, aeration, additives, and maceration duration. Our analysis revealed four main recipe categories, characterized by the type of manure, manure-to-water ratio, maceration duration, and other parameters.

The first category is found in the center of the country where we met farmers who sell poultry tea and others who buy it. The second category is mainly found in the center of Tunisia. The third class is somewhat scattered. 50% of the surveys of the 4th class are found in the South. Farmers in this region are more motivated and interested in their oases and believe that the teas improve the fertility of their soils and the quality of their dates.

Our results highlight significant variability in the physicochemical properties among HMT recipes. The physicochemical properties of HMT in categories 1 and 2 were relatively similar from one recipe to another, indicating low variability in physicochemical composition within these categories. In contrast, recipes in categories 3 and 4 were more complex, with varying maceration durations, aeration, and the addition of additives. Some recipes, prepared over extended maceration periods, are richer in nutrients, confirming the farmers' observations. Also, the age of the manure used for making the teas influences the physicochemical characteristics of the teas. The more mature and well-decomposed the manure, the higher its nutrient concentration.

Update for yield-based BNF estimation and belowground contribution of faba bean (Poster #152)

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Keywords: N_2 fixation; legumes; pulses; cropping systems; crop rotation

1. Introduction

Grain legumes (pulses) are interesting parts in sustainable crop rotations due to their ability of biologic nitrogen fixation (BNF). Among them, faba bean has a huge potential to derive nitrogen (N) from the atmosphere (Walley *et al.* 2007; Liu *et al.* 2019; Palmero *et al.* 2022). However, empirical results suggest that they are mostly N self-sufficient when balancing only the aboveground contribution. Throughout the literature there are often cited estimations of large additional N contribution from the belowground part (belowground factor ~1.4). This mostly switches the N balance of faba bean from negative/neutral to surplus in contrast to only accounting the aboveground part, with consequences for the evaluation of rotational effects and/or risk of losses. We critically revised this popular belowground factor and derived an updated yield-based BNF estimation for faba bean.

2. Materials and Methods

Two datasets were compiled from previously published literature between 1966 and 2023: (1) for assessing the relation of belowground N to total plant N from 42 values reported in 14 primary studies (field and greenhouse experiments) and (2) for assessing the relationship between seed yield and BNF from >300 values reported in 51 primary studies. From this comprehensive data we derived a new belowground factor) and an estimation of seed yield based BNF (aboveground only as well as total including belowground contribution). As a case study this newly derived functions were used to calculate N fixation and N balances from German national statistics data in comparison to the legal framework (German ordinance on nutrient-flow balances, StoffBilV 2017).

3. Results and Discussion

A critical review of the commonly used belowground factor (1.4) based on our empirical relation between belowground and aboveground N in faba bean plant material reveals a previous overestimation and leads to a smaller factor of 1.15. Applying this new belowground factor together with our comprehensive dataset 2 we found a mean N fixation of 49 kg per Mg faba been seed yield. In terms of N balances, a minimum fixation of 135 kg (2.76 Mg dry matter seed yield) is needed to reach a surplus. Compared to previously derived functional relationships, this assessment is much lower than other results including belowground contributions (Unkovich *et al.* 2010; Anglade *et al.* 2015; Palmero *et al.* 2022). Compared to the legal framework our functional relation results in 15% lower estimations of N fixation and 50% lower N balances from faba bean cultivation across Germany (1999-2023). This leads to a considerable different valuation of faba bean pre-crop and rotational effects in European cropping systems.

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Identification of metabolic markers of potassium sources utilisation in oil palm (Poster #11)

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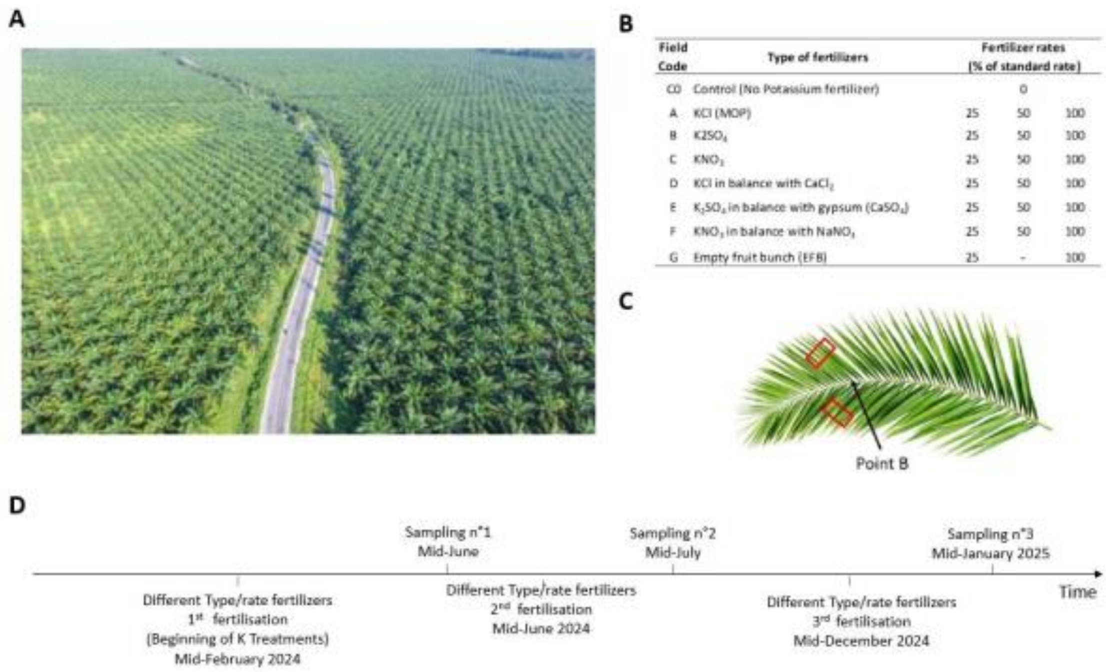
Keywords: potassium; deficiency; oil palm; metabolomics



Field Code	Type of fertilizers	Fertilizer rates (% of standard rate)		
C0	Control (No Potassium fertilizer)		0	
A	KCl (MOP)	25	50	100
B	K2SO$_4$	25	50	100
C	KNO_3	25	50	100
D	KCl in balance with $CaCl_2$	25	50	100
E	K_2SO_4 in balance with gypsum ($CaSO_4$)	25	50	100
F	KNO_3 in balance with $NaNO_3$	25	50	100
G	Empty fruit bunch (EFB)	25	-	100

Figure 1. The study design. (a) Aerial view of oil palm trees in North Sumatra (Novethic 2018). (b) Table of the different potassium 'K' sources and rates used in our study. (c) Picture of an oil palm leaf showing the sampling location (red rectangles) at point B of the leaf. (d) Timeline showing the treatments and sampling periods in our study

1. Introduction

Oil palm (*Elaeis guineensis* Jacq.) stands as the leading global oil-producing crop, representing a production of approximately 75 Mt y^{-1} (FAOSTAT). However, the present challenge of oil palm cultivation is to meet global food demands while respecting the environment. To achieve this, it is crucial to control the use of fertilizers, in particular potassium (K). Potassium is the most critical nutrient in palm oil production since oil palm growth and yield are highly dependent on K fertilization [1,2]. In fact, oil palm is a highly K-demanding species, not only due to nutrient requirements for bunch production but also because it is typically cultivated in naturally K-deficient regions. Additionally, substantial amounts of K are removed during fruit bunch harvesting, leading to a loss of up to 75% of the K fertilization input [2]. As a result, heavy K fertilization is employed, costing about $1 billion globally.

Quite understandably, intense efforts have been devoted to enhancing fertilization strategies and exploring precision agriculture to accurately monitor K needs.

Presently, K fertilization decisions are based on leaflet K content using the LD (leaf diagnosis) method [3], but its technical limitations have led to a search for better monitoring methods. Metabolomics and machine learning of metabolic signatures emerge as promising tools, opening avenues for precision agriculture in oil palm industry. Our recent studies utilizing potassium chloride (KCl) as a potassium source reveal metabolic traits linked to K availability [1,4,5]. However, monitoring K fertilization stays challenging due to its interdependence on other nutrients [6].

Here, we are conducting an analysis of leaf metabolism coupled to elemental analyses, using oil palm trees of two commercial varieties, Eka1 and Eka2, grown in the field in North Sumatra (Indonesia). Our specific objective is to apply different K sources with varied concentrations to explore metabolic markers and study nutrient interactions related to different K sources, which will allow us to monitor K fertilization with higher accuracy. Also, it will allow us to assess the robustness of metabolic traits associated with K availability.

2. Materials and Methods

The field is located at the SMARTRI station (North Sumatra, Indonesia) and sampling will be carried out in June 2024 and January 2025. Overall, 126 oil palm trees will be studied. They belong to two varieties: Eka1 and Eka2. Eka1 and Eka2 have been chosen here since they are two very common varieties used in oil palm agroforestry. Oil palm trees will be subjected to four levels of potassium fertilization with 7 K sources applied proportionally with growth (Figure 1. B, D). Leaflets will be used for analyses and sampled at B point (Figure 1. C).

Gas chromatography coupled to mass spectrometry (GC–MS) analyses will be carried out as in [1]. 1H-NMR analysis will be performed on a Bruker Advance 600 MHz spectrometer. Mineral content analysis will be done as well. Then multivariate analysis of metabolomics data will be carried out.

3. Results and Discussion

The study aims to explore the metabolomic response of palm trees to various potassium sources and examine the antagonistic and synergistic effects between nutrients. Additionally, it seeks to evaluate how different potassium (K) sources influence the precision of leaf potassium status assessment. Furthermore, we aim to identify potential metabolomic markers that could serve as universal indicators of potassium levels, with the ultimate goal of optimizing LD technique or substituting it with more efficient metabolic tools.

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Assessing the carbon footprint of wine production in Germany to identify additional climate change mitigation potentials in viticulture (Poster #287)

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Keywords: LCA; wine; greenhouse gas emissions; climate change mitigation; LCIA

1. Introduction

The agricultural sector is responsible for approximately 10-12 % of the anthropogenic greenhouse gas (GHG) emissions and hence, contributes substantially to climate change. On global scale, the wine value chain emits about 0.3 % to anthropogenic GHG emissions (Rugani *et al.*, 2013). In countries with increased wine production and consumption, these rates might be even higher (Amienyo *et al.*, 2014). Despite the fact that vineyards account for 0.6 % of Germany's total agricultural area, Germany as one of the top-ten global wine producers and top-five countries in wine consumption offers significant lever for GHG mitigation in the wine sector. So far, little is known about the climate change mitigation potentials of the German wine sector. Hence, this study aims to assess the status-quo of GHG emissions of German wine production and identify opportunities for additional GHG reduction and climate change mitigation.

2. Materials and Methods

Therefore, we collected explicit production and corporate data for the fiscal year 2022 from 100 wineries, using a quantitative questionnaire through face-to-face online and in-person interviews. The data encompassed all information relevant to comprehensively quantify any material and energy flows in the farm-specific production system. The Life Cycle Assessment (LCA) under the ISO 14040 guidelines was chosen as the methodology for the environmental evaluation of wine production. The scope of the LCA was “cradle to gate,” encompassing the production processes of the establishment of the trellis system, grape production, vinification, and bottling. The functional units of the LCA were defined as one kilogram of grapes, one litre of wine, and one bottle of wine. For the creation of the Life Cycle Inventory (LCI), the ecoinvent database v. 3.9.1 allocation cut-off was utilized as a data basis, with impact scores calculated using the CML v4.8 2016 Life Cycle Impact Assessment (LCIA) method. In total, eleven impact categories were considered including climate change, acidification, freshwater ecotoxicity, marine ecotoxicity, terrestrial ecotoxicity, non-renewable energy resources, eutrophication, human toxicity, metal/minerals resources, ozone depletion, and photochemical oxidant formation. While the focus is on GHG emissions, the inclusion of further impact categories allows for a more extensive evaluation of the environmental impact of German wine production. For the LCA calculations, and statistical analysis, the software R was used.

3. Results

In the grape production phase, including the establishment of the trellis system, of the wine value chain, diesel consumption and the trellis system have the largest impact on GHG emissions. An important factor in diesel consumption are various management measures in vineyards conducted with machinery, where we find a substantial variability between wineries regarding the number of measures and respective tractor rides. Furthermore, for the establishment of the trellis system, the materials used cause significant differences. The use of non-impregnated hardwood poles and bamboo rods for the young vines reduces the environmental impact of the trellis system distinctly in comparison to alternative materials from impregnated wood and zinc-coated steel. During the vinification phase, energy usage is often responsible for GHG emissions. However, there are distinct differences between wineries caused by vinification methods that require high energy. Nevertheless, the overall highest impact factor on most impact categories is the wine bottle.

4. Discussion and Recommendations

At the establishment of the vineyard, the selection of material is important for the reduction of GHG emissions in grape production. The utilization of impregnated wood poles should be avoided because they have a short durability and a high impact due to the impregnation. In the grape production phase, the possibility exists that a reduction of emissions could be achieved by avoiding non-essential management measures on the vineyards with machinery. During vinification, high-energy methods like mash heating should be circumvented, if possible. Furthermore, traditional passive wine cellar cooling has advantages in terms of emissions compared to active cooling. Finally, a sector-wide adoption of a reusable bottle system could potentially reduce the emissions caused by the wine bottle.

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Legume residue recovery and rhizodeposition: an underestimated source of soil nitrogen (Poster #69)

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Keywords: legumes; nitrogen balance; residues recovery; rhizodeposition

In this study, we evaluated the impact of three nitrogen (N) balance calculation methods on N surplus in a five-crop rotation. A complex but precise N balance calculation method revealed a more realistic assessment of legume contribution in crop rotations, considering N surplus, cumulative surplus, and efficiency of N inputs. This method highlighted the significant role of red clover as a green manure on the N surplus of subsequent winter wheat crops in both conventional and organic cropping systems. Notably, an additional mineral fertilizer rate of 150 kg N ha^{-1} led to a complete transformation into N surplus, suggesting its use is unreasonable.

For crop rotation modeling, it's recommended to use a N balance considering all N inputs and outputs. When factoring in crop residue return and rhizodeposition, the advanced N balance surplus increased by 201%, 187%, and 268% in the conventional N100, N150, and Organic systems, respectively, compared to the simplified N balance.

Soil health indicators in Technosols vegetated with Atlantic grassland species (Poster #36)

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Keywords: circular economy; microbial respiration; organic nitrogen; Gijón Ecoresiliente; soil amendments

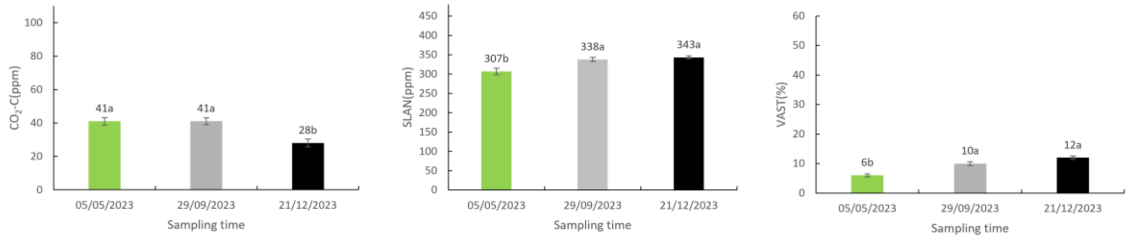

Figure 1. Mean values of CO_2-C, SLAN and VAST at three sampling times (± SE). Bars with different letters (a>b) indicate significant differences at $p < 0.05$ (Tukey's test)

1. Introduction

Recovery of environments altered by human activities can be hampered by the lack of stockpiled soils, which are required for restoration work and planting. However, large amounts of by-products are produced during the treatment of solid urban waste and construction and demolition waste. Many of these secondary products can be recycled to create Technosols. Soil health management is one of the most effective methods for the sustainable maintenance of productive soils. Typical soil fertility analyses often do not include physical or biological soil indicators that could provide insights into soil health, help explain problems related to crop growth and reduce the need to use synthetic fertilisers and plant protection products (Oliveira *et al.*, 2020). The aim of this research was to evaluate three soil health indicators in six types of Technosols sown with diverse Atlantic grassland species.

2. Materials and Methods

Six different Technosols were created by mixing Recysoil (made with sewage sludge compost and fine aggregates obtained from recycling construction waste) (70%) and stockpiled soil (TA) (28%) with 2% by volume of different organic amendments. The following six Technosols were created: T1=Recysoil+TA; T2=Recysoil+TA+Biochar; T3= Recysoil+TA+Sludge hydrochar; T4= Recysoil+TA+Hydrochar organic fraction; T5= Recysoil+TA+Hydrochar paper-cardboard; and T6= Recysoil+TA+Worm humus.

The experimental design was completely randomised, with 6 treatments (Technosols) replicated 3 times. The Technosol plots (3 m x 4 m) were established between 15/3/2023 and 4/4/2023. The plots were then left for a period of 1 month to allow stabilisation of the organic material.

On 4/5/2023 the plots were sown with diverse (37 species) Atlantic grassland seeds (6 g/m^2).

Soil sampling (upper 20 cm layer) was carried out at three different times (on 5/5/2023, 29/9/2023 and 21/12/2023) in each plot.

The following soil health indicators were analysed, in two replicates of the soils sampled at the three different times: soil microbial respiration (CO_2-C, ppm), potentially mineralizable organic nitrogen (SLAN, ppm) and stability of soil aggregates to water (VAST, %) (Solvita Kit, Woods End Laboratories Inc., Mt. Vernon, ME, USA).

An analysis of the variance (ANOVA) was performed to check the effects of Technosols and sampling time.

3. Results

The Technosols were characterized by neutral pH and high contents of organic matter and main nutrients.

There were no statistically significant differences between the Technosols in regard to the three soil health indicators assessed but there were differences between sampling dates (Figure 1).

The values obtained for microbial respiration were intermediate decreasing between first and third sampling time, potentially mineralizable nitrogen was intermediate-high increasing between first and third sampling (Brinton, 2019a, 2019b) and aggregate stability to water was low although it increased between the first and the third sampling (Brinton, 2016).

4. Discussion

The lack of significant differences between the Technosols may be due to the short time since establishment, so that the microorganisms had not yet been able to mineralize the organic matter present in the Technosols and form stable aggregates. Three soil health indicators will continue to be monitored every 2-3 months, until the end of the project (at the end of June 2025), to enable calculation of an overall health and fertility index for each Technosol.

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Acknowledgements

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Weed response to long-term cultivation practices (Poster #48)

Jan Winkler

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Keywords: weed vegetation; spring barley; long-term trials; tillage; straw management

1. Introduction

Long-term field trials are a unique scientific tool that can be used to study changes in the weed species spectrum under different management practices over time.

2. Materials and Methods

The long-term field trial was located at the Žabčice Experimental Station (South Moravia Region, Czech Republic). The field trial was established in 1970 and was designed as a long-term monoculture of spring barley with different management practices. Two variants of basic tillage and three variants of straw management were used in the experiment. The tillage variants were (i) traditional tillage: basal tillage is done by plowing to a depth of 0.22 m, pre-sowing preparation and seeding, (ii) minimization tillage: basal tillage is done by disk tillage to a depth of 0.12 m, pre-sowing preparation and seeding. Straw management options: (a) straw is harvested and transported after harvest, (b) straw is left in place and incorporated into the soil after harvest, (c) straw is burned after harvest.

The weed assessment was carried out using the counting method. Monitoring was carried out between 2001 and 2018. The time of evaluation was always the same stage of spring barley and before herbicide application. Statistical processing of the data was done by correspondence analysis (CCA).

3. Results

A total of 49 weed species were found during the monitoring period. Based on the weed response, the agricultural practices can be divided into three groups. The first group is traditional practices involving plowing (traditional tillage), harvesting and straw removal, which are technologies that have been used for a long time. The first group is more suitable for typical, less damaging weed species (*e.g. Amaranthus* spp., *Anagallis arvensis*, *Echinochloa crus-galli*, *Lamium purpureum*, *Microrrhinum minus*, *Papaver rhoeas*, *Persicaria lapathifolia*, *Persicaria maculosa*, *Polygonum aviculare*, *Silene noctiflora*, *Veronica persica*, *Veronica polita nebo Viola arvensis*).

The second group consists of minimum tillage practices and straw incorporation. These practices have been newly applied in recent decades. Each of these groups of management practices induces a different weed response. The second group creates more favorable conditions for the occurrence of difficult to control and atypical weed species (*e.g. Avena fatua*, *Consolida orientalis*, *Convolvulus arvensis*, *Datura stramonium*, *Elytrigia repens*, *Fallopia convolvulus a Galium aparine*).

The third group consists of the straw burning variant, which is purely experimental and cannot be applied in practice on large areas for legal reasons. The third group, represented by straw burning, seems to be the most effective method of weed control. Higher abundance of *e.g. Cirsium arvense*, *Fumaria officinalis*, *Lamium amplexicaule*, *Sinapis arvensis a Stellaria media*.

4. Discussion

Several studies have shown that management practices can be combined and work synergistically to reduce weeds. Using a combination of management practices to control weeds provides some protection against potential herbicide failure. This makes control more effective under changing environmental conditions. Straw management and tillage affect the soil environment (nutrient dynamics, C:N ratio, physical properties, light conditions, *etc.*), which also affects weeds. Straw and post-harvest residues can have an allelopathic effect on the germination of some weed species.

In the future, we can expect a change in the species composition of weeds even in spring barley stands. The occurrence of typical species such as *Avena fatua*, *Fallopia convolvulus* will probably decrease and, on the contrary, the occurrence of invasive species (*Echinochloa crus-galli* or *Amaranthus* spp.) will increase. The established weed community in spring barley monocultures consists mainly of native and domesticated species (apophytes and archaeophytes). Barley stands, regardless of the cultivation methods used, do not allow the spread of new invasive weeds. However, even here there are changes in the species composition of weeds caused, among other things, by climate change.

Matching decision to environmental triggers increases crop intensity and reduces risk in variable climates (Poster #123)

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Keywords: farming systems; decision support; simulation modelling; subtropical agriculture

1. Introduction

The decision of when and what to plant in a particular field is the decision that faces all farmers. For farmers in regions with variable climates and both summer and winter sowing options, such as the subtropical grains regions of eastern Australia, planting the wrong crop at the wrong time can have severe economic consequences (Angus *et al.*, 1980; Whish *et al.*, 2007), but more importantly influence future economic returns and systems decisions. The final decision on the choice and position of crops in a sequence is tempered by the environment, the personal preferences of the farmer, their risk profile, historic herbicide decisions, existing weed, disease and pathogen burdens, current markets, and prices. However, in variable climates, that rely on stored soil water, a rotation requires specific phases to refill soil water reserves, these phases are referred to as fallows.

Despite the acknowledged benefits of the fallows, they are also an area of inefficiency, but their removal has the potential to intensify a rotation and improve profit. Previous studies have examined the pareto-optimal trade-offs within these grain systems and showed summer cropping, and an increase in cropping intensity was needed to achieve higher gross margins (deVoil *et al.*, 2006; Hochman *et al.*, 2020), but this in turn significantly increased financial risk of unprofitable crops. The aim of this paper was to identify key criteria within the system that facilitated the inclusion of opportunity crops to maintain system profitability while minimising the risk of unprofitable crops within the rotation.

2. Methods

Using historic simulations, the probabilistic relationship between initial soil water and final yield was assessed. Using this knowledge a range of simple rules were developed to identify the circumstances when intensifying a sequence had the best chance of success. These rules were then implemented within the Agricultural Production Simulation Model (APSiM) (Holzworth *et al.*, 2018) and used to compare against current rotational strategies practiced in the region.

3. Results

Strategically intensifying the rotation by relating current soil water conditions to historic yield probabilities, maintained high gross margin returns while reducing the risk of unprofitable crops.

4. Discussion

The use of rules was successful; however, they are specific to each environment. The more variable the environment the more valuable the rules. The use of the rules was not always positive, all environments, demonstrated losses caused by the rigidity of the rules, with crops not sown when an opportunity to sow arose just after the rules time frame. However, these losses were easily offset by the reduction in the number of unprofitable crops. Not all decisions have an immediate economic value. On occasions, especially during or after drought, there can be a benefit in planting a cereal crop even when its chance of being profitable is low. This is because systems that rely on the capture of water, need to protect the soil surface to improve infiltration and reduce erosion (Freebairn *et al.*, 1986). These rules do not capture this, but they provided a framework for grain growers to discuss the benefits and costs of their decisions.

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Agro-industrial waste as phosphorus source in a crop rotation (Poster #350)

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Keywords: phosphorus; crop rotation; organic fertilizers

1. Introduction

Phosphorus (P) is an essential element for plant nutrition. The current fertilization strategies rely on mineral fertilizers, obtained from non-renewable and finite resources, whose production will peak in the coming decades. In a scenario of world population growth, reducing dependence on mineral fertilizers while maintaining/increasing agricultural productivity is essential. To this end, fertilizers strategies should involve P recycling by using agricultural residues. The aim of the work is to evaluate the efficiency of different agricultural residues as P fertilizers in a rainfed crop rotation cycle representative of Mediterranean regions: wheat-sunflower-pea.

2. Materials and Methods

Two experiments under field conditions were carried out in south Spain for 3 years involving as treatments: composted olive oil mill, horse manure vermicompost, and mineral P fertilizer which were applied at 30 kg P ha^{-1}, and a control without fertilizer. The same rates of potassium and nitrogen were applied to all the treatments. Phosphorus fertilizer was applied before sowing only to the first crop (wheat).

3. Results and Discussion

Fertilization with composted agricultural residues was effective as P source for crops. In the first experiment, the highest grain yield of wheat was obtained with olive oil mill compost However, in the second crop of the rotation (sunflower), the horse manure vermicompost showed a significant increase (41%) relative to mineral fertilizer and non-fertilized control. In the second experiment, vegetable waste vermicompost led the highest grain yield of wheat. Phosphorus uptake by pea in the first experiment was increased significantly with olive oil mill and vegetable waste vermicompost (mean value of 11.1 kg ha^{-1}) compared to mineral fertilization and non-fertilized control. Olsen P in soil amended with organic P sources maintain their value of 7.2 mg kg^{-1}, slightly higher than control without fertilization at the end of both crop rotations. However, mineral fertilization led to the highest Olsen P values in soil, which however decreased over time more quickly than organic fertilizers. It can be concluded that the composted agricultural residues studied can be used as effective P sources for crops, and thus may contribute to decrease the dependence on mineral P in agriculture and consequently to the sustainability of agricultural systems.

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Towards a tool to support the design of plant protection solutions in the context of fruit growing (Poster #241)

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Keywords: orchards; multiple pests; pest management; modelling; multi-criteria decision-making.

Reducing the use of chemical products requires sustainable control of plant pests based on a number of alternative control levers *e.g.* cultural practices, planned biodiversity, biopesticides, physical barriers, *etc.* However, these alternative levers have only partial efficacities. Consequently, it is necessary to combine several complementary alternative methods to reduce pesticides and to maintain an effective crop protection. Moreover, the changing societal and industrial expectations are pushing to consider the impacts of agro-ecosystems on the environment, social equity and human health aside of their agronomic and economic performances. Stakeholders in the ecological transition have contrasting preferences and need information tailored to their points of view in order to assess strategies. To evolve production methods towards systems based on pesticide-saving while ensuring sufficient production in terms of quantity and quality, it is necessary to adopt an integrated approach that considers multiple performances and multiple stakeholders. A combination of qualitative knowledge and quantitative data and models is crucial for this purpose.

Thus, the ODACE project (2021-2024), funded by the Ecophyto 2+ programme, aims to support stakeholders as they consider strategies for reducing the use of chemical pesticides in orchards. This requires a better understanding of pest-crop interactions and how they can be managed through practices and planned biodiversity. Using a modelling approach, the project proposes to develop an ergonomic and interactive tool to support users (advisors, network leaders, trainers and learners) to design production strategies incorporating alternatives to pesticides, within existing or new frameworks.

Our approach is based on the coupling of fruit pests-crop and multiple pests' injuries mitigation models to predict the multiple performances of several alternative levers to chemical pesticides. First, we developed a pests-crop model accounting for ten major apple pests belonging to seven functional groups to assess the effect of multiple pests on orchard ecosystem services (Lacroix *et al.*, 2024). This model is an upgrading of QualiTree, a quantitative tree-soil crop model able to predict 9 ecosystem service indicators related to fruit production (quantity and quality), climate regulation, soil fertility and the water cycle. Then, we used the Injury Profile SIMulator (IPSIM), a qualitative aggregative hierarchical model, to predict crop injury profile of each considered pest in terms of cultural practices, and the abiotic and biotic environment. Thus, we developed multiple pests' injuries mitigation models. The outputs of those models are used as inputs by pests-crop model. We considered several stakeholder's profiles (conventional, organic, pesticide-free) in different production situations in France, with contrasting preferences. We used numerical analysis techniques allowing the exploration of the coupled models in order to identify suitable scenarios (combinations of control levers) for each stakeholder profile. Finally, multi-criteria decision support and clustering methods were used to select a small number of scenarios suited to the user's context and preferences.

The final goal of our tool is to provide the stakeholders with new scenarios that increase the ecosystemic services and do not decrease the economic outcomes. The candidate scenarios obtained will illustrate the co-design approach and open up prospects for the agro-ecological transition.

Varietal resistance as an IPM tool for Scottish barley crops (Poster #322)

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Keywords: IPM; barley; resistance; Rhynchosporium

1. Introduction

Rhynchosporium leaf scorch (causal agent *Rhynchosporium graminicola*) is a devasting disease of barley. To control the diseases, fungicides are used heavily to maintain grain yield and quality. To prevent the overuse and unnecessary application of pesticides, farmers are being encouraged to adopt Integrated Pest Management (IPM) strategies that combines a range of management options to manage diseases. However, adoption of these strategies requires reliable information on the contribution of varietal resistance for plant disease management. Selecting varieties based on their disease resistance rating has long been regarded as a cornerstone of IPM. However, for growers to be able to use varietal resistance as a means of reducing fungicide inputs they must be know when and how to do so and be confident in their decision-making ability.

Environmental conditions, such as temperature and rainfall, can alter the relationship between pathogen and host and hence affect disease levels, which can influence the efficacy of pest management tools and techniques. Unless the grower is confident that combining chemical and non-chemical management techniques will reduce the fungicide requirement and protect the yield for that crop, then pesticide usage practices are unlikely to change. This study examined the effectiveness of variety resistance in the management of barley leaf scorch across years and sites in the UK.

2. Materials and Methods

Three field trials were sown in each of three years in Scotland and Northern Ireland, providing a total of nine winter barley trials. Nine varieties were sown and grouped according to their resistance rating for Rhynchosporium on a 1-9 scale (1=highly susceptible and 9=highly resistant). The crops were treated with fungicide to control the powdery mildew (*Blumeria graminis*) and Ramularia leaf spot (*Ramularia collo-cygni*). Routine treatments of fertiliser, herbicides and insecticides were applied over the whole trial site. The trials were assessed for disease levels at several crop growth stages during the growing season. At harvest, grain yields for individual plots were measured and recorded. As there were no weather stations at the three sites, the seasonal precipitation and average daily temperature data for the local region were obtained from the UK Met Office.

For the statistical analysis, the treatment means for the early-season and mid-season disease scores, and yield were calculated from the plot level data. The impact of weather on the disease was analysed using the beta regression, and therefore the percentages were transformed to proportions for the analysis. To assess the effect of resistance rating on the mid-season disease score and the yield, the difference in disease between varieties with resistance rating 8 averaged across all treatments, and the other resistance ratings were calculated.

3. Results

The regression analysis (pseudo R^2 = 0.75) identified that the interaction of the resistance rating with both the cumulative rainfall for the previous autumn, winter and spring, and the winter temperature had a significant impact on early disease levels, which is before the most important foliar fungicidal spray (applied at stem extension) for Rhynchosporium control. The level of disease was increased by elevated winter temperature and total rainfall. In addition, higher spring temperatures reduced disease levels while increased autumn temperature increased disease levels. Similar patterns for environmental influence on disease were observed for the mid-season disease assessment. The effect of these environmental factors on visually observable Rhynchosporium symptoms was moderated by the varietal resistance rating with the trend showing fewer disease symptoms in varieties with higher resistance ratings. Varieties with higher resistance ratings also displayed less variation in disease symptom expression between years.

4. Discussion

Through examination of the various environmental factors that influence Rhynchosporium disease levels in Scotland and Northern Ireland we have identified the conditions in which the benefits of growing highly resistant varieties are likely to be achieved. Such information will allow growers to make more informed decisions regarding varietal choice and pesticide usage in their winter barley crops. This work highlights the importance of early disease surveillance to identify crops at risk.

Legacy effect on a spring barley crop established the year after the cultivation of different grain legumes grown as either sole crops or as intercrops with spring barley (Poster #328)

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Keywords: grain legume; intercrop; legacy effect; spring barley; yield

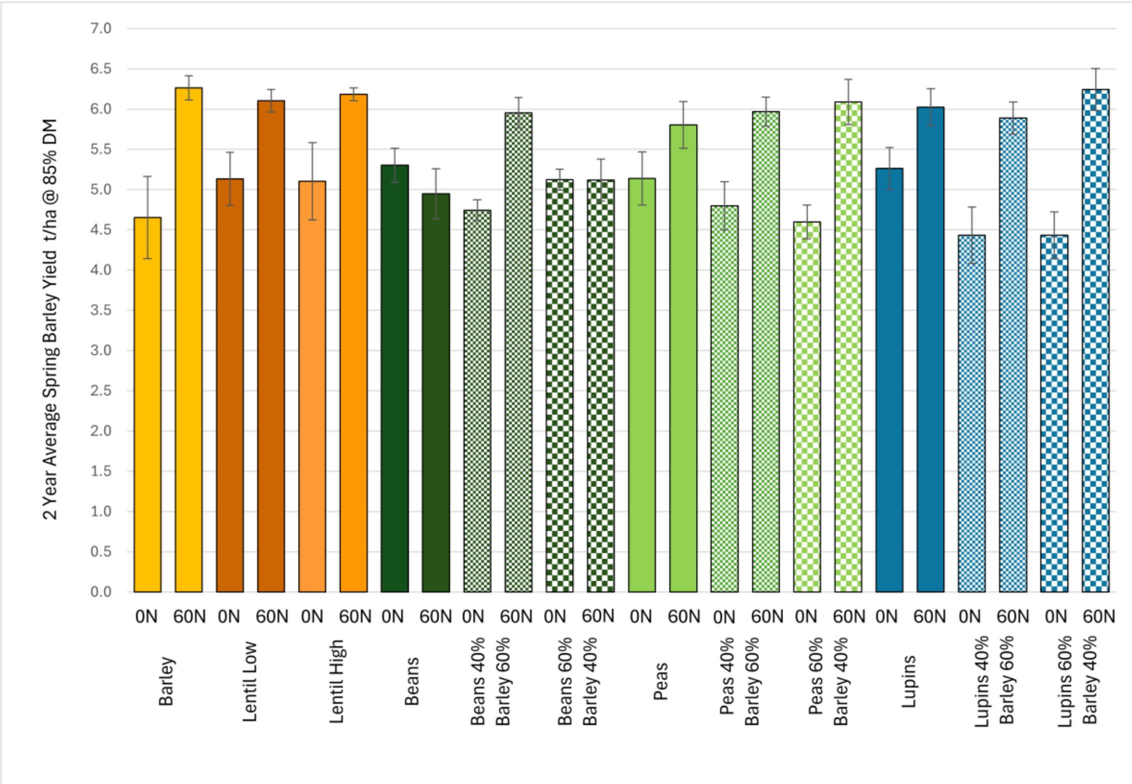

Figure 1. Average yield of two spring barley crops grown in consecutive years (2020 & 2021) after the same pre-crop treatments, including a spring barley sole crop, and grain legumes grown as sole crops or as intercrops with spring barley. These were grown with zero N, or with an application of 60 kg N/ha. Error bars represent standard error of the mean (n=4)

1. Introduction

The use of intercrops has started to gain interest amongst farmers, particularly those practicing organic or agroecological principles, as this approach is known to help maintain crop yields under reduced input conditions through improved resource use efficiency and can help limit yield variation across seasons associated with unusual weather patterns. Some national Governments are also starting to become aware of the use of intercrops, particularly those Governments with policies striving to achieve Net Zero at some point in the future. Much of the research on intercrops to date has focussed on the season the intercrops are grown, but legacy effects on soil and following crops in the rotation are less well known (Pappa *et al.* 2012). This paper focuses on some of these legacy effects based on the growth of a spring barley crop cultivated on the same plots used to grow a range of grain legumes as either sole crops, or in a mixture (intercrop) with spring barley the previous year.

2. Materials and Methods

A range of grain legumes were established in both 2019 and 2020 in Aberdeenshire, Scotland (UK) in replicated small plot (1.5m x 12m) field trials. The same crops and seed ratio treatments were used in each year and the soil was a sandy loam with moderate P and K indices and a pH of around 6.0. Crops included spring barley (var. Westminster) as a control treatment, as well as green lentil (var. Anicia) at 2 densities (both with a spring oat supporting crop sown at 20kg/ha), field beans (var. Fuego) as either a sole crop, or as an intercrop with spring barley in a 40:60 or 60:40 ratio of the recommended seed rate for each crop species. Similar sole crop and intercrop ratios (with barley) were also used for peas (var. Zero 4) and lupins (var. Iris). In 2020 and 2021, *i.e.* the years following the sole crop and intercrop cultivation, the pre-crop effect of those treatments were evaluated by superimposing a spring barley crop onto the same plots and taking this through to harvest with a small plot combine. At establishment, half of each plot (5m x 1.5m) received no N fertiliser and the other half received 60kg N/ha. P and K were applied across the whole trial area at recommended rate. A range of assessments and measurements were taken, but the focus here is on the combine yield of the follow-on spring barley crops, particularly the average yield across both years to indicate consistency of performance across seasons (Figure 1).

3. Results and Discussion

In almost all cases, the addition of 60 kg N/ha resulted in a significant elevation in yield compared to the same pre-crop with no N applied and generally had lower variability (smaller error bars). ANOVA performed on the spring barley averages from both years for the Zero N treatments indicate significant yield increases ($P \leq 0.001$) compared to the barley pre-crop control, with least significant difference (LSD) indicating any yield above 5t/ha was statistically greater than the control. The lentils, sole crop beans and beans intercropped at the higher ratio, sole crop peas and sole crop lupins all achieved an improved legacy yield. The other pre-crop treatments showed no yield increase but may have provided other benefits not highlighted in this paper.

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Developing a robust model for Ramularia leaf spot prediction in barley crops (Poster #331)

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Keywords: barley; disease; risk forecast; IPM; yield loss

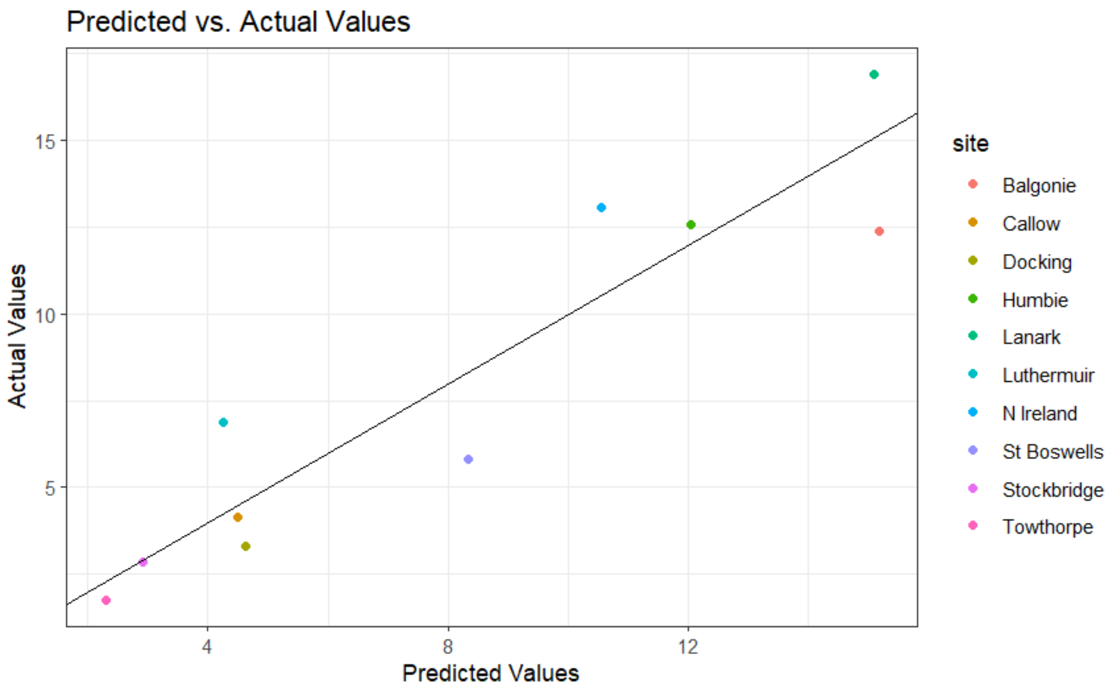

Figure 1. Prediction model for UK sites (2017) based on rainfall (p=0.0008)

1. Introduction

Ramularia leaf spot (RLS) is a major economic pathogen for barley crops across many temperate regions. Symptoms appear late in the growing season, usually after flowering has taken place. (Havis *et al.*, 2015) The disease reduces grain yield and quality, primarily through the reduction in late season photosynthetic area. There are no resistant varieties available to barley growers, so control relies on the use of fungicides. The last permitted application date for most fungicides is before flowering and therefore before symptoms have appeared in the crop *i.e.* a prophylactic spray. As more countries move to a system of Integrated Crop management with only timely and justified fungicide sprays applied there is a pressing demand to quantify the risk of RLS in a crop at a time point at which control options are still available.

Previous studies have demonstrated that RLS severity in crops is influenced strongly be environmental variables. Radiation levels and rainfall after ear emergence and flowering have been shown to increase disease symptoms in crops but the time point is too late for management interventions. Research in Norway suggested a relationship may exist between relative humidity in the crop at the start of stem extension and final disease severity and other studies have looked at the role of leaf wetness at stem extension but none of these studies produced a robust model that growers could use (Havis *et al.*, 2015; Mulhare *et al.*, 2021).

More recent work in Argentina looked at the impact of accumulated temperature and precipitation between the end of tillering and the end of stem extension as a guide to final disease severity. This study looked at data from the UK wide trials run to produce a Recommended list for spring barley to see if a model could be developed. The UK contains 11 distinct meteorological regions and the trials were distributed across them.

2. Materials and Methods

A series of spring barley trials were run across the UK in 2016 and 2017 to assess the agronomic potential and disease resistance of existing and new spring barley varieties. Disease levels were scored in the trial and a late season assessment of RLS levels on the F-1 leaf layer was carried out at BBCH 80. Weather data was obtained from met stations co-located at the trial sites. Accumulated temperature and rainfall were collected from the sites between the described growth stages and an analysis carried out to see if the parameters could predict disease levels.

3. Results

The results from the analysis of the 2017 UK trial dataset suggests a relationship could be drawn between accumulated rainfall in the crop between BBCH21 and BBCH39 and final disease severity (Figure 1).

4. Discussion

Barley crops remain at risk from RLS until significant disease resistance is found in breeding material. The fungus has also shown to develop resistance rapidly to the major fungicide groups so available products need to be carefully managed. The number of fungicide application applied to a crop is known to influence resistance development. A robust risk forecast for RLS would allow growers to apply fungicides only when risk is high and use the fungicides judiciously. In addition they would be following IPM principles.

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Bypassing lock-ins preventing from innovation in cropping systems through co-construction: preliminary results of EXPLORE research project in Wallonia (Belgium) (Poster #358)

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Keywords: stakeholders' arenas; transition's lock-ins; crop system diversification; food chain resettlement

Prospectives studies enables to envision possible and desirable futures. They are particularly used in agroecological transition and sustainable food regime studies. To name a few, the Ten Years For Agroecology (TYFA) model demonstrate how Europe can be food self-sufficient without using pesticides and artificial fertilizers (Poux and Aubert, 2018), the Afterres2050 scenario suggests ways for the French food system transition (Couturier *et al.*, 2016), and, more recently, still in France, the TRANSFood project is focusing on food regimes' transition at the individual scale (Kesse-Guyot, 2021).

In Wallonia (Belgium), public authorities support food systems transition through several strategies and policies. On one hand, the referential for sustainable food systems published in 2018 had led to the Manger Demain strategy (2019) as well as Food Wallonia action plan (2019). On the other hand, the TERRAÉ platform has been created in 2022 to build an agroecological transition referential and execute an ambitious action plan.

Despite these local policies and prospective studies' demonstrations, we collectively struggle to engage in agroecological transition for sustainable food diet, at global, local and individual scales. Indeed, several lock-ins for food systems' transition have been identified in numerous agricultural sectors, and have been well documented in the Belgian and Walloon contexts (Baret *et al.*, 2013; De Herde *et al.*, 2019; Lauvie and Stassart, 2016).

Started in late 2023, the EXPLoring innovative crOpping management for sustainable futuRE-proof food systems (EXPLORE) project, aims to design innovative agro-ecological cropping systems targeting sustainable and healthy dietary regimes in Wallonia. To do so, the project lean on three complementary work packages willing to:

- Work with stakeholders to redesign cropping systems and identify potential lock-ins and ways to overcome them (WP1);

- Mathematically simulate the desired innovative cropping systems and assess their different yields and trade-offs in terms of environmental impacts in the face of present-day and future climatic conditions (WP2);

- Investigate how agroecological levers empower regulation mechanisms for pests and weeds (WP3).

Gathering a research team of agronomists, economists and sociologists, the EXPLORE project rely on an interdisciplinary and co-constructive approach. EXPLORE WP1 main research question ask how co-constructed prospectives scenarios focusing on cropping systems can foster changes in food systems at larger scales. We will particularly analyze lock-ins preventing from matching supply and demand at local and regional scale, as well as tensions occurring between these scales (field, farm, territory and region).

The first step of the WP1 rely on the solicitations of several networks to identify existing initiatives and evaluate stakeholders' interests in working on crop system diversification and food chain resettlement (*i.e.* Food Policy Councils, Farmers working group, Local Action Groups, *etc.*). Depending on previous results, we will construct specific arenas where stakeholders will be invited to build prospective scenarios bypassing lock-ins preventing from innovation in cropping systems. Complementarily with WP2 (modelling), these scenarios' abilities to match local production and demand as well as minimizing agriculture environmental impacts will be evaluated and results will guide arenas' discussions.

In the end, this presentation will discuss EXPLORE WP1 provisional results about (1) arenas constitutions in regard to existing initiatives in Wallonia and (2) lock-ins identified as key topics to address in these arenas. The results will rely on literature review, semi-structured interviews with food system stakeholders as well as two preliminary workshops organized with researchers between April and July 2024.

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Suitability and response velocity of xylem microtensiometers for the continuous assessment of xylem water potential in trees (Poster #103)

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Keywords: microtensiometers; soil-plant-atmosphere continuum; xylem water potential; sap-flow; transpiration

1. Introduction

The measurement of xylem water potential in plants has always been a necessity in the study and modelling of the soil-plant-atmosphere continuum, which drives and explain the water flux through plants and crops. Until now, the available methods for the measurement of water potential were discontinuous, destructive, and labor-intensive. The recent appearance of innovative xylem microtensiometers opens new interesting perspectives in this field of study. Nevertheless, the functioning principle of these new sensors relies on the assumption of a constant equilibrium in water potential between the sensor porous-membrane interface and the surrounding unmodified and conductive xylem. This is physically impossible, as a coupling medium of finite water conductivity is necessarily present bridging the living xylem and the sensor membrane. This work describes simple experiments aimed to assess the response of these new microtensiometers to quick changes in the water potential of living trees.

2. Materials and Methods

Xylem microtensiometers (FloraPulse Co., Davis, CA, USA) were installed in the trunk of two 5-year-old olive trees in the summer of 2022 in Córdoba, Spain, and read at 1-min intervals. The trees were planted in 50-L pots; one of the trees was chosen because it showed strong stomatal oscillations. The soil in the pots was kept at field capacity (soil water potential near zero) by automatic drip irrigation. An advanced sap-flow system (Testi and Villalobos, 2009) was also installed in each tree, monitoring sap velocity at 5-min intervals. On 20 September the canopy of the non-oscillating tree was wetted by a sprayer pump, to stop transpiration abruptly, completely, and continuously during an hour.

3. Results

1) Oscillations: the oscillating tree showed sap flux oscillations up to 1.9 L/h of amplitude (*vs.* maximum flux of 2.6 L/h at the peak), with periods between 45 and 65 min. The microtensiometers were able to show oscillations in the xylem water potential of around 5 bars in amplitude, with the same period as the sap oscillations.

2) Wetting experiment: the wetting of the canopy stopped the transpiration; the sap flow decreased abruptly close to zero in few minutes, reflecting only the refilling of the tree capacitance. Before the wetting (which began at 11:00, solar time) the microtensiometer was showing decreasing xylem water potential, and marked -7.4 bars. The xylem water potential inverted its naturally decreasing trend between 3 and 4 minutes after the wetting started, and after 60 minutes of zero transpiration the xylem water potential was -5.70 bars. The water potential returned to the decreasing trend around 10 minutes after the canopy wetting was stopped, *i.e.* the time needed for the canopy to dry up completely.

4. Conclusions

The microtensiometers installed in living trees showed a remarkable small response time at least qualitatively, *i.e.* they detect impulsive changes in the soil-plant-atmosphere continuum in terms of minutes. Nevertheless, the time required for reaching the new equilibrium seems much longer. Thus, the quantitative response after abrupt changes in the water status may well require specific corrections to use these new sensors in tracing changes in the soil-plant-atmosphere continuum occurring in less than a day. For applications involving slower physiological processes – for example monitoring water status in trees for irrigation scheduling – corrections are probably unnecessary.

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The effects of compost on the feeding activity of soil biota (Poster #262)

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Keywords: Bait-lamina test; decomposition; feeding activity; organic farming; soil fauna

1. Introduction

Soil organisms play a crucial role in providing essential ecosystem services such as transforming organic matter, nutrient cycling, forming soil, and regulating pests and diseases (Saccá *et al.* 2017). To support the biological activity in the soil, organic fertilizers like composts are often used (D´Hose *et al.* 2016, Sánchez-Monedero *et al.* 2019), especially in organic farming where mineral fertilizers and pesticides are limited. Therefore, a study to investigate how different types of compost affect the feeding activity of soil biota under organic farming conditions using bait-lamina tests was conducted.

2. Materials and Methods

The investigations were carried out in a strip trial on a field managed by an organic farm. The trial included an unfertilized control as well as variants with biowaste compost, green waste compost and farm compost, respectively. Each compost was applied at a rate of 180 kg N/ha as well as at a rate of 360 kg N/ha in May 2020 and in March 2023 Bait-lamina tests were performed using PVC strips containing 16 holes filled with a mixture of 70% cellulose powder, 27% bran flakes, and 3% active coal. From 12 May to 23 May 2023 and from 30 October to 10 November 2023, 16 of these filled PVC strips were placed vertically into the top 15 cm of soil in each plot of the trial. Afterwards, the PVC strips were removed again and air-dried. To measure feeding activity in the soil, the disappearance of the cellulose-bran mixture from the holes of the PVC strips was evaluated on a scale of 0 (holes still filled) to 1 (holes completely empty) in 0.25 steps.

3. Results

During both sampling periods, all three compost types showed an increase in feeding activity across the entire sampling depth in comparison to the unfertilized control. In May 2023, the biowaste and farm composts had the most pronounced effect, while in November 2023, the green waste compost at full application rate had the highest feeding activity.

4. Discussion

The temporal differences between the biowaste and green waste composts may be due to variations in their organic compound stability. Green waste composts, made from woody materials with higher lignin contents, may lead to more stable composts, explaining the delayed effect on soil feeding activity. These differences in biological activity may also impact nutrient release from the composts, which warrants further investigation.

All in all, the bait-lamina tests suggest that composts can enhance soil biological activity, which can support associated ecosystem services.

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Cover crop residues mitigate impacts of water deficit on sunflower during vegetative growth with varietal differences, but not during seed development (Poster #24)

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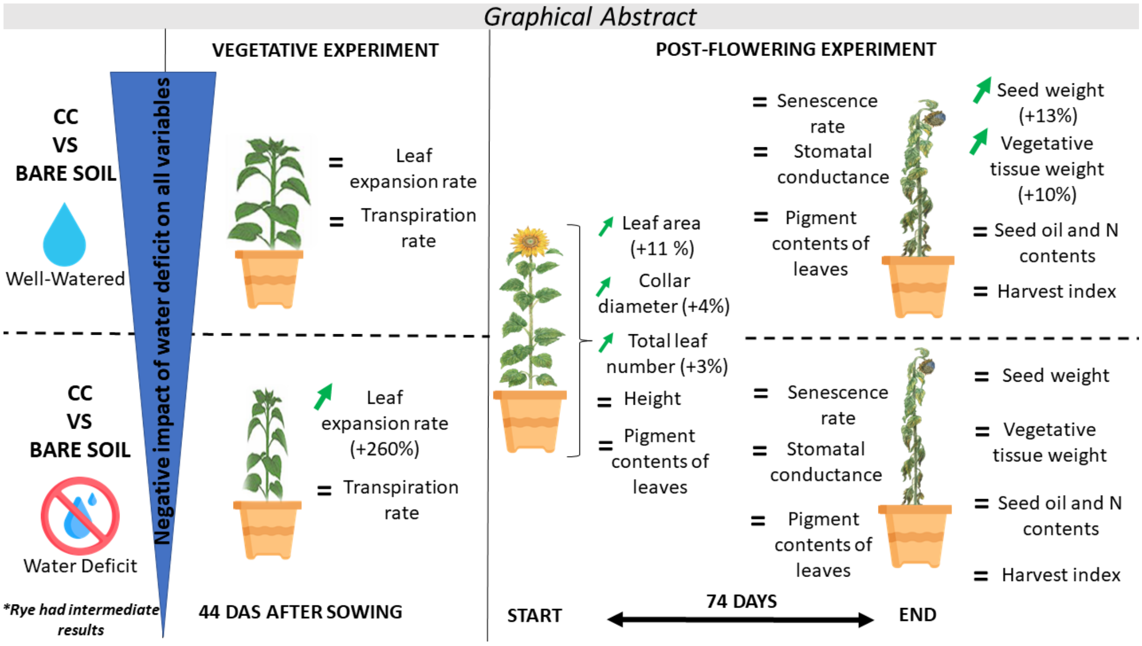
Keywords: agroecological transition; climate change adaptation; drought; ecosystem services; vetch



1. Introduction

Drought, as a major environmental factor that limits plant growth and photosynthesis, is a challenge for agriculture in the context of climate change. High temperatures and drought stress impact crops as a function of their stage of development and genotypic tolerance. Choosing adapted sunflower (*Helianthus annuus* L.) varieties and management practices can mitigate impacts of water deficit on growth, physiology and productivity, but with complex genotype × environment interactions. Cover crops (CC), used mainly as catch crops and/or green manure, can release mineral nitrogen after destruction, which influences growth and development of the following crop.

2. Materials and Methods

Here, we studied how nitrogen released by CC residues can influence water deficit responses of sunflower. In semi-controlled experiments, using the high-throughput phenotyping platform Heliaphen, we tested impacts of water deficit on vegetative and post-flowering stages of four sunflower varieties in pots, in which CC residues of rye (*Secale cereale* L.) or vetch (*Vicia villosa* R.) had been incorporated before sowing. We studied impacts of water deficit during the vegetative stage on sunflower growth and transpiration and water deficit during the post-flowering stage on sunflower physiology and productivity.

3. Results

Under well-watered conditions, CC residues of vetch increased sunflower growth and productivity. Under water deficit conditions, CC residues mitigated the water-deficit response when applied during the vegetative stage, by limiting a decrease in growth, but they did not mitigate it post-flowering. Varieties responded differently to CC residues during vegetative and post-flowering stages. During seed development, severe water deficit cancelled out positive impacts of CC on productivity.

4. Discussion

CC residues induced the release of mineral N during the vegetative stage, which increased the leaf expansion rate and mitigated the decrease in leaf expansion under WD during the vegetative stage. This increase in growth caused by CC residues, particularly of vetch, can explain sunflower's higher productivity in the presence of CC, which could be due mainly to the increase in carbon assimilation, with more leaf area at flowering, *via* an increase in interception of solar radiation by leaves and in redistribution of assimilates from vegetative tissues to seeds. However, post-flowering water deficit canceled out the positive impacts of CC on productivity by decreasing carbon assimilation and redistribution of assimilates.

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Lucie Souques, Lionel Alletto, Nicolas Blanchet, Pierre Casadebaig, Nicolas Bernard Langlade. Cover crop residues mitigate impacts of water deficit on sunflower during vegetative growth with varietal differences, but not during seed development. European Journal of Agronomy, 2024.

Plant growth promoters-based biostimulant as a tool to reduce mineral fertilization in rice (Poster #161)

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Keywords: efficient microorganisms; microbial diversity; yield; sustainable agriculture

1. Introduction

Current agriculture relies heavily on the excessive mineral fertilizer application, which have severely degraded 40% of the world's agricultural soil (Zhang *et al.*, 2017). To tackle this issue, modern agriculture is confronted with the task of identifying alternative strategies to traditional mineral fertilization, which allow its reduction or replacement. Among these alternatives, Plant Growth Promoters (PGP)-based biostimulants are gaining attention, since they have proven effective in enhancing soil microbial activity (Kumar and Verma, 2019) and can increase crop yield by different mechanisms, including nutrient solubilization, nitrogen fixation or phytohormone secretion (du Jardin, 2015). The aim of this study was to determine the effect of reducing the mineral fertilization rate together with the application of a PGP-based biostimulant on rice yield, plant biometric and physiological parameters, as well as on the rice rhizosphere-associated microbiome.

2. Materials and Methods

A field experiment with rice (Oryza sativa var Hispagran) was carried out in Isla Mayor (Sevilla, Spain). The treatments tested consisted of the application of a conventional rate (C) of 150 kg N ha^{-1} and half of conventional rate (½C) 75 of kg N ha^{-1}. These two rates were either applied alone or combined with the biostimulant (BS) Sullicab® (Corteva AgriSciencesTM), consisting in a four Bacillus strain cocktail (40% *B. licheniformis*, 20% *B. safensis*, 30% *B. pumilus* and 10% *B. velezensis*). Fertilization was applied in one amendment before sowing. At the end of the crop cycle plant biometric and physiological parameters were determined prior to grain yield determination. Rice rhizosphere samples of C, ½ C and ½ C-BS were also taken to determine the microbial diversity by bacterial 16S rRNA and fungal ITS1 amplicon sequencing.

3. Results

The application of ½C fertilizer rate induced a decrease of 35% (down to 5.638 kg ha^{-1}) in grain yield with respect to the C rate (8.735 kg ha^{-1}). The addition of BS to the C fertilizer rate did not exert any effect in terms of grain yield. However, when BS was supplemented to the ½C fertilizer rate, this decrease was recovered by 61%, obtaining a yield of 7.516 kg ha^{-1}. Besides, the application of BS significantly increased root development (both in terms of volume and dry matter), the flag leaf area and its total chlorophyll and carotenoid contents.

Regarding the rhizosphere bacterial communities, differences in terms of alpha diversity were observed between the C and ½C in richness and evenness, and between ½C-BS and C just in evenness; being diversity in C lower than in the other treatments. No differences were observed in fungal alpha diversity. The changes observed in bacterial community composition were explained by 25% due to BS application, and by 37% due to the fertilizer rate. The fungal community composition was influenced by both BS and fertilizer rate, in 19% and 17%, respectively.

4. Discussion

The amendment of BS together with reducing fertilizer application resulted in a promising strategy, as BS was able to recover about 61% of the yield lost due to the fertilizer rate reduction. In line with the fact that the fertilization impacts community structures, leading to a decrease in bacterial alpha diversity in the root environment (Reid *et al.*, 2021), in this trial the bacterial diversity was more significantly influenced by the fertilizer rate than by the application of the BS, which agrees with the greater effect of the fertilizer rate on grain yield.

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Global analysis of variability in thermal stress thresholds for common wheat: potential underestimate of risk due to uncertainty (Poster #139)

Mael Aubry

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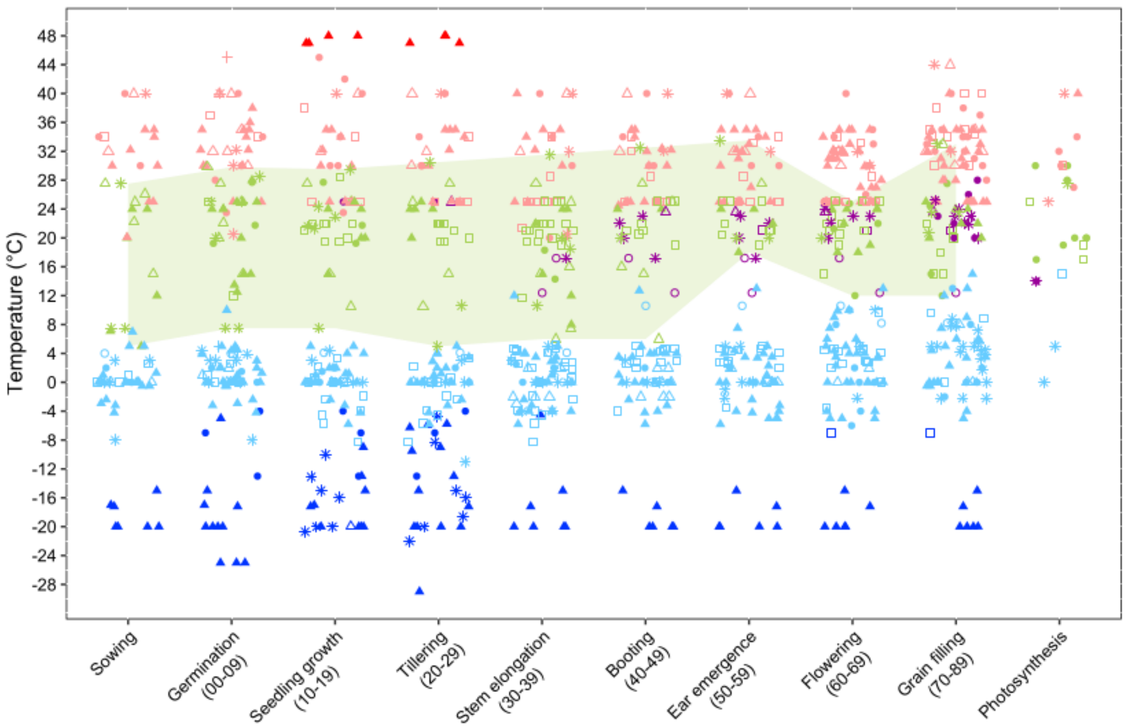
Keywords: thermal stress thresholds variability; agroclimatic risk; climate change; common wheat



1. Introduction

Climate extremes such as high temperatures, droughts and floods are likely to become more frequent, intense and prolonged and to decrease yields regardless of the spatial scale [1]. These climate extremes create agro-climatic risks, which are defined as the combination of hazard, exposure and vulnerability, for wheat crops [2]. Given the particular sensitivity of wheat to temperature, which varies throughout its development cycle and differs among varieties [3], accurately assessing threshold temperatures is crucial to estimate the influence of temperature on the growth and development of wheat.

Potential damage to the plant or its future yield depends on the intensity and duration of the stress, and the damage can be offset if the temperature becomes more optimal. The interaction between the intensity and duration of stress makes selecting thresholds complex due to the wide variety of combinations. This also makes it challenging to compare the methods used to identify thresholds. Many studies have examined uncertainty in agro-climatic risks associated with crop models and/or climate models [4]. To our knowledge, however, no study has examined the variability in threshold temperatures for a given crop species in the literature as another source of uncertainty.

The main goals of this review were to (i) illustrate the high variability in the thresholds used in the literature over the past 20 years, (ii) identify reasons for it and (iii) illustrate the influence of the stress threshold selected on an associated risk indicator. Ultimately, it may provide guidelines for selecting thermal stress thresholds in future studies and promote consistency among them.

2. Materials and Methods

For this exploratory work, we reviewed the literature on temperature stress thresholds for common wheat (global analysis) without using a meta-analysis approach. We have only selected articles that define thresholds for specific phenophases rather than calendar periods. We use “phenophase” to refer to the nine phases of wheat (BBCH 0 to BBCH 9).

We added 83 references in the literature from 1999-2023 to the 51 references cited by Porter and Gawith [3] (total: 134). Based on the methods used, we divided the 1127 thresholds identified into six types: maximum (Tx), minimum (Tn) and maximum night temperatures (HNT), which are harmful but not lethal to the wheat crop; optimum temperature for growth and development (Topt); minimum lethal temperature (LTn) and maximum lethal temperature (LTx).

3. Results

In this review, we highlight the high variability and inconsistencies in the thresholds used in the scientific literature. The stress thresholds for lethal cold, damaging cold, hot night and damaging heat has high variability (standard deviation of 4.5°C, 3.5°C, 2.9°C and 5.2°C, respectively). We show that this variability is due in part to differences in the geographic location, type of wheat (winter or spring) or biological process (growth or development). Taking into account these three main categories simultaneously decreased the variability in stress thresholds by 46% (from 35% to 65% depending on the stress). This variability impacts the estimation of agro-climatic risks for wheat crops. For example, a 2°C difference in the stress threshold for grain-filling phase decreased heat stress by up to 45% in France.

4. Discussion

Understanding the type of process targeted by the thresholds (development or growth) and the methods used in each study to define them is important, as they may partly explain why stress thresholds with the same name differed. Given the importance of the thresholds selected to estimate climate risks to wheat crops, as well as many other hazards, focusing only on thermal stress thresholds does not adequately assess the overall risk and future of the wheat-production sector.

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Dietary fibers in wheat and barley grains and their impact on wheat dough quality (Poster #226)

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Keywords: arabinoxylan; beta-glucan; conventional; organic; weather

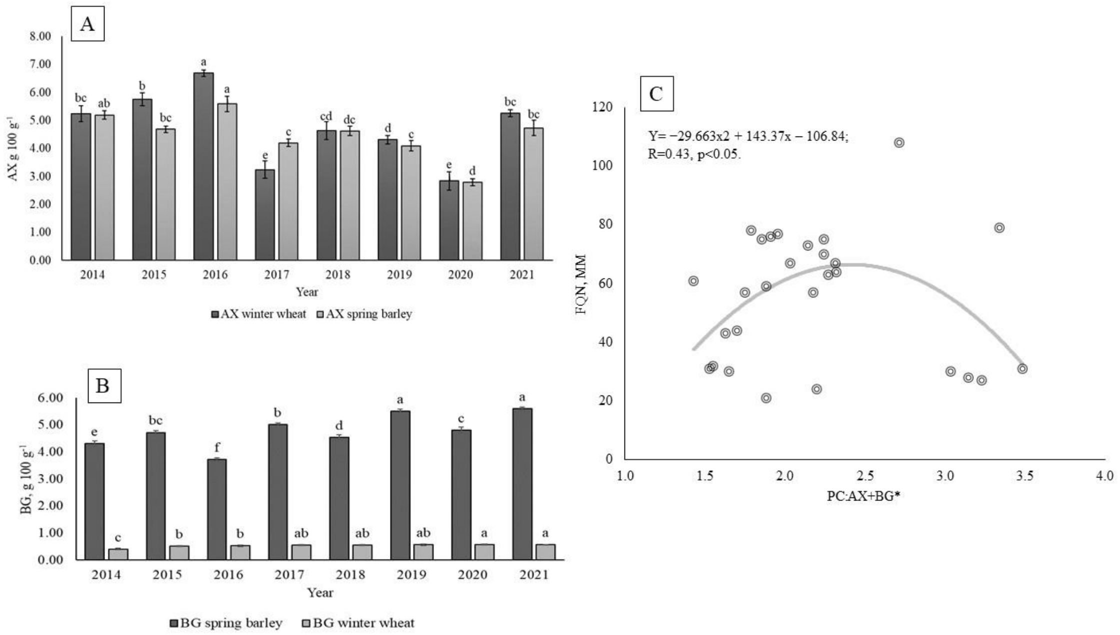

Figure 1. A. The arabinoxylan and B. the beta-glucan content as an average of N treatments in winter wheat and spring barley flours in different years, g 100 g-1; letters on bars refer to comparison between different cropping years of the same species; bars with the same letter are not significantly different (P <.05); C. Influence on dough quality number (FQN, mm) of PC:AX+BG ratio. PC, protein content (%); AX+BG, total amount of arabinoxylans and β-glucans (%)

Adaptation to climate changes adjusts our views on food production and consumption. There is a shift towards reduced fertilizer use in agriculture and zero waste production systems, leading to the importance of whole grains and their complete valorization. Cereal grains contain not only starch and proteins, but also dietary fibers, such as arabinoxylan and beta-glucan, which importance in human health has been acknowledged widely. With the spread of organic farming, it has become necessary to understand how the choice of cropping system affects protein, arabinoxylan (AX), and beta-glucan (BG) contents and ratios in grains, and how it influences the baking properties of the dough. The effects of organic and mineral N fertilizers and content of AX and BG and on the protein content (PC) and their ratio (PC:AX+BG) influence on rheological properties of wheat dough were investigated.

Grain samples were collected from long-term field experiment in Tartu County (58°22′ N, 26°40′ E) in 2014–2021. The objective of the experiment was to compare the effect of (i) cropping system (organic with cattle manure and off-season cover crop; conventional with mineral nitrogen (NH_4NO_3; 0, 40-50, 80-100 and 120-150 kg N ha^{-1}) and (ii) year conditions on winter wheat `Fredis` and spring barley `Anni` wholegrain flours BG and AX content and (iii) to evaluate fiber: protein ratio impact on wheat dough rheological properties (farinograph and alveograph values).

The content of arabinoxylan and beta-glucan in wheat was 4.54 - 5.12 and 0.40 - 0.57 g 100 g^{-1} respectively and in barley 4.00 - 4.51 and 3.74 - 5.60 g 100 g^{-1} respectively. The content of fibers in grains was affected mainly by year (weather) conditions (Korge *et al.*, 2023; Khaleghdoust *et al.*, 2024). Higher temperatures during tillering and grain filling period increased both grains AX values, while higher precipitation during grain filling had negative effect on grains BG content. In barley and wheat, fertilization up to 150 kg N ha^{-1} did not have a significant effect on BG content. For AX content the effect of fertilizer treatments and cropping systems was indirect and was expressed through their effect on grain yield, 1000 kernel weight and test weight. Dietary fibers can successfully be obtained from organic or low-nutrient systems, however, as its content depends on a year, there is a need for a good prediction model.

Protein content of grains was affected by cropping system and weather conditions combined. Mean protein content of wheat grains over experimental years was 10.1-14.6%. There was a positive correlation between grain protein and AX content. Better winter wheat dough quality can be obtained with higher N treatments and lower or average yield and it depends on fiber to protein ratio, which influence dough quality indicators. Protein to fiber ratio depended more on fiber due to its higher fluctuation between years. Higher dough quality was achieved with protein to fiber ratio between 2-2.2:1. Higher fiber content gave higher dough water absorption capacity, dough development time and quality number of dough.

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Biostimulation effects of liquid vermicompost extract in chickpea are cultivar-dependent (Poster #99)

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Keywords: chickpea; liquid vermicompost extract; plant growth; soil nutrition; microbial activity

Chickpea, an important component of diversified cropping systems in Mediterranean environments, often face significant challenges when grown in low-input systems. These limitations, including nutrient deficiencies, water stress, and soil health, can reduce grain yield and nutritional quality. Biostimulants, such as liquid vermicompost extract (LVE), offer innovative solutions to enhance soil fertility and promote plant growth. LVE, which is rich in beneficial microorganisms, contains plant growth-promoting rhizobacteria (PGPR). These microbes can improve nutrient cycling and soil fertility through mechanisms such as nitrogen fixation, phosphorus solubilization, and fostering positive interactions with arbuscular mycorrhizal fungi (AMF).

This study investigated the interaction effects of LVE on different chickpea cultivars and its impact on various aspects of plant growth, soil nutrition, and microbial activity. A field experiment was conducted at the Centre for Agri-Environmental Research 'Enrico Avanzi' in San Piero, a Grado, Central Italy. LVE was applied throughout the crop's growth cycle, from sowing to flowering, and various soil and plant parameters were measured until harvest. The results revealed significant cultivar-specific responses to LVE application, with the Sultano cultivar demonstrating a 26% increase in biomass, highlighting a positive cultivar-LVE interaction. Grain yield also exhibited variations, with LVE significantly increasing yield in the Pascia (40%) and Ares (32%) cultivars, while decreasing it in the Vittoria (-23%) and Reale (-20%) cultivars. Mycorrhizal colonization rates varied, suggesting complex interactions between LVE, soil conditions, and plant traits. LVE application improved the mycorrhizal inoculation potential of the soil. These findings provide preliminary insights into the potential of LVE to enhance chickpea productivity in low-input systems. The observed positive interactions between specific cultivars and LVE underscore the significance of tailored approaches for optimizing yield and quality. Further research is imperative to refine LVE application strategies and unravel the underlying mechanisms to ensure sustainable legume production.

Considering research impacts along the way in a project on agricultural transition pathways (Poster #291)

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Keywords: real-time assessment; steering research projects; transformation pathway; management tool; ASIRPA in itinere

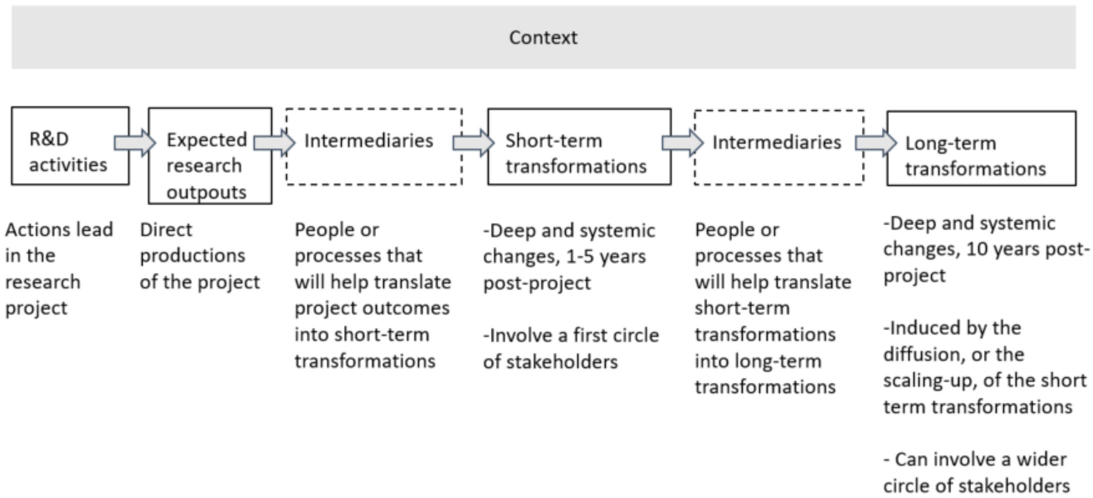

Figure 1. Adaptation of the "Impact Pathway" from ASIRPA in itinere, to the AMPERA project

1. Introduction

Agroecological transition can be a lever for meeting the multi-dimensional and interdependent challenges of sustainability. However, issues relating to food and biomass production and the reduction of associated environmental impacts, as well as those linked to the protection of natural resources, biodiversity and the services provided by agricultural landscapes, are still mainly dealt with separately by scientists, public decision-makers, and territorial services, and on a sectoral basis.

In this context, in the collaborative interdisciplinary research project AMPERA (metabolic and landscape approach for a territorialised agro-ecological transition in livestock farming), we sought to design an innovative framework for the collective co-construction, sharing and appropriation of knowledge - with farmers, planners and territorial stakeholders. Therefore, we implement a specific method towards explicitly considering our targeted research impacts along the research process.

2. Approach

We implement the ASIRPA in itinere methodology (Joly *et al.* 2015, Matt *et al.* 2023), which is innovative in the research impact literature, and adapt it to the project. The principle of ASIRPA is to explicitly identify the social and/or agroecosystem transformations targeted by the research, in order to set up an appropriate research approach. Its central assumption is that a better understanding of the mechanisms leading to the desired transformations enables the research process to be more effective in contributing to these transformations. Indeed, transformations are not just the consequences of the project outputs, but involve “a long-term process that needs the involvement of multiple stakeholders” (Matt *et al.* 2023). We will therefore be working “in itinere”, returning regularly to the understanding and management of this process, throughout the project. This will enable us to highlight key areas of focus and milestones for the upcoming project years to ensure that the outcomes are effectively aligned with the desired transformations.

3. Materials and Methods

Our research is carried out in 2 local communities in Brittany (western France). We are working with two groups: the project partners and the territorial stakeholders. We involve them in reflecting on the desired transformations and the intermediaries for achieving these transformations in project management. Therefore, we adapted the “Impact Pathway” from ASIRPA (Figure 1).

The desired transformations are deep and systemic changes to which we want the project to contribute. They can affect agro-systems, ecosystems, human organisations, knowledge production and education... The intermediaries are the people or processes that will help translate the project outputs into short-term transformations and then scale-up to long-term transformations.

Three workshops where organised, one with the project partners and one with the stakeholders in each of the territories we work with. We also conduct individual interviews with the partners and stakeholders. The workshops and interviews aim to identify how each person and the project collective sees and understands (1) the issues at stake (2) the transformations desired by stakeholders and partners; (3) how we can find synergies between the 3 dimensions of the project: production/circularity/ecosystem.

4. Results

The first results show that, (1) the desired transformations are not the same depending on the disciplines involved. Therefore, building a common definition of these transformations is not evident; (2) transformations are sometimes not in line with the intended results of the project (*e.g.* an intended output on the evolution of practices *versus* a desired transformation in public policy); (3) discussing transformations contributes to the interdisciplinary approach and even to the interactions between partners in the project.

5. Discussion

The expected output is to increase the probability that this collaborative research-action project will actually contribute to farms and territories transformations.

We also hope this study will enable us to (1) understand better the territories project dynamics in the field of agroecology; (2) identify common grounds and discrepancies among the perspectives of territorial stakeholders as well as with project partners; (3) identify points of attention to manage the project in a collaborative way.

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Contribution of in-plot exchanges between farmers and scientists to knowledge hybridization: a case study in cocoa agroforestry systems in Côte d'Ivoire (Poster #245)

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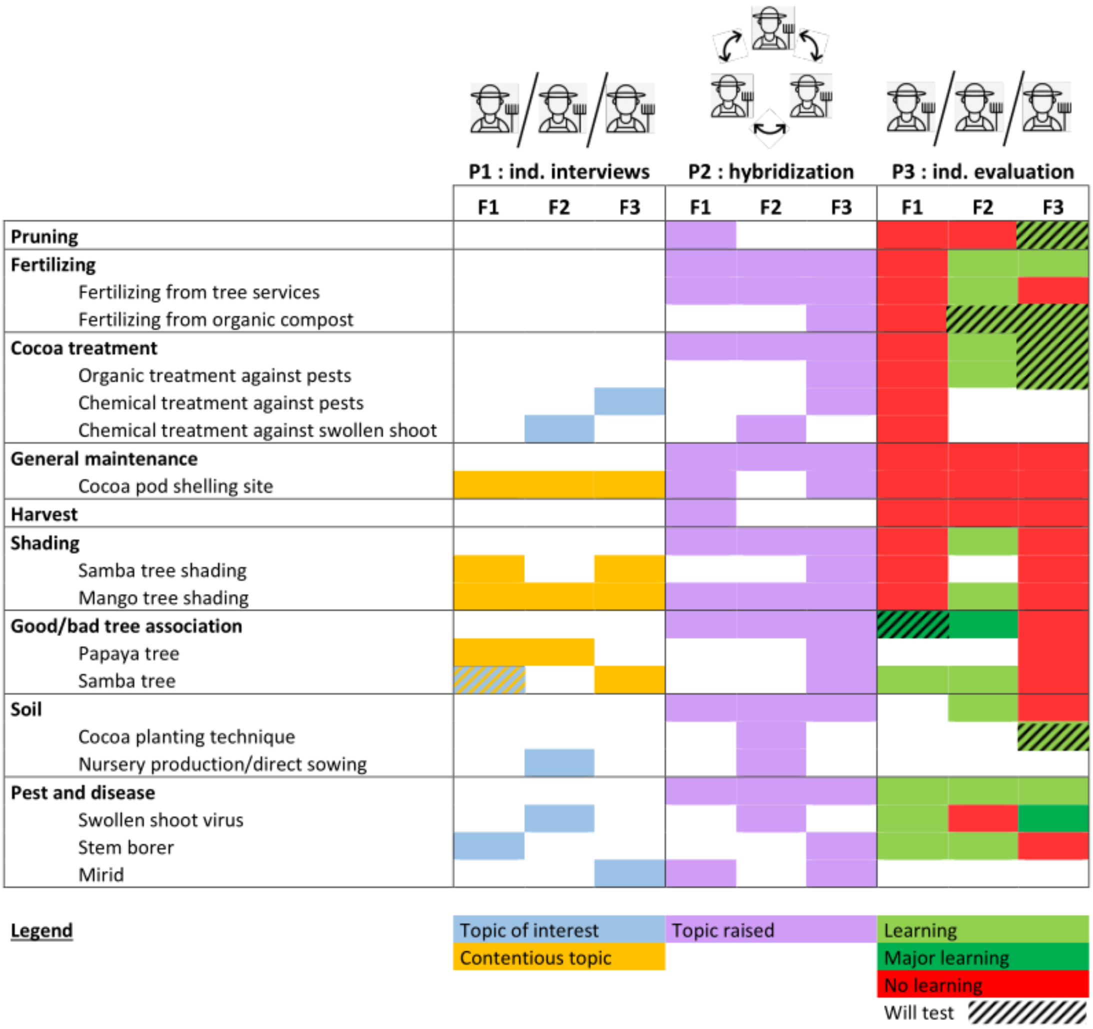
Keywords: knowledge hybridization; cocoa agroforestry; agricultural practices; experiential and academic knowledge



Over the past two centuries, agricultural production methods have been pushed towards monospecific systems intensive in chemical inputs, with negative impacts on the environment and climate. A global awareness of the need to change the production patterns is gradually emerging (Sanchez *et al.*, 2022). The aim is to identify synergetic agro-ecological solutions that are both socio-economically viable and environmentally friendly, as quickly as possible. Given the complexity of these issues, it is essential to recognise the value and relevance of informal/local knowledge and to build agroecological innovations around it (Sumane *et al.*, 2018). Hybridization of knowledge is one way of achieving this; it is defined as the connection of knowledge from different sources with a view to action (Loyce *et al.*, 2021). Co-designing agricultural practices may greatly benefit from this action-oriented knowledge generation. Our objective was to explore/experiment knowledge hybridization through in-plot exchanges on the agronomic functioning of cocoa agroforestry systems (AFS) and associated practices, in order to assess its hybridizing potential.

We developed an innovative methodology for analyzing the hybridization of knowledge that took place between five participants, including three cocoa farmers, an ethnobotanist and an agronomist. As our main objective was to ensure farmers benefited from the project, the evaluation methodology was focused on what cocoa AFS knowledge they gained from this experience. The methodology consisted of three different phases: (P1) an initial phase, during which we used mind maps to take stock of each participant's individual knowledge, (P2) a phase of exchange between the different participants, on each of the three farmers' AFS, to review and compare the individual knowledge, whether similar or divergent, identified in P1, and (P3) an individual debriefing to obtain feedback from each participant on their perception of the approach and to assess the hybridization, *i.e.* the knowledge learned or transformed between P1 and P2. The work was carried out in Côte d'Ivoire in the plots of three farmers from three different cocoa-growing localities but within the same phytogeographic area, so as to increase the likelihood that their cocoa-growing knowledge would be varied and complementary.

The results show that the participants learned new knowledge, notably about the benefits or drawbacks of certain shade trees on the provision of services and disservices. For example, one farmer learned that Ricinodendron heudoletii (Akpi) would supply water to the cocoa tree from the soil in the dry season *via* root system, while another understood that the infestation of borers on these cocoa trees was favored in the proximit of Triplochiton scleroxylon (Samba) as it harbored and allowed the proliferation of these borers. Some farmers were also able to learn about planting and pruning techniques, biofertilization and treatment with biopesticides. It is particularly interesting to note that information exchanged by farmers percolates far better than information exchanged between researchers and farmers. Farmers were particularly interested to hear from first hand experiences, and keen to imagine new trials to test their assumptions. This learning process remains quite successful, with around 46% (minimum 26% and maximum 71%) of topics for which farmers learned something between P1 and P3. On the other hand, participants' evaluation of the methodology indicates that they are very appreciative of the approach, and would like to see more actions of this type implemented by their agricultural cooperatives or by national technical advisory institutes.

The hybridization process has undoubtedly resulted in the transmission of information in addition to the knowledge already acquired but not explored in phase P1. Unfortunately, our evaluation method, perhaps too restrictive, does not capture this hybridization. It would also be interesting to be able to dissect plot exchanges using other analysis methods from the language sciences and didactics, which would probably enable us to better understand why knowledge exchanged by peers is better transmitted. This raises the question of how we researchers can become part of an exchange between farmers to achieve this hybridization. Finally, one of the limitations of our exploratory approach is that we have only looked at verbal exchanges in the plot. It would therefore seem appropriate to use the same methodology to try and evaluate other types of knowledge transmission tools, such as written, audiovisual and other media commonly used to hybridize knowledge.

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Kyrgyzstan's croplands: haven or threat to biodiversity? (Poster #197)

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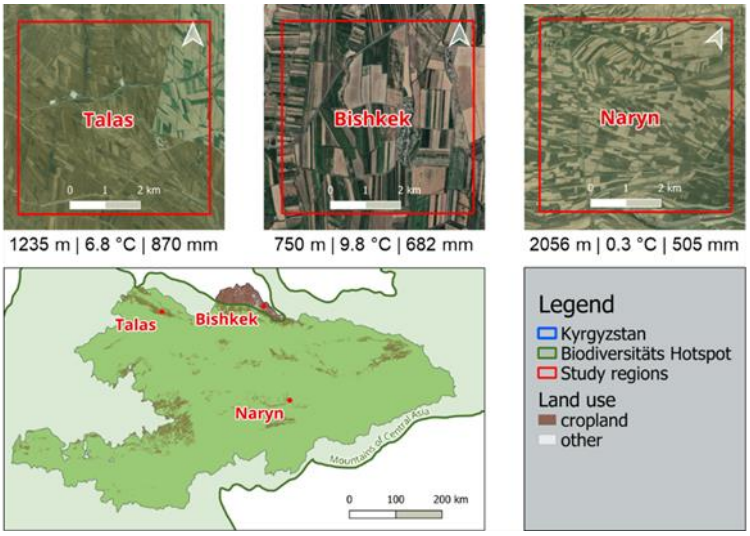
Keywords: segetal flora; central Asia; biodiversity hotspot; biogeographical patterns; climate-driven habitat shifts



1. Introduction

The nexus between agricultural land use and biodiversity loss poses a huge challenge worldwide. Amplified by the effects of climate change, the biodiversity hotspot "Mountains of Central Asia" (MoCA) is under increasing threat (Mustaeva *et al.* 2019). Despite the small proportion of arable land in the total hotspot area, it harbours one of the richest segetal floras globally, comprising an abundance of endemic species (CEPF 2017; Nowak *et al.* 2014a). Comprehending the composition and distribution patterns of segetal plant species is essential to crafting a farming system that harmonizes stable yields with the conservation of biological diversity. Vegetation studies which address this issue are largely lacking in Kyrgyzstan, a country located at the centre of MoCA. To fill this research gap, our project “Sustainable Silk Road 4.0” embarks on a three year campaign of vegetation monitoring in Kyrgyzstan´s croplands.

2. Methods

Cropland vegetation is mapped in three major floristic regions of Kyrgyzstan over a period of three years. In each region, a cropland area of 5 x 5 km is selected for investigation (see attachment). Ground truth data is collected along two transects (each 2500 m in length): one is set orthogonal to the adjacent north-facing slope, the other parallel to it. Along each transect, rectangular plots of 1 x 10 m are placed in an alternating manner at the edge and centre of the fields. All vascular plants, including crops, are recorded and their relative abundance measured in each plot. The collected data is analysed with emphasis on factors such as crop type, distance to slope and positioning within the field as well as the relationships between the local assemblages and the regional species pool. The intra- and inter-regional disparities will be compared subsequently.

3. Results

Species richness and species composition differ greatly between the three regions. Only two weed species were shared by all regions. The most frequent species in each region was absent in the other two. More segetal species were recorded in higher altitudes and towards the edges of the fields. Reversely, the average vegetation cover was greater in the centre plots. The number of weeds typical of scree vegetation increased with proximity to the slopes.

4. Discussion

Most arable lands in MoCA are situated in narrow valleys, separated from one another by mountain ranges that foster a vast array of ecological niches, supporting a myriad of species (Nowak *et al.* 2014b). The scree vegetation in particular is very diverse (Nowak *et al.* 2016). As a result of climate change, the natural habitats of many such species are being altered or lost entirely (Raduła *et al.* 2021). Studies in Tajikistan have shown that a vertical range shift can result in some species finding secondary habitats in extensively used arable lands (Nowak *et al.* 2014a). The initial findings of our first year´s field mapping indicate that a comparable phenomenon is taking place in Kyrgyzstan. Over time, accelerating environmental changes could fundamentally alter the plant compositions in croplands. Mountain ridges serve as physical barriers to dispersal, leading to notable differences among the regional floras. This year´s field data will provide further insights into these patterns. The interconnections between regional species pools and local assemblages are currently under investigation.

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Adapting the DSSAT-CROPGRO model for narrow-leaved lupin (*Lupinus angustifolius*) (Poster #348)

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Keywords: narrow-leaved lupin; model; garman plant production; DSSAT; legumes

1. Introduction

Increasing legume production is a crucial goal of agricultural policy in Germany and the EU, aiming to boost regional protein supply, diversify crop rotations, and mitigate climate change by replacing N fertilizers in cropping systems and by providing alternative plant-based proteins for human nutrition. Narrow-leaved lupin (*Lupinus angustifolius*) shows promise for temperate climate regions. It is traditionally grown in Northeast-Germany but with potential to wider adaption. The anticipated warming trend in the climate is having noteworthy effects on the growth and yield of lupin and hence its suitability in different parts of Germany and other potential growth regions globally.

Process-based agroecosystem models (AEM) assess genotype × environment × management interactions. AEM capture the soil-plant-atmosphere system simulating crop phenological development, growth and yield formation in hourly to daily time steps. The decision support system for agro-technology transfer (DSSAT) is a widely used modelling platform (Jones *et al.*, 2003) that comprises models for more than 40 different crops. Within DSSAT the generic CROPGRO model is available that is parameterized for different legumes, including peanuts, soybean and faba beans. However, there is so far no lupin model available in DSSAT. Hence, this study, we aim to adapt the DSSAT-CROPGRO model for lupin.

2. Materials and Methods

Beginning with the CROPGRO faba bean model (Boote, *et al.*, 2002), chosen for its similarity to lupin, we gather information comparing lupin and faba bean characteristics from various sources and available in-house datasets. A valuable source of multi-environment phenological and yield data are the post-registration variety trials. The respective authorities of different states conduct and report those trials annually aiming at informing farmers on regionally recommended genotypes (*e.g.*, Jentsch *et al.*, 2017; Zenk *et al.*, 2017). We further use data from an experiment conducted at the JKI station in Berlin, where four shifted sowing dates are tested annually over three years. The experiment comprises additional data on crop growth, *i.e.*, leaf area index and biomass time series over the growing season. For model adaptation, we decided to go for the common narrow-leaved lupin cv. Boruta first, a cultivar released 2001, which is still cultivated up to date. Boruta is characterized by a determined, *i.e.*, terminal, growth habit featuring a rather clear phenology with little overlap of vegetative and generative growth on the same plant. The assembled dataset encompasses a comprehensive collection of nearly 50 site-years of data for cv. Boruta, providing a robust foundation for our model parametrization. We split the data in ~2/3 for model calibration and ~1/3 for model evaluation.

First, we adapt selected model coefficients building on published sources and define specific coefficients, *e.g.*, maximum grain size, based on analysis of our extensive dataset. For further adapting the model we calibrate multiple cultivar and ecotype coefficients, and utilize the time-series estimator tool (TSE) integrated in the DSSAT framework (Röll, *et al.*, 2020). Notably, this advanced tool facilitates the synchronization of the calibration process across various coefficients and time-series data. Here we first start from phenology parameters, including temperature response, then growth parameters, and finally yield parameters to capture the unique growth characteristics and patterns specific to lupin.

3. Outlook

The developed CROPGRO lupin model assesses management options, sowing dates, and densities across German regions under current and future climates. As a new crop in DSSAT, it enables the assessment of lupin in different crop rotations at various sites. This will allow to thoroughly assessing its potential to substitute synthetic N fertilizer in crop rotations and evaluate its contribution to resource use efficiency. As the DSSAT AEM simulates daily N2O emissions, the model also allows considering direct and indirect N_2O emissions according to Tier 3 approach in GHG accounting. This allows a thorough assessment of the climate change mitigation potential of lupin cultivation in Germany.

Future enhancements involve simulating indeterminate varieties and improving resilience to drought and heat stress through targeted experiments.

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Are legumes climate-smart pre-crops in intensive wheat cropping systems? (Poster #30)

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Keywords: pulses; GHG emissions; sustainable intensification; nitrous oxide; resource use efficiency

1. Introduction

Legumes are well-known for their beneficial pre-crop and rotational effects (Ditzler *et al.*, 2021; Zhao *et al.*, 2022). However, climate effects are rarely included in analyses under European pedo-climatic conditions (Binacchi *et al.*, 2023). Within the joint research project “ISLAND” environmental and agronomic effects of winter wheat after pulses and green manure legumes in contrast to cereal pre-crops is holistically investigated.

2. Materials and Methods

At two sites in the north (“Kiel”) and the south (“Munich”) of Germany, similar field trials were established in 2022/2023 with nitrogen (N) rate experiments (5 equidistant levels from 0 to 320 kg N ha^{-1}) after contrasting pre-crops with comprehensive field data collection including weekly greenhouse gas measurements and UAV borne spectral/thermal imaging as well as periodic plant, root, and soil sampling.

3. Results and Discussion

First results from the northern site after one cropping sequence showed clear benefits of leguminous pre-crops. Economic optimal N rates (EONR) were 23-44% lower, whereas grain yield was 11.0-12.7% higher. Therefore, N use efficiency was increased by 40-69%. A higher green area index in winter wheat after faba bean and grass-clover enabled higher radiation interception resulting in better radiation use efficiency (+11-12.5% compared to cereal pre-crops). From spectral images we could, furthermore, see a better and prolonged N uptake after legumes (largest effect during the last third of the growing season). Significant lower canopy temperatures in winter wheat plots after legume pre crops during a hot day additionally indicated better water acquisition potential and root development. Direct nitrous oxide (N_2O) emissions showed an inverse pattern between preceding and succeeding crops: significantly lowest emissions were observed during grass-clover cultivation and highest during winter wheat following grass-clover. This led to similar cumulative direct nitrous oxide emissions (1.5-1.79 kg N_2O-N ha^{-1} in 327 days) when considering both phases. N-fertiliser savings of 56-108 kg from calcium ammonium nitrate can further contribute to reduced upstream emissions (up to 396 kg CO_2-eq ha^{-1}). However, challenges with establishment as well as utilization or marketing of the legume pre-crops must be considered in a holistic evaluation on farm scale as well.

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Nitrogen and potassium interactions: impacts on winter wheat yield and biomass in different climatic-soil conditions (Poster #43)

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Keywords: winter wheat yield; nitrogen fertilization; potassium fertilization; dry matter accumulation; agronomic optimization

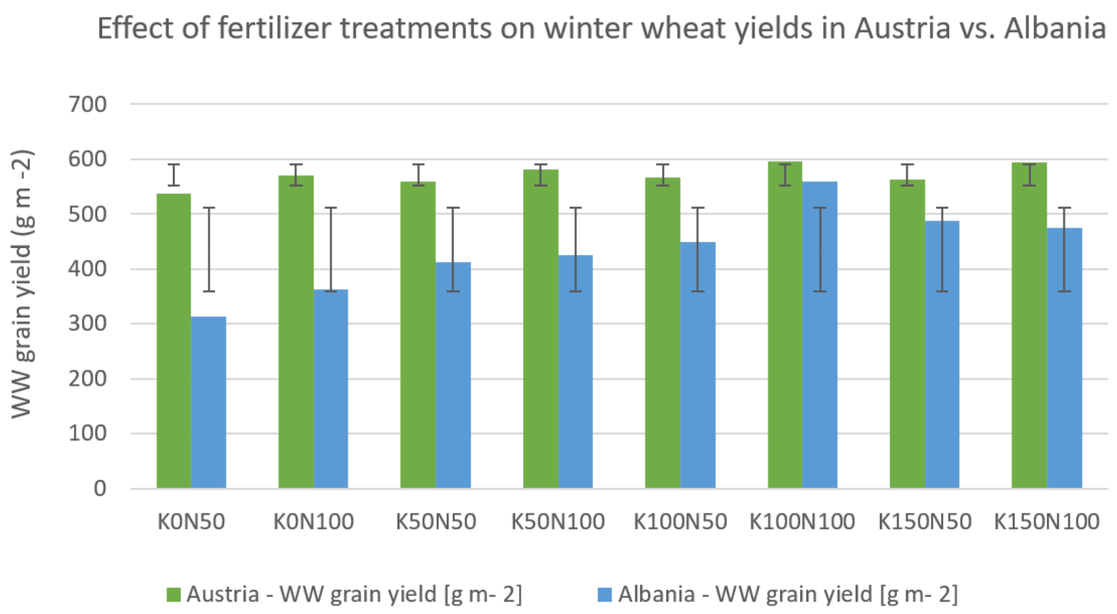

Figure 1. The chart shows how different fertilizers affect winter wheat yields in Austria and Albania, with the error bars indicating yield variation for each treatment

Nitrogen and potassium are fundamental nutrients that are pivotal for the growth of wheat, and their equilibrium markedly influences agricultural output. Understanding the nuanced effects of nitrogen and potassium fertilization on different components of winter wheat yield is important for sustainable agricultural practices and enhanced food production.

Two experiments were established in different soil-climate zones of Europe, one in Eastern Austria at the Experimental Farm Groß-Enzersdorf of BOKU, Vienna (Vienna) and the other at the Didactic Experimental Farm of the Agricultural University of Tirana (Albania) during 2022-2023. The two-factorial experiments were in randomized complete block designs with four replications. Four K mineral fertilization rates (0, 50, 100, 150%) and two N mineral fertilization rates (50 and 100%) were randomly assigned. At Groß-Enzersdorf, an Austrian winter wheat cultivar 'Arnold' was selected, while at the Didactic Experimental Farm, Albanian 'UBT-2' was planted. Agronomic data included quantitative assessments of crop yield alongside evaluations of dry matter content in both grain and straw.

The statistical analysis at Groß-Enzersdorf demonstrated that nitrogen and potassium fertilization did not significantly influence the dry matter yield of grain or straw, nor the overall yield of winter wheat. Notably, the interaction between nitrogen and potassium also did not yield significant differences in these variables. Conversely, at the Didactic Farm, nitrogen presented a moderate but significant impact on yield ($p = 0.010$), while potassium's influence was pronounced and highly significant ($p < 0.000$). Furthermore, their interaction effect was statistically significant ($p = 0.033$), suggesting a synergistic influence on yield. For crop residue, the interaction between nitrogen and potassium was significant ($p = 0.048$), whereas for aboveground biomass, significant effects were observed for potassium ($p = 0.001$) and the interaction between the two nutrients ($p = 0.011$). The graphical analysis, which included a comparison of means, showed that at Groß-Enzersdorf, the K50N100 treatment achieved the highest dry matter accumulation in grains, and the K100N100 treatment produced the highest straw yield. In terms of biomass, the K150N100 treatment led to the greatest yield at the Didactic Experimental Farm. These results highlight the complexity of nutrient interactions and their variable impact on different yield components of winter wheat. The findings from the two sites provide valuable insights into the complex interactions between nitrogen and potassium fertilization and their differential impact on winter wheat production. Soil analysis can determine if the lack of significant results for N and K treatments at the Experimental Farm Groß-Enzersdorf is because the existing fertilizer recommendations are optimal or if it is due to limitations related to soil nutrient supply, type, pH, or moisture availability. The mean and standard deviation for grain yield reveal that Austria has higher average grain yields and less variability in those yields compared to Albania.

Results show that combined nutrient strategies may be needed for optimal outcomes, highlighting the importance of customized agronomic practices and ongoing monitoring for sustainable productivity enhancement in agriculture.

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Assessing the establishment and impacts of interseeded cover crops on soil properties and silage corn yield and quality in a boreal climate (Poster #186)

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Keywords: cover crops; yield stability; soil properties; forage quality; silage corn

Figure 1. Establishment of cover crop mixtures interseeded in silage corn at V4-V6 stage

1. Introduction

Newfoundland and Labrador (NL) situated in the boreal region and faces crop production challenges due to low soil fertility, short growing seasons, and low crop heating units or growing degree days). Cover crops (CCs) have potential to improve soil fertility, soil quality and health (O'Reilly *et al.*, 2012), reduce erosion (Blanco-Conqui *et al.*, 2011), and enhance productivity through weed suppression (Bolandi Amoghein *et al.*, 2013) and supplying additional forage. However, the short growing season restricts seeding of CC mixtures after harvesting primary crop. Interseeding CCs into corn can improve chances of establishment. A field research trial was conducted to: 1) assess the establishment potential of CC mixtures interseeded into silage corn, 2) determine the effects of interseeded CCs on yield and quality of silage corn, and 3) evaluate the effects of CC mixtures on soil physio-chemical properties.

2. Materials and Methods

A field trial was conducted in Pynns Brook, NL, Canada (49.087° N, 57.541° W) (2022 & 2023). Silage corn was seeded on 3 × 4-m plots on May 25, 2022, and June 7, 2023. The experimental design was a randomized complete block design with 15 CC treatments replicated four times. CC mixtures were seeded:1) berseem clover + annual ryegrass (BCAR); 2) BC + cereal rye (CR); 3) BC + triticale (TR); 4) birds trefoil (BT) + AR; 5) BTCR; 6) BTTR; 7) hairy vetch (HV) + AR; 8) HVCR; 9) HVTR; 10) red clover (RC) +AR; 11) RCCR; 12) RCTR; 13) BTBCTR; 14) HVBCTR and 15) control (no CC). CC mixtures were interseeded into silage corn at the V4 - V6 stage. Silage corn was harvested on 7 October 2022 and 15 October 2023. CC biomass was sampled using 0.5m x 0.5m quadrats on 26 October 2022 and 7 June 2023). In 2023, CC mixtures could not be established due to poor germination. To determine soil physio-chemical properties, soil samples were collected from 0-15cm depth using a stainless auger before corn planting and after harvesting CCs.

3. Results

There were significant differences in biomass accumulated from different CC mixtures. RCTR produced the highest biomass (5.95 Mg ha^{-1}), followed by RCAR and RCCR which produced 3.82 Mg ha^{-1} and 3.81 Mg ha^{-1} biomass yield, respectively. The lowest biomass (0.255 Mg ha^{-1}) was from BTCR. There was no significant effect of CC mixture on the silage corn yield. However, corn yield significantly varied by year. Silage corn was 30% higher in 2023 compared to 2022. Interseeded CC mixtures did not significantly affect silage corn forage nutritional quality, soil bulk density, porosity, or organic matter and mineral nitrogen contents).

4. Discussion

Interseeded CC mixtures in silage corn established well in 2022 (Figure 1), but there was poor establishment in 2023 due to early-season incessant rain seeding. In all mixtures, grasses consistently established, but BT did not germinate. Ultimately, grass-legume proportions in the final CC biomass were variable, and this could have implications on nitrogen capture or contributions from these CC mixtures. These findings demonstrate potential for some grass-legume combinations to contribute substantial biomass when interseeded into silage corn at the V4 – V6 stage. However, due to climatic/seasonal variability, more data is needed before recommendations can be made.

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Environmental and economic assessment of German oat milk value chain using an integrated LCA-LCC approach (Poster #316)

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Keywords: oat milk; value chain; LCA-LCC; scenario analysis

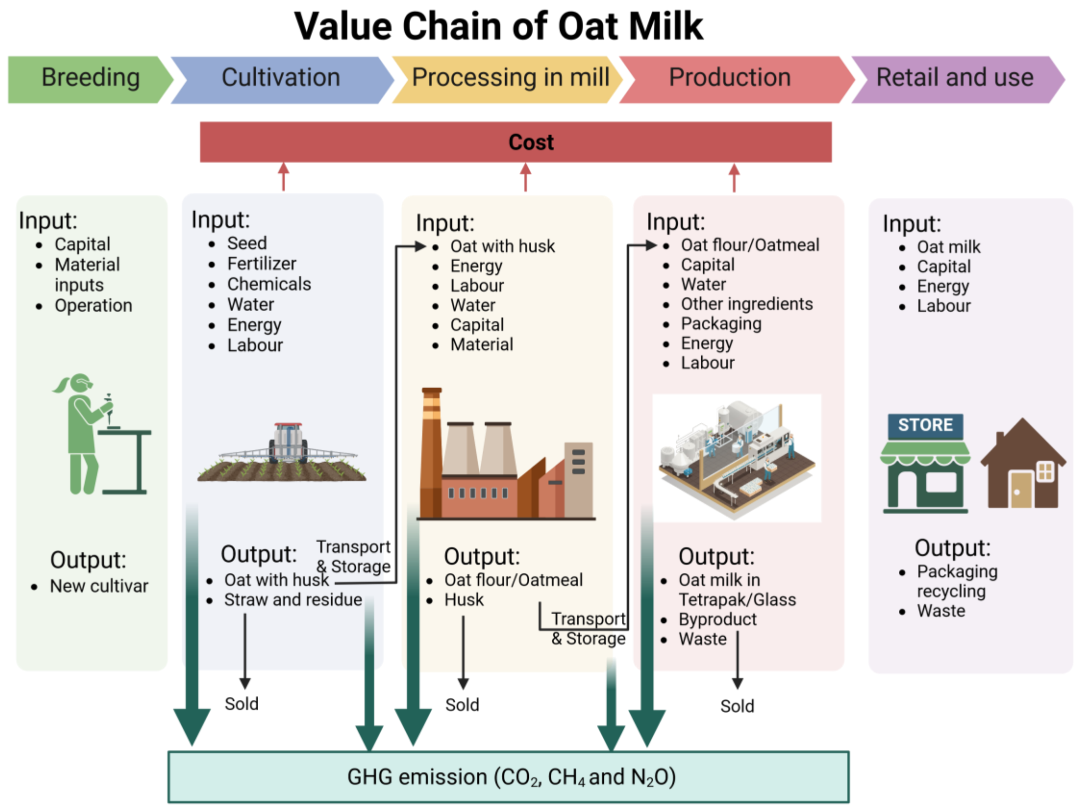

Figure 1. Value chain of oat milk

The trend towards a more plant-based diet and growing concerns about climate change have led to an increasing interest in dairy alternatives in the last years. With a 56% share of the total milk alternatives market, oat milk is currently the most popular plant-based milk in Germany (BMEL 2023). However, the area of oat cultivation in Germany has decreased by almost 40% in the last 20 years: from 230,000 ha in 2001 to 140,000 ha in 2023(AMI 2012; Statistisches Bundesamt 2024). At the same time, only 30% of the oat processed in German mills are of German origin (Müller and Voigt 2023). This gap between the decreasing oat cultivation area and the increasing demand for oat milk in Germany is huge and largely compensated by the international oat trade.

In the TRIP project (in German:Treibhausgasreduktion durch innovative Züchtungsfortschritte bei alternativen pflanzlichen Proteinquellen) we investigate the whole value chain of oat milk (see Figure 1) and apply Life Cycle Assessment (LCA) and Life Cycle Costing (LCC) to assess the status quo of the environmental and economic performance of oat cultivation, processing and oat milk production in Germany. In addition, we conduct a scenario analysis of different greenhouse gas (GHG) mitigation options throughout the whole value chain. We aim to provide different stakeholders in the value chain with a better understanding of different GHG mitigation options and their impacts on GHG emissions and costs, so that stakeholders can make better decisions towards a more sustainable oat milk production.

The main stages in the value chain of oat milk were identified as breeding, cultivation, processing in the mill, production, and sales and consumption. The scope for an integrated LCA-LCC analysis covers the partial value chain from oat cultivation up to the gate of the oat milk producer. The GHG emission of oat cultivation in Germany is modeled with DSSAT and in a mixed model considering different influences of cultivars, management and environment. Input and output informations from oat processing in the mill and oat milk production are collected through questionnaires. We aim to quantify the individual contributions of the cultivation, processing and production stages to the total GHG emissions and costs of 1 liter oat milk. In this way, hotspots and opportunities for improvement for oat milk in terms of reducing GHG emissions and costs will be identified for further scenario analysis.

Scenario analysis will then extend the scope of the value chain analysis up to breeding at the beginning and down to the consumer at the end of the value chain. It will assess the potential of different oat origins, packaging and new varieties to reduce GHG emissions and costs. These potentials will be quantified and ranked according to the economic cost of reducing a unit of GHG emissions. The final result are expected in July 2024.

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Management of sanitary and environmental impact of agricultural phytosanitary practices: case of farms in the southwest of France (Poster #269)

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Keywords: pesticide impact; indicators; environmental risk; human health risk; organic farming

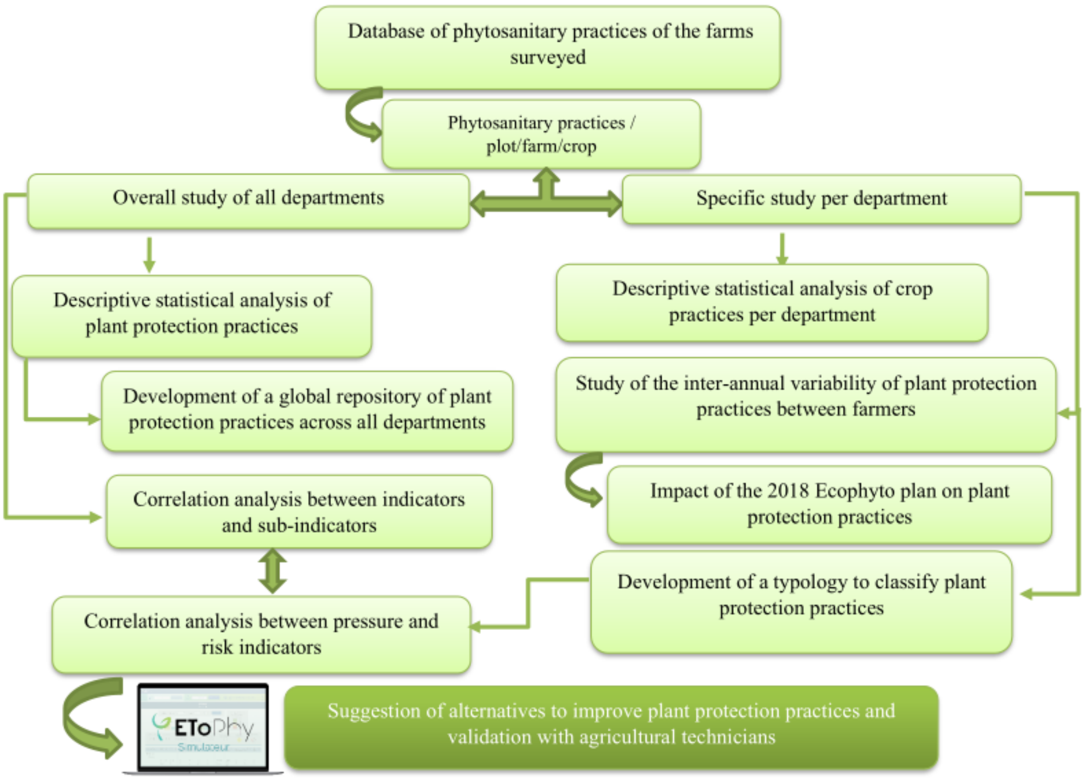

Figure 1. Conceptual model of the work process

1. Introduction

The extensive use of pesticides currently constitutes a major environmental and public health issue (Inserm, 2013; Berardi Tadié and Bonvarlet, 2019). several indicators have been used to evaluate pesticide pressure: TFI, NODU and QSA. Other generic, simple and flexible indicators are used in this context: IRSA and IRTE (Mghirbi *et al.*, 2015) to assess the potential risk of phytosanitary products and their impacts on human health and non-target organisms. The objective of this study is to analyse plant protection practices according to cropping and production systems (conventional/integrated and organic) to assess and manage the risk associated to diffuse phytosanitary pollution at field level located in the southwest of France.

2. Materials and Methods

This study aims to define a methodological framework for using and enhancing a database of agricultural phytosanitary practices collected between 2009 and 2019 in four French departments (Gironde, Tarn-et-Garonne, Gers and Hérault) to assess the impact of these practices in terms of phytosanitary pressure (TFI), health risk (IRSA) and environmental risk (IRTE) calculated by the EToPhy software (Le Grusse *et al.*, 2014).

The impact of crop treatment practices was analysed in two stages: (1) a global correlation analysis between the different indicators and studying the variability of the indicators and sub-indicators for each crop, across all departments, (2) analysing the phytosanitary practices of crops between departments, followed by an interregional comparison of the south and southwest of France. Based on this analysis, a repository of phytosanitary practices was developed to compare the use of pesticides between crops and production systems (conventional/integrated and organic) according to a typology of phytosanitary practices which makes it possible to define 3 levels of crop treatment practices (low input, medium input, high input).

3. Results

The results of the global correlation analysis between the different indicators according to the crops show a medium or even strong correlation between phytosanitary pressure (TFI) and risk (IRSA and IRTE). Overall, the more the TFI increases, the greater the risk to human health and the environment, but at equivalent TFIs, risk levels may vary greatly depending on the products used. These results lead us to the analysis of the variability of crop protection practices and their relationship with climatic factors to justify the choice of the crop treatment practices applied at farm level in the different departments.

The crop repository shows the variability of phytosanitary practices according to the cropping and production system (conventional/integrated, organic) for each crop. The results show that arboriculture consumes the most pesticides, especially apple trees. In addition, organic farming poses a higher risk to the environment than conventional farming due to the excessive use of copper and sulphur. The analysis of crop treatment practice types makes it possible to deal with the most toxic products to human health and the environment by determining the contribution of each product to risk and pressure, and the target that it corresponds to.

4. Discussion

Agri-environmental indicators are used to build tools for the analysis and management of phytosanitary practices. These tools make it possible to study the relationship and the variability between the pressure and the potential risk of pesticides according to crops. They also help de fine priorities for the implementation of other levers to reduce the use of pesticides and improve the health and environmental performance at farm level. This work also shows the importance of developing a repository that takes stock of the difference within phytosanitary practices between crops and production systems at a regional and departmental level.

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Study of the evolution of various products from a wastewater treatment plant as fertilizer in acid and basic agricultural soil (Poster #104)

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Keywords: acid and basic agricultural soil; incubation soil experiment; circular economy opportunities; wastewater treatment plants; fertilizer

1. Introduction

According to FAO, the total fertilizer nutrient demand was 185,063 million tons in 2016, and this demand was forecasted to grow to reach 200,919 million tons in 2022 (FAO, 2022), leading to the search for new sources of fertilizers. On the other hand, rational use of fertilizers is necessary, since long-term fertilization can deeply affect the physiochemical and biological soil properties. In addition, the incomplete capture and poor conversion of fertilizer could also cause water pollution and global warming through gas emissions (Masclaux-Daubresse *et al.*, 2010). Therefore, it is crucial to evaluate the effectiveness of new fertilizers, not only considering the productivity of the crops but also studying their effect on soil properties and the environment.

2. Materials and Methods

Laboratory incubation under controlled temperature (25ºC) and soil moisture conditions (De Soto *et al.*, 2023) was used in the evaluation of several materials from two wastewater treatment plants (WWTPs) in Navarre (Spain) as fertilizers in soils with different pH values (8.16 and 6.05). The characterization of the samples was carried out at the beginning of the trial and at 3, 6, and 9 weeks. All samples were analyzed in triplicate.

3. Results

The electrical conductivity increased in all experiments, since the amendments provide soluble salts to the soil. However, there was a decrease in pH values after the soil incubation.

It was observed an increase in available P (Olsen) and organic matter values after the incubation experiment. Finally, in relation to N, it was observed an initial NH_4^+ release and a latter nitrification during the incubation.

4. Discussion

The electrical conductivity increase was due to the amendments providing soluble salts to the soil. This parameter should be controlled in the case of continued applications of the amendments, since it can cause problems in the growth of crops (Porta-Casanellas *et al.*, 2011).

The observed evolution of the total and mineral N can be explained by a stimulation of biological activity in soils (Bernhard, 2010). In relation to these results, there was a decrease in pH values after the soil incubation, very likely due to the nitrification process. This decrease in time could be a long-term problem (especially in soils with low carbonate content), since soil acidification can cause, among other problems, the dissolution and loss of soil inorganic C (Raza *et al.*, 2020).

The initial increase in Olsen P observed was proportional to the dose in both soils. However, the experiment with acidic soil showed higher values of available P, because pH is a key factor in the evolution of P in soils. In relation to organic matter, the application of the products tested produced an increase in organic matter and contributed to the maintenance of soil moisture.

5. Conclusions

The studied materials from the WWTPs can be seen as potential fertilizers for agricultural soils and can promote circular economy opportunities for the wastewater industry. However, the application of these materials in agricultural soils should be further investigated before becoming common practice due to the observed gains in electrical conductivity and decreases in soil pH values due to the nitrification process.

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Using simple cultivar phenotyping and photothermal algorithm to explore the suitability of spring-sown grain legumes in France (Poster #230)

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Keywords: agroecology; grain legumes; phenotyping; photoperiod sensitivity; crop feasability

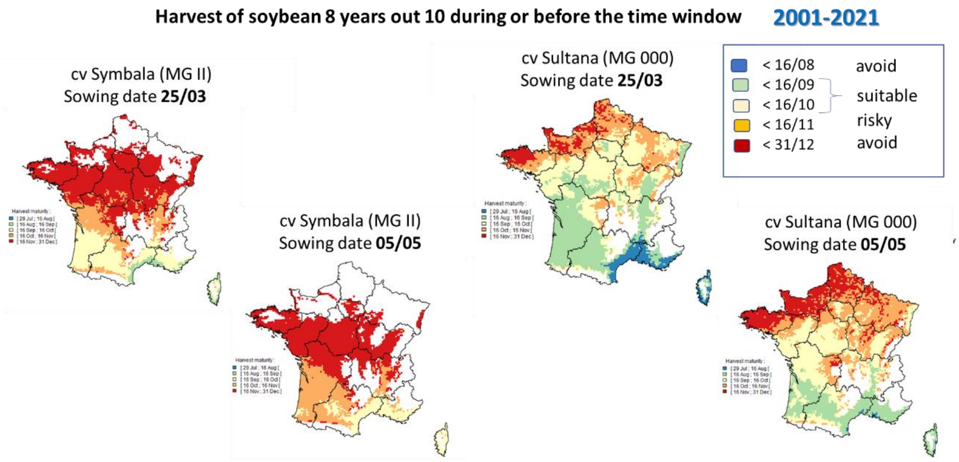

Figure 1. Graphical representation of the crop feasibility at France level for 2001-2021 period: application to soybean for two varieties (Cv Symbala, MG II; Sultana MG 000) and two sowing dates

To develop new cropping strategies (*e.g.* early sowing, double cropping) and explore suitable cultivation areas for grain legumes under current and future climates, an accurate prediction of crop phenology under different photo-thermal conditions is a pre-requisite. This means the simulation of the onset and length of the main phenophases between emergence and physiological maturity as a function of temperature and photoperiod.

For that purpose, a simple phenology algorithm (SPA) was developed and calibrated for soybean (*Glycine max*) in controlled conditions then satisfactorily evaluated at field level in SW France (Schoving *et al.*, 2020) but with less accuracy at national level (Bourgeois *et al.*, 2023).

Using the same approach, SPA was applied to three other spring-sown grain legumes: chickpea (*Cicer arietinum*), faba bean (*Vicia faba*), and field pea (*Pisum sativum*) with as an attempt to propose a generic method for phenology prediction in grain legumes. In 2022, SPA was calibrated for 2 cultivars of chickpea (Elixir, Twist), faba bean (Espresso, Victus) and pea (Karpate, Kayanne), and for 6 cultivars of soybean (from MG 000 to II).

Before being applied, SPA requires the calibration of 7 genotypic parameters determined from the literature, dedicated experiments or optimization. Two experiments were set up for this calibration: a) a pot experiment on the Heliaphen platform at INRAE Auzeville (lat. 43°31’ N, long. 1°28’ E) under natural conditions with 4 to 5 planting dates (from March to July) and a phenological monitoring thrice a week in order to unravel the effects of photoperiod from temperature accumulation; b) an experiment on germination response to temperature (from 3 to 43°C) under controlled conditions (cold room and incubator) in order to determine the three cardinal temperatures (Tmin, Topt, Tmax) for germination. A photothermal time formalism was used to evaluate by optimization the sensitivity of each cultivar to photoperiod, and the optimal Physiological Development Days of the cultivar to complete a given phenological phase (PDD). The optimization of the PDD plant parameter from hourly temperature values instead of daily values improved the prediction of phenology by SPA.

Data from the national post-registration network of Terres Inovia used for varietal recommendations were collected from to 2017 to 2021 for the corresponding varieties of grain legumes in order to evaluate the predictive quality of SPA.

Historical series of daily temperature were retrieved from the SAFRAN historical reanalysis which covers France at 8 × 8 km resolution. The SPA model was applied on each of the 8602 grid cells (height < 600 m) on the 2001-2021 period to produce maps of suitability at national level (Figure 1).

Cardinal temperatures were determined for the 4 grain legumes species: Topt ranged from 24.4 °C (faba bean) to 28.0 °C (field pea) and Tmax from 33.6 °C (chickpea) to 36.8°C (field pea). Faba bean and chickpea were confirmed as long day plants and soybean as a short day plant especially for the late-maturing varieties. Surprisingly, pea behave as a short day plant until flowering. With the assumption that the simulated date of physiological maturity was close to the actual date of harvest, SPA resulted in a reasonable prediction of the length of the growing season (with average RRMSE of 13.9 % to 16.7 % as a function of the crops). Using SPA, maps of crop feasibility at France level could be proposed for each variety as illustrated (Figure 1).

After some improvement (effect of more extreme daylengths, refined simulation of emergence and harvest dates…), this methodology combining cultivar phenotyping and simulation could be expanded to winter-sown grain legumes, later sowing dates (double crops) and future climates in order to promote the diversification of cropping systems with grain legumes.

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Acknowledgements

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Contribution of agroforestry to climate change mitigation: a case study from Wendhausen, Germany (Poster #359)

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Keywords: agroforestry; climate change; green house gas; life cycle assessment; trade off

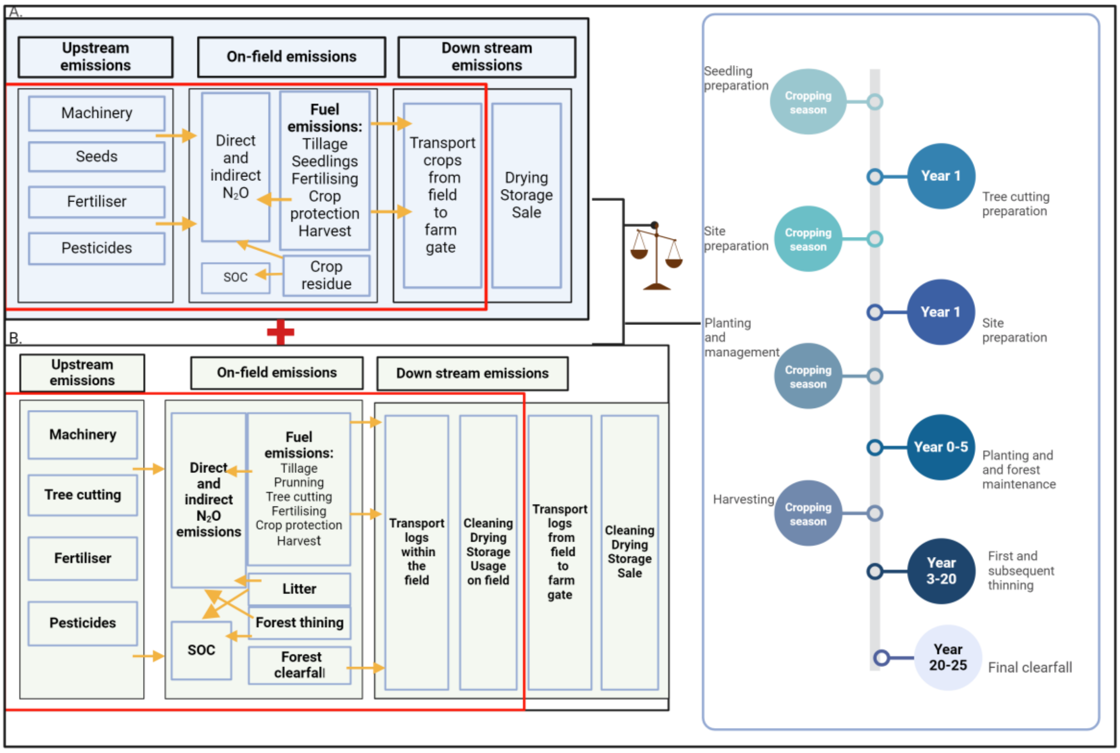

Figure 1. System boundary and LCI data collection in a short crop rotation agroforestry system

1. Introduction

Agroforestry systems (AFS) especially alley cropping systems with short rotation coppices (SRC), have emerged as promising solutions for mitigating climate change by offering carbon sequestration and greenhouse gas (GHG) emission reduction benefits compared to conventional agriculture practices. While AFS has shown promise in mitigating climate change, it is worth noting that agroforestry is not a one-fits-all solution, considering the multitude of possible systems that can be designed for various site-specific pedo-climatic conditions. The efficiency of agroforestry in climate change mitigation relies on a detailed understanding of local conditions and respective management strategies, including crop rotations and tree species selection. In this context, there is a knowledge gap on SRC's specific role and effectiveness and the quantification of SRC contributions within the agroforestry framework for mitigating climate change. This study aims to address this gap by evaluating the contribution of SRC agroforestry systems to climate change mitigation building on long-term data of an experimental agroforestry-system in Germany.

2. Materials and Methods

The study site in Wendhausen, Northern Germany, covers an area of 30 hectares with an elevation of 85m A.S.L. The climate in the region is temperate, with average annual temperature of 9.8°C and average annual precipitation of 616 mm (Swieter *et al.*, 2019). The soil properties are heterogeneous, with the soil in the agroforestry control system (ACS) characterized by a silty clay texture, while a clayey loam texture characterizes the reference cropland field.

The experiments include an AFS with a control field of about 3 hectares located next to it. The AFS consist of nine poplar strips with a distance of 10 m wide (from tree to tree); 10,000 plants/ha with planting association 0.5 m x 2 m. Tree strip widths are 96 m (wide agroforestry area), 48 m (narrow agroforestry area) plus a 1.5 m seam width on each side. Trees are 3 polar clones: Max (*P. nigra* x *P. maximowiczii*), Hybrid 275 (*Populus maximowiczii* x *P. trichocarpa*), Koreana (*P. koreana* x *P. trichocarpa*). In both, the AFS and the control, crop rotation includes winter oilseed rape and winter wheat.

Primary data from various AFS management processes and secondary data collected from various sources including databases such as the Ecoinvent are used to establish the life cycle inventory for the different AFS-treatments and cropland control treatment. A detailed model of the system showing various operations are shown in Figure 1. The impact assessment focuses solely on the impact category climate change (GHG). It follows the life cycle GHG emissions (from cradle to farm gate), in accordance with DIN EN ISO 14040 (DIN, 2021) within the study's system boundaries (Figure 1). To derive the life cycle GHG emissions, two functional units (FU): (1) total GHG emissions per hectare (GHGL; kg CO_2e ha^{-1}) and (2) carbon footprint per unit product (CFP; kg CO_2e kg^{-1}) are calculated as follows:

Total GHGL (kg CO_2e ha^{-1}) = Upstream emissions (kg CO_2e ha^{-1}) + On-field emissions (kg CO_2e ha^{-1}) + Downstream emissions (kg CO_2e ha^{-1})

Total CFP (kg CO_2e ha^{-1}) = (Total GHGL)/(Wood / Yield) (〖kg CO_2e ha〗^(-1)/(MT 〖ha〗^(-1)))

3. Results and Discussion

The study assesses greenhouse gas (GHG) emissions in an agroforestry system (AFS), emphasizing the significant contributions of fertilizer inputs and N_2O emissions in the crop component. Emissions in the tree component stem from CO_2, CH_4, and N_2O from soil management and agricultural activities. Soil organic carbon (SOC) changes positively impact AFS *versus* cropland farming. Higher diesel consumption in AFS cropping is attributed to machinery maneuvering around trees. AFS shows potential for climate change mitigation through carbon capture and substitution of fossil fuels with short rotation coppice (SRC) wood. However, the comparison of AFS with cropland may provide an incomplete picture and the comparison of AFS with cropland, pure SRC might be a fairer, and policy relevant option that should be considered.The study highlights the importance of site-specific factors in determining the effectiveness of agroforestry systems in mitigating climate change.

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Exploring the potential of temperate early arable land agroforestry systems for climate change mitigation (Poster #363)

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Keywords: agroforestry; climate change; mitigation; short rotation coppice; temperate

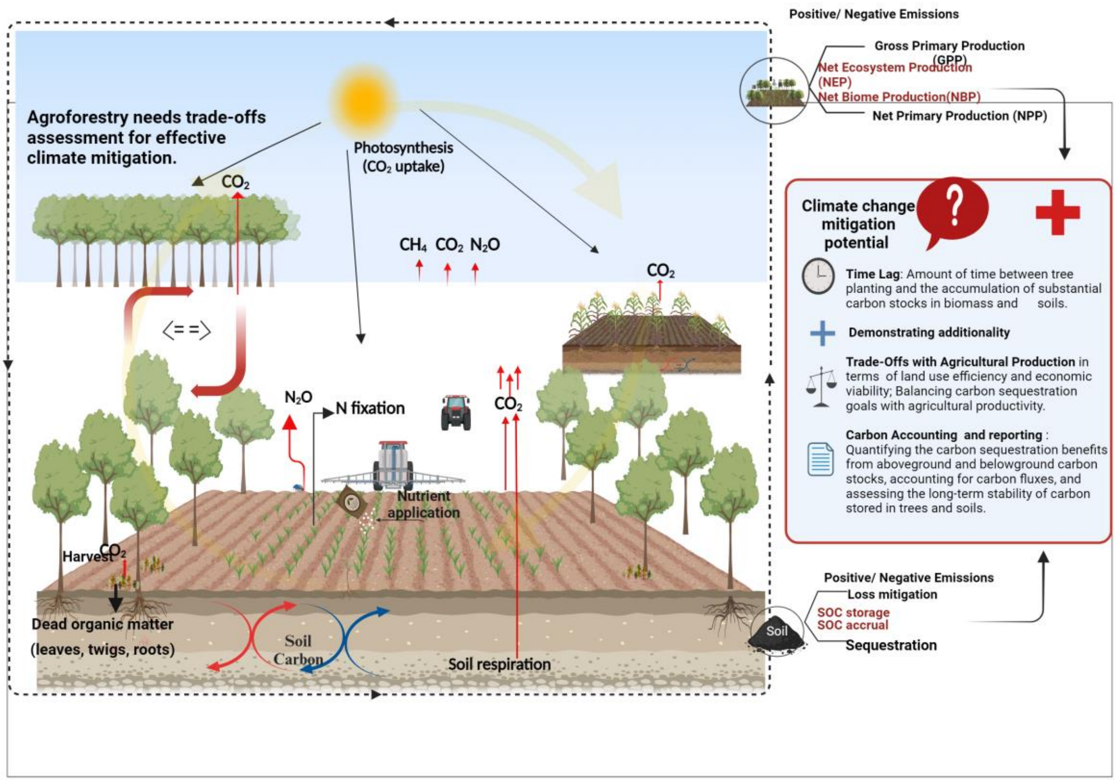

Figure 1. Synthesis on the exploration of AF for climate change mitigation

1. Introduction

In comparison to temperate monoculture arable cropping systems, short rotation coppice agroforestry systems (AF) presents a unique opportunity for enhanced carbon sequestration and climate change mitigation due to its integrated approach combining trees with various agricultural components. While both systems aim to improve sustainability, agroforestry's ability to store carbon in aboveground and belowground biomass as well as soil organic carbon offers additional benefits for mitigating climate change. However, the effectiveness of AF in mitigating climate change is influenced by various factors, including trade-offs between benefits and drawbacks. Understanding these trade-offs and balancing agroforestry's carbon sequestration with land use benefits while ensuring long-term climate mitigation effectiveness is essential for sustainability. Despite this growing recognition of agroforestry as a nature-based solution for climate change mitigation, there is still a lack of comprehensive data and research on carbon sequestration in temperate AF systems. This scarcity of information contributes to uncertainties in estimating the actual impact of agroforestry on reducing greenhouse gas emissions. There is therefore the need to explore the effectiveness of AF as a climate change mitigation strategy in temperate early arable land agroforestry systems by building upon existing knowledge and addressing key challenges in the field. By carrying out such a study, the results can provide a rigorous and evidence-based summary of the challenges and opportunities associated with AF in temperate regions for climate change mitigation, which can guide further research and policy.

2. Materials and Methods

To explore the potential of AF practices in climate change mitigation, a systematic review process synthesizing existing literature using the PRISMA methodology will be used. Literature databases such as PubMed, Web of Science, Scopus, and Google Scholar will be queried using specific keywords and will include studies on carbon sequestration in soils, climate benefits of AF practices, assessing trade-offs, and optimizing AF practices specific to temperate regions. Resultant studies from the data base searches will be analysed for suitability and inclusion for the final analysis. Inferential status will be employed to show the number of studies that fit the key words and the aim of the study.

3. Results and Discussion

The review will highlight the importance of balancing the benefits and drawbacks of AF practices for effective climate change mitigation (Figure 1). Trade-offs between implementing AF for carbon sequestration and potential benefits foregone by not utilizing the land for alternative purposes pose significant challenges. Addressing these challenges requires a nuanced understanding of the economic, social, and environmental implications of AF as a climate change mitigation strategy. Furthermore, assessing the durability and adaptability of AF practices is crucial to ensure their sustainable contribution to global climate objectives and maximize co-benefits for long-term development. Realistic knowledge of outcomes and local co-development of applied research are essential for informing farmers' decisions on adopting AF and optimizing its climate mitigation potential. Overall, a concerted effort is needed to overcome the pitfalls and challenges associated with AF practices to maximize their effectiveness in climate change mitigation while balancing agricultural productivity and sustainability.

Predicting and interpreting potato yield at field scales using Random Forest model for a whole country (Poster #137)

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Keywords: random forest; extrapolation; yield; uptake; uncertainty

1. Introduction

The random forest (RF) machine learning model has been applied successfully for crop yield prediction in recent years (Silva *et al.*, 2023). But extrapolation of predictions to other areas or other years where the feature space or time is considerably different from that of the training data very likely produces unreliable results (Wadoux *et al.*, 2021). Yield measurement error can also be an important source of uncertainty and needs to be quantified. Furthermore, prediction uncertainty arising from limited knowledge about the nutrient supply (soil and fertilizer)-uptake-yield relationship (de Wit, 1953) may affect model performance and interpretation. If yield is predicted directly from soil nutrient contents, fertilizer application and other environmental variables, the contribution of uptake to yield would be masked. To the best of our knowledge, prediction uncertainties due to the lack of understanding about the nutrient-uptake-yield relationship have not been clearly addressed. The objective here is to evaluate the performance of trained RF models and to quantify the contributions of different uncertainty sources with potato cultivation in China as an example.

2. Materials and Methods

A dataset of 2183 field-year observations was collected from a total of 491 fertilizer experiments in nine Chinese provinces from 2017 to 2019. The RF model was trained using 38 explanatory variables and default hyperparameters. The importance of selected variables was assessed by variable importance plots and partial dependence plots. The explanatory variables were then classified into five groups. The relative importance of each group was calculated by dividing the model efficiency coefficient (MEC) of a RF model using only that variable group by the sum of the MECs from all RF models using the five variable groups individually (Torres-Matallana *et al.*, 2021). Since sampling locations in the study area were spatially and temporally clustered, model performance was evaluated not only by 10-fold cross-validation (CV) but also by leave-block-out (LBOCV), leave-site-out (LSOCV), and leave-year-out cross-validation (LYOCV).

3. Results

Model performance decreased considerably when extrapolating over space and time. From 10-fold CV to LBOCV to LSOCV to LYOCV, the root mean square error (RMSE) increased from 3.4 to 8.3 to 9.1 to 10 t/ha, while the MEC decreased from 0.92 to 0.64 to 0.53 to 0.43. Cumulated sunshine duration and topography position index were the most important explanatory variables, while for the importance of variable group, weather and management groups were more important for yield prediction than soil, topography and fertilizer groups. Actual fresh potato yield ranged from 7.2 to 76 t/ha. The standard deviation of the yield measurement error was estimated as 3.1 t/ha, which equals 31% of the RMSE for LSOCV. For LSOCV, incorporating uptakes without fertilization, uptakes, and yields without fertilization as covariates reduced the RMSE by 5.6% to 50% t/ha, increased MEC by 9.6 to 64%, and decreased bias by 6.3% to 65% t/ha.

4. Conclusion

The fitted RF models could explain a substantial part of the potato yield variability in China, although there was a considerable residual error when extrapolating model predictions to other areas or years. Yield measurement error accounted for one-third of the residual error, while incorporating uptakes without fertilization, uptakes, and yields without fertilization as covariates significantly improved model prediction performance.

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Genotype x Environment interactions on soybean yield components and variability in Northern Germany (Poster #233)

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Keywords: genotype; environment; interaction; soybean; yield variability

Soybean [*Glycine max* (L.) Merrill] and its derived products are presently the most traded plant-based protein source on a global scale (USDA 2021). Soybean has remained a minor crop in Europe since its first introduction, although it is a popular feed supplement for livestock. Given its high demand in Europe, current efforts are aimed at expanding production to non-traditional areas made viable by rising temperatures. However, grain yield and stability have been low in many areas, necessitating the identification of critical factors contributing to this observation. Multi-environmental trials are needed to identify stable and adaptable cultivars for optimizing agronomic productivity.

The objectives of the study were: (i) to assess the genotype by environment (GEI) influence on soybean crude protein, grain, and protein yields to explore the influencing factors contributing to the variability in Northern Germany and ii) to identify superior genotypes as well as ideal environments for growing and breeding in Northern Germany.

Field experiments were conducted over three consecutive seasons in three distinct sites (Dahlem, Dedelow and Müncheberg) from 2019-2021. The study employed nine commercially available soybean cultivars of different maturity groups. All experiments were laid out in a randomized complete block design at sites with no soybean cultivation history.

Grain yield varied significantly ($P < 0.01$) among the years and sites. Mean soybean grain yield across years was 2060 kg ha^{-1} and ranged from 1527 kg ha^{-1} at Müncheberg to 2503 kg ha^{-1} at Dedelow. A large portion of the total variance in all studied parameters was explained by environment, followed by GEI, while a small portion was attributed to genotypes. Environments contributed 82.8%, 67.6% and 80% of total variation in grain yield, crude protein, and protein yield in soybeans, respectively. The GEI accounted for 7.7%, 14.6% and 11.1% variations in grain yield, crude protein, and protein yield in soybeans, respectively. This reflects not only the influence of the environment on soybean production but also the differential performance of soybean genotypes under diverse agro-environmental conditions in Northeast Germany. Among the tested genotypes, only Merlin consistently showed high stability and productivity, re-echoing the need for investment in breeding along with improvement in agronomic management practices to mitigate the impacts of critical factors affecting soybean productivity in Central Europe.

Deciphering crop-weed competition in aerobic rice culture in a temperate climate condition (Poster #76)

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Keywords: aerobic rice; light competition; quadrat sampling; weed management; yield loss

1. Introduction

Aerobic rice culture employs direct-seeding of dry rice seeds into unpuddled soils, with the field kept unflooded throughout the growing period to save irrigation water (Kato and Katsura, 2014). The method often leads to severe yield loss compared with the conventional transplanting method in flooded fields due to weed infestation (Jabran and Chauhan, 2015). For the judicious use of herbicides and the effective mechanical weeding in sustainable agriculture, we need to understand the weed community growths and their impacts on crop yield. The objective of this study was to evaluate the effects of various weed management practices on the growths of weeds and crop in aerobic rice culture in a temperate climate condition of Japan.

2. Materials and Methods

A field experiments was conducted at the Institute for Sustainable Agro-ecosystem Services, University of Tokyo, Nishitokyo, Japan (35°44'N, 139°32'E) during the summer of 2023. Rice (cv. Hitachihatamochi) was aerobically grown at a seeding rate of 100 kg ha^{-1}. Three weed management treatments – no weeding, hand weeding at 35 days after sowing, and complete weeding – were compared (Figure 1). Shoot growths of both rice and weeds were measured four times, as well as grain yield at maturity. Additionally, light interception of rice and weed canopies were separately measured to estimate the cumulative radiation intercepted and radiation use efficiency of rice and weeds. In no weeding plots, 16 quadrats in total were placed, and the coverage of each weed species was monitored during the crop growth period.

3. Results

The crop yield in the no weeding treatment was 25% compared with complete weeding. In no weeding, cumulative radiation intercepted was only 68% of that in complete weeding, due to severe light competition with weeds. Interestingly, there was no significant difference in radiation use efficiency of rice crop between no weeding and complete weeding. Meanwhile, the cumulative radiation intercepted of rice crop receiving only one weeding at 35 days after sowing was comparable to that in complete weeding, resulting in no yield loss (351 *vs.* 349 g m^{-2}). In no weeding plots, the 16 quadrats were classified into four clusters based on the coverage of each weed species. Even with similar total weed coverage, the quadrats with higher proportions of Persicaria lapathifolia and Digitaria ciliaris exhibited significantly lower rice yields than others.

4. Discussion

This study, for the first time to our best knowledge, directly measured the light interception and radiation use efficiency of crop and weed community separately in natural crop-weed competition (Colbach *et al.*, 2021). This study suggests that a single weeding at an early growth stage can alleviate light competition between rice and weeds, thereby maintaining higher yields in aerobic rice culture in a temperate climate condition of Japan. It was also evident that not all weed species contribute equally to crop yield reduction. Particularly, Persicaria lapathifolia showed vigorous growth immediately after rice emergence, which made the early weeding effective.

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Waterlogging and heat stress interactions on wheat yield and components (Poster #194)

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Keywords: wheat; waterlogging; high temperatures; stress interactions; yield

1. Introduction

Over the last decades, there has been an increased frequency of intense rainfalls [1]. Thus, waterlogging events are becoming and will be more common, jeopardizing the performance of crops. As the higher frequency of storms is associated with increased temperatures [2], the frequency of crops being exposed to both stresses will increase. Wheat is crucial for food security and will be more frequently exposed to waterlogging and heat stress, even in Mediterranean regions [3]. The economic damage produced by waterlogging or heat in wheat has been evidenced in many studies [4,5,6]. Although most literature assume synergistic interactions among stresses [7], it has not been yet analyzed how these stresses interact on wheat yield: *i.e.*, whether they are synergistic or antagonistic; which is the aim of this study.

2. Materials and Methods

We conducted an experiment involving 3 bread (Artur Nick, Santaella, Acorazado) and 3 durum (Euroduro, Don Ricardo and Athoris) spring wheats grown under 4 treatments (control, waterlogging, heat stress, and combining both stresses). Plants were grown individually in plastic tubes (8.5 cm diameter and 100 cm length) placed outdoors. At the onset of stem elongation (DC30, 8), the tubes designed for waterlogging were placed into waterproof plastic bags and filled with water until covering 3 cm from soil surface for 15 consecutive days. Then, plastic bags were removed, and plants were watered daily. Two days after waterlogging ended (*i.e.*, at booting, DC40, 8), plants assigned to heat stress (heat alone and combined with waterlogging) were placed under portable tents with transparent polyethylene increasing daily temperature (+3ºC daily average at midday) for 15 days. After that, tents were removed, and plants continued growing until maturity, when yield and components (biomass and harvest index; numerical components) were quantified.

3. Results

As expected, there was genotypic variability in yield responses to the stresses but not related to the different species. Averaging across the 6 cultivars, yield was reduced by all treatments: by 33.7±7.3, 24.7±7.8, and 44.9±6.4%, when affected by waterlogging, heat stress, and both stresses combined, respectively. This means that collectively and considering all genotypes together waterlogging and heat were antagonistic on their effects (*i.e.*, the exposure to waterlogging mitigated the effect of heat, through conferring a sort of general acclimation to the plants that had been stressed before the imposition of the heat). However, this only reflects overall general result. The SEs shown above are relatively large because there was genetic variation in sensitivity, with most cultivars showing the antagonistic effect reflected in the average behavior, whilst one exhibited an additive type of effect and another a synergistic type. The variability in response reflected more intra- than inter-specific variation, the antagonistic effect was dominant in both species. Considering the effects of the individual stresses, yield seemed in general more sensitive in durum than in bread wheat. The effects of treatments on yield operated mainly through affecting grain number (mainly though the number of grains per spike) with more exceptional effects through grain weight. Also, the stresses seemed to have affected more growth of the plants than the partitioning to yield.

4. Discussion

The responses observed in yield and its components prompt consideration not only of genotypic variability, which serves as a tool for selecting varieties more tolerant to waterlogging and high temperatures, but also of the interactions between these consecutive stresses. Contrary to the expectation that prior stress leads to greater reductions in subsequent stress, most combined stress cases in our study resulted in yield reductions lower than anticipated based on additive responses to individual stresses. The antagonistic interaction between stresses identified in our experiment may offer insights for understanding and mitigating the impact of waterlogging and heat stress occurring concurrently in wheat cultivation scenarios.

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How can agricultural production be reconciled with environmental preservation: 'Land sparing' *versus* 'Land sharing'? (Poster #32)

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Keywords: agricultural production; environmental preservation; land sharing; land sparing; data envelopment analysis method

Reconciling agricultural production with environmental preservation is one of the most challenging issues in the agricultural sector. We address this issue by considering two strategies for land management: 'land sharing' and 'land sparing'. Taking into account farm categories, we use an efficiency analysis utilising the DEA method to measure the potential for implementing these two strategies. Fam categories are defined according to two criteria: the level of agricultural land productivity measured by the yield index and the level of subsidies received by farms. Applied to farm data from the Meuse department for the period 2006–2016, the results show that agricultural production can be reconciled with environmental preservation by sparing 16 % of farmland for the environment or by reducing the use intensity of intermediate inputs by 13 % on all farmlands. Considering our farm categorisation, regarding the criterion of land productivity, our findings suggest that land sparing would be more appropriate for less productive farms and land sharing for more productive farms; regarding the level of subsidies, both land sparing and land sharing would be more appropriate for large farms that receive less subsidies. The more farms increase in size and receive subsidies, the less they contribute to the two strategies. Our results underline the importance of considering farms' characteristics in implementing an agricultural land management strategy for environmental preservation.

Effects of different amendments on aggregate stability and microbial communities of coastal saline–alkali soil in the Yellow River Delta (Poster #243)

Shan Li

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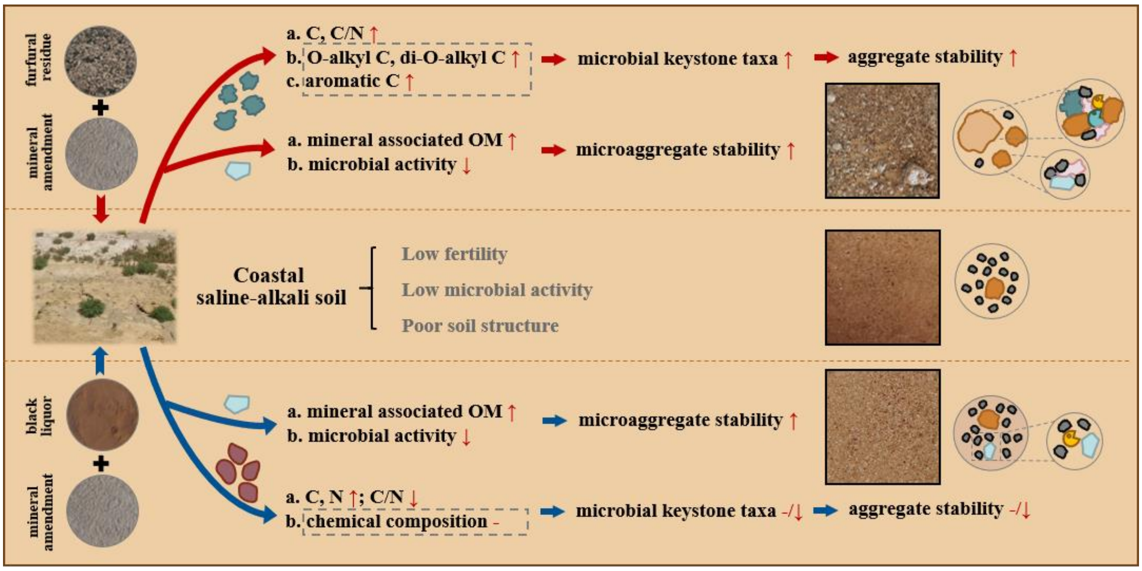
Keywords: chemical composition; organic amendment remediation of saline–alkali soil; solid-state 13C CPMAS NMR; water-stable aggregate



1. Introduction

The coastal wetland of Yellow River Delta (YRD) is one of the largest, most integrated and youngest wetlands in the warm temperate zone of China, and the YRD has the most reserve land resources in the east coast. While, soil salinization in this region induced and compounded problems like low fertility, low microbial activity, and poor soil structure, seriously affecting ecological balance and agricultural development. In consequence, the remediation and comprehensive utilization of coastal saline–alkali soils in this region are of great significance to solve the shortage of agricultural land and promote the development of ecosystem restoration and agricultural economy. At present, a large number of scholars have studied the effects of different amendments on the remediation of saline–alkali soils in the YRD, but few studies have provided technical guidance on the mechanism for the selection of effective amendments in this region.

2. Materials and Methods

In this work, furfural residue (particulate; C/N: 51.87; O-alkyl C + di-O-alkyl C: 42.35%, aromatic C: 40.89%) and black liquor (dissolved; C/N: 3.11; O-alkyl C + di-O-alkyl C: 32.20%, aromatic C: 28.32%) were tested to examine their effects on chemical properties, water-stable aggregate fractions, chemical compositions of solid-state soil organic matter (SOM), gloaming-related soil protein (GRSP) contents and microbial communities of coastal saline–alkali soil under a 400-day incubation experiment. Furthermore, organic amendments mixed with mineral amendment (4:1) were employed to explore the interactions between organic and inorganic amendments. And we selected the days (R(0.25) max day) when the water-stable macroaggregate fraction (>0.25 mm, R0.25) of each treatment was the highest according to the results of water-stable aggregate fractions. Then, the solid-state SOM chemical compositions (13C NMR) and quantified soil microbial communities on the R(0.25) max and 400th days were measured. Finally, we linked these parameters to explore how organic amendment qualities and inorganic amendment addition affected the formation and stability of aggregates.

3. Results

1) Furfural residue reduced the soil pH and increased SOC, TN, C/N, and DOC; black liquor reduced the soil pH and C/N, but increased EC, water-soluble Na+, SOC, TN, and DOC; and the addition of mineral amendment limited these effects on soil properties.

2) Furfural residue improved the water-stability of aggregates while black liquor had a slight negative effect, and mineral amendment further increased the fraction of water-stable microaggregate; Furfural residue and black liquor significantly affected the increase of GRSP, while mineral amendment slightly reduced the effect of furfural residue.

3) The chemical composition of solid-state SOM changed greatly with the input and decomposition of furfural residue, compared with black liquor.

4) Furfural residue and black liquor significantly changed the compositions of soil bacterial and fungal communities, while mineral amendment obviously influenced the effects of black liquor more than those of furfural residue; Furfural residue reduced the alpha diversities of fungi while mineral amendment limited these effects, and black liquor reduced the bacterial alpha diversities.

5) The Pearson correlation analysis showed that water-stability of aggregates were positively correlated with soil C/N and GRSP, and negatively correlated with EC, Na+, TN, and DOC. Furfural residue had obvious impacts on soil C/N, water-stability of aggregates, and GRSP, but black liquor obviously affected soil EC, Na+, TN, and DOC.

4. Conclusion

Our findings demonstrate that organic amendment qualities and inorganic amendment addition could significantly influence the formation and stabilization of aggregates in coastal saline–alkali soil. High soil C/N and the relative abundance of effective chemical compositions (O-alkyl C, di-O-alkyl C, and aromatic C) of solid-state SOM have stronger and longer effects on the water stability of aggregates by increasing the relative abundance of keystone taxa (such as orders Rhizobiales and Sordariales) and GRSP contents in soils. The qualities (primary form, C/N, and chemical composition) of organic amendment are the key factors in affecting the form, C/N, and chemical composition of SOM. In addition, O-alkyl C and di-O-alkyl C fractions of solid-state SOM promote the rapid and intense formation of macroaggregates, while aromatic C make the aggregate stability more durable. We also found that abundant N inputs have no positive or even negative influence on the formation and stability of aggregates. Inorganic amendment addition further increased the fractions of microaggregates, while having negative effects on microbial activities.

How crop associations can exploit efficient use of natural resources while reducing the dependency on external inputs (Poster #110)

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Keywords: agroforestry; cover crop; intercrops; strip crops; trap crops

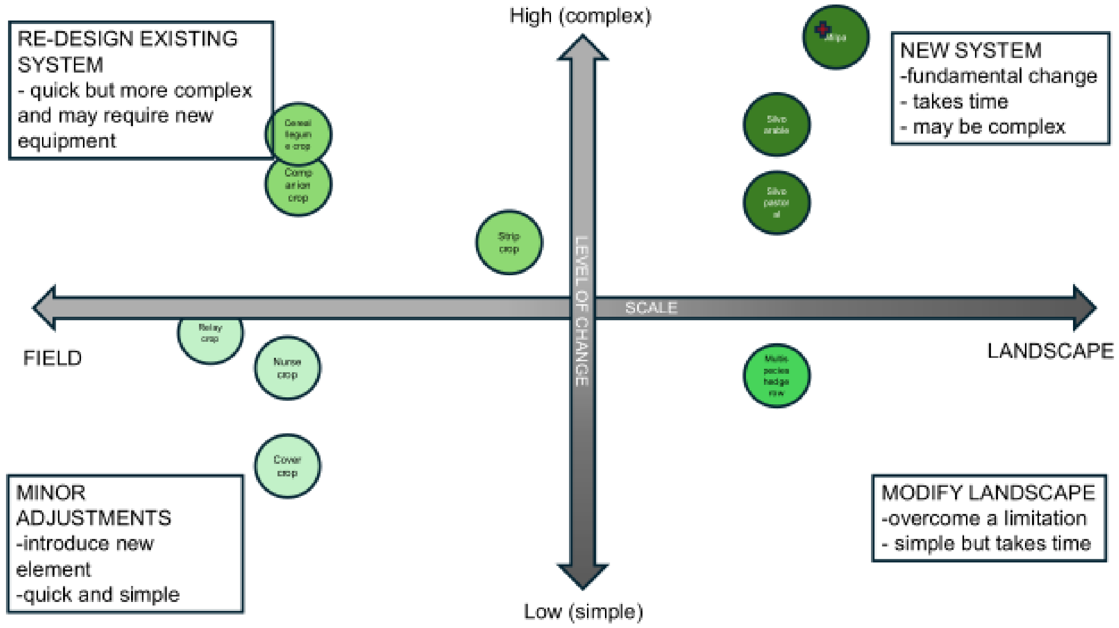

Figure 1. A schematic visualization of some crop associations, their roles, spatial scales and the complexity of their introduction in farming systems

1. Introduction

Crop association is the concurrent cultivation of different crops on the same land at the same time, so to maximize their synergic biological interactions. Integrating crop associations into existing cropping systems and farm landscapes may increase farm resilience by promoting efficient use of natural resources while reducing the dependency on external inputs [1]. However, the uptake of these practices on commercial farms in Europe is still low due to the complexities of implementing them into farming systems.

2. Materials and Methods

The paper is the result of the work of the EU CAP Network Focus Groups on “Crop associations including Milpa and protein crops” [2]. We selected five of the most frequent crop associations in Europe (*i.e.*, cover crops, intercropping, strip cropping, trap crops, and agroforestry). We described the service or product they provide, and the challenges for their adoption. We also discussed their suitability in different farming systems and environments.

3. Results

Crop associations greatly differ in functions, spatial scales, and the complexity of their introduction in farming systems (Figure 1).

Cover crops are grown between periods of regular crop production primarily to protect or improve soil [3]. They can increase subsequent crop yields, enhance soil fertility, and reduce soil erosion, nutrient leaching, and weeds. Challenges include the development of mixtures where one species doesn't dominate and the termination of the cover crop (especially under organic conditions where herbicides cannot be used).

Culturing more than one crop on the same field is called intercropping and may allow land sparing and, simultaneously, raise yields. Specifically, intercropping cereal with legumes may deliver several ecological services because the morphological and physiological differences between the two species benefit their mutual association [4] even if harvesting the two crops separately could be challenging.

Trap cropping is a crop association deployed to attract, divert, intercept, and/or retain targeted insects or the pathogens they vector to reduce damage to the cash crop [5]. The main challenges are land use, insect pest specificity, and having access to the knowledge to properly plant the trap crop.

Strip cropping (the practice of growing different crops side by side in strips [6]) can reduce infestations of diseases and insect pests and favor the presence and activity of pest natural enemies. Tillage, fertilization, pesticide application, and irrigation at the strip level can be more challenging than in larger plots.

Agroforestry is the practice of deliberately integrating woody vegetation (trees or shrubs) with crop and/or livestock production systems to benefit from the resulting ecological and economic interactions. This can reduce the loss of nutrients, sediments, and agrochemicals to water, increase biodiversity, and the aesthetic appeal of the countryside. The uncertainty of long-term performance projections of agroforestry systems can be an obstacle to their adoption.

4. Discussion

By comparing the different alternatives for crop associations, we described that some options give results in several dimensions and might be encouraged without requiring settlements. Some others may be of interest in certain contexts and will be the subject of trade-offs according to the production objectives of each farmer and his/her risk aversion.

Our study provides a theoretical framework for addressing aspects of resilience and sustainability of production systems that integrate crop associations, exploiting practical examples for different agro-pedo-climatic contexts. We also highlighted that for crop associations to have long-winded and lasting impacts, other agroecological practices should be integrated.

Finally, our work based on cross-disciplinary dialogue and collaboration may lead to novel perspectives and innovative insights on crop associations.

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Genetic gains in wheat yield and its physiological attributes under contrasting conditions (Poster #85)

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Keywords: *Triticum aestivum*; grain yield; fruiting efficiency

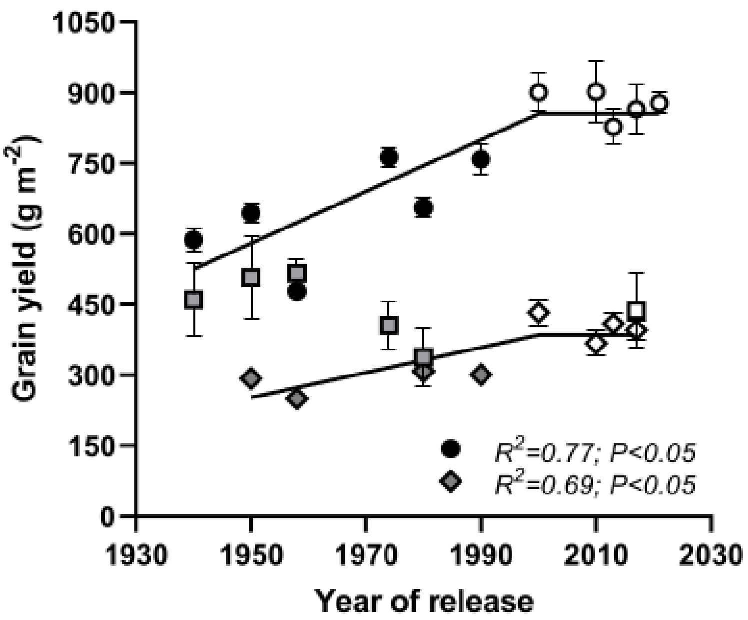

Figure 1. Relationship between grain yield and year of release. Symbols correspond to early sowing (circles), late sowing (squares) in Lleida and early sowing in Valladolid (rhombus) as well as traditional (closed symbols) and modern cultivars (open symbols). Vertical bars are the standard errors. Lines stand for the adjusted bi-linear regression, when significant (see R^2s inset)

Yield improvement in wheat (*Triticum aestivum* L.) has shown signs of yield stagnation in Spain [1,2,3,4] and other countries in Europe [5,6,7]. Furthermore, prospects for genetic gains and adaptability are challenging in the context of climate change, where the occurrence of extreme events and erratic weather difficult genotypic selection and jeopardizing genetic gains. Retrospective studies documenting physiological changes in wheat attributable to breeding can contribute to identify avenues for adaptation and selection. This study aimed to determine the physiological bases for yield differences between traditional and modern wheat cultivars of a Mediterranean region, and to quantify yield and yield-related genetic gains under contrasting growing conditions.

Three field experiments comparing 11 bread wheat cultivars (released between 1940 and 2021) representing different eras of genetic improvement in Spain were carried out during the 2022-2023 growing season. Field experiments consisted in two early sowing dates differing in water availability and location (irrigated in Lleida and rainfed in Valladolid) and a late sowing in Lleida with contrasting photothermal conditions.

Yield gains varied in magnitude and significance among environments. Gains were clear from 1940 to 2000 in the early sowing under both irrigated and rainfed conditions, while no clear gains were evidenced thereafter (Figure 1). These gains were related to a higher number of grains per m² and per spike rather than to spikes per m^{2}, as well as improvements in fruiting efficiency. Harvest index has remained constant in cultivars released from 2000 whereas total biomass showed a positive linear trend for the whole period. On the other hand, there were no clear gains in the late sowing.

The absolute yield gain was much higher under irrigation than in rainfed conditions (5.5 and 2.6 g m^{2} yr^{-1}, respectively). However, yield gains estimated in relative terms (respect to the yielding condition) was the same in both conditions (c. 0.7% yr^{-1}). The differential expression of genetic gain in absolute terms revealed a loss in yield stability with breeding and therefore yield in modern varieties was more penalised than in traditional cultivars when grown under resource-limited environments. This might be related to the fact that higher yield potential would be dependent on the responsiveness to environmental improvements.

Yield was similarly penalised due to lack of irrigation or sowing late. However, the trends changed differently depending on the source of variation. With a similar trend when the penalty was due to reduced resources, whilst the trend was lost when the penalty was due to a change in photothermal conditions.

Trends observed in grain per spike indicate a need for increased focus on enhancing total biomass and spike fertility, while considering potential trade-offs with grain size.

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Effects of a thermopriming based acclimation strategy on the seed yield and quality and on the root morphology and exudation in two Brassica species (Poster #12)

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Keywords: heat stress; thermopriming; root exudation; seed yield and quality; oilseed rape; camelina

Climate change is one of the major challenges of the 21st century as the effects on the agricultural sector, are excepted to be massive, therefore jeopardizing food security. Among the climatic constraints, heatwaves have become more intense and more frequent which represent a threat to most crops, particularly during their reproductive stage which is the most critical period for seed yield and quality. Oilseed species such as oilseed rape and camelina are species mostly affected by heat stress, causing significant yield losses and a decreased seed nutritional and physiological quality. In this context, solutions to maintain sustainable productivity of these crops have been explored and rely on different levers. Varietal selection and improvement of crop management techniques are two main current levers to attempt either adapt to heat stress or alleviate its effects. However, they are limiting, especially because of genetic erosion (Esquinas-Alcázar 2005) and because their efficiency relies on the pedoclimatic conditions (Chen *et al.* 2005; Gao *et al.* 2021). This prompts agronomists and ecophysiologists to develop additional strategies that would explore the inherent ability of the plants to acclimate. Stress acclimation result from a sensitization to stress that allows organisms to respond to subsequent stresses and eventually overcome their negative effects. This priming effect is triggered by a based on a pre-stress exposure that can be similar or of different nature to the later stress. Thermopriming, which consists of applying moderate heat stress before a more intense heat stress, could help plants to acclimate following several mechanisms (Serrano *et al.* 2019; Balazadeh 2022; Liu *et al.* 2022). However, although acclimation has been widely described in terms of impacts on the development of aerial parts and on yield, very few studies have focused so far on its effects on root morphology and functions such as root exudation and the link between exudation and establishment of yield. In this study, we aimed at analyzing the effects of thermopriming not only on seed yield and quality but also on root morphology and exudation in oilseed rape and camelina. For this, at the onset of pod formation, we tested the effects of a moderate heat stress (pre-stress) consisting of a gradual increase in temperatures from 24 to 28°C for 5 days before an intense heat stress consisting of 5 days at 28°C with a daily heat peak of 5 hours at 33°C. First of all, our results showed that oilseed rape and camelina have contrasting strategies in terms of response to heat stress. Indeed, camelina seems to respond to the stress by increasing its investment to the roots by enhancing root prospection and modifying the quality of exudates, unlike oilseed rape, which seems to undergo heat stress by increasing the C exuded. Similar observations were made for seed yield and quality. Indeed, while heat stress had little effect on seed yield and quality in camelina, they were negatively impacted upon heat stress in oilseed rape. Moreover, these two species respond differently to the heat stress when they were previously exposed to the gradual increase, thus meaning they had contrasting acclimation strategies. In oilseed rape, thermopriming reduced C exudation and maintained yield and grain quality in comparison with heat stress alone, whereas it had a more negative impact on exudation and seed yield for camelina as a consequence of cumulated negative impacts of both temperature events.

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Rice blast control drives yield benefits from variety mixture in rice: a global meta-analysis (Poster #1)

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Keywords: rice

Rice blast, caused by the fungus *Pyricularia oryzae*, is the most important disease of rice globally. Variety mixture has proven potential to reduce the incidence of rice blast and increase yield, but the effectiveness of variety mixture as a disease control method varies, and the general effectiveness and yield benefits of this agroecological practice have not been demonstrated. Here, we present a global synthesis of experimental data on the effect of variety mixture on rice blast. Based on 1255 disease observations from 38 research publications, the relative yield in mixture (yield in mixture divided by yield in monocrop) increased with disease incidence in the monocrop, for hybrid rice from 0.92 to 1.06 as disease incidence in the monocrop increased from 0 to 100%, and for glutinous rice from 0.16 to 0.30. Variety mixture reduced the odds of disease by 68% on average. The average reduction in disease odds was substantially greater in blast-susceptible glutinous rice varieties (80%) than in more blast-resistant hybrid rice varieties (34%), but still substantial and significant in the latter. The disease control effect of fungicides and variety mixture were additive. Blast-resistant hybrid rice varieties became much more susceptible to blast at high than low fertilizer N input but the disease controlling effect of mixture was unaffected by fertilizer N input. The results show that variety mixture is an effective agroecological practice, particularly for the cultivation of indigenous varieties with high market value but low blast resistance.

Identifying and engaging Communities of Practice focused on soil health (Poster #183)

Tove Ortman

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Keywords: living labs; participation; soil health; transdisciplinary research

There is a broad agreement that in order for science to enable actual change and foster real-life innovations, we need to connect practitioners to researchers (Lang *et al.*, 2012; McPhee *et al.*, 2021). How can researchers find and engage farmers and other stakeholders and involve them in the research process? One emerging method for transdisciplinary agricultural research is so called agroecosystem living labs, were scientist work together with farmers and other stakeholders in order to address complex transdisciplinary problems, and explore innovative agricultural practices (McPhee *et al.*, 2021). In the process of establishing living labs, networks and partnerships have been shown to be key enabling factors to succeeding (Berberi *et al.*, 2023). Identifying already existing networks of practitioners can therefore be an advantage when developing participatory initiatives such as living labs (Hvitsand *et al.*, 2022). In the project PREPSOIL (Funded by the European Union under the Mission Soil (project number 101070045), which aims to raise awareness and engagement about soils in Europe, we map so called Communities of Practice, which is a way of describing groups of practitioners who share a concern for sustainability challenges, and have an interest for developing techniques or approaches. The purpose is both to enable practitioners that share an engagement for soil health to engage within and across countries, but also to document groups that use innovative practices to enhance soil health. A starting point for identifying Communities of Practice has been national stakeholder groups – *e.g.* National Hubs, regional networks around agricultural advisors, researchers or NGOs focused on soil health. On the PREPSOIL homepage there is also an opportunity for stakeholders to sign up themselves, and engage in a forum. After identifying groups of actors, the research partners of PREPSOIL documents the groups by making a video interview and helping the group to describe themselves at the PREPSOIL homepage. The process is ongoing during 2024, with the aim of documenting 80 communities of practice across Europe.

Preliminary results of the mapping process are that the language barrier is proving to be a challenge in order for practitioners in different regions of Europe to engage together, *e.g.* on the online forum. In addition, the collaboration with other Communities of Practice or researchers might seem time-consuming, with unclear actual direct gains for the group. Research initiatives, *e.g.* living labs, that involve Communities of Practice should be closely connected with an actual problems that the practitioners face, in order to motivate participation. There also seems to be a need for resources and structure – *e.g.* enabling study visits or translated news pieces which are easily accessible, in order for the groups to be able to exchange knowledge across countries. The role of researchers and agricultural advisors as mitigators of the learning processes seems important, as well as funding for activities. One way of simplifying communication and initiatives for living labs and other initiatives which is under development within PRESOIL is an app, where researchers can communicate and collaborate with stakeholders and citizens through so called soil quests. How this type of technology can enable more engagement and collaboration within potential living lab initiatives is yet an open question, but it seems clear from the experiences of PREPSOIL that these types of tools are needed in order to make participation in research more accessible and functional.

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Phase-specific genotype-by-light interactions determine kernel number and yield potential in wheat (Poster #28)

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Keywords: environmental fluctuation; wheat; plant breeding; yield physiology; yield component

Wheat is grown in variable environments and the fluctuations during critical developmental phases may have significant effects on final grain yield, especially in the context of increasingly frequent climate extremes. Therefore, it is important to understand the impacts of short-term (days) natural fluctuations of environmental variables during specific physiological phases that correspond to the formation of yield components (spike number, SN; kernel number per spike, KpS; and thousand kernel weight, TKW) and may contribute to explaining the gap between potential and actual yields in wheat. Using a novel statistical approach, we first estimated the sensitivities of SN, KpS and TKW to variations in global radiation, temperature and precipitation across 81 time-windows ranging from double ridge to seed desiccation in 220 winter wheat cultivars. Most time and cultivar specific sensitivity responses occurred in time windows corresponding to the major physiological sub-phases during spike and kernel development. Interestingly, kernel number per spike was the most sensitive yield component affected by short-term fluctuations of light and temperature, especially during the sub-phase between yellow anther and tipping and at pre-grain filling. We further tested 16 wheat cultivars differing in their stage specific sensitivity of KpS to light intensity in growth chamber experiments. Our data confirmed the sub-phase specific effects of light on floret development and kernel abortion during the yellow anther and tipping phases, and the sensitivity differed by a factor of three between cultivars. Our results reconcile contradicting findings from previous studies, reveal previously undetected effects of environmental fluctuation and provide deep insight into cultivar specific three-way interactions between phenology, yield formation and environmental fluctuations. This information can be further used to optimize yield potential.

A collaborative approach to diversified soybean-based cropping system: design of four OFE in North-Eastern Italy (Poster #318)

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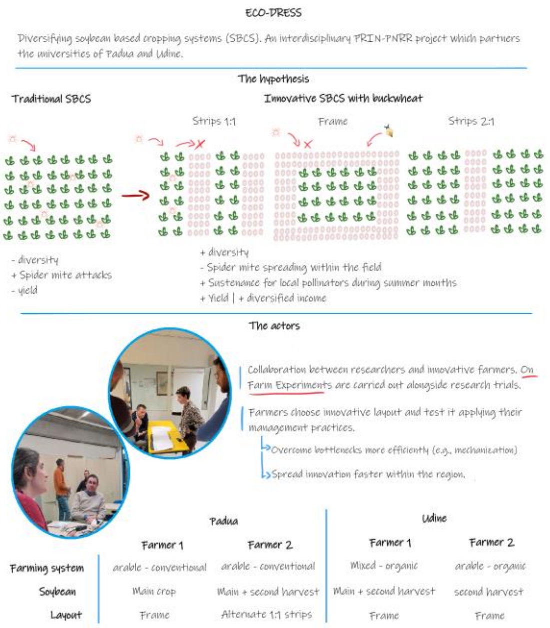
Keywords: intercropping; soybean; buckwheat; on-farm experimentation



In Italy, soybean is mainly cropped in Veneto and Friuli Venezia Giulia accounting 2/3 of the national surface. In these areas, soybean-based cropping systems (SBCS) appeared to be poorly diversified where soybean is cropped since long term, thus it is vulnerable to both abiotic and biotic stresses hampering its productivity. Indeed, a serious issue is represented by the two-spotted spider mite, *Tetranychus urticae* Koch, which is a polyphagous pest mite characterized by short life span, high fecundity and ability to develop resistance to many acaricides. Another pest affecting soybean is the invasive brown marmorated stink bug *Halyomorpha halys* (Stål), able to feed on different aboveground soybean tissues preferring the pods where they induce seed damage with yield loss.

The ECO-DRESS project aims at re-designing SBCS testing alternative patterns of strip cropping with *Fagopyrum esculentum* (buckwheat), a pseudo-cereal characterized by fast germination, fast growth and soil cover. It is commonly used for its allelopathic properties against weeds and as nectar provisioning plant host of parasitoids.

The researchers have designed three different SBCS based on different intercropping schemes of soybean and buckwheat according to different hypothesis of soybean production and pest control to be tested in their experimental farms in Veneto and Friuli Venezia Giulia regions: 1) alternate strips of soybean-buckwheat (1:1), narrow strips of buckwheat in soybean fields (2:1) to maintain a dominant production of soybean, soybean framed by buckwheat to control the two-spotted mite. Moreover, a group of farmers experienced in soybean or buckwheat cropping have been invited, in both regions, to participate to a meeting with a presentation of the ECO-DRESS project and discussion of possible design of similar experiments in their farms. Main points of discussion where the sowing date of the experiments (soybean/buckwheat as main crops or double crop), the seeds to be used (same cultivars provided by scientists or own cultivars), how to manage the harvest of the two crops, the experimental layout to implement (Figure 1). After the discussion, for each region, two farmers were selected for hosting ‘on-farm experimentation’ (OFE) about the introduction of innovative SBCS promoted by the project. More specifically, after having known all the different SBCS, each of them with the help of researchers tried to identify the most suited to his farm. After that, some meetings were organized in order to discuss how properly tailoring the SBCS selected to the farm machinery, the fields location and the farm business as usual. The OFE will be carried out in 2024 and 2025.

Interspecific variability in seed germination and seedling emergence dynamics of cover crop species (Poster #211)

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Keywords: cover crops; seed germination; seedling emergence; seedling mortality; modeling

Cover cropping holds the potential for spatio-temporal diversification of cropping systems, which can help address food security and enhance environmental sustainability (Quintarelli *et al.* 2022). Yet, the global adoption of cover crops (CCs) by farmers is limited. One of the reasons of this poor CC adoption is difficulties to ensure a good CC establishment (Lamichhane and Alletto 2022; Feng *et al.* 2024). A better understanding of seed and seedling traits of CC species can guide their choice and sowing dates for an improved CC establishment.

We conducted laboratory experiments to characterize seed germination and seedling growth dynamics of five CC species namely crimson clover (*Trifolium incarnatum* L.), faba bean (*Vicia faba* L.), fodder radish (*Raphanus sativus* L.), phacelia (*Phacelia tanacetifolia* Benth.), and sudan grass sorghum (*Sorghum drummondii* (Steud.) Millsp. & Chase.). The measured variables were the speed of germination, seedling elongation dynamics (shoot and root growth), and seedling mortality under clods, the latter being an indicator of CC seedlings ability to overcome mechanical obstacles in the seedbed during emergence. Observed results on seed germination, seedling heterotrophic growth, and seedling mortality under clods (with different clod sizes, spatial distribution in the seedbed) were fitted to a Gompertz function, a Weibull function, and a probability function, respectively.

Crimson clover, fodder radish, sudan grass sorghum and faba bean showed high germination rates (97, 91, 99 and 99%, respectively) while phacelia had much lower germination rates (62%). The dynamics of seed germination, seedling shoot and root growth dynamics and seedling mortality were well-modelled by the adjustments used. Thermal time (TT) required to reach 50% seed germination was 14, 15, 20, 37 and 55℃d for crimson clover, fodder radish, sudan grass sorghum, faba bean and phacelia, respectively. Concerning shoot elongation dynamics, the final shoot length of crimson clover was significantly lower than that of the other four species ($p<0.05$). The final root length of crimson clover and fodder radish was significantly lower than that of the other three species ($p<0.05$). TT required to reach 50% of the maximum length differed significantly among species ($p<0.05$) only for root with the highest values for faba bean (62℃d) followed by crimson clover (37℃d), fodder radish (35℃d), sudan grass sorghum (30℃d) and phacelia (10℃d). Significant differences in seedling mortality rates were found among species ($p<0.05$) only for bigger clod sizes when the clods were not buried into the seedbed, with the highest mortality rates for crimson clover followed by sudan grass sorghum, phacelia, fodder radish and faba bean. Likewise, significant differences ($p<0.05$) in seedling mortality rates among the species were observed when the clods were buried into the seedbed, with crimson clover showing the highest mortality rates followed by fodder radish, phacelia, sudan grass sorghum and faba bean.

This is the first study to determine reference values for heterotrophic shoot and root growth dynamics and seedling tolerance to a mechanical stress of the seedbed of the five CC species mentioned above. These results will be used to parametrize the SIMPLE emergence model (Durr *et al.* 2001) followed by the assessment of its prediction quality, based on available data from historical field experiments in France. Furthermore, simulations will be performed taking into account both the baseline and future climate scenarios across contrasted soil and climatic conditions to determine the seedling emergence rates of the five CCs in relation to sowing depth, seedbed structure, sowing dates, *etc.*

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Yield gap assessment of spring barley in Germany using STICS, DSSAT and APSIM multi-model ensemble (Poster #279)

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Keywords: yield gaps; potential yield; farmer's survey yield; spatial simulations; multi-model ensemble

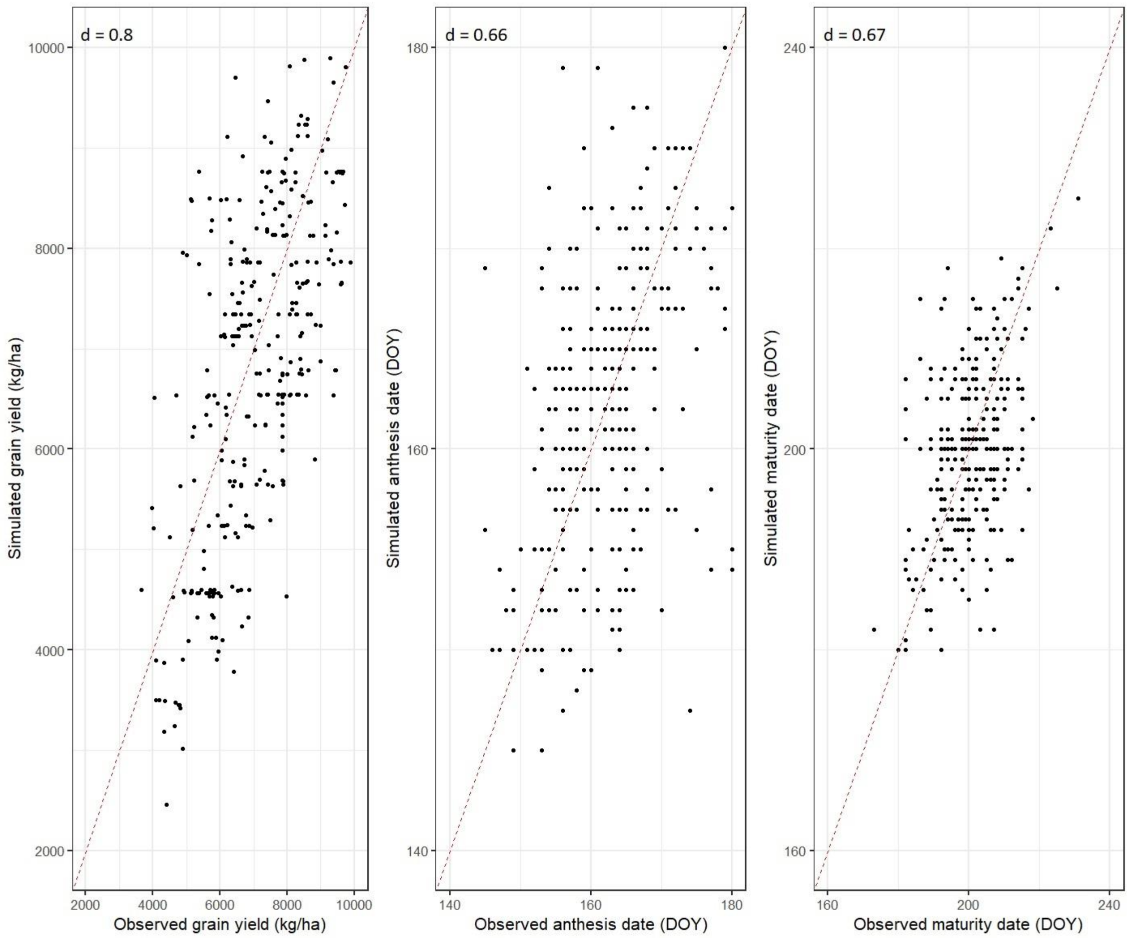

Figure 1. Observed *versus* simulated grain yields, antheisis, and maturity for spring barley over Germany using STICS crop model

1. Introduction

Barley (*Hordeum vulgare* L) is one of the world's primary cereal crops, and it ranks second in Europe after bread wheat (*Triticum aestivum*). In Germany, spring and winter barley account for 1.9 million hectares, whereas winter wheat covers 3 million hectares. Assessing yield gaps in agricultural crops is crucial for optimizing production and ensuring food security (Guilpart *et al.*, 2017). Analyzing yield gaps enables one to evaluate scenarios for food security and find chances to increase crop productivity (Van Ittersum *et al.*, 2016). The majority of research on the evaluation of yield gaps, however, has been based on the yield potential simulation of a single crop model.

2. Materials and Methods

Here, we utilized advanced modeling techniques to evaluate the yield gaps of four spring barley cultivars (Avalon, Barke, Quench, RGT Planet) across 30 locations in Germany over 19 growing seasons (2000-2018). The APSIM Next Generation (Holzworth *et al.*, 2018), DSSAT, and and STICS (Brisson *et al.*, 2003) multi-crop models were parameterized, calibrated and evaluated, enabling a spatially explicit analysis considering different sowing dates (March and April), and differences in soil characteristics. The calibration process was performed using the R packages CroptimizR (Buis *et al.*, 2023) and CroPlotR (Vezy *et al.*, 2023).

3. Results and Discussion

The calibration showed robust agreement between observed and simulated phenology (anthesis and maturity dates) and grain yield (Figure 1). By integrating R-based calibration procedures, we were able to fine-tune model parameters efficiently, accounting for spatial and temporal variations in environmental conditions and crop responses. This approach not only improved the accuracy of yield predictions but also provided insights into the sensitivity of the models to different input variables. Our results revealed significant variations in yield potentials among the cultivars and across the geographical locations. APSIM Next Generation and STICS models demonstrated robust capabilities in simulating the complex interactions between environmental factors, crop management practices, and genetic traits of the cultivars. The spatially explicit approach provided insights into the regional variations in yield potential and identified areas with significant yield gaps between potential simulated yield and on-farm yields. Moreover, the impact of sowing dates on barley yield was elucidated, with March sowing generally exhibiting higher yield potential compared to April sowings, albeit with notable variations depending on the cultivar and location. These findings underscore the importance of optimizing sowing strategies to maximize barley yields in different regions of Germany. Overall, our study highlights the utility of advanced modeling techniques for assessing yield gaps in spring barley cultivars at a spatially explicit scale.

4. Conclusion

The insights gained from this research can inform targeted interventions and agronomic practices aimed at bridging yield gaps, ultimately contributing to sustainable intensification of barley production in Germany. It will also facilitate using the evaluated models in developing a decision support system for agroforestry simulations of various crop rotations across Germany.

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C and N dynamics in innovative cropping systems associated to anaerobic digestion systems in commercial farms (Poster #314)

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Keywords: anaerobic digestion; innovative cropping systems; nitrogen dynamics; ecosystem services; modeling

1. Introduction

The development of anaerobic digestion plants associated to agricultural farming systems allow biogas production that benefits farmers and society but raises questions on impacts and ecosystem services provision generated by this development. In literature, many studies have focused on digestate application and fertilising value, in experimental trials; most of them are short-term studies and very few of them take account of the whole cropping system, including crop new sequences that can be associated to anaerobic digestion systems.

In the Metha3G research project, we considered anaerobic digestion as an opportunity to redesign cropping systems and contribute to agro-ecological transition, by reducing environmental impacts and maximizing some ecosystem services provision. Then, to this end, we studied carbon (C) and nitrogen (N) in innovative cropping systems associated to anaerobic digestion systems in commercial farms.

2. Materials and Methods

We selected 10 plots in 3 commercial farms having individual or collective anaerobic digestion systems for 10 to 15 years. We consider these farmers as pioneers as they experiment with combinations of new practices as they go along: shallow or no tillage, anaerobic digestion, cover crop management and diversified cropping systems including legumes.

We measured over 2 years some variables considered as related to ecosystem services such as stocks of soil organic and mineral N, plant N at different dates (especially energy crops), potential mineralisation of soil C and N, enzymatic activity and soil stability. Beyond the assessment of ecosystem services, we acquired the variables related to N dynamics to calibrate and evaluate Syst'N® (Parnaudeau *et al.* 2012, Bedu *et al.* 2023), a tool for estimating N losses in cropping systems.

3. Results and Discussion

The first results show differences between farms, one of them having particularly high levels of soil C and N and then a high soil stability. The differences were difficult to assign only to practices related to the anaerobic digestion system (digestate management and energy crops), as soil and tillage differ from one farm to another. Nevertheless, we can describe real and consistent cropping systems and their results in terms of impacts and ecosystems services.

The quality of the first simulations with Syst'N® was variable but promising. Some plots were from the outset well simulated with Syst'N®, in terms of soil N mineral dynamics and plant N. Others need calibration especially when there are several species associated on the plot; this work is ongoing. The next step will consist to test different scenarios of cropping system management to identify the best ones.

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Impact of *Venturia oleaginea* infection on the gas exchange of olive leaves (Poster #66)

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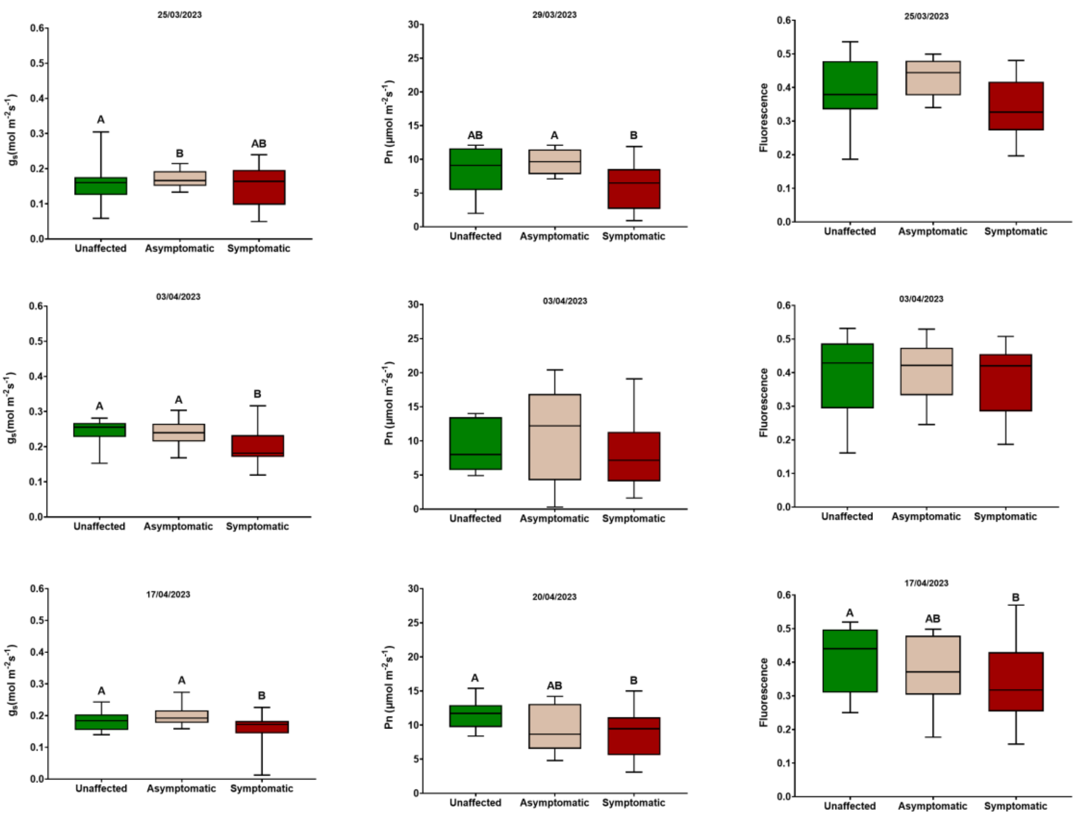
Keywords: photosynthesis; *Olea europaea*; olive leaf spot; stomatal conductance



1. Introduction

The olive is the main tree crop in regions with Mediterranean climate, being cultivated on extensive areas in most countries of Southern Europe. Olive leaf spot, caused by the fungus *Venturia oleaginea*, represents one of the most important foliar diseases for the olive tree crop worldwide. Dispersal of the fungus occurs mainly through spores of the pathogen that are washed away by raindrops in spring and autumn. Infected leaves remain asymptomatic for weeks or months, depending on the environmental conditions (Viruega *et al.*, 2013). After this incubation period, affected leaves show spots, circular leaf bundles and necrosis of the central nerve underside. Eventually, disease progression results in the defoliation of infected leaves, which has a direct impact on crop productivity. On the contrary, the impact of the presence of *Venturia oleaginea* in the photosynthesis and transpiration rates of infected leaves is unknown. This study aims to fill this gap by evaluating the gas exchange of asymptomatic and symptomatic leaves as compared with that of control unaffected leaves.

2. Materials and Methods

Leaf-level measurements of stomatal conductance (gs), net photosynthesis (Pn) and clorophyll fluorescence were conducted in a field experiment with ‘Picual’ trees using a gas analyzer (CIRAS2, PPS Co. Ltd., UK) and a porometer/fluorometer (LI-600, LI-COR Biosciences GmbH Nebraska, USA). Measurements were performed in 2023 on three dates between late winter and early spring. 80 fully expanded leaves were selected and labelled for the measurements in each date, 40% of them showing visible symptoms of olive leaf spot. After the measurements, the same leaves were excised and immersed in a solution with 5% of NaOH for 30 min in the lab. This procedure was used for detecting latent infections, which allowed us to group the leaves into three categories (‘unaffected’, ‘asymptomatic’ and ‘symptomatic’). Differences among leaf categories were evaluated with an analysis of variance (ANOVA). Treatments were compared according to the Least Significant Differences at $P \leq 0.05$. When ANOVA assumptions were not fulfilled, the Kruskal-Wallis test was used, and leaf categories were compared by Dunn's test at $P \leq 0.05$. In all cases, measurements performed under low irradiance conditions (active photosynthetic radiation < 1000 μmol m^{-2} s^{-1}) were excluded from the analysis.

3. Results

On average, symptomatic leaves showed lower gs and Pn values (≈20% and ≈24% lower, respectively) as compared with unaffected ones, but statistical differences were not systematically found. Leaves with asymptomatic infections showed intermediate values, not being statistically different from those recorded in unaffected leaves in most cases. Besides, *V. oleaginea* infections generally had no impact on chlorophyll fluorescence.

4. Discussion

This study represents the first thorough study evaluating the impact of olive leaf spot on the gas exchange of symptomatic and asymptomatic leaves of olive trees. Our findings revealed a relatively consistent reduction of gs and Pn in the leaves exhibiting visible symptoms. However, the differences concerning unaffected leaves were not always statistically significant. The decrease in Pn detected in olive leaves showing visible symptoms of *Venturia oleaginea* (*i.e.*, symptomatic) may have an impact on biomass production and yield. However, the lack of consistent reductions in asymptomatic leaves points to defoliation being the primary driver of yield loss by the disease. Further research would be needed to obtain a clearer picture in any case.

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Improving valorisation of cattle farming through territorial dialogue: a case study in Loir river valley, France (Poster #366)

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Keywords: cattle farming; valorisation; local concertation; dialogue

1. Introduction

PRESENCE project (imPRovE SErvices of boviNe livestoCk in tErritories) is based on the observation that cattle farming (milk and meat), a key sector for Pays-de-la-Loire region's economy (western France), is currently experiencing a decline, particularly in areas where the density of farms is lower (Ben Arfa *et al.* 2009). In addition, in the wake of milk quota suppression and reduction in subsidies, dynamics have changed and upstream to downstream relationships have strengthened.

In this context, major changes are now taking place even within densely farmed areas. Difficulties in passing farms on and land abandonment have been noted in some local areas despite rather favourable overall conditions. These structural and spatial changes are at the heart of the challenges of maintaining agricultural production and employment in the territories, quality of products, but also preservation of landscape and environmental resources.

However, only a few actors share a systemic vision that can result in a collective and individual strategic decision-making process, facing sustainability and productivity challenges of livestock farming.

The objective of PRESENCE project is therefore to shed light on the dynamics of cattle farming in the Pays de Loire region at several scales (regional, territorial *i.e.* group of municipalities, and farm level). This involves among other tasks to create space and time for dialogue and innovation that can generate an alignment of stakeholders' strategies in a shared vision, to step from geographical proximity to organised proximity (Torre, 2002).

2. Materials and Methods

In order to establish a lasting arena for multi-actor discussion about cattle farming perspectives, we have chosen to implement a specific method of consultation in each of PRESENCE's case study fields, *i.e.* in the Loir valley river (south of Sarthe department), in La-Roche-sur-Yon city urban area (in Vendee department), and in the Coevrons intermunicipal area (in Mayenne department).

This method is called "territorial dialogue", which consists of putting together different actors concerned about the same issue, with different perspectives, who will not debate about it, but will try to understand each other. This method has been developed by local practitioners since 2000s' (Barret *et al.*, 2014), and have proven to be very effective in mutual understanding and conflict resolution.

We have found this method to be very well adapted to the case of cattle farming problematics, engaging different actors among this sector. Therefore, we have listed a set of 25-30 people in Loir valley region who are concerned by the evolution of cattle farming.

3. Results

They have been interviewed individually first, in order to collect their perception about the issue, namely the decline of cattle farming in their territory, and capture their needs regarding the situation: what is important to them in this farming activity? What is valuable to them, for this territory? Through this concertation method, we aim at accessing people's deep-seated needs, such as acknowledgement, security, freedom, belonging, *etc.* (Fisher *et al*., 2011).

Following the series of individual interviews, a concertation meeting takes place, where everyone expresses their perception and needs in front of the others, and the ultimate goal of this meeting is that each of them can understand the position of the others.

In this process, PRESENCE researchers have taken three different roles: one is to guide the concertation process with a neutral posture, another is to bring scientific input regarding cattle farming evolution and the last is to observe the stakeholders at play.

4. Discussion

This poster will present this unusual consultation method used in environmental and agricultural issues and show how the interaction between local stakeholders with researchers can bring very relevant outputs for policy makers, in the specific context of cattle farming.

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Calibrating and validating soil moisture simulation under heterogeneous soil conditions in a diversified cropping system (Poster #264)

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Keywords: agro-ecosystem models; soil heterogeneity; soil moisture simulation; diversified cropping systems

Agro-ecosystem models can be useful to assess a wide range of spatial and temporal diversification strategies, as they are able to capture the crops interactions with heterogeneous soil and environment. The models can support the design of diversified field arrangements with limited experimental efforts. However, a prerequisite for their ability to capture these heterogeneities is the adequate simulation of soil water dynamics, as water availability is one major driver for crop growth. The simulation of soil water dynamics is dependent on the layering of the soil profile, particle size distribution (sand, silt and clay) and soil hydraulic parameters which are often derived by employing pedotransfer functions. Additionally, the model requires information on soil bulk density, which influences these parameters. Therefore, in this study we calibrated and validated an agro-ecosystem model, implemented within the SIMPLACE modelling framework (Enders *et al.*, 2023), by using the HYPRES and the German Manual of Soil Mapping (Sponagel *et al.*, 2005) pedotransfer functions and by adjusting bulk density for the top- and subsoil. The agro-ecosystem model was previously calibrated and validated for crop growth and phenological development of rapeseed, barley, winter wheat, winter rye, sunflower, maize, soybean and lupine. Experimental data were collected in the 70 ha "patchCROP" landscape experiment, located within a young moraine landscape in Brandenburg, Germany. A total of 12 soil profiles were used for this study. Soil texture was manually assessed in the field. Additionally, a subset of augers was analyzed in the laboratory for particle size distribution. This data was then used to extrapolate and correct the soil textural classes from the manual readings. The soil showed a strong heterogeneity, particularly in the subsoil, ranging from fully sandy profiles to profiles with a loamy layer in the subsoil. In addition, volumetric water content data from soil moisture sensors at the experimental site was used to evaluate model performance for the calibration and validation steps. The sensors were positioned at depths of 30, 60 and 90 cm at 12 locations within the field. The distance from the soil moisture sensor to the soil auger location was always smaller than 4 m. Calibration and validation was carried out by using weather data from an on-site weather station, crop management, phenology data and the soil auger information. For the simulation of the soil water balance, the SimComponent <SlimWater> was used, which employs a tipping-bucket approach by dividing the soil profile into layers of 5 cm thickness. 7 soil profiles were used for calibration and 5 for validation over a time span of 2 years. The calibrated model was able to reasonably simulate the seasonal dynamics of the soil water balance. The model set-up using soil hydraulic properties based on HYPRES was able to better capture soil moisture dynamics as it effectively captured most of the crops' water extraction patterns, as well as the differences in soil moisture due to soil texture. The model error was largest after intense rain events for soils with a loamy texture in the subsoil. While the maximum simulated and observed moisture level agreed, the model tended to underestimate the duration required for a substantial increase in subsoil moisture content. For textures with relatively high clay contents, the simulations showed a mean absolute error of <6% for the volumetric water content, while under sandy conditions the mean absolute error was <3%.

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Utilizing multispectral vegetation indices to predict spring barley yield using remote sensing under different drought conditions and sowing patterns (Poster #339)

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Keywords: spring barley; drought stress; sowing pattern; climate change; remote sensing

1. Introduction

The increase in both the frequency and severity of drought occurrences poses a significant threat to the stability of crop yields and the quality of grains. Accurate yield prediction is crucial to mitigate the impact of climate change and optimize yield production. Early yield prediction during the growing season is critical for accurately informed decision-making regarding resource allocation, risk management, and policy-making (Bailey-Serres *et al.*, 2019).

One promising approach is integrating multispectral data with predictive models, as it can provide valuable insights into environment x management x genotype interactions and aid in developing crop adaptation strategies (Maes & Steppe, 2019). This study aims to develop predictive yield models for five spring barley genotypes, *i.e.*, Morex, Golden Promise, BCC1589, HOR7985, and RGT Planet, under different irrigation treatments and sowing patterns. Using vegetation indices derived from multispectral data, we seek to capture the optimal phenological stage to predict yield and identify phenotypical traits beneficial for drought tolerance.

2. Materials and Methods

The field experiment was conducted in 2021 and 2022 at the experimental fields of the Julius Kühn Institute in Berlin-Dahlem. Three irrigation treatments were applied: rainfed, supplementary irrigation (applied when plant available water capacity (PAWC) < 30% and refilled to 70%), and non-limiting irrigation (applied when PAWC < 50% and refilled to 100%). Two sowing patterns were implemented with a sowing density of 290 seeds/m²: equidistant sowing in a triangular pattern with a 6 cm distance between single plants and conventional row drilling at an 11 cm row distance. Throughout the growing season, multispectral data was collected using the Micasense Altum camera mounted on a DJI M300 copter. The copter was operated at a flight height of 20 m with a speed of 2.1 m/s. The side overlap ratio of the images was 70%, and the front overlap ratio was set at 80%. From the multispectral data, we retrieved relevant vegetation indices, including the normalized difference vegetation index (NDVI), optimized soil-adjusted vegetation index (OSAVI), and crop water stress index (CWSI) using an image processing pipeline including Pix4D mapper, QGIS, and Rstudio. We used linear mixed models, including the different vegetation indices at different phenological stages as covariates under the combination of the different experimental treatments. The selection of the best-performing model for each genotype under separate treatments was based on the Akaike Information Criterion (AIC).

3. Results and Discussion

An early yield prediction at the end of tillering was particularly possible for the Golden Promise genotype using SAVI and OSAVI, indicative of plant vigor, and for RGT Planet using NDRE (representative of chlorophyll content) and CWSI. There was no significant difference between predictive models for the two sowing patterns. Comparing predictive models under different irrigation treatments, we have concluded that the best predictive model under the rainfed treatment used NDRE and OSAVI as covariates at the end of anthesis. The selected models were cross-validated using observed data, which provided satisfying results. Through plotting partial regression of the different covariates contained in the selected predictive models of Golden Promise, BCC 1589, and Morex, early drought stress at the end of tillering was found to be associated with reduced drought stress response at flowering, which was reflected in increased yields after early drought stress in these three genotypes. Our findings highlight the potential efficacy of utilizing UAV-derived multispectral data and vegetation indices to predict yield in barley genotypes under varying drought situations.

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Agrobiodiversity: characterization, assessment, and designing cropping systems for the Future (Poster #213)

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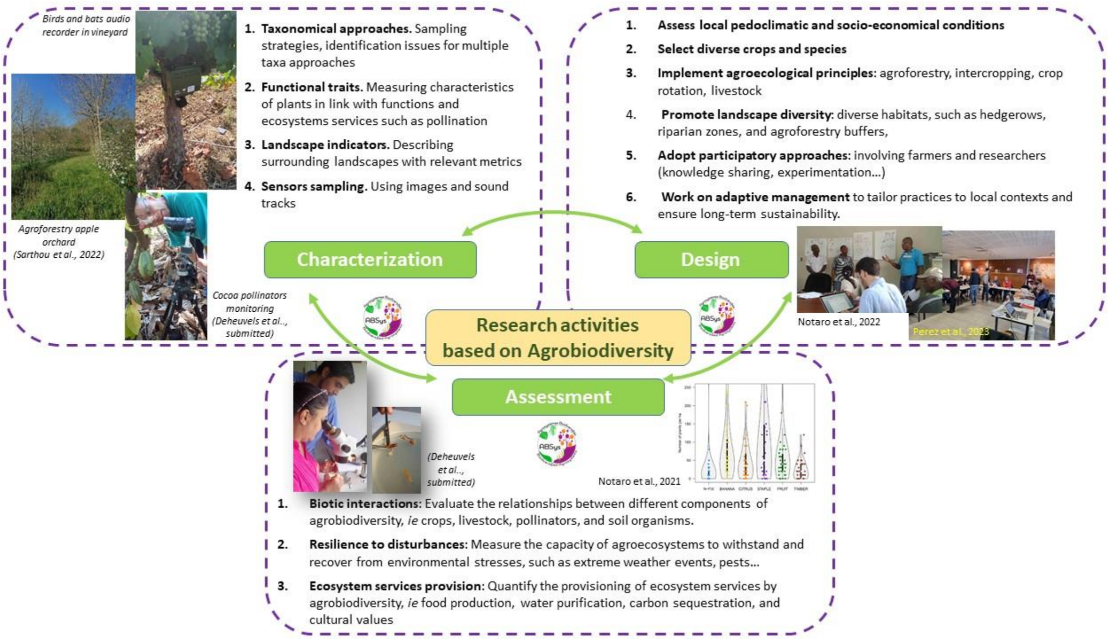
Keywords: agroecological transition; research framework; stakeholders; methodology



Agrobiodiversity, as both the spontaneous and the deliberately introduced biodiversity found in cultivated fields, fosters a number of ecological services (Rafflegeau *et al.*, 2023). The understanding of the linkages between agrobiodiversity and these services is a driver of agricultural management strategies. The agroecosystems can be designed through biodiversification in space and time, and managed in order to promote desired agrobiodiversity traits connected to ecological services. We offer an analytical framework for research based on agrobiodiversity, that relies on the Characterization- Assessment-Design triad (Figure 1). We illustrate it by recent research work conducted by the ABSys research unit (INRAE, Institut Agro, CIRAD), whose scientific project is built on the mobilization of biodiversity for the agroecological transition.

Characterization

Agrobiodiversity encompasses the variety of agroecosystems and of plants, animals, fungi and microorganisms. Its characterization involves mobilizing a wide range of scientific disciplines such as genetics, phylogeny and the correlated disciplines (entomology, ornithology, *etc.*), ecology and agronomy. Several tools and metrics are used by agronomists for describing agrobiodiversity: among the most classical, i) the taxonomic approach to estimate the diversity of species based on biology expertise; ii) the functional one relying on the measurement of functional traits among the species (Violle *et al.*, 2007), iii) the AgroBioDiversity Indexes recommended by FAO (FAO, 2004). These latter aim at enabling policymakers, non-governmental organizations, civil society leaders and businesses to understand relationships between dimensions of agrobiodiversity across the food system, compare agrobiodiversity across countries, and identify priority interventions to enhance agrobiodiversity for more sustainable food systems (Jones *et al.*, 2021). The challenge of describing and quantifying biodiversity in highly biodiverse fields requires developing or adapting sampling strategies to account for various compartments in space (*e.g.*, crop, grass strip, hedgerow) and time (*e.g.*, intra-annual variation of population densities). Depending on the researchs focus, a compromise between high-resolution monitoring in small fields (*e.g.*, agroforestry apple orchard) and low-resolution monitoring in large-scale field networks (*e.g.*, national scale pest monitoring) is necessary. Emerging sensor technologies, such as sound and image collection, offer opportunities to enhance biodiversity monitoring across different production systems.

Assessment

The impact of diversification strategies is generally reported in literature through the comparison of different types of systems (*e.g.* diversified *vs* non-diversified or gradient of diversity) instead of analysing changes in a given system over time (De Beenhouwer *et al.* 2013). The assessment of agrobiodiversity involves its evaluating spatial and temporal dynamics as well as functional roles within agricultural ecosystems. In ABSys team, recent work has evaluated the effects of associated crops on cocoa productivity in complex cocoa-based agroforestry systems (Notaro *et al.*, 2021). The study showed that cocoa productivity increased with nearby Fabaceae and to a lesser extent with timber trees. However, other species, such as food-producing trees, decreased cocoa productivity, though this effect diminished with distance.

Design

Designing agrobiodiversity-enhanced systems requires a multidisciplinary approach, integrating social sciences, agronomy and ecology concepts, as well as technology. Incorporating indigenous knowledge aids in using locally adapted varieties and sustainable management techniques (Notaro *et al.*, 2022, 2021). Engaging stakeholders, such as farmers, local communities (Labeyrie *et al.*, 2021), scientists, and policymakers, from the start is crucial for transitioning to agroecology. Incorporating local knowledge, preferences, and socio-economic considerations ensures the feasibility and acceptance of innovative agricultural systems. Finally the explicit integration of monitoring, adaptation, and tactical management is essential to ensure their sustainability. This involves evaluating the performance of agrobiodiverse systems over time and employing adaptive management strategies to address changing environmental conditions, market dynamics, and socio-economic factors, thereby ensuring the resilience and sustainability of agricultural production. Emerging technologies such as connected water probes, in-field cameras and images from drones and automated monitoring systems, offer valuable tools for effectively monitoring and managing complex agrobiodiversified systems (Bellon Maurel *et al.*, 2022).

Agrobiodiversity offers perspectives to address agricultural challenges by promoting sustainability and resilience of agricultural systems, as well as provisioning multiple ecosystem services. By characterizing, assessing, and designing cropping systems that prioritize agrobiodiversity, we can build resilient landscapes capable of feeding a growing population while safeguarding resources. This framework clarifies the scale and the methods used, and might also be relevant to identify potential knowledge or methodological gaps at the interface of the three axes.

Direct and indirect effects – mediated by mesoclimate – of landscape structure on carabid beetle communities and their consequences on weed seed predation in winter cereals (Poster #59)

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Keywords: landscape; climate; weed seed predation; plant-animal interactions; agricultural practices

1. Introduction

At the landscape scale, agricultural intensification resulting from the loss of semi-natural habitats, reduction in land-cover diversity and increase in field size is a major threat to biodiversity and the delivery of ecosystem services [1,2]. In addition, climate change has an increasing role in the decline of biodiversity [3,4,5] and is posing a growing threat to agriculture and food security [6]. Increasing the quantity of semi-natural habitats (*e.g.* hedgerows, grasslands) and landscape heterogeneity (in terms of composition, *e.g.* diversity of land-use types, and of configuration, *e.g.* density of edges between different land-cover types) could help mitigate the loss of biodiversity and its associated ecosystem services. Landscape can directly affect biodiversity by providing different habitats and resources (*i.e.* food, refuge) around the fields and by promoting the dispersal and colonization in field of organisms. Landscape can also have indirect effects by modifying mesoclimate, and especially air temperature. Carabid beetles are abundant and widespread natural enemies of insect pests and weed seeds in arable fields, thus playing a key role in agricultural landscapes [7,8]. They also are known to be dependent on landscape [9] and local abiotic (*e.g.* farming practices [10]) and biotic (*e.g.* standing weeds [11]) factors. In the present study, we tested the hypothesis that in combination with local drivers (farming practices and weed cover), landscape has a direct and indirect (mediated through mesoclimate) effect on carabid beetle communities and has a consequence on weed seed predation. We focused on winter cereal fields, which represents the most important crop in Brittany.

2. Materials and Methods

We selected twenty 1 km × 1 km landscape windows along uncorrelated gradients of semi-natural habitat amount and landscape heterogeneity. For each landscape window, we recorded air temperature through automatic sensors. We sampled 77 fields within these landscape windows, where we monitored carabid beetle communities and seed predation for two weed species (*Viola arvensis* and *Poa annua*). SEMs were built to test for the direct and indirect effect of landscape structure on carabid beetle richness, activity-density and composition, and on weed seed predation, for two sampling time (May and June 2023).

3. Results

In May, the activity-density of granivorous and omnivorous carabids increases with a high amount of grasslands, a low amount of hedgerows. It depends also on farming practices. Their composition depends on both compositional heterogeneity and farming practices. In June, the richness of granivorous and omnivorous communities increases with a high weed cover whereas activity-density increases with a high amount of grasslands. Their composition depends on grassland and hedgerow amount, maximum air temperature and weed cover. We found an indirect effect of landscape on carabids mediated by mesoclimate. A high amount of grassland increases the maximum air temperature, which in turn affects the composition of granivorous and omnivorous carabid communities. Lastly, we found cascading effects of the richness and/or activity density and/or composition of communities affects the predation of *Viola arvensis* and/or *Poa annua*.

4. Discussion

These results highlight grasslands' importance for carabid beetles as a source habitat providing resources, sites for reproduction and overwintering and refuge from in-field disturbances. Additionally, they reveal that grasslands can increase air temperature, particularly in late spring (July), likely due to reduced vegetation height after grazing or mowing. Increase in air temperature affects carabid beetle composition, likely by influencing traits related to thermotolerance. Overall, grasslands play a key role in agricultural landscapes, affecting directly and indirectly (by modifying maximum air temperature), carabid communities and the weed regulation service they support.

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Pea-wheat intercropping brings novelty to grain production in Serbia (Poster #361)

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Keywords: pea; wheat; intercropping; grain; Serbia

Intercropping is a cropping system that enables maximizing the utilization of limited agricultural land by effectively using resources, soil, water, and solar energy. Growing two or more crops in the same field through intercropping was efficiently used for forage production in Serbia for decades (Mikić *et al.*, 2015). Legume-cereal mixtures are efficient in terms of inputs, especially nitrogen fertilizers, while at the same time are protein sources for animal diets. However, the previously approved potential of intercropping for grain production (Jensen *et al.*, 2015; Monti *et al.*, 2016) increased interest in the application of intercropping in this part of Europe to enhance wheat production and improve grain quality.

Under the Horizon Europe project IntercropVALUES (www.intercropvalues.eu), the research team from the University of Novi Sad, Faculty of Agriculture (UNSFA) started to develop the concept and method of pea-wheat intercropping mixtures for grain production. The innovative approach includes developing the grain production process, it is also based on understanding the entire value-chain concept through Co-innovative Case Studies (CICS). Therefore, the UNSFA established the research trial at the experimental field in autumn 2023 and spring 2024, and the crop stand at the commercial organic stakeholder in autumn 2023. At the experimental field trial, the focus is on testing the performance of the selected pea and wheat varieties defining the traits of these species ideotypes. Pea-wheat-environment interactions will be analyzed to identify the most suitable mixture for grain yield production based on complementarity and reduced competition. The advantages of intercropping as a cropping system and the suitability of the selected crops and varieties will be analyzed through soil health parameters with an emphasis on soil nitrogen content.

Alongside this, at the CICS level, the gathered information will be used to understand barriers in the intercropping process developing mechanisms and solutions for better implementation of intercrop systems on the farm level, and up to the final commercial product. The results obtained in this research should be a step forward for implementing pea-wheat intercrop for grain yield and environmental benefits in this part of Europe.

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Acknowledgments

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The effect of hill country topography on subterranean clover development (Poster #53)

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Keywords: grassland; legume; microclimate; phenology; regeneration

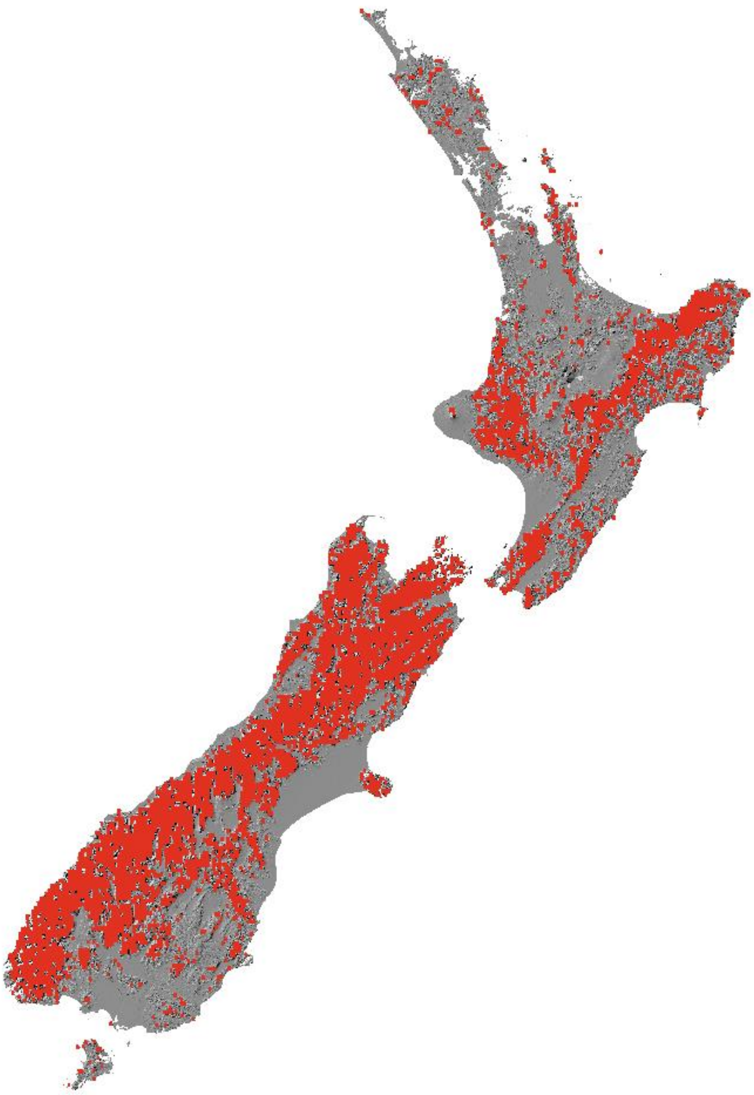

Figure 1. New Zealand map displaying the selected hill country zones. The red pixels represent the >= 15-degree slopes

1. Introduction

Subterranean clover (*Trifolium subterraneum* L.) is a valuable component of regenerative agricultural systems. This legume naturally regenerates from seeds set in previous seasons, which eliminates the need for re-sowing because it maintains a seed bank of 'hard' seeds.

Some of these remain dormant for germination in later years. The ability to avoid drought by producing dormant seeds and burying them, ensures survival and persistence (Moss *et al.* 2022).

It is a common winter annual clover species present in European grasslands (Vasileva and Vasilev, 2020) and summer dry environments in Oceania (Goward *et al.* 2023). It provides high-quality (ME and crude protein) biomass during late winter and early spring and fixes atmospheric nitrogen. This contributes to nitrogen cycling, and pasture productivity.

We quantified subterranean clover life cycle at multiple scales to optimize the use of subterranean clover for animal productivity given the importance to both local and nationwide pasture productivity and persistence in hill country landscape.

2. Materials and Methods

Subterranean clover phenological events in complex hill country topography was evaluated on a nationwide aspect map raster of the slope direction of each cell created from a digital elevation model (DEM) using GIS. Aspect is the compass direction that a slope faces which determines microclimate, vegetation, and soil erosion of a hill country terrain. Slopes were classified in north, northeast, northwest, east, southeast, south, southwest, west aspects.

The assessment excluded the areas below 15 degrees because the aspect effects on those relatively flat areas were minor. The vegetative (fourth trifoliate leaf, V6) and reproductive (50% plants flowering, R3) phenophases were quantified by considering a mean value estimated (expressed as Julian days) from a 45-year timespan (1972-2017) for late flowering cultivars. Regressions were derived from field observed data and published. Only sowing periods occurring in a decreasing photoperiod direction (autumn to winter) were considered (Guo *et al.* 2022).

3. Results

For late maturity cultivars, the mean time to reach V6 was 124.5 ±12.61 days on an east aspect, 125.3 ± 13.09 days on the north face aspect and 127.7 ± 15.26 days on west aspect. On the northern aspects of the North Island the times to reach V6 and R3 were 105.9 ± 2.12 and 277 ± 7.21, respectively. In contrast, in the southern aspects of the South Island plants required a longer time to reach V6 and R3 (129.4 ± 22.27 and 334.6 ± 23.64).

4. Discussion and Conclusions

Understanding how subterranean clover phenological development changes with aspect can assist agronomic management decisions on a catchment or farm level. The quantification of key phenological events of subterranean clover on different land aspects demonstrated the opportunities to refine pasture management in complex hill country environments. It ensures that forage of higher quality and yield can be integrated on hill country farm systems and allows farmers to make informed decisions around pasture management for more resilient and longer lifetime pastures.

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Coupling a crop-soil model and life cycle assessment to reduce GHG emissions of crop rotations (Poster #212)

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Keywords: crop model; LCA; crop rotation; GHG emissions

1. Introduction

Diversified and legume based crop rotations, particularly when including catch and cover crops, can increment soil organic matter (SOM) and nitrogen (SON) stocks, capture excess nitrogen after harvest of main crops, and biologically fix N_2 from the atmosphere. Thus, greenhouse gas (GHG) emissions can potentially be minimised by capturing additional CO_2 and by reducing the demand for synthetic N fertiliser, the main contributor to N_2O emissions in many conventional planting systems. However, farmers tend to be hesitant to test new crop rotations without evidence of positive effects on crop yields and climate. Process-based plant-soil models can simulate nutrient cycles, plant growth and GHG emissions, accounting for site-specific soil properties, weather, and plant related processes. Life cycle assessment (LCA), fed with data from such process-based models can improve GHG flux estimations compared to commonly used tiers 1 and 2 (static emission factors) to the potentially more accurate tier 3 level. Thus, coupling a process-based model with LCA can enhance understanding the effects of crop rotations on GHG emissions and help farmers to explore promising crop rotations on a knowledge base.

The Julius Kühn Institute's KlimaFFolgen project is developing such a coupled tool in order to provide

a) a user friendly web application for practitioners to explore crop rotations on selected plots;

b) a scientific tool for regional assessment of trends including projections under different climate scenarios (RCPs).

2. Materials and Methods

Our decision support tool builds on the SYNOPS platform (https://synops.julius-kuehn.de), originally designed for spatially explicit risk assessment of pesticide applications. Once the user selects a plot, historical or future daily weather data on a 1km^2 grid (German Weather Service) as well as soil properties (BÜK 200 by BGR) are assigned to this location. Typical regional crop rotations (remote-sensing based; Preidl *et al.* 2020) as well as default management data are suggested, but can be overwritten by the user.

We use DSSAT 4.8 to simulate plant growth and soils, including an implementation of DayCENT for SOM dynamics. Our partial LCA covers the system from cradle to farm gate over the entire crop rotation, representing several agronomic and environmental indicators.

3. Results

A tour through the web application demonstrates how data are entered and processed in the decision support system.

Plant growth in our approach on crop rotations has already been validated for SouthWest Germany (Attia *et al.* 2024; Marohn *et al.* 2023). First results of a specific validation of N_2O emissions, simulated by DSSAT-DayCENT for seven sites across Germany, are presented for the first time at the ESA conference. SOC stocks, GHG emissions and crop yields as well as leached NO_3^- (agronomic / environmental indicator) are simulated for a real baseline and compared to hypothetical scenarios with additional legumes and reduced mineral fertiliser levels.

4. Discussion

The decision support tool can assess effects of improved crop rotations and management on C and N dynamics relevant to plant nutrition and climate change. The system will enable more detailed analyses of crop rotations and management, *e.g.* on benefits, trade-offs and permanence of measures under different rotations including catch and cover crops, improved synchronisation and dosage of fertiliser application. We also discuss expectations of the different target groups – *e.g.* user friendliness, communication of uncertainties – and hardware / software requirements for parallelised mass runs.

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Yield as affected by heat waves on wheat cultivars of contrasting grain weight (Poster #343)

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Keywords: *Triticum aestivum*; high temperatures; fertile florets; grain number; grain weight

1. Introduction

Heat waves (characterized by consecutive days of exceptionally high maximum temperatures) will be more frequent and may adversely impact on both grain number per m^2 (GN) and average grain weight (AGW). Wheat genotypes may vary in their response to heat waves, exhibiting differences in the significance of each component in determining yield and in their tolerance to heat stress [1]. AGW is more conservative than GN and therefore cultivars can be characterized by their AGW. What has not been considered in depth is whether the characteristic AGW of the cultivar could be related to the tolerance to heat waves.

There are different approaches to study the effect of high temperatures on yield and quality but none of them is perfect [2]. In this study we compared two alternative methods to impose heat weaves under field conditions (i) portable chambers with transparent polyethylene films covering the plots and (ii) infrared heaters installed on top of plots.

The main aims of this study were to (i) study cultivars of contrasting AGW in unheated conditions would differ in sensitivity to heart waves, (ii) determine whether the approach used to impose the heat wave treatment alters the results, and (iii) characterize two modern, well-adapted cultivars grown in Spain that could be used in strategic crosses.

2. Materials and Methods

The experiment was carried out at Lleida, NE Spain. Treatments consisted of two modern wheat genotypes (Santaella and Arthur Nick) exposed to heat waves. The experiment was fertilized and irrigated during the whole cycle.

Heat treatments consisted in a direct imposition of heat waves under field condition: there was an unheated control, and two timings of exposure to heat waves, starting at either booting (DC 55, [3]) or the beginning of the effective grain filling period (DC 72). Heating treatments were imposed using either portable polyethylene tents [1], or infrared heaters [4]. The dynamics of floret development [5] was followed from the onset of stem elongation (DC 30) until anthesis (DC 65) and at anthesis total biomass and its partitioning and the number of fertile florets were determined. At maturity (DC 92) total biomass, its partitioning and yield and its components (GN and AWG) were also determined.

3. Results and Discussion

The unheated controls yield of A Nick was higher than that of Santaella, due to producing a much higher GN (so that the higher yield was combined with smaller AGW).

The exposure to heat wave reduced yield in both cultivars, but clearly more in the one that reached higher yields in the unheated controls, and in both timings. Averaged across the two ways of imposing the heat, yield was reduced by c. 17 and 6% in pre-anthesis and by c. 17 and 9% in post-anthesis in A Nick and Santaella, respectively. The pre-anthesis heat reduced yield though affecting GN while post-anthesis heat reduced always the AGW but also in some cases induced abortion of grains (0-11% and 4-6% in A Nick and Santaella, respectively the range depending upon the approach used to impose the heat wave).

Pre-anthesis heat reduced grain number more or less similarly, regardless of whether the treatment was through polyethylene tents or the infrared heaters. The effect was consistently stronger in A Nick, the cultivar with the higher GN in the unheated control (c. 17 and 7% in A Nick and Santaella, respectively). In A Nick, the pre-anthesis heat only marginally reduced the number of fertile florets at anthesis and, therefore, the reduction in GN was mediated through affecting the level of abortion of the grains, whilst in Santaella the reduction in GN was related to that in the number of fertile florets at anthesis (through affecting the allocation of resources to the juvenile spikes where florets are developing).

Post-anthesis heat reduced the AGW more in A Nick (c. 10-18%, depending on the heating mechanism) than in Santaella (c. 8-9%), despite the fact that in the unheated controls the size of the grains was smaller in A Nick (38 mg grain-1) than in Santaella (44 mg grain^{-1}).

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Breakthru: developing compaction resistant wheat. Rooting performance of ethylene insensitive spring wheat under different cultivation treatments (Poster #356)

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Keywords: rooting; wheat; cultivations; soil compaction

Soil compaction is a significant challenge impacting crop production, with 36% of European soil having high or very high susceptibility to compaction (Van Camp *et al.* 2010). Compaction in the topsoil (c. 0-0.4 m) is often caused by the increasing weight of agricultural machinery and poor tillage practices, including the management of soil in the wrong conditions. Deeper in the soil profile high bulk densities are caused by overburden pressure, resulting in roots being clustered in soil biopores (Zhou *et al.* 2020). Compacted soil stunts root growth, reducing water and nutrient uptake and consequently impacting yield. The Breakthru project builds on the recent discovery that rice roots can penetrate highly compacted soil by disrupting their sensitivity to the plant hormone ethylene (Pandey *et al.* 2021). Breakthru is investigating this concept in wheat.

Eight spring wheat genotypes, differing in their sensitivity to ethylene, were grown in the field under three cultivation treatments to compare their rooting performance. The trial took place in the 2023 harvest year in the UK on a silty clay loam soil. Genotypes grown originated from multiple sources including UK Recommended List varieties and varieties bred in CIMMYT. Cultivation treatments of low (ploughed), medium (flat lift) and high (direct drill) soil strength were introduced to differ the soil penetration resistance in the top 0.3 m of soil. To understand how root performance was impacted by the soil environment, penetrologger measurements were taken at multiple points during the season and bulk density was assessed post-harvest. Crops were monitored throughout the season to analyse potential physiological differences between genotypes and cultivation treatments. These involved assessments of plant establishment, leaf chlorophyl levels, disease assessments, pre-harvest yield components and final yield. Root performance was assessed through 'shovelomic' (Trachsel *et al.* 2010) measurements at crop tillering and root washing from soil cores down to 1 m depth post anthesis.

This poster will present the results from the first of two planned trial seasons. Rooting performance will be compared across the cultivation treatments and the influence of ethylene insensitivity on crop rooting will be discussed. The influence of the soil environment on crop rooting, from penetration resistance and bulk density assessments, will be analysed and any links between rooting performance and aboveground physiology measurements will be presented.

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Diversified cropping systems with cereal and legume intercropping to maintain sustainability (Poster #242)

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Keywords: mixed cropping; grain yield; biomass

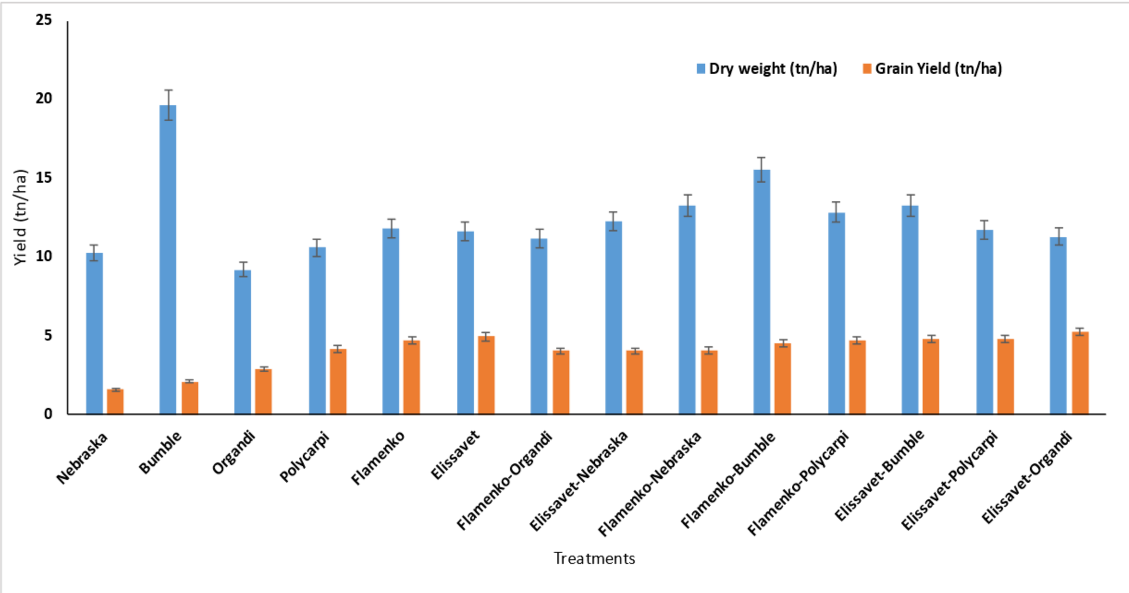

Figure 1. Dry and grain yield for the different faba bean - wheat treatments

1. Introduction

Intercropping received significant attention in recent years due to its advantages within cropping systems. It notably contributes to enhancing biodiversity (Cappelli *et al.*, 2022). In contrast, monoculture systems, characterized by intense use of fertilizers, pesticides, and herbicides (Ren *et al.*, 2014), lead to soil degradation, biodiversity decline and impair agroecosystem functionality (Brooker *et al.*, 2021). Hence, there is an urgent need to adopt practices that enhance biodiversity while ensuring high productivity and sustainability.

The objective of the present study was to assess the performance of four faba bean and two winter wheat cultivars as sole crops and intercrops, with the aim of identifying the most suitable combination of them.

2. Materials and Methods

The experiment was carried out during 2022–2023 growing season, at the experimental farm of the Aristotle University of Thessaloniki in northern Greece (40◦32′07.7″ N22◦59′20.5″ E). Two bread wheat (Elissavet and Flamenko) and four faba bean (Polycarpi, Organdi, Nebraska, and Bumble) varieties were used. These cultivars have differences in maturity, plant height, and grain size. The characteristics that were studied were morphological, physiological, and agronomic at three stages of plant development. The data were analyzed with the analysis of variance (ANOVA) method within the methodological frame of General Linear Models, using the IBM SPSS, Version 27.0 statistical software (IBM Corporation, Armonk, New York, United States).

3. Results

Two cultivars Flamenko and Bumble monocrops and also their intercrop obtained the highest yields for biomass (Figure 1). In addition, Organdi-Elissavet and Polycarpi-Elissavet treatments recorded the highest grain yield (Figure 1).

4. Discussion

In the present study, it was found that the wheat cultivar can be used in an intercropping system for biomass production is Flamenko and from faba bean. On the other hand, Elissavet is a wheat cultivar that is more suitable than Flamenko, for the grain yield. Therefore, intercropping systems of wheat with faba beans using proper cultivars can be used by the farmers as they can give higher biomass and grain yield and utilize the environmental resources more efficiently (Brooker *et al.*, 2021; Michalitsis *et al.*, 2024).

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Acknowledgement

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Making MONICA fit for simulating water, carbon, and nitrogen dynamics in grasslands (Poster #257)

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Keywords: simulation; modelling; remote sensing; grassland; ecosystem services

Grasslands are an important component of land use in Europe, and the differ considerably in species composition, yield potential and management. Typical use cases include grazing with animals and mowing for haymaking, but mixed use and other forms of use also exist. Wet grasslands have recently come into focus, as many of them have been drained in the past to prolong the production season and improve access with heavy machinery. Under drainage, the previously accumulated organic matter in the soils got in contact with oxygen, and began to mineralise in high rates. The massive amounts of CO_2 that are consequently emitted contribute considerably to European nations' CO_2 balance, which is why rewetting strategies are now being developed to reverse this process.

Mechanistic agroecosystem models are often used to assess the performance of crop and grassland systems, looking at productivity and related ecosystem services and disservices. For grassland systems, the MACSUR project has earlier demonstrated that simulation models are much less developed and supported as compared to cropland systems. One of the reasons may be that grasslands systems seem much more complex to simulate, because of the multiple species being involved at the same time.

We are presenting here the recent advances of the MONICA model (Nendel *et al.* 2011) for grassland systems. The most important features include (i) the determination of grassland systems in Germany and their mowing frequency using remote sensing, (ii) the determination of lowland grasslands with frequent contact to ascending groundwater and the groundwater distance dynamics in these areas, (iii) the simultaneous simulation of carbon, nitrogen and biomass dynamics, and (iv) the response of the species communities to changes in groundwater levels.

Remote sensing provides a wall-to-wall 10m resolution map of permanent grassland systems in Germany (Schwieder *et al.* 2022). The mowing frequency can be used to provide indications for the use intensity. Based on this, the input of additional nitrogen can be assumed to inform MONICA. From groundwater head data and remote sensing, a groundwater distance map (first plant-accessible aquifer) has been created (Raza *et al.*, under review). This map includes the average minimum and maximum distance within a year. MONICA assumes a sine wave between min and max value, and uses this groundwater baseline for daily updates from evapotranspiration and precipitation terms. Ascending groundwater is computed using empirical capillary rise rates, in dependency of soil texture and groundwater distance. This allows to simulate additional water supply to the grassland community, related productivity benefits and the effect of other biophysical processes (Khaledi *et al.* 2024b). The biggest challenge for mono-species simulation models is the fact that grassland communities change their composition in response to changes in water supply (Khaledi *et al.* 2024a). This requires that MONICA will need to communicate with a competition model. In this case, the GRASSMIND model (Taubert *et al.* 2020) will deliver species community changes in response to water supply, but also other environmental and management factors, so that MONICA can simulate the correct biomass growth on the basis of this information.

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From theory to practice: how to assess the effects of sustainable soil management on One Health? (Poster #309)

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Keywords: conservation agriculture; on-farm experiment; agroecology; transdisciplinarity; soil health

1. Introduction

The contribution of healthy soils to One Health has been a widely researched topic lately and is theoretically already demonstrated (Banerjee and van der Heijden, 2023; van Bruggen *et al.*, 2019). Acknowledging the extent of agricultural soil degradation, a radical shift to sustainable soil management (SSM) is needed to regenerate soils and move toward healthier soils at large scale.

However, in practice, many limits still make it difficult to demonstrate the effects of SSM on One Health in the field. Indeed, there is no harmonized existing protocol to assess SSM, soil health or even food quality, making it difficult to compare study results with each other. Also, most studies lack systemic approaches when assessing the effects of SSM on soil health, or other parameters of the One Health components, often considering a single practice (*e.g.* no-tillage) effect on soil health or on single soil properties. Furthermore, most agronomic researches currently rely on experimental plots, which is not satisfactory to provide a systemic and complete vision of the diversity of situations that may be encountered in the “real life”. This often makes the findings of these studies difficult to extend to larger scales (Lacoste *et al.*, 2022). We propose to provide a feedback from a 2-year monitoring study where we attempted to overpass these limitations by setting-up a large on-farm experiment in North-Western France, through the monitoring of more than 80 winter wheat fields owned by pioneer farmers (+ 5 years after their transition to sustainable systems) and conventional farmers (tillage-based with little or no intercropping).

2. Materials and Methods

22 pioneers and 22 conventional farmers were selected in 2021 and associated by pairs of neighbouring farms located in North-Western France. Pioneer farmers were selected based on their compliance with conservation agriculture principles on field for at least 5 years according to the criteria defined by the Food and Agriculture Organization of the United Nations (FAO, 2014) (*i.e.* minimal soil tillage or absence of soil tillage, crop diversification and/or complexification of crop rotation, and permanent organic covering of soils through introduction of cover cropping or mulching with crop harvest residues). Conventional farmers’ systems are tillage-based and their plots used for the study were ploughed at least 2 years before the beginning of the study. Each of the 22 pairs of farms have the same pedoclimatic conditions and are geographically close. The same wheat variety was grown within a pair of farmers. Each farmer committed to participate to the 2-year monitoring study by leaving available one plot grown with winter wheat for each year of study (*i.e.* in total 44 plots for campaign 2022 and 42 plots for 2023 – one pair of farmers dropped in 2023). This allowed us to monitor farmers’ agricultural practices and assess soil health and their grain production, with limited effects of environmental variables.

3. Results and Discussion

We show that it is possible to set up a robust farmer network that discriminates agricultural management practices allowing to demonstrate the importance of SSM on One Health. We propose a feedback on the choice of indicators for assessing SSM, soil health and grain nutrient density, since some of them appear to be more relevant than others in such on-farm studies. We also propose a methodology to study direct and/or indirect effects of SSM on One Health. Our results demonstrate the feasibility of on-field One Health research applied to SSM. This on-farm study was made possible only thanks to the involvement of a diversity of stakeholders, thereby bridging gaps between farmers, the academic researchers and farm advisors.

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Bioblitzes in agroecosystems across Europe: a tool to favor biodiversity conservation by gathering farmers, scientists and general public (Poster #268)

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Keywords: citizen sciences; biodiversity inventories; biodiversity knowledge; participation outcomes

1. Introduction

In the context of a global biodiversity crisis, biodiversity in agroecosystems has been shown to be particularly affected by the intensification of agricultural practices. As agricultural land accounts for 39 % of land use in Europe, farmers are key actors in biodiversity conservation initiatives. Local initiatives have already proven beneficial, showcasing the potential for proactive approaches. To develop collective solutions, it is crucial to re-establish the connection between agriculture, science, and society, despite the negative public perception of management decisions regarding the environment. To address the environmental crisis, it is imperative to establish a communication space that will help to clarify the causes and consequences of the crisis, and to raise awareness among all stakeholders related to the issue, who rarely have the opportunity to talk to each other. To restore this social connection and to foster the relationships between various stakeholder groups, we implemented a participatory biodiversity inventory, a BioBlitz in an agricultural field. This citizen science event aimed to present flowering strips as an effective tool to enhance habitat for biodiversity. Using a questionnaire and observations of the event organization in each country, we evaluated if such a BioBlitz may raise awareness among a large and diversified group of participants, thus indirectly contributing to changes of agricultural practices, and thereby to conservation of biodiversity in a conventional agricultural environment.

2. Materials and Methods

The study is based on 5 study sites of the ConservES project (West and North of France, Belgium, Germany and Czech Republic), located along a European climate gradient, between May and June 2023. The Breton team provided the organizational guidelines for their colleagues in the other sites in order to ensure a similar organization in each country. We implemented a questionnaire about motivations to participate, expected and effective outcomes to evaluate the success of the BioBlitz towards the objective to show that conventional fields harbor a small but important biodiversity, which can be increased by planting flower strips alongside hedgerows as proposed by the Conserves project. We also compared the coordination of the event between different countries to understand the factors that influence the success of the BioBlitz.

3. Results

There were between 55 and 1085 observations per site and between 55 and 445 different species were identified. The observations were opportunistic or followed either a simplified protocol used by scientists in the project or an existing citizen science protocol. The database was standardized among all sites and filled in by the participants ("experts" and "non-experts").

Taxonomic identifications were done to genus or species levels. The uncertainty associated with the observers remains in the database, but is minimized by expert verification and in case of doubts by indicating a higher taxonomic level. The questionnaire has been completed by 124 people. Although they were the target profile, few farmers were able to attend .. In terms of knowledge gained during the event, participants (n=94) reported that they mainly learned how to identify species (n=30) and learned new sampling or observation protocols (n=24). Some participants were amazed at the biodiversity they encountered. According to our experience, the success of the BioBlitz depended on (i) the involvement of researchers from the agricultural sector, (ii) the choice of location and (iii) communication before and during the event.

4. Discussion

Although bioblitzes are not very common in agricultural settings, they should be given more attention in participatory science. As people were surprise to observe so many species, Bioblitzes appear as potential tools to raise public awareness of biodiversity in conventional agricultural areas. They may thus highlight its intrinsic value, and its role in ecosystem services as well as the need for its conservation in agroecosystems. Despite the relevance of Bioblitzes as a participatory observation and sampling tool along a broad geographical gradient, the experience gained from ConservES's Bioblitzes shows that their design requires to leave room for plasticity to take account of local factors. In general, bioblitzes offer a privileged space and time for science-society interactions, making it possible to combine the needs for science to obtain data and for citizens to take ownership of conservation.

Estimation of available days for mechanical weeding with J-DISTAS: relevance and limits in cropping systems evaluation (Poster #333)

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Keywords: workability; soil structure; organic farming system; strategic decision tool; cropping systems evaluation

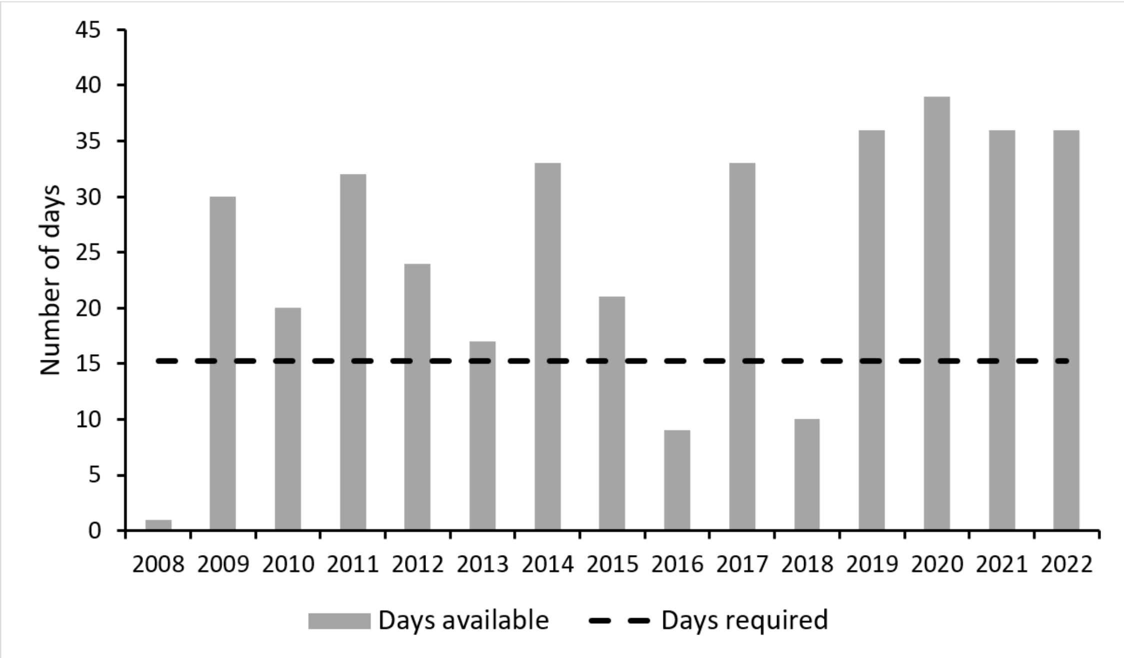

Figure 1. Number of available days estimated by the J-DISTAS tool and days required for wheat mechanical weeding operations of March to May at the Boigneville site. Required days is the number of days needed to carry out the number of weeding operations of experimental system on typical farms (surface and machinery) in Boigneville area

1. Introduction

Success of agricultural operations largely depends on field conditions. A day is considered available if conditions are favourable for both soil preservation and operation success, *i.e.* if the soil is workable and trafficable and weather conditions appropriated. Predicting available days is thus of prime interest to ensure both soil structure preservation and efficient weeding. The J-DISTAS project created a tool to estimate the number of available days within a period of interest. The MadeInAB project aims at evaluating innovative weed management practices efficiency at the cropping system level. Available days for mechanical weeding are calculated with the J-DISTAS tool to evaluate (i) the tool consistency with real field operations and (ii) the possibility to generalise innovative practices at farm level.

2. Materials and Methods

Three experimental sites from the MadeinAB project, with contrasted pedoclimatic contexts, were selected for this study: Boigneville (91), Corbas (69) and Kerguéhennec (56). All mechanical weeding operations were registered since the beginning of the experiments (2008, 2014 and 2013 for Boigneville, Corbas and Kerguehennec respectively), resulting in 291 observations.

Available days for mechanical weeding were estimated with the J-DISTAS tool, based on the aggregation of soil workability and suitability of climatic conditions, estimated on a daily basis by the tool (Métais *et al.*, 2023). Estimated available days were then compared with real mechanical weeding operations on the three experimental sites to evaluate the tool consistency. The possibility to generalise innovative practices at farm level was estimated by extrapolating the time required for mechanical weeding operations at the experimental sites to the size of the typical farm in their respective regions.

3. Results

Available days estimated by the J-DISTAS tool are more restrictive than real mechanical weeding operations: respectively 34.8, 30.0 and 50.0 % of mechanical weeding in Boigneville, Corbas and Kerguehennec experiments were done during days deemed unavailable by the J-DISTAS tool. The unavailability of these days was mainly due to a poor workability. Nevertheless, when comparing different periods, the J-Distas tool has a good estimation for the situations where the available days are the most restrictive.

At Boigneville, J-DISTAS estimated that there are not enough available days for efficient mechanical weeding of wheat from March to May one year out of five (Figure 1).

4. Discussion

The J-DISTAS tool allowed identifying the number of available days for a given cultural operation, here mechanical weeding, for the period considered. Compared to days when mechanical weeding was actually performed, the tool's under-estimations may be partially due to experimenters' decisions to work sometimes in unfavourable conditions. In addition, its accuracy could be improved by optimising workability calculation: differences between the J-DISTAS estimations and observed operation dates may be partially explained by the depth of workability calculation (10 cm), higher than the real working depths (less than 5 cm).

The comparison between available days and time required to apply the system of Boigneville at farm scale highlighted the risk that the proposed solution could not be implemented at a sligthlty high frequency. Consequently, our recommendations for this site are to be accompanied by strategic advice on the type and capacity of machinery to acquire to be able to implement the innovative practices on real conditions.

Detailed knowledge on factors limiting the availability of days can help (i) identifying the machinery characteristics that could be modified, (ii) changing the schedule or altering the cropping system by allowing a cultural operation in good operation conditions. Further work is currently done to analyse available days for other field operations (tillage and sowing).

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Acknowledgements

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Climate change and resilience of Catalan agriculture: interdisciplinary and multi-scale boost for diversification with legumes as a mitigation and adaptation strategy (Poster #16)

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Keywords: adaptation; climate change; legumes; mediterranean; mitigation

Agriculture accounts for around 14% of global greenhouse gases (GHG) emissions. Field crops, mainly cereals, cover around 520,000 ha, out of a total of 828,000 agricultural ha in Catalonia, NE Spain. Their productivity is based on management practices that involve low crop diversity, long periods of bare soil exposed to degradation, and the use of large amounts of nitrogen fertilizers, leading to GHG emissions into the atmosphere and significant C footprint. In this communication we will present the on-going activities of the recently launched Legitimada project and its first results. The main objective of Legitimada is to create knowledge and socio-economic impact in the mitigation and adaptation to climate change in Catalan agricultural production through an interdisciplinary and multi-scale strategy based on the diversification of agricultural systems with legumes. Legitimada is based on biological nitrogen fixation by legumes and bacteria symbioses and on legume capacity to provide protein to the human diet with a low environmental footprint, as a mitigation strategy and adaptation to climate change.

Field experiments will be devoted to assess the role of the introduction of legumes (as single crops, intercropped with cereals or oilseeds and/or as cover crops) on soil organic C sequestration and the mitigation of GHG emissions in agricultural systems representative of Catalonia: semi-arid and cool environments of the interior, sub-humid areas of the coast and irrigated areas of the Plana de Lleida. At the same time, the potential of bean (*Phaseolus vulgaris* L.) local genetic diversity will be analyzed for its adaptation to water stress and high temperatures in horticultural and arable crop systems. Finally, mitigation and adaptation strategies will be upscalled to the overall arable crop surface in Catalonia, taking into account the different edaphic, climatic and management characteristics through process-based modeling with STICS. Modeling will be used as an educational technology tool or virtual laboratory for teaching and disseminating knowledge to University and professional training students of the agri-food and pedagogical fields (*e.g.* future agricultural technicians, farmers and teachers of experimental sciences).

Weeding pineapples crops without herbicides or plastic mulch? Critical period of weed interference in pineapple crops on Réunion Island (Poster #121)

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Keywords: agroecology; *Ananas comosus*; weed competition; agroecosystem; integrated weed management

As the first fruit produced on the island, the 'Queen Victoria' pineapple (*Ananas comosus* [L.] Merr.) holds an important role in the economy of Réunion Island. However, to reduce pest damage and ensure profitable production, pineapple crop remains largely intensive, relying heavily on synthetic inputs. Weeds are one of the most significant biotic constraints for pineapple producers, which are primarily controlled through plastic mulch and herbicides. The plastic mulch is not a long-term solution due to its composition and management after the pineapple cycle. French legislation is increasingly restrictive on the use of chemicals including herbicides, in response to demand for healthier and more environmentally friendly foods. More agroecological alternative solutions are needed, but studies on weed control during pineapple crop are limited. Understanding the impact of weeds on pineapple crop is essential for implementing effective solutions.

Because pineapple is a slow-growing plant with shallow roots, it suffers greatly from weed competition, particularly during a period of crop-weed interference defined as critical and which can reduce the crop's production capacity (Knezevic *et al.*, 2002; Oliveira *et al.*, 2021). Understanding this critical period would enable pineapple producers to optimize their weeding program, by knowing when to weed and reducing the number of interventions. The objective of this study is to determine the critical period of weed interference in pineapple crops. We aimed to address two research questions: i) What is the critical period of weed interference? ii) Which pineapple traits are affected by weeds, in terms of vegetative development, yield and quality at harvest? We conducted a field experiment at the CIRAD station on Réunion Island in 2022. The 3-replication design included 2 weeding regimes: weed-free plots (hand-weeded; CT) and weedy plots (no weeding; WD). Each regime consisted of 7 levels of weed duration, varying every 2 months from pineapple planting to harvest at 14 months *i.e.* 0, 2, 4, 6, 8, 10, 12 and 14 months of weed control or pineapple-weeds coexistence.

The results showed that the presence of weeds led to yield losses, in proportion to the weed cover duration: the longer weeds were present in pineapple plots, the higher the yield losses. Weed-free plot yields reached 33.9±5.9 tonnes per hectare, compared with 0.14±0.13 t/ha for the plots with the most weeds. The critical period of weed interference for a 5% yield loss was between 3 and 11 months after planting, *i.e.* 240 days. Beyond 8 months of coexistence between pineapples and weeds since planting, yield loss could reach 90%. The leaf emergence rates and weight of pineapple plants were significantly affected by the weed presence. Despite the continued presence of weeds, the pineapple plants remained alive at the end of the experiment but their cycle length was significantly prolonged, with flowering rates not exceeding 10% beyond 6 months of pineapple-weeds coexistence. In addition, pineapple quality at harvest was significantly affected from the fourth month of weedy plots. Fruit analysis showed lower Brix (sugar content) and higher acidity. These results suggest that yield reduction could be explained by a strong competition for resources between weeds and pineapples, with the degree of competition increasing with the duration of coexistence. This competition influenced pineapple yield components, reducing fruit weight, size and quality.

Understanding the critical period of weed interference is useful to do integrated weed management programs and facilitate the development of agroecological pineapple production systems based on the introduction of biodiversity to provide services such as weed control, soil fertility, erosion control. Combine knowledge of weed community composition and pineapple-weed interactions through a functional trait-based approach, it is possible to determine the type of species and the strategic time for planting cover crops and intercrops.

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Cereal crop yields as dependent on the soil water availability in differently management Chernozem soils (Poster #198)

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Keywords: soil water; cereal yields; modeling

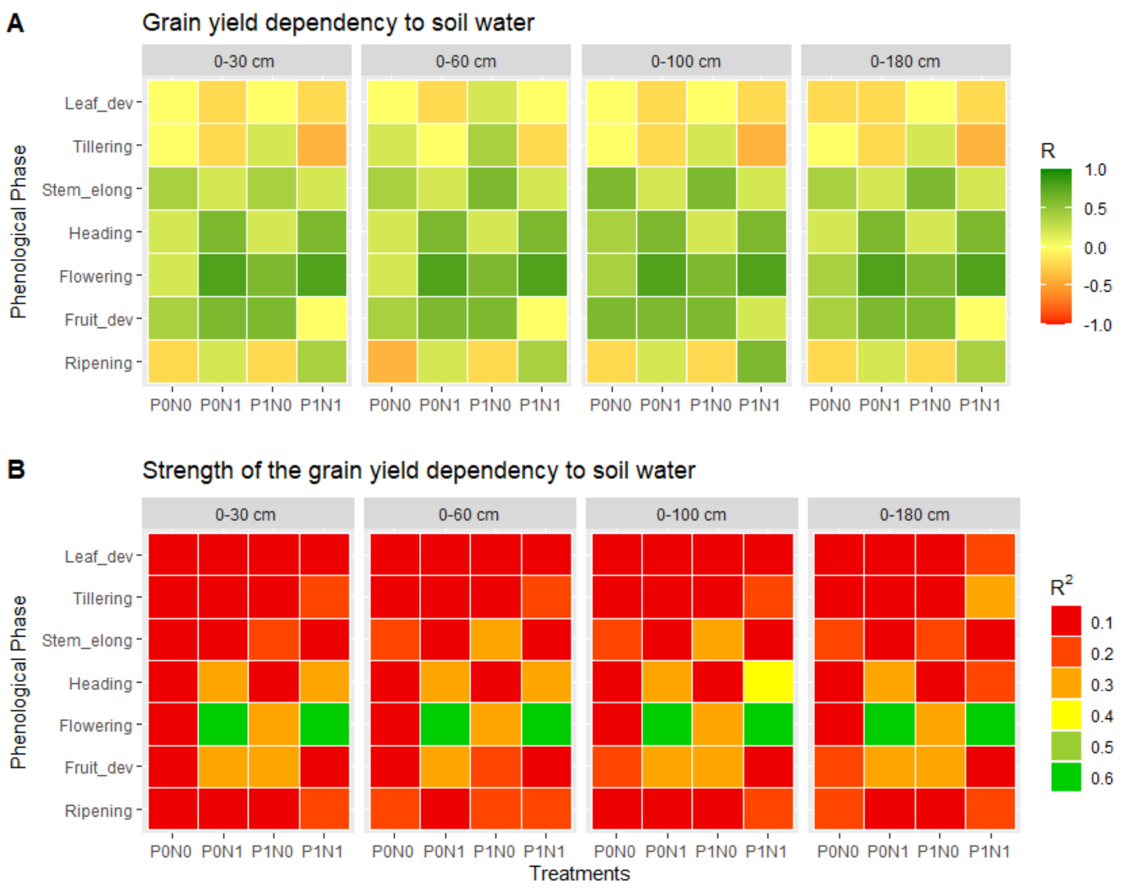

Figure 1. (A) Grain yield dependency (correlation coefficient, R) to the available soil water during phenological phases (Leaf development, tillering, stem elongation, heading, flowering, fruit development, ripening) for different nitrogen and tillage treatments for layers of various depths. (B) Strength (coefficient of determination, R^2) of the grain yield dependency to the available soil water during phenological phases

Understanding agricultural processes and their interaction with the environment is essential to improve agricultural practices in regards to climatic changes. In particular the management of soil water needs to be optimized to improve the crop resilience against extreme weather events and to obtain stable yield levels (Gaona *et al.*, 2022). The most fertile soils in Germany occur in areas with Chernozem soils, which provide high availability of essential nutrients like nitrogen and optimal hydraulic conditions. This is to achieve high yields for the cultivation of cereal crops (Altermann *et al.*, 2005). However, these areas tend to get dryer, which is why this study aims to identify phenological phases crucial for the yields of winter wheat and winter barley in their dependency to the available soil water.

The experiment was conducted at the test site in Bad Lauchstädt (51°24'N, 11°53' E; 118 m.a.s.l.) with a mean temperature of 10.66°C and annual mean precipitation of 425 mm from 2013 until 2022 (difference of -58 mm to mean precipitation for the period 1896 - 2019) on loess soils enriched with carbonates. The plots of 20x22 m were set up with a three annual crop rotation of rape seed, winter wheat and winter barley as a typical regional crop rotation with crop residues returned. As part of the experiment, this study compares the dependency of cereal yields to the soil water available for the four management systems set up:

(i) conventional tillage with plow (P1) with a standard rate of N-fertilizer according to professional practices (N1),

(ii) conventional tillage with plow (P1) with half of the standard rate of N-fertilizer (N0),

(iii) conservational tillage practice (P0) with a standard rate of N-fertilizer according to professional practices (N1),

(iiii) conservational tillage practice (P0) with half of the standard rate of N-fertilizer (N0).

To understand the complex dynamics of yield development for agricultural crops and the interaction of environmental factors such as soil and weather with agronomic practices, agricultural models are useful tools to model these interactions. Modelling the soil water dynamics helps to reduce the error of the soil water observations as well as to generate complete datasets for specific depths without gaps. Therefore, the agricultural soil model CANDY (Carbon and Nitrogen Dynamics) was used to model the soil water and nitrogen dynamics in depth of 0-30, 0-60, 0-100 and 0-180 cm. To improve the model performances, adjustments to the soil physical conditions (field capacity and saturated water conductivity) done with observations of the soil water dynamics at depths of 10 cm, 45 cm, 100 cm and 180cm during the period of 2013 to 2022. To evaluate the impacts of soil water on grain yield of cereal crops, the amount of water for every phenological phase were accumulated based on plant specific BBCH values and has been set in relation to the yield observations with simple linear models.

The results show that the water availability during the flowering and fruit development have the strongest impact on the yield development of the cereals (Figure 1). Positive correlations were observed within all treatments except the P0N0 treatment. Low fertilization and conservational tillage show the lowest relationship for water availability during the phenological sensitive phase.

Moreover, the soil water availability during phenological phases until the fruit development had an increased impact on the yield. In our case, the greatest effect is observed for the phases heading, fruit development as well as fruit development. Furthermore, both N1 plots showed the highest correlation (R2) during the flowering phase with values up to 0.57. As a consequence, the soil water available during this phase plays an important role for the nitrogen uptake of crops.

The results also, revealed a low influence between soil water and crop yield with in the first phenological phases. However, soil water showed a positive correlation with increased influences in progressed phenological phases.

Uncertainty of wheat carbon footprints – the role of N_2O estimation method (Poster #281)

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Keywords: greenhouse gas emission; carbon footprint; N_2O; life cycle assessment

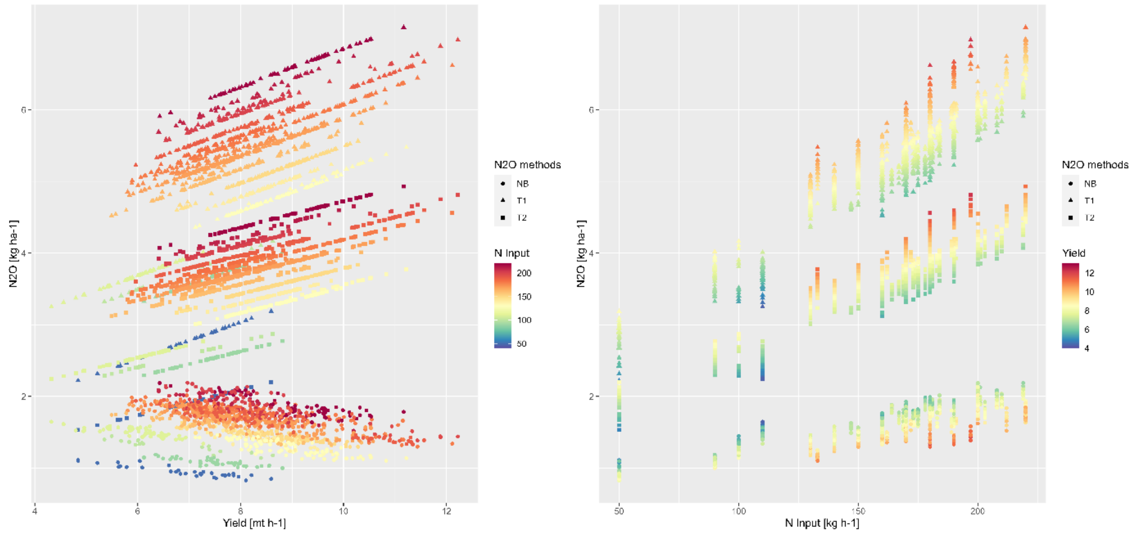

Figure 1. N_2O emissions (kg h^{-1}) calculated using three methods in relation to yield (mt h^{-1}) and N input (kg h^{-1})

1. Introduction

This study evaluates the variability in the carbon footprint of winter wheat production in Germany, with a focus on nitrous oxide (N_2O) emissions. It aims to identify significant contributors to emissions variability and suggest improvements in estimation methods.

2. Materials and Methods

Employing "Value for Cultivation and Use" trials, we analyzed the impacts of different nitrogen fertilizers, crop protection energy requirements, fuel usage, and N_2O estimation methods. Monte Carlo simulations were utilized to address uncertainties in greenhouse gas emission data and estimation techniques.

3. Results

Our findings reveal that N_2O emissions, significantly influenced by the choice of estimation method (Figure 1), can alter the carbon footprint calculations by up to 60%. The type of nitrogen fertilizer and the energy for crop protection also substantially affect emissions, leading to a broad range of carbon footprint outcomes.

4. Discussion

The variability in N_2O emissions underscores the urgent need for accurate and standardized estimation methods in agricultural assessments. This research advocates for enhanced collaborative efforts to refine lifecycle assessment methodologies and adopt more reliable techniques. By improving N_2O emission estimates, we can advance sustainable agricultural practices and effective climate change mitigation.

Invasion of exotic weeds caused losses in crop yield and vegetation diversity (Poster #7)

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Keywords: exotic weed; crop-weed competition; vegetation diversity; weed management; soybean

Exotic weeds have invaded into agroecosystem including crop fields and field margin area, causing various damages including losses in crop yield and vegetation diversity. We conducted a three-years field study to evaluate the impacts of exotic weeds on vegetation in field margin area and soybean yield. Exotic weed species invaded into soybean field such as velvetleaf, speen amarath, and common ragweed competed for light, resulting in reduced light transmittance into soybean canopy, led to stem elongation and reduced branching, and thus resulted in a significant soybean yield loss. Rectangular hyperbolic model enabled to predict soybean yield losses caused by both single and multiple weed interference. Exotic weeds invaded into field margin areas such as bur cucumber, giant ragweed, and Japanese hop grew faster and more vigorously than background vegetation and caused a significant reduction in perennial plant species, ultimately resulting in a significant loss of vegetation diversity. Our findings clearly demonstrate that invasive exotic weeds can compete against not only crops but also native plant species. A long-term strategy is required to manage invasive exotic weeds in agroecosystem based on understanding of physiologic and ecologic aspects of exotic weeds.

Drought research, particularly forecasting and plant genetics, as the key to food security (Poster #305)

Roland Baatz, Gohar Ghazaryan, Michael Hagenlocher, Claas Nendel, Andrea Toreti, Ehsan Eyshi Rezaei

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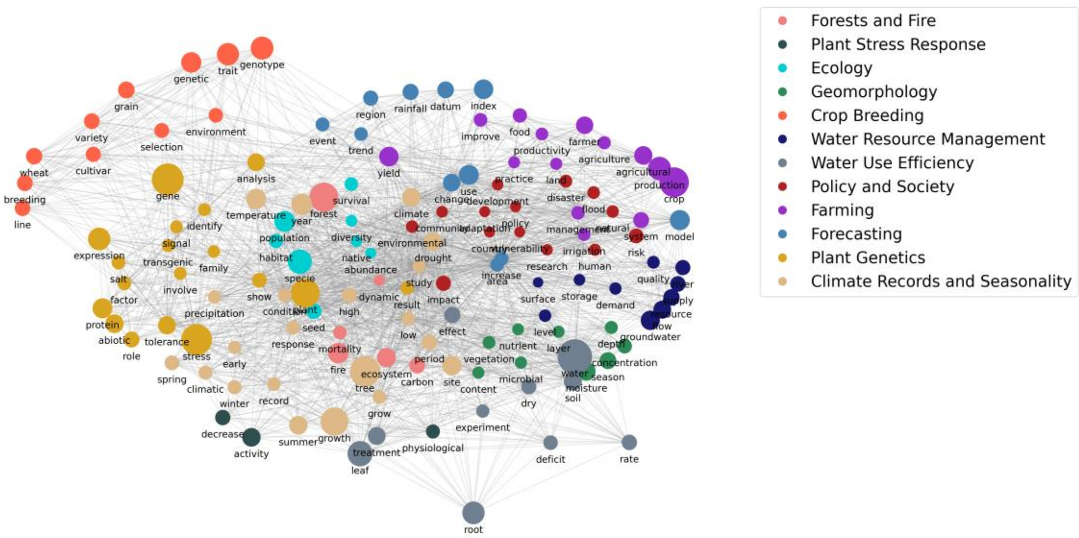
Keywords: review; drought research; forecasting; plant physiology; plant genetics



Food security has become a focal point for global efforts in the era of climate change. As crop's droughts exposure intensifies through climate change, scientists have focused on developing both predictive models and plant genetic solutions to address this threat on food security.

Our investigation, based on over 130,000 scientific abstracts from Elsevier's Scopus database, highlights the extensive and diverse research efforts in this field. We map the research landscape on drought into fine, medium, and coarse thematic areas using an unsupervised machine learning method. Since the 1980s, the number of drought research studies has increased exponentially. Research topics "plant genetics" and "drought forecasting" are particularly dominating in recent years and decades. Both showing a still positive upward trend which indicates where researchers and funding agencies allocate their interest, output and funding in the context of drought.

The genetic approach in drought research focuses on developing crops that are resistant to drought stress. Recent advances in plant genetics, plant breeding" and plant stress response, can be highlighted as gene expression analysis as active response to drought stress, stress tolerance, and anti-oxidative mechanisms in plants.

Parallel to this, predictive research has experienced significant growth. Here, the areas of remote sensing, drought indices and modelling are major avenues for enabling predictions, quantify drought impacts and identify appropriate counter-measures.

It is also notable that despite a decline in the relative proportion of research on topics such as ecology and water use efficiency, the absolute number of research papers in these areas continues to increase. This illustrates the breadth and depth of research efforts in the field of drought research.

In conclusion, we emphasize the relevance of the findings for identifying research trends, promoting interdisciplinary collaborations, quantifying the significance of various research areas for policy and strategic decisions in the context of drought issues, and serving as a foundation and inspiration for the development of new research projects by providing a data-driven and comprehensive picture of drought research.

What are the drivers for change in agricultural systems in territories? Crop succession as an indicator of change (Poster #196)

Elise Ygaunin, Maude Quinio, François Coléno, Aude Barbottin

Presenter: Elise Ygaunin (elise.ygaunin@inrae.fr)

Keywords: territorial dynamics; crop succession; pesticide use

1. Introduction

In France, numerous public policies and private schemes have been implemented to support the development of agricultural systems that are less dependent on chemical inputs, and rely on landscape restructuring to preserve the environment and biodiversity. These policies have led to changes in cropping and livestock systems that can be assessed at territorial level.

Previous studies have shown that crop rotation and succession are strong indicators of changes in cropping and livestock systems (Mignolet *et al.*, 2004; Ballot *et al.*, 2017) used to propose prospective scenarios (Debolini *et al.*, 2013). Nevertheless, the various factors influencing changes in crop succession and rotation, at the territorial scale, have rarely been studied.

In this study, we have focused on changes in crop succession observed over the past 15 years in two contrasting territories in France. Our objective is to characterize the influence of national and territorial drivers of the changes observed in crop succession and their effects on pesticide use at the territorial scale.

2. Materials and Methods

Two contrasting territories in terms of pedoclimatic conditions, cropping systems and factors influencing them have been selected for this study: the Regional Natural Park of Pilat (70,000 ha) and the PDO Chaource production area (327,900 ha).

Changes in cropping and livestock systems were characterized by using the LPIS data, organic farming areas declarations, and crop succession. Crop succession were characterized for the period 2007 - 2021 for these two areas and the French departments in which they are located (Martin *et al.*, 2021).

Factors influencing changes in cropping and livestock systems were identified through interviews with local stakeholders (*e.g.* farmers, agricultural advisors, political actors). A complementary analysis of available documentation and regulations was also carried out.

3. Results and Discussion

The work presented here focuses on the PDO Chaource area which is located in two departments and shows that changes in crop successions over the last 15 years have been limited. One of the main factors of change in the area is the abandonment of livestock farming in favor of cereal crops, resulting in a 20% decrease in farms producing PDO Chaource milk over the past decade. Interviews highlighted that this decline of livestock farms that produce PDO Chaource has been observed despite the tangible benefits this designation offers, such as increased milk prices and positive consumer perception. However, this decline does not affect the production of Chaource cheese, as milk production currently surpasses demand.

Consequently, milk that is not sold under the PDO label is being revalorized through various means.

This decline in livestock farming has led to the replacement of meadows by cash crops, which in turn has increased the risk of phytosanitary pressure on the area. Nevertheless, this replacement is hindered by the soil's characteristics, which are not conducive to cereal cultivation, and by the adoption of agri-environmental measures aimed at reintroducing grass into meadows in specific regions.

Organic farming is expanding in both departments, with an average increase in certified areas of 26% between 2021 and 2022, but remains concentrated in specific areas to facilitate collection, storage and processing facilities. Finally, diversifying crops remains challenging due to limited markets for specialized crops like soybeans, and the diverse composition of soils within the PDO region.

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Effect of different organic-mineral fertilization systems on yields and N-use efficiency (under controlled environments) (Poster #215)

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Keywords: nitrogen use efficiency (NUE); nutrient management; organic-mineral fertilizing strategies

1. Introduction

A good management of nutrients in agriculture is crucial for adequate plant growth and development, but a major problem is low nutritional efficiency. A large amount of the nutrients, especially nitrogen, is lost into the atmosphere or enters ground- and surface waters unused causing major harm to ecosystems. Many farms in Germany and generally in Europe raise live-stock or produce biogas – which are both a source of fertilizer as a byproduct. Mineral fertilizers, animal manures, legumes and biogas slurries are the most common sources of nitrogen addition to soils. In agricultural practice, fertilizers are commonly used in combination, including both organic and mineral types, because most of the total nitrogen in organic fertilizers is in the organic form and it is not directly plant available.

The aim of this study was to evaluate the effect of different organic-mineral fertilizing strategies on nitrogen use efficiency and yields at a sandy soil.

2. Materials and Methods

The fertilizers were evaluated in pot experiment (completely randomized system) as a nutrient source for silage maize plants. The trial consisted of five treatments (four organic and one mineral): unseparated biogas digestate (UBD), separated solid extracted from the digestate using screw-press separators (SSBD), separated liquid biogas digestate (SLBD), Farmyard Manure (FYM) and mineral fertilizer – calcium ammonium nitrate (CAN) *i.e.*, control without any fertilization (CTRL). Each Mitscherlich pot (diameter 20 cm, height 21 cm, capacity 6,2 l) is filled with 6 kg of sieved, sandy soil. There were four repetitions per treatment with the same total amount of nitrogen applied (expect the CTRL). After sowing and in the initial phases of plant growth, the irrigation ratio was set at 50 % of the maximum water holding capacity. The ratio was later increased to 80 %. The SPAD - 502 meter is used for measuring the chlorophyll content in the leaves, as it is related to the nitrogen status of the plant. Thirty random measurements are taken per pot in total – three times in August 2022.

At the end of the season, 97 days after sowing, the plants from each pot were harvested and weighed for their fresh mass. The samples of harvested material were grinded and collected in bags with small air holes. After weighing the fresh mass, the samples for analysis were dried for 48 hours at 60 °C and then analysed for the nitrogen content by Dumas method.

3. Results and Discussion

The more nitrogen absorbed by the plants, the higher the chlorophyll concentration was. The results indicate a significant increase in chlorophyll content early in the month of August 2022 for CAN, which remained sustained at an elevated level. This resulted in prolonged vegetation and a lengthened period of greenery. Further, the application of SLBD and SSBD treatment resulted in a higher starting level of chlorophyll content when compared to FYM and UBD treatment, implying that the type of fertilizer utilized has a notable impact on plant growth and chlorophyll content. The Tukey Test is utilized in the significant analysis of variance (ANOVA) for assessing whether differences exist between the means of groups with regard to the yields obtained in the pots. According to the results obtained, statistically significant differences were found among the control, manure, and mineral treatments. In conclusion, a high nutrient efficiency is a result of synchronizing nitrogen supply according to the demand. This can be reached with mineral and organic fertilizers but might further be influenced by factors not considered in the experiment – like timing and weather.

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Landscape unit: a framework for discussing the representativeness of cropping system (Poster #167)

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Keywords: territory; crop rotation; spatialisation; SYPPRE

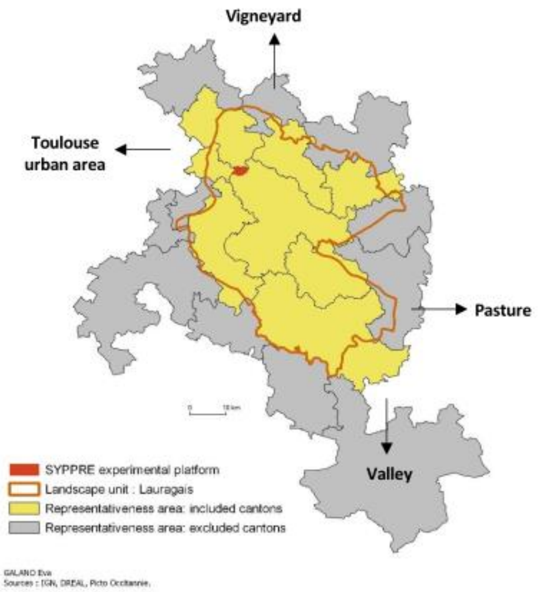
WORKSHOP RESULT

Canton icluded in the landscape unit (LU) :

- If more than 50% of the canton's area is included in the LU: Representativeness area
- If less than 50% of the canton's area is included in the LU: canton is excluded

Adjacent canton to the landscape unit: canton is excluded.

	SURFACE (HA)
Landscape unit	260 000
Representativeness area	280 000
Agricultural Area of the representativeness area	170 000



CROPPING SYSTEMS	% OF AGRICULTURAL AREA
Sunflower - Durum Wheat	12 %
Sunflower - Wheat	6 %
Sunflower - Wheat - Winter cereal	9 %
Sunflower - Wheat - Spring cereal	9 %
Sunflower - Wheat - Cereal and other cultures	21 %

→ Cropping systems whith sunflower and weat : 57 % of agricultural area

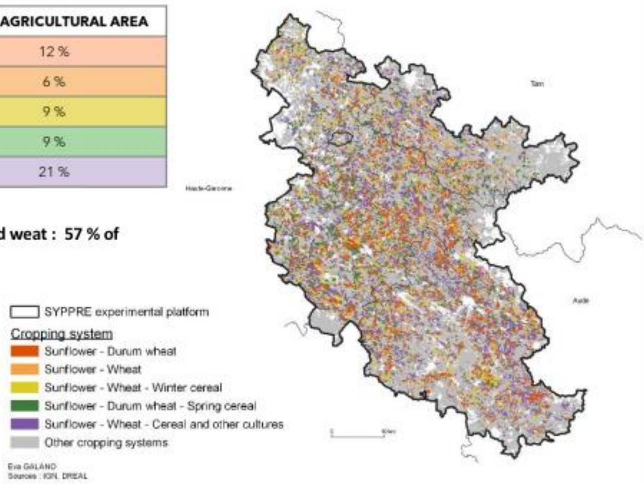


Figure 1. Delimitation of the representativeness area of the SYPPRE platform: clay-limestone slopes of Lauragais

Figure 2. Cropping systems in the SYPPRE Lauragais representativeness area

While agronomists traditionally consider the level of organization of the plot or the farm in their approaches, the consideration of a higher level of organization such as the territory has been continually advocated for 20 years (Boiffin 2004). Indeed, agriculture is facing challenges such as environmental issues (climate change, natural resource management, biodiversity preservation) or social issues (peri-urban context, local food sovereignty, multifunctionality of agriculture). Those challenges pertain to levels of organization that do not coincide with the plot or the farm, and concern actors beyond farmers. Therefore, a territorial approach is required and must be multidisciplinary, involving agronomists, geographers, geomaticians, ecologists, and sociologist to tackle its various dimensions.

The goal of this study is to objectify the description of cropping systems that compose a given territory. Here, the territory is considered as a dynamic level of organization defined by both physical characteristics and socio-cultural constructions (*i.e.* created and maintained by interactions among the various actors involved), (Boiffin 2004). All these components are covered by few delimitations, except this based on landscapes that are built through the ecological and sociological relationships they harbour. In France, a delimitation into landscape units was developed to characterize all its landscapes (Franchi *et al.* 2015).

The question for agronomists is how to delimited the representativeness areas of a given cropping system with help of landscape unit. We used the SYPPRE experimental platforms as case studies to discuss the representativeness of their reference systems, established according to local experts, in relation to the cropping systems in the area under consideration. This case study presented here focuses more precisely on the SYPPRE Lauragais platform in Southwestern France (Toqué *et al.* 2015). The approach is built around iterative co-design workshops (Figure 1), leading to the delimitation of the landscape unit based on cantons (an administrative unit covering several municipalities that proves to be operational). The use of RPG Explorer software (Martin *et al.* 2016) then allows us to analyse the rotations practised and their proportion within the representativeness area.

The Lauragais landscape unit delimits a homogeneous agricultural area in clay-limestone slope areas. It is surrounded to the North by vineyard, to the West by the Toulouse urban area, and to the east by pasture for livestock farming. To the South, the slope areas give way to valleys. Characterization of cropping systems shows that the SYPPRE reference system based on a sunflower-cereal rotation is predominant in the territory, covering 57% of the systems (Figure 2). However, this rotation is extended with an additional crop (barley, rapeseed, maize *etc.*) on 45% of the surfaces.

Through the various workshops, the landscape unit emerged as a relevant delimitation choice for approaching territories and questioning the representativeness of cropping systems. It indeed gained conceptual adherence and practical appropriation. Characterization of cropping systems allowed local experts to assert or reposition their vision and future scenarios for their agricultural territory. In some cases, the workshops have led to new questions (*e.g.* water management) for a better understanding of territorial systems. However, we are aware of the spatial limitations to which recommendations from system trials can be applied. The next step of this work will focus on delineating relevance areas: areas which are concerned by similar problems of a point of interest. The hypothesis is that work on representativeness area conducted on SYPPRE platforms can be extrapolated to relevance area (*e.g.* soil erosion) in different territories. In any case, such a work of territory delimitation will the starting point of multidisciplinary study.

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Acknowledgments

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Are intercrops and cover crops efficient to mitigate pesticide dependency and leaching risks in low input cropping systems? (Poster #250)

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Keywords: agroecology; environmental impacts; crop diversification; long-term cropping system experiment

In conventional cropping systems (CS) of Southwest France based on short-term rotation of durum wheat - sunflower, a long bare soil period occurs (Bonnet *et al.*, 2021). These CS strongly depend on chemical fertilizers and pesticides, leading to environmental contamination. For the transitioning to agroecological CS needs novel agronomic integrative strategies such as crop diversification, incorporating legumes, intercropping, and cover cropping of fallow periods are key levers for reducing input use (Plaza-Bonilla *et al.*, 2017).

In this study, CS were designed to lessen dependence on N fertilisers and pesticides and avoid environmental impacts. Among the strategies employed, we hypothesize that intercropping effectively reduces pesticide use and thus potential environmental transfer risks. Furthermore, cover crops are well-known to reduce nitrate leaching, and by limiting or slowing drainage can facilitate pesticide degradation (Alletto *et al.*, 2012), which can help mitigating pesticide transfers to groundwaters.

Over six cropping seasons (2011-2016), three CS aiming at reducing fertilisers and pesticides (by half as much as possible) were evaluated on experimental plots at the INRAE Toulouse station. The 6 CS tested were: (i) a Low Input system (LI) (with sunflower, wheat, and sorghum), (ii) a Very Low Input system (VLI) including a legume (faba bean) in the rotation and wheat cultivar mixture, and (iii) a system with legumes InterCropped (IC) (durum wheat-pea, soft wheat-faba bean, sunflower-soybean) in the 3-year rotation. Each plot was replicated three times, starting at each of the 3 crops in the rotation, with half of each plot managed either with bare soil (BS) or with a cover crop (CC), leading to test 6 CS.

Technical managements were adapted to each CS and were recorded in order to calculate Treatment Frequency Index (TFI) to assess pesticide use in the 6 CS tested.

Lysimetric plates were installed at 1 m-depth in each plot for collecting drainage water. More than 500 samples were analysed for their concentration in active compounds from 2011 to 2016. All the molecules applied since 2004 were analysed in the drainage water, resulting in the analysis of 33 to 44 molecules applied, depending on the plot.

Differences in TFI were observed among the 6 CS with lower values for the LI system, followed by IC, and then VLI system. Higher TFI in the IC and VLI systems were primarily attributed to high weed infestation and poor mechanical control due to rainy periods. Cover crops did not affect TFI across all 6 CS.

Cumulated mean drainage (mm) displayed a decreasing trend across systems, ranging from 380 mm in the LI system to 176 mm in the IC system, with the VLI system intermediate at 201 mm. Moreover, cover crops did not induced a significant reduction of water drainage, which is coherent with their early destruction as designed for limiting water consumption.

The most prevalent pesticides detected in the samples were two herbicides, S-metolachlor and fenuron, with a maximum concentration of 12.7 and 1.1 µg/L, respectively. Surprisingly the insecticide imidacloprid, primarily used as seed treatment, was also measured with a maximum concentration of 1.3 µg/L.

Cumulative mean pesticide loss (including all quantified molecules) during the 2011-2016 period ranged from 0.8 g/ha in the LI system with cover crops to 4.2 g/ha in the LI system without cover crops. Introducing cover crops consistently led to a reduction in pesticide losses across the various systems, with reductions of approximately 2-fold for IC, 2.7-fold for VLI, and 5.3-fold for LI.

Overall, according to decision-rules applied, pesticide applications were reduced to levels over 50% lower than conventional practices for the respective crops, demonstrating the feasibility of achieving the objectives outlined in the French Ecophyto plan.

In terms of reducing pesticide leaching, the results highlight the crucial benefits of managing the fallow period using cover crops to reduce pesticide transfers, in addition to well-known ecosystem services. These results further underline the multi-service nature of cover crops. Additionally, the introduction of intercrops appears to also contribute to the reduction of pesticide transfers, mainly because of a reduced application frequency.

The effects of 39-year continuous mineral and organic nitrogen fertilization in an albic luvisol soil in Germany (Poster #251)

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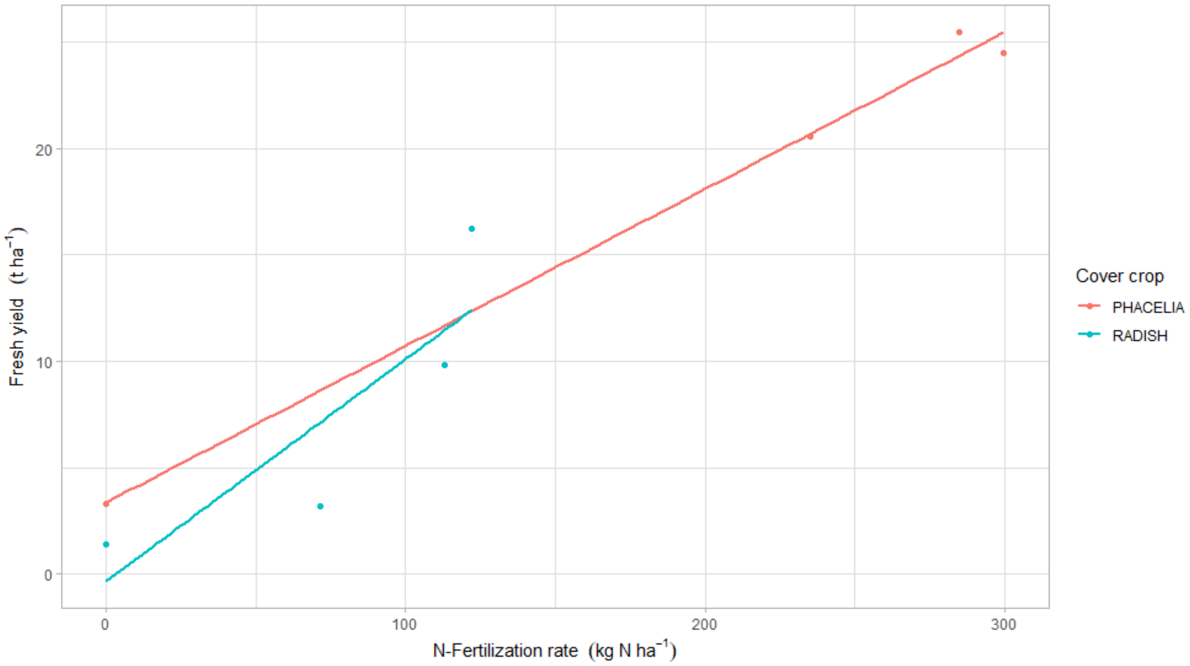
Keywords: cover crop; long-term experiment; nitrogen; fertilization



1. Introduction

A 39-year field experiment has been conducted continuously since 1984 in Germany, to evaluate the effects of a combined supply of organic and mineral nitrogen on the biomass of two different selected cover crops.

2. Materials and Methods

The field experiment is located at the experimental Station Berlin-Dahlem (Humboldt-Universität zu Berlin, Germany). The site has the following characteristics: 66.7% sand, 20.7% loam, and 12.6% clay, 0.03% of total N content, 0.35 % of total organic carbon, and 0.0 % of CaCO3. Three different regimes of N mineral fertilization and the two cover crop species radish (*Rafanus sativus* var. *oleiformis* Pers.) and phacelia (*Phacelia tanacetifolia* Benth.) were examined. The mineral nitrogen fertilizer used is calcium ammonium nitrate (CAN). The treatments used in plots having spring barley (*Hordeum vulgare* L.), corn silage (*Zea mays* L.), and winter wheat (*Triticum aestivum* L.) as main crops are the following: cover crop or straw with no mineral nitrogen fertilization (CN0), with low nitrogen mineral fertilization rate (CN1), with medium nitrogen mineral fertilization rate (CN2), with high nitrogen mineral fertilization rate (CN3), only high level of mineral nitrogen fertilization (AN3). The leaf chlorophyll content of cover crops was estimated using a SPAD chlorophyll meter. Twenty SPAD measurements were taken for each plot of radish and phacelia, and the average was calculated. Cover crops were harvested on the 24 total plots of phacelia and radish on which the previous year had been sown, in two different field, spring barley and winter wheat. For each plot, four technical replicates of 0.25 m^2 were harvested and pooled to provide a single sample, respectively. The fresh matter (FM) of each sample was determined. Samples were dried at 105 ºC to a constant dry weight and dry matter (DM) and dry matter content (DMC) were determined (Shipley and Vu, 2002).

3. Results

FM and DM yields, and SPAD measurements of phacelia and radish were significantly ($p < 0.05$) associated with N fertilization from CN0 to CN3 treatments. FM of phacelia and radish ranged from > 10 t ha^{-1} and ~ 5 t ha^{-1} to ~ 40 t ha^{-1} and ~ 20 t ha^{-1} as the phacelia has a higher biomass and therefore a higher availability of organic N. DM yields of phacelia and radish ranged from ~ 1 t ha^{-1} to ~ 3 t ha^{-1} and ~2.5 t ha^{-1}. SPAD values increased as nitrogen fertilization levels increased for phacelia from ~ 10 to ~ 20, for radish from ~ 30 to ~ 40. DMC was negatively affected by increasing N-fertilization for phacelia from ~ 0.15 g g^{-1} to ~ 0.05 g g^{-1} and for radish from ~ 0.25 g g^{-1} to ~ 0.10 g g^{-1}. Linear regression shows that phacelia responds more strongly to increasing doses of nitrogen up to values of 25 t FM ha^{-1} compared to radish (~ 15 t FM ha^{-1}).

4. Discussion

Phacelia could provide organic nitrogen to the main crop that has high N requirements. Herrera *et al.*, 2010 reported that phacelia has a high N uptake of 9.85 g N m^{-2} through a combination of high shoot biomass and root intensity present in the upper soil state. Radish could be a source of organic N for those main crops with low nitrogen requirements. It needs, if used as green manure, an additional dose of mineral N as it alone would fail to fully meet the needs of a subsequent main crop (Ruark *et al.*, 2018).

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Exploring diverse practices in sugarcane straw management: a case study in Réunion island (Poster #143)

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Keywords: straw; farmers; agronomic benefits; input reduction; strategies

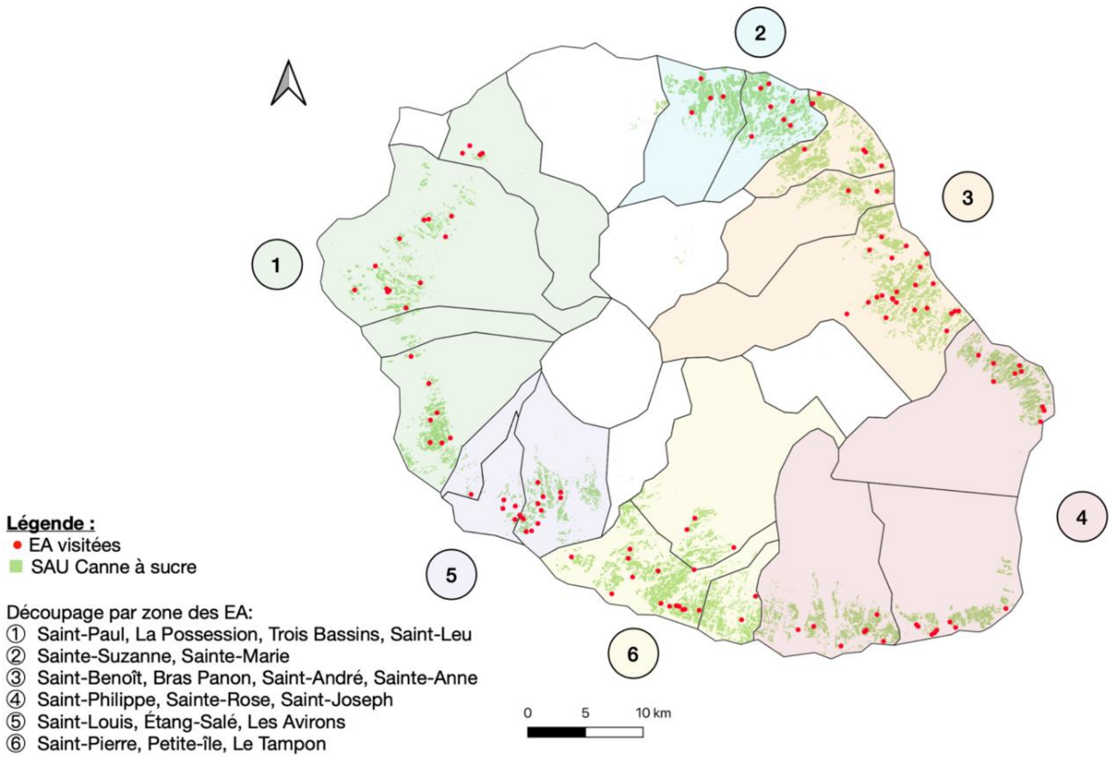

Figure 1. Réunion Island divided into study zones

Sugarcane cultivation is vital to Réunion Island's agricultural economy, but growers face challenges like labor scarcity and rising costs. Utilizing sugarcane straw for weed control and soil fertilization offers a potential solution. This study examines grower practices in response to agronomic, environmental, and socio-economic dynamics. Through interviews with 128 growers, factors influencing straw production and export were identified, including variety choice and climate variations. While growers emphasize straw's benefits, concerns about pests and herbicide effectiveness persist. Optimizing straw utilization is crucial for addressing contemporary challenges and ensuring agricultural sustainability on the island.

Spring fertilisation with green ammonia - option for future organic farming? (Poster #98)

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Keywords: organic agriculture; resource use efficiency; climate change; nitrogen; sustainable intensification

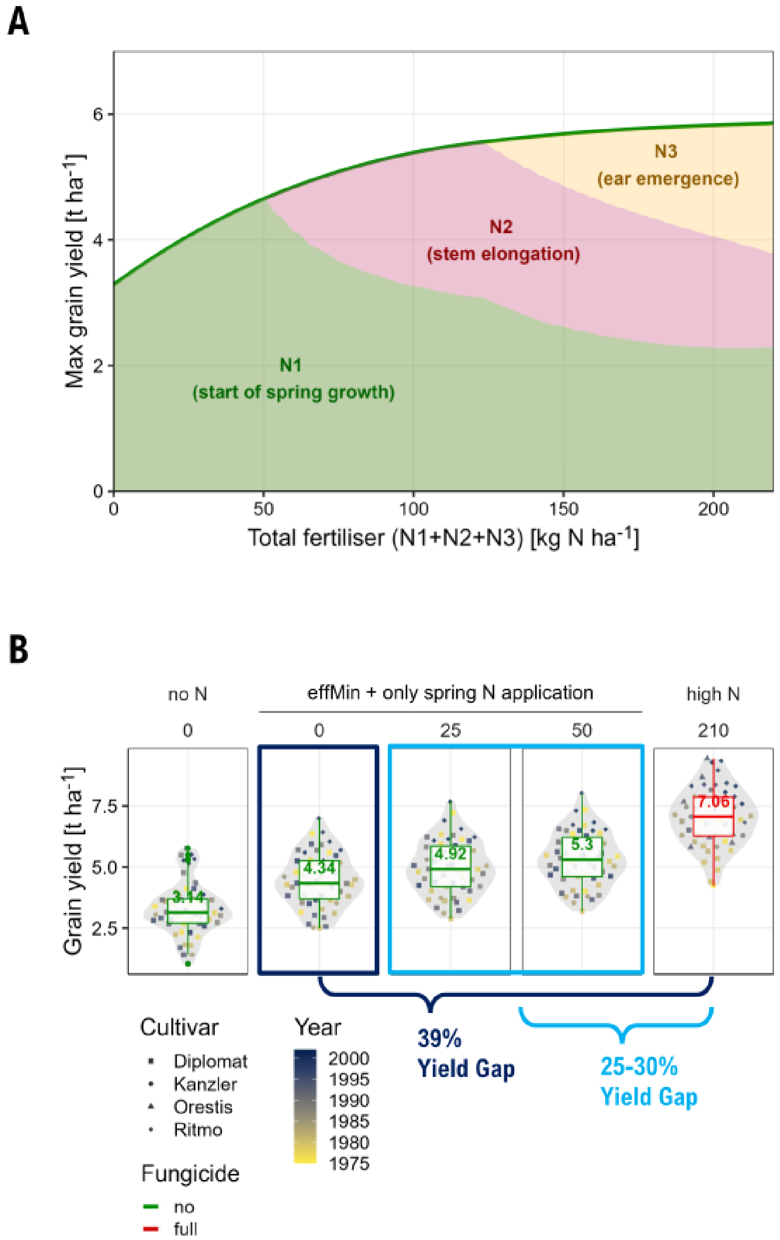

Figure 1. (A) Optimal allocation of total N fertilisation into the three splits (colour shadings) for maximal grain yield under low external input intensity (no fungicides) (B) potential yield effects of moderate mineral spring N application in low-input systems with assumed net N mineralisation of 40 kg compared with conventional high N input (3 split applications) according to the German fertiliser ordinance. All estimations derived from 27 years of experimental data with 2 field replications each

1. Introduction

In the near future, we will (hopefully) live in a de-carbonised economy and CO_2-neutral produced nitrogen (N) fertiliser from green ammonia will likely be standard in conventional agriculture. The use of such sustainable produced mineral N fertiliser products could become an option in organic farming within strictly limited and regulated rates for applications only in early spring. Compliance monitoring is then expected to be available nationwide and publicly accessible from spectral remote sensing data.

Even though, organically managed soils are known for their high fertility and potential to deliver nutrients from mineralisation processes, the synchrony of plant N demand and supply in early spring is rather poor. Cool temperatures during the important yield determining phase between double ridge and terminal spikelet stages cannot ensure a proper N nutrition for maximal sink formation. Hence, a moderate support from rapidly plant available mineral N fertiliser would help to bridge this gap during the start of the vegetation period in spring.

2. Materials and Methods

To assess the potential for yield increase from moderate N fertilisation in we used a long-term field experiment (established in 1974) from the experimental farm “Hohenschulen” at Kiel University with full-factorial combined N rate variation (0,40, 80, 120 kg N ha^{-1}) at all three split applications (beginning of spring growth, stem elongation, ear emergence), leading to overall 64 N treatments. This was implemented in a winter oilseed rape – winter wheat – spring oats – winter barley crop rotation with N rate variation only in wheat and barley in an inverse pattern, resulting in the same amount of total N applied on each plot after one rotational cycle (Sieling and Kage 2021, 2022). Additional fungicide treatments were included within subplots and until 2002 a comparison of full fungicides against no fungicides was available to derive effects of only moderate N but no further synthetic plant protection as estimation for conventional *versus* low external input. The used cultivars shifted over time and reflected breeding progress.

3. Results

Highest grain yields in low intensity systems (up to 50 kg N) were achieved from only spring applications (Figure 1A). N response functions showed steeper slopes for N applications only in spring compared to only at later splits or at more applications than the first split. Long-term average grain yields under spring-supported moderate N input environments without additional synthetic plant protection were between 4.9 and 5.3 t ha^{-1}. Under typical conventional three split applications of total 210 kg N ha-1 the average yield was 7.1 t ha^{-1}. The yield gap of low-N-input systems to typical conventional high-N-input intensity of 39% could be reduced to 25-30% with N fertilisation of 50 or 25 kg ha^{-1}, respectively (Figure 1B). When considering shifting 1 kg N fertiliser from high-N-input into low-N-input systems, the yield effect would be doubled (10-15 *versus* 25-30 kg grain yield per kg N input in typical conventional compared to low-N-input with spring N support).

4. Discussion

Environmental impacts such as nitrate leaching, or N balance surplus are rather small during early spring applications since leaching below the root zone is unlikely as are problems with high post-harvest N-surplus. Gaseous losses are likely to be less pronounced under low N-input intensity due to a non-linear relationship between fertiliser N input and N_2O emissions (Shcherbak *et al.* 2014). Therefore, a shifting of about 25-50 kg mineral N fertiliser from conventional into low-N-input cropping systems would significantly reduce the net environmental burden in terms of GHG emissions., we could observe a clear increase in apparent fertiliser N recovery over time of which a major contribution might be attributed to newer cultivars (Sieling and Kage 2021).

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Using DSSAT to examine the interannual weather variation in forage maize productivity in Asturias and Galicia (Spain) (Poster #17)

J.A. Oliveira, K.J. Boote, F.A.A. Oliveira, M.J. Bande, A. Carballal, A. Martínez-Fernández, G. Hoogenboom

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Keywords: crop modeling; maize silage; CSM-CERES-Maize; FAO maturity groups; weather data

Figure 1. Comparison of whole plant dry matter production (kg DM ha^{-1}) simulated using 23 years of meteorological data in the seven locations for the six cultivars studied

1. Introduction

Process-based crop models are excellent tools for quantifying the effects of management, genetics, soil and weather on growth, development, and yields (Addiscott and Wagenet, 1985). Oliveira *et al.* (2023) initiated the adaptation of the CSM-CERES-Maize model of software platform Decision Support System for Agrotechnology Transfer (DSSAT) (Hoogenboom *et al.*, 2019) for forage maize and, to simulate growth and development of three forage maize cultivars for three sites of Asturias, Spain.

The objective of the present study was to use the CSM-CERES-Maize model in combination with the seasonal analysis of DSSAT to quantify the influence of interannual weather variation on forage maize production in Asturias and Galicia.

2. Materials and Methods

With the aim of examining the interannual variation in whole plant dry matter production, the model was executed with long-term historical meteorological data for 23 years from 2000 to 2022 with three cultivars (SE1-200, FAO-200; SE2-300, FAO-300; SE3-400, FAO-400) for three sites of Asturias and with three cultivars (XU1-200, FAO-200; XU2-300, FAO-300; XU3-400, FAO-400) for four sites in Galicia.

The genetic coefficients of the cultivars used in the simulation were obtained according to Oliveira *et al.* (2003).

For the simulations, the usual sowing and harvest dates for the trials in Asturias and Galicia were used.

3. Results

The estimated genetic coefficients for three cultivars (SE1-200, SE2-300, SE3-400) for three locations in Asturias and for three cultivars (XU1-200, XU2-300, XU3-400) for four locations in Galicia for three years were the following:

P1 (ºC day): SE1-200 (145), SE2-300 (215), SE3-400 (230), XU1-200 (115), XU2-300 (160), XU3-400 (175).

P2 (Days): 0.3 for all the cultivars.

P5 (ºC day): SE1-200 (705), SE2-300 (650), SE3-400 (660), XU1-200 (590), XU2-300 (590), XU3-400 (580).

G2 (Nº grains): 650 for all the cultivars.

G3 (mg day^{-1}): SE1-200 (6), SE2-300 (7), SE3-400 (7), XU1-200 (7), XU2-300 (8), XU3-400 (8).

PHINT (ºC day): 40 for all the cultivars.

As an example, the simulated mean values for the 23 years of meteorological data for dry matter production for each of the cultivars for the study sites in Asturias and Galicia were plotted (Figure 1).

For all locations, the highest yield was achieved with the cultivars that had the longest growth cycle (SE3-400 and XU3-400) during the growing season. The average daily weather conditions for maximum temperatures ranged from 21.3 to 26.0 °C, for minimum temperatures it ranged from 9.8 to 15.8 °C, and for total solar radiation it ranged from 15.8 to 23.0 MJ m^{-2} day^{-1}; total rainfall during the growing season ranged from 109.5 to 313 mm.

4. Discussion

The CSM-CERES-Maize model was adapted to simulate forage maize yields by calibrating the genetic parameters of six cultivars: SE1-200, SE2-300 and SE3-400 in three locations and three years in Asturias, and XU1-220, XU2-300 and XU3-400 in four locations and three years in Galicia.

The calibration, together with the use of historical meteorological data (2000-2022) from the study sites, allowed simulation of the whole plant dry matter production of the six cultivars during the 23-year period. A specific model for forage maize is expected to be included in the DSSAT platform. Use of the new model should help to optimize management practices and harvest decisions in forage maize.

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We are grateful for a grant provided by the “OECD Co-operative Research Programme” to support a research visit by the first author at the University of Florida, Gainesville, Florida, USA in 2022.

Agro-economic performances of cropping systems under low pesticide use and organic production in Brittany (Poster #77)

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Keywords: cropping systems; phytosanitary products; organic farming; performances; diversification

The recognized impacts of phytosanitary products on human and ecosystems health call for a deep modification of cropping systems. In Brittany, cropping systems are mainly aimed at providing animal feed. If the breeding of ruminants allows the valorization of fodder and therefore the presence of perennial crops in rotations, this is not the case with the breeding of monogastric animals. In these systems, reducing the use of phytosanitary products is challenged by the difficulty of controlling weeds in rotations composed solely of annual crops.

Three cropping systems with little or no use of phytosanitary products were tested from 2018 to 2023, as part of the DEPHY EXPE 2 Syno'phyt project. Crop rotations were designed to provide feed to pig or poultry farming (grains, oilseeds and protein crops). Pest management strategies and associated decision rules were co-constructed within the framework of workshops organized regularly during the first two years of the project, gathering stakeholders from varied backgrounds (INRAE, technical institutes, farmers…). The three systems are: "Reference 2025 system" (SR), based on a corn-wheat rotation, reducing by half the use of phytosanitary products compared to the Breton average IFT of a corn-wheat rotation; "Agroecological system" (SA), based on a 7-year rotation integrating protein crops, reducing the use of phytosanitary products by 75% compared to this same reference; "Organic farming system" (SAB), based on a 5-year rotation integrating protein crops and crops intended for human food, without using any phytosanitary products. These three systems were implemented at the Kerguéhennec experimental station, in the center of Morbihan. All crops were present each year. The systems were monitored for 5 growing seasons. The data collected during these 5 years concerns (i) the technical itineraries, recorded under Systerre tool; (ii) crop yield components, (iii) crop health status, (iv) weed density and biomass. The systems were evaluated on their agronomic, economic and working time performances.

The results show satisfactory agronomic performances: in SR, the yield objectives are achieved 2 out of 5 years for wheat and 4 out of 5 years for corn; in SA, 3 out of 5 years for wheat and corn, 5 out of 5 years for rapeseed, 1 out of 5 years for field bean, 2 out of 5 years for triticale and pea association; in SAB, 4 out of 5 years for oats, field bean and corn, 2 out of 5 years for buckwheat and triticale-pea association. The management of annual and perennial weeds is satisfactory in SA and SR, satisfactory for annuals but very unsatisfactory for perennials in the SAB. The average margin over the 5 years is 1066 ± 187 €/ha in SAB, 974 ± 138 €/ha in SR and 895 ± 96 €/ha in SA. Working time is increased by 1 hour on average in SR (7h35/ha) compared to SAB and SA which have similar working times, 6h29/ha and 6h43/ha respectively. The work schedule is very different from one system to another, with work peaks more pronounced in the SR. The results of this trial show that reducing phytosanitary products is possible without extending the rotation but at the expense of working time. Weed management was satisfactory in experimented systems, with a vigilance on the management of perennials in these rotations solely composed of annual crops. The choice of cultivated species was consistent with the initial constraints of the project (link to breeding), but questions emerge regarding the structuring of the agri-food sector, in terms of valorization of “minor” crops and the possibility of collecting and sorting crop associations managed conventionally.

Frost and heat impact on grain yields: challenges in its modelling (Poster #128)

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Keywords: crop model; extreme weather; wheat; canola; barley

1. Introduction

Frost and heat events affect plant development, growth, and yield, adding pressure to global food security and leading to economic loss depending on their timing, severity, and duration. Climate change projections and optimal pairing of variety and sowing dates to minimise the combined risk of drought, heat and frost stress are prime examples of applications that need models which account for extreme temperatures. Thus, revising current knowledge on the impact of such events from a modelling perspective is warranted. Our aim is to review the scope and limitations in yield response functions that simulate the impact of heat and frost.

2. Methodology

We review the current knowledge of the physiological impact of timing, intensity, and duration of heat and frost events on the yield of major annual grain crops and the opportunities to improve damage functions for crop modelling. A summary of model analytical functions and threshold temperatures is provided, modelling assumptions are made explicit, and future requirements are discussed. We outline the problem and current situation; then, we briefly explore the physiological effects of frost and heat stress and summarise experimental studies on temperature effects on various crops at different developmental stages. We present different modelling assumptions and approaches. Lastly, we discuss the immediate, medium, and long-term research opportunities to improve the modelling of heat and frost on annual grain crop yield.

3. Results

Conceptually, a frost or heat temperature threshold is the critical temperature at which crop damage starts and peaks. The frost and heat temperature thresholds vary with crop species, cultivar, and crop development stage. To determine the temperature thresholds for heat and frost, the reports of trait *vs* temperature, fitted functions, and inflexion points are necessary. These data must account for genotype, genotype x environment, genotype x management, and genotype x management x environment effects. The full summary is available at Richetti *et al.* (2024).

Models do not account for acclimation, compensation, pathogen-induced freezing and psychrophiles. Interactions of extreme temperatures with radiation, water supply and demand, and nitrogen availability are not explicit in models, but some of these might emerge depending on the model structure. Lastly, it is important to note that abiotic stresses such as frost, heat, and drought are likely to have combined effects that are not simply additive.

Models used different approaches to simulate effects of extreme temperatures in crops; some models have functions to act on crop survival, leaf area index, grain number, grain weight, and yield. In scaling plant population density and leaf area index, the effect of extreme temperatures is carried over to yield *via* capture of resources – radiation and water. Scaling of yield and yield components is usually direct, based on empirical "penalty" functions.

4. Discussion

The general response functions that account for setting the maximum grain number pre-flowering and grain size post-flowering times seem to be valid across a range of crops, not only for wheat, as previously proposed (Barlow *et al.*, 2015). However, deriving the temperature thresholds and response functions for occasional, extreme temperature stress events is challenging. The temperature differences between air and canopy also present a gap that needs addressing. A limitation to model crop responses to extreme temperatures is our superficial understanding of the underlying processes. Lastly, the development of frost and heat response functions should be in the form of elegant and robust equations that achieve both biological rigour and model simplicity to improve crop modelling outputs. This should help to bridge the gap between the understanding of the effects of frost and heat stress at the cellular and plant organ level and the agronomically relevant effects experienced at the field scale.

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PULSAR: a France 2030 project for unlocking white lupin from field to fork (Poster #181)

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Keywords: legume; genomics; intercropping; nutrient use; plant physiology; food science

Legumes have the capacity to produce protein-rich seeds for food and feed, and thus play an important role in promoting resource-efficient agriculture, and sustainable and healthy diets. However, protein-rich grain legumes, such as pea, faba bean and lupin, which can fix the nitrogen from atmosphere, account for only 2 to 3% of cultivated land in Europe. In France in particular, investments in research and development for these species have been modest in the past years, and have been mainly dedicated to pea, with very little interest in lupin. Thus, lupin is considered as an "orphan" species, remaining still very poorly known. In France, only ten varieties of white lupin are available to farmers. Yet, lupins have considerable potential for protein production and human health, as similarly to soybean, they produce high level protein seeds, with essential amino acids, micro-elements, and omega 3-rich oil. The low interest of farmers for lupin is mainly explained by yield variability, damages due to drought and water excess, and a low competitiveness against weeds. In addition, this species which is little known to consumers can cause food allergy. The PULSAR project brings together a multidisciplinary consortium of seven research units from the Ecole Supérieure des agricultures (ESA) and the French Research Institute in Agriculture, Food and Environment (INRAE), and two private companies, Kedelaï and Cérience. PULSAR has the ambition to pave the way for increased lupin cultivation and use for human consumption.

PULSAR aims to improve knowledge in lupin biology, agronomy and food science, and to provide applicable solutions to broaden the range of lupin varieties available for efficient and resilient cropping systems. It also aims to investigate the potential of fermentation to improve lupin digestion and mitigate its potential allergenic nature. For this purpose, the PULSAR consortium will characterize the French national collection of white lupin (*Lupinus albus* L.) genetic resources and identify lines relevant to the context of global warming and resource saving. From an agronomic point of view, PULSAR proposes to intercrop the lupin with a service plant, a practice allowing weed limitation and enhancing the system resilience to hazards. By using intercrops, the project is perfectly aligned with agroecological principles, *i.e.* low chemical inputs and sustainable agriculture based on biological processes. PULSAR will also analyse the physiological functioning of lupin in order to better understand the links with the seed protein quality. Given the growing demand for fermented plant-based products in relation to their health benefits, the Food science teams will study the effect of fermentation by lactic acid bacteria or filamentous microscopic fungi on allergenicity and digestion of lupin proteins and seeds. The acceptability of the products resulting from these fermentation processes to the consumers will be assessed by performing sensory analysis. PULSAR is the first project of this scale dedicated to lupin and can be therefore a major lever for developing lupin cultivation and industry in France.

Acknowledgements

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Effect of the reduction of fertilization by iron chelates on photosynthesis, stress parameters and production of mandarin trees (Poster #185)

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Keywords: iron nutrition; sustainable agriculture; plant stress; photosynthesis; plant production

1. Introduction

Iron is an essential micronutrient for plants with a very important role in their metabolism. 80-90% of Fe is located in chloroplasts. Therefore, any imbalance in foliar Fe homeostasis will affect chlorophyll synthesis and the photosynthetic apparatus [1]. However, excess Fe can cause phytotoxicity, especially in waterlogged soils, through the generation of reactive oxygen species (ROS), such as the hydroxyl radical (.OH), which can cause damage at the cellular level [2].

2. Materials and Methods

In this work, we proposed to reduce the application of Fe chelates in the fertirrigation of mandarin trees of the "Nadorcott" variety, grafted on Macrophylla. The study was carried out in Pozo Estrecho (Cartagena, Spain), in a soil containing a low organic matter content, basic pH and high levels of Fe (about 30 g/kg soil) owned by a private company, dedicated to the production of citrus. We proposed to reduce the application of Fe chelates by 25% and 50% in relation to the conventional fertirrigation regime applied by the company. After 5 months of applying these reductions, an analysis of mineral nutrients in soil, roots and leaves was carried out. Likewise, the contents of chlorophyll, flavonols and anthocyanins, chlorophyll fluorescence parameters, lipid peroxidation (marker of membrane damage) and peroxidase activity (POX), as a biochemical marker of Fe, were determined in the leaf. Finally, the effect on production and fruit quality was also determined.

3. Results and Discussion

The results showed that the reduction in the application of Fe led to a decrease in its levels in the soil, without affecting the contents in roots and leaves, in relation to control plants (conventional fertirrigation). On the other hand, the Fe reduction treatments did not affect the leaf chlorophylls, flavonols and anthocyanins contents. When analyzing the chlorophyll fluorescence parameters, no changes were observed in the photochemical quenching parameters [Fv/Fm; Y(II) and qP], but an increase in the non-photochemical quenching parameters (qN, NPQ) took place, which can be considered as a defense mechanism of the chloroplasts. On the other hand, the electron transport rate (ETR) in the chloroplast remained unchanged. This is very interesting, since it must be taken into account that Fe takes part of numerous electronic transporters in the photosynthetic electronic transport chain of the chloroplast [3] and that a reduction in Fe fertilization does not negatively affect ETR, which indicates that the company can reduce the application of Fe chelates.

The reduction in Fe fertilization did not affect the stress state of the trees, as reflected by the data on lipid peroxidation and leaf POX activity, a biochemical Fe indicator. Finally, the production and quality data were not affected by the effect of the reduction in Fe fertilization.

Altogether, our results support the viability of the reduction in the Fe application without negatively affecting either the physiology of mandarin trees or their production.

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Limited volume irrigation: management by the Irré-Lis tool (Poster #164)

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Keywords: irrigation; water balance; maize; limited volume; water restrictions

1. Introduction

Irrigation is a practice facing increasingly strong constraints, whether due to climatic reasons (extreme climatic demand, rainfall deficit...) or technical reasons (equipment park, instantaneous flow rates).

The operational management of irrigation is carried out by the agricultural world through modeling tools (water balances) or soil water monitoring probes. It is mainly done at the scale of the crop campaign and aims for optimal crop needs. At most, a restriction is applied only to the water quota in case of water deficit context.

Arvalis propose its own water balance tool: Irré-Lis. A new functionality, currently under development, allows, in a hypothesis of irrigation limitation, the determination of an a priori optimal irrigation strategy considering the agro-environmental context of the plot.

Irré-Lis Limited Volume (VL) was thus used in situ on maize in 2022 and 2023 to compare, at constant irrigation quota, the technical performance (yield component) between management by water balance *via* classic Irré-Lis *versus* management *via* Irré-Lis VL.

2. Materials and Methods

Irré-Lis is a classical water balance model, operational in sell crops (Gendre *et al.*, 2018). Its VL functionality, usable only in maize, simulates firstly, over the last 20 years, water balances to determine the volume necessary for a given context and sowing date. Then, by applying irrigation restrictions (farmer's quota, equipment constraints) and a set of irrigation strategies (start and end stage of irrigation, dose, water round return time, all over for 3 phases of the vegetative cycle), Irré-Lis VL determines the best strategy, a priori, in the given restriction context for the farmer.

In order to test, at identical quotas, the added value of VL management compared to classical management (irrigation as soon as the RU is exhausted), Arvalis, in partnership with the Maïsadour cooperative, tested in 2022 and 2023 with a farmer in Gers, in a trial with reel irrigation, the application of these two approaches on maize. The two VL scenarios were:

- 2022: 93 mm applied; 25 mm every 8 days from 15 leaves
- 2023: 122 mm applied; 20 mm every 10 days from 10 leaves then 25 mm every 8 days from SLAG

3. Results

In 2022, a year characterized by high climatic demand (ETR/ETM = 0.58), VL management led to a gain of +15.85 q/ha, representing +16.36% compared to classical Irré-Lis management. By waiting for the 15 leaves stage (1st irrigation at +4 days/classical management), it allowed accompanying the plant during critical periods, including towards the end of the cycle.

In 2023, mechanical constraints prevented irrigation from starting on time (at 10 leaves). This prevented the discrimination of irrigation management. Ultimately, VL management resulted in -2.05 q/ha, representing -1.42% compared to classical management (non-significant result), with the last irrigation occurring 8 days after the last VL irrigation.

4. Discussion

In a context of strong water stress (2022), the VL strategy, considering local climatology, produced particularly interesting results.

The observation is less better in humid conditions. The equipment factor (startup of installations) is a key element. The performance of Irré-Lis VL is therefore highly dependent on the campaign's climatology and the rigor of application of the proposed schedule.

Finally, only one VL strategy was tested. It would be interesting to test multiple strategies simultaneously to verify the robustness of the simulations and the ranking of potential scenarios by Irré-Lis VL.

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Future farming: can autonomous field robots facilitate the implementation of diversified agroecological landscapes? (Poster #237)

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Keywords: digital technologies; diversified cropping systems; robotics; mechanical weeding; maize

1. Introduction

Agricultural diversification was highlighted as one of the most promising strategies to achieve sustainable transformation. Diversification of crops in space and time is claimed to enhance ecosystem services and to maintain biodiversity, but also increases labor and time to manage those cropping systems. Therefore, autonomous agricultural robots could play a major role to facilitate the cultivation and management of diversified fields.

2. Objective

In this study, the experimental infrastructure patchCROP, a landscape experiment aiming at the spatial and temporal crop diversification at the landscape scale, was used to test the autonomous, lightweight robot Naio Oz for the mechanical weed control in maize for 0.5 ha fields (Grahmann *et al.*, 2024). Naio Oz was originally developed for vegetable production but can be equipped to control weeds mechanically by harrowing and hoeing in arable crops and thus offers the potential to reduce chemical herbicides. It has an electric engine, works autonomously up to 8 hours and navigates between crop rows through precise RTK GPS signals and previous path planning.

3. Materials and Methods

Fields managed with the Naio Oz robot were compared to conventionally managed fields under contrasting soil conditions of silty and sandy sands in the topsoil. The robot was tested in 2022 and 2023 in grain maize, and preliminary data of 2024 will be available for the conference. Weed species and density, vegetative growth and crop yields of grain maize have been determined as well as SOC for each cropping cycle.

4. Results

In 2022, the mean weed coverage using the robot in silty sand varied between 13% and 35%, whereas the conventional patch had a weed coverage of only 2%. In 2023, mechanical weed control in sandy sand with the robot resulted in 3 to 14% weed coverage, whereas the conventional patch had less than 1% of weeds. The weed coverage in silty sands was lower with mechanical robot weeding, ranging from 1 to 7%, but 2% with chemical weed control. In 2022, maize yields were very low in treatments with mechanical weeding due to prolonged drought conditions over summer, high weed pressure by Chenopodium album and additional water stress with soil movement after harrowing and hoeing. In sandy soils, all treatments experienced yield failure. In 2023, maize yields in silty soils were similar across treatments averaging 9t/ha, but sandy soils resulted in 3 to 5 t/ha. At harvest in 2022, SOC ranged from 1% in silty sand to 0.75% in sandy sands in the first 20 cm soil depth.

5. Discussion

Due to staff unavailability for robot supervision as well as inefficiencies through missing experience in appropriate seed bed preparation and path planning criteria in 2022, the robot was not used in all reduced patches as previously planned. Hence, the number of interventions varies between fields and years, making a statistical comparison inappropriate. In the second study year, weather conditions hampered proper timing and field entrance of the robot, facing many rainy days and GPS signal interference.

6. Conclusions

The study provided in-depth insights for the appropriate and timely use of the robot and showed its potential to support chemical pesticide reduction without yield losses in grain maize when soil water availability is not limited to the crop. Otherwise, we also recognized its limitations in on-farm conditions. With regard to the critical timing of weed management activities, a fleet of robots could increase efficiency, although the technical feasibility for the joint cultivation in the same field still needs to be explored by further development of current robot models.

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Grahmann *et al.* 2024. Co-designing a landscape experiment to investigate diversified cropping systems. Agricultural Systems (accepted) https://doi.org/10.1016/j.agsy.2024.103950

Assessing the contribution of diversified rotations, low-input management systems and hedgerows, at local and landscape scales, to the multifunctionality of agroecosystems

(Poster #293)

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Keywords: multifunctionality; diversified rotation; low-input system; hedgerow maintenance

1. Introduction

Face with climate change and biodiversity crisis, it is essential to move towards more sustainable agricultural systems that produce while limiting impacts on the environment. Nature based-solutions enhancing the multifunctionality of agricultural systems are promising but challenging. For example, pest control, can be based on prey-predator relationships by promoting crop auxiliaries. Indeed, little is known about the factors that determine, in agroecosystems, the simultaneous provision of multiple ecosystem functions (*i.e.* the multifunctionality), underlying the support of goods and services to society (Manning *et al.*, 2018). Diversified rotations, low-input management systems, and hedgerow maintenance, at local and landscape scale, are nature based-solutions that could promote multifunctionality (Tamburini *et al.*, 2020). In addition to the paucity of research investigating the effects of these strategies on multiple functions simultaneously, there are also knowledge gaps about the effects of their implementation at local and landscape scales on the multifunctionality of agroecosystems. Filling these gaps is essential to identify the scales at which these strategies should be implemented and combined. We therefore ask to what extent the implementation of diversified rotations, low-input management systems, and hedgerow maintenance, at local and landscape scales, contribute to the multifunctionality of agroecosystems and underlying functions.

2. Materials and Methods

The study was conducted in the Zone Atelier Armorique, Brittany, western France. A total of 30 winter wheat fields were selected for analysis, each bordered by at least one hedgerow and at least one hedgerow-free area. The fields were chosen based on three criteria: diversity level in the rotation, level of input use in the management system, and hedge-density landscape gradient. Diversity levels in the rotation were obtained from georeferenced field data declared by farmers over the past 8 years. Levels of input use in the management systems were obtained through farmers' interviews. Hedgerow density was measured within a 1 km buffer radius around each field in the Zone Atelier Armorique. This allowed us to define the hedge-density landscape gradient. The multifunctionality of the fields was assessed by considering five ecosystem functions (soil quality, pest control, pollination, biodiversity conservation, food production) and two socio-economic performances (working time, gross margin). Proxies for each function will be measured. For example, we will measure the abundance of carabid beetles and spiders for the pest control function and the abundance of pollinators for the pollination function. The proxies of ecosystem functions were measured at several distances from the two field borders (the one with the hedgerow, the one without the hedgerow): 0 m, 2 m, 10 m.

3. Results

The results are currently being compiled; this summary was submitted before they were available. The results will focus on the effects of rotation diversity and distance from hedgerows on abundance of carabid beetles and spiders (pest control), abondance of pollinators (pollination) and tonnes of wheat per hectare (food production). We expect greater agroecosystem multifunctionality in fields with more diversified rotations and low inputs. Agroecosystem multifunctionality should also be greater near hedgerows than field centre. We expect pest control, pollination and yield to be higher in fields with diversified rotations than in fields with less diversified rotations. With respect to distance from the hedgerow, pollination and pest control should decrease with distance from the hedgerow. On the other hand, yield should be lower near the hedgerow than in the centre of the fields but higher 10 m from the hedgerow than in the centre of the field. These results will allow us to develop ways of managing more multifunctional agroecosystems.

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Adapting service crop termination strategy in viticulture to increase soil ecosystem functions and limit competition with grapevine (Poster #192)

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Keywords: sustainable viticulture; cover crops management; ecosystem functions; agroecology; diversified cropping systems

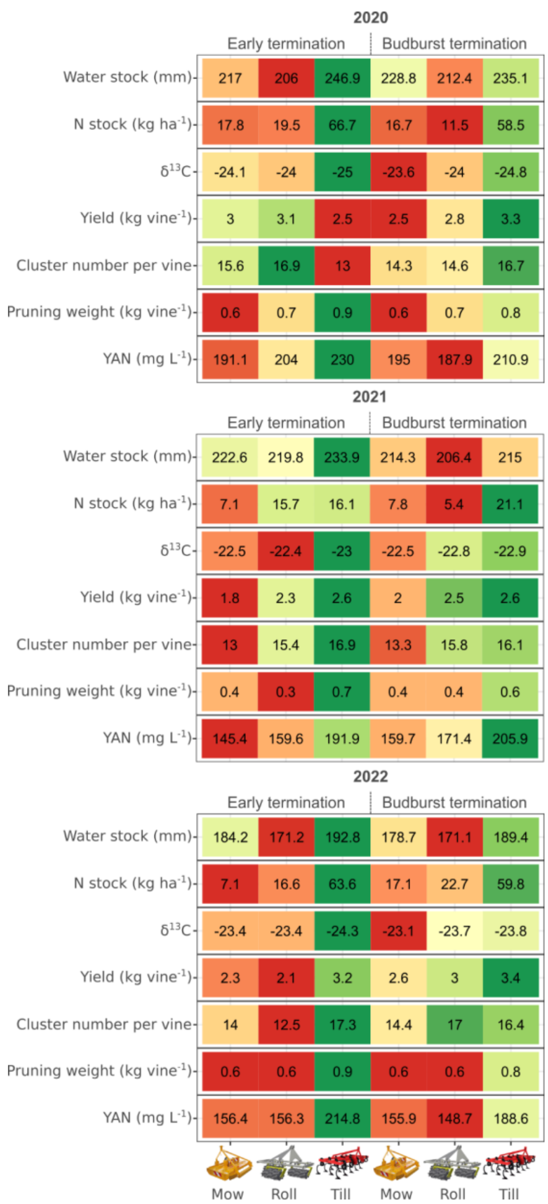

Figure 1. Average values of variables measured in 2020, 2021, and 2022 across the six treatments. The first three columns correspond to early termination, and the next three for termination at budburst. For each variable, the color gradient ranks the various treatments from the lowest value (red) to the highest (green). For δ13C, the colors classify water stress from the lowest (green) to the highest (red). N: nitrogen; YAN: yeast assimilable nitrogen; Mow: mower; Roll: roller-crimper; Till: mower + soil tillage

1. Introduction

In viticulture, addressing contemporary challenges such as the reduction of pesticide use, the agroecological transition, or the adaptation and mitigation to climate change effectively involves soil management practices, especially with the use of service crops (Abad *et al.*, 2021a, 2021b). Service crops are grown to provide provisioning, regulation and maintenance, and cultural ecosystem services (Garcia *et al.*, 2018). However, service crops can also negatively affect grapevine vigor and yield due to competition for water and nitrogen (Celette and Gary, 2013), underscoring the importance of cover crop management to achieve a balance between services and dysservices, a topic that is yet underexplored in scientific literature.

2. Materials and methods

Over three years, this research examined six different service crops termination strategies, that combined two termination periods (early termination *vs.* termination at grapevine budburst) and three methods of termination (mowing (M), mowing combined with tillage (T), and roller-crimping (R)). Various indicators were recorded from 2019 to 2022, including service crop variables (biomass, C:N ratio, weed suppression, and post-termination mulching), soil properties (organic matter, microbial biomass, water, and inorganic nitrogen stocks), grapevine variables related to water stress (pre-dawn leaf water potential, δ13C), yield components (cluster number and yield), vigor (pruning weight) and juice quality (yeast assimilable nitrogen).

3. Results

Permitting service crops to grow until grapevine budburst increased biomass production by two to three times compared to early termination. Among the termination methods, tillage proved the most efficient. Early destruction with tillage exhibited minimal regrowth and consistently reduced weed biomass during grapevine flowering in two out of three years, effectively suppressing the resurgence of specific sown species, particularly among Poaceae. In contrast, roller-crimping was less effective in terminating service crops but better-conserved plant residues on the soil surface. Enhanced soil microbial biomass was observed under budburst termination strategies, particularly when combined with no-till methods. Tillage-based termination also effectively halted service crop transpiration, and resulted in higher soil water stocks and grapevine water status (Figure 1). In 2020 and 2022, soil tillage treatments resulted in soil inorganic nitrogen stocks around 60 kg ha^{-1}, nearly quadrupling compared to other methods, aligning closely with the annual nitrogen needs of grapevines (Figure 1). This trend was reflected in the yeast-assimilable nitrogen levels in grape juice. Pruning weight varied notably across termination methods, with tillage-based treatments yielding higher weights per vine than roller-crimping and mowing (Figure 1). Overall, vineyard yields ranged from 7.25 to 13.7 t ha^{-1}, approximately corresponding to 52 to 98 hL ha^{-1} per hectare, suitable for Protected Designations of Origin limiting yields to 40 or 60 hL ha^{-1}, but possibly restrictive for Protected Geographical Indications allowing 90 hL ha^{-1}, or unregulated productions.

4. Discussion

In the context of the Mediterranean climate, increasingly characterized by dry winters due to climate change, tillage-based termination strategy appears to be a safer strategy to maintain grapevine vigor and productivity, while also enhancing soil ecosystem functions. However, this approach's suitability may depend on specific yield goals and wine market values. Additionally, other strategies could be considered to facilitate cover crop management strategies more favorable to soil biological activity, such as the use of more vigorous grapevine varieties and rootstocks, or those better adapted to drought conditions (Simonneau *et al.*, 2017).

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Characterisation of repeated heat stress in oilseed rape: analyses of yield, seed quality, and –omics signatures (Poster #73)

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Keywords: oilseed rape; heat stress; seed quality; memory; priming

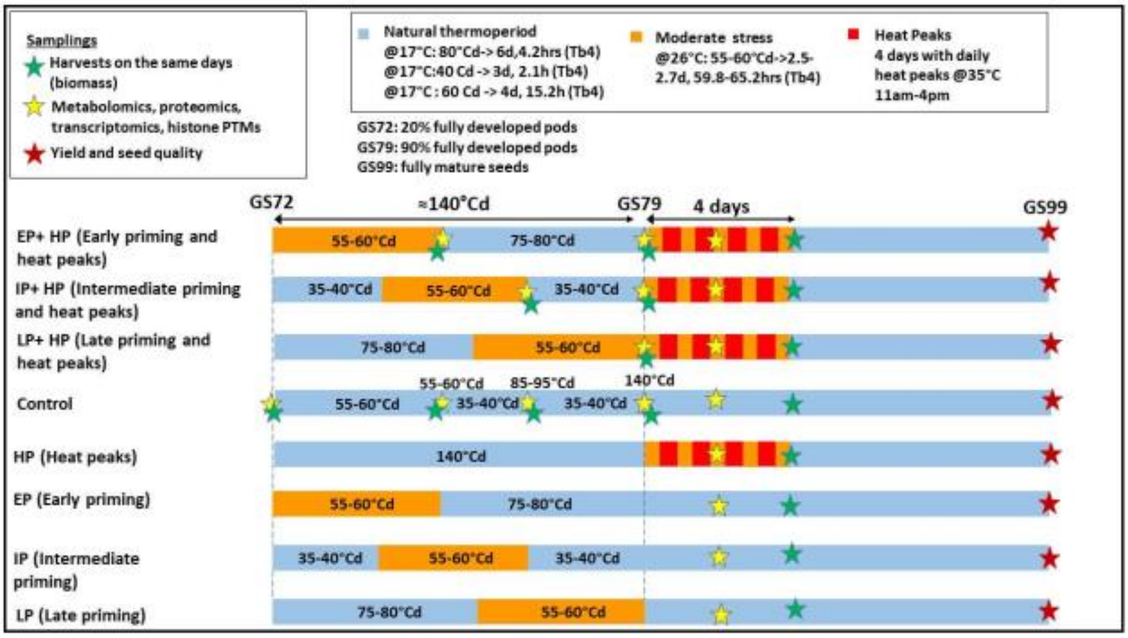

Figure 1. Temperature and duration details of the tested stress sequences and sampling points

1. Introduction

Recent data indicates a significant increase of mean air temperature and a higher heat waves' frequency (IPCC, 2021), which lead to detrimental effects on crop yield and products quality. Consequently, it becomes a necessity to produce thermotolerant cultivars which implies to decipher the mechanisms underlying heat stress tolerance. Moreover, it is proved that a first stress exposure can impact on the magnitude of the effect of later exposures to stress as a consequence of the first stress induced-information, followed by its storage and retrieval, namely stress memory (Crisp *et al.* 2016; Kinoshita and Seki 2017; Lamke and Baurle 2017). Stress memory can be (i) either beneficial as the first stress exposure triggers a priming effect which alleviates the negative effects of subsequent stresses or (ii) negative when the effects of successive stresses cumulate and amplified. This phenomenon constitutes a promising approach to explore in the perspective to promote stress tolerance in crops (Wang *et al.* 2017, Liu *et al.* 2023). Stress memory implies biochemical modifications, hormone balance adjustments and epigenetic regulations such as post transcriptional modifications (PTMs) of histones, which in turn modify gene expression (Liu *et al.* 2023). Therefore, stress memory, either positive or negative, reflects specific -omic signatures that could be used to identify genes and physiological functions that, arguably, play a critical role in memory acquisition, and consequently, in stress acclimation (Lamke and Baurle 2017, Gallusci *et al.* 2023).

Nevertheless, which scheme of stress – in terms of pre-stress features – induces positive memory in plants remains blurred and further research is needed.

2. Materials and Methods

A greenhouse experiment in oilseed rape (ORS, cv. Aviso) was designed to further test the effects of different heat stress sequences (from October 2023 until July 2024). Based on prior findings (Magno *et al.* 2021 and Delamare *et al.* 2023) and literature-based evidence (*e.g.* Lamke and Baurle, 2017), different durations of recovery phase (*i.e.* period between two stresses) were tested. Pre-stress sequences (Figure 1) were designed to last ca. 140°Cd, in order to avoid any age effect, afterwards, the plants were exposed to an intense heat stress (Figure 1). Leaves and pods will be collected, and stored at -80°C for omics analyses. Furthermore, during the heat stress sequences, chlorophyll fluorescence, NIRS reflectance, organ biomass and nitrogen content will be measured. At seed physiological maturity, the agronomic traits (yield and yield components, seed nutritional and germination qualities) will be measured.

3. Expected results

As observed in Magno *et al.* (2021), 5-day recovery in between the mild and the intense heat stress did not lead to priming effects as most of the plant performances were lowered, thus reflecting cumulative negative effects of both the mild and the intense stresses. Contrastingly, a gradual increase prior to the intense heat stress (meaning no recovery phase) as tested in Delamare *et al.* (2023) induced priming effects on yield and several seed quality criteria. Therefore, we conjecture that we will find contrasting results on plants' performances according to the three pre-stress modalities *i.e.*, the EP being penalizing, while IP and LP being priming. Besides, significant changes in the metabolome as well as a broad identification of transcripts, proteins and PTMs (Ding *et al.* 2012, Serrano *et al.* 2019, Pratx *et al.* 2023) are expected.

4. Discussion

After the interpretation of the aforementioned expected results and the incorporation to the existed literature, we aim at (i) identifying specific- omics signatures that reflect a positive memory (priming) and (ii) decoding the mechanisms that induce a possible priming effect. The acquisition of this knowledge will facilitate future breeding programs providing novel stress response markers.

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Effect of sown flower margins on pollinators, crop productivity and soil properties in intensive agriculture (Poster #258)

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Keywords: annual flowering plants; legume swards; native plant species; pollinators; soil organic carbon

1. Introduction

To halt the loss of biodiversity in agricultural landscapes, the European Union's Common Agricultural Policy promotes the implementation of practices that benefit the climate and the environment - various non-productive activities. One of them is the flowering plant margins on field edges. Multifunctionality of flower margins is very different depending on landscape composition, management regime, location, and organism groups *etc.* Therefore, a detailed assessment of their benefits and risks is required. The aim of this study was to determine the effect of differently sown flower field margins on pollinators, crop productivity and soil properties.

2. Materials and Methods

The experiment was carried out during 2013–2018 at two experimental sites Joniškėlis (JON) and Akademija (AKD) of Lithuanian Research Centre for Agriculture and Forestry. The floral sward strips were established on the edges of intensive farming land (field size > 5 ha). The strip were seeded with four plant mixtures: 1) perennial grasses, control (PGS): *Festuca arundinacea* Schreb., *Festuca pratensis* Huds., *Festuca rubra* L., *Phleum pratense* L., *Dactylis glomerata* L., *Agrostis capillaris* L. *etc.*; 2) perennial legumes (PLS): *Trifolium pratense* and *repens* L., *Onobrychis viciifolia* Scop., *Medicago sativa* L., *Lotus pedunculatus* Cav. *etc.*; 3) annual flower plants (AFP): *Helianthus annuus* L., *Fagopyrum esculentum* Moench, *Borago officinalis* L., *Sinapis alba* L., *Phacelia tanacetifolia* L., *Linum usitatissimum* L., *Lupinus luteus* L., *Melilotus albus* L., *Trifolium resupinatum* L. *etc.*; 4) natural grassland with native plant species (NGS): the base cover: *Poa palustris* L., *Poa compressa* L., *Corynephorus canescens* L. *etc.*; flowering meadow plants: *Trifolium rubens* L., *Medicago lupulina* L., *Vicia cracca* L. *etc.*, *Centaurea jacea* L., *Agrimonia eupatoria* L. *etc.*

3. Results

The highest value of the floristic index was found in the AFP and PLS field margins. The AFP margin was characterized by an earlier onset and a longer duration of flowering. The following plant species started flowering earliest there: *Linum usitatissimum* L., *Fagopyrum esculentum* Moench, *Sinapis alba* L., *Phacelia tanacetifolia* Benth; *Melilotus officinalis* (L.) Pall. flowered longest and *Helianthus annuus* L. In the NGS margin native plant species flowered profusely: *Medicago lupulina* L., *Achillea millefolium* L., *Galium boreale* and *mollugo* L., *Hypericum perforatum* L, *Centaurea jacea* L., *Heracleum sibiricum* L., *Plantago laceolata* L. In Joniškėlis, the total number of pollinators in the flower margins was 33% lower than in the flower margins compared to Akademija. Most of the pollinators were representatives of the following orders: Hymenoptera, Diptera and Coleoptera. The two areas differed considerably in the pollinators number of the order Hymenoptera, which was lower in the more intensive farming area of Joniškėlis. When comparing the margins of different composition, it was found that the highest number of pollinators was found in the AFP and NGS strips. During the five-year period, the plants of the flowering margins due to their strong and rich root system, enriched the soil with organic matter (especially PGS and NGS) and improved the top layer and sub layer soil properties at the field margins. The response to crop yield was not consistent.

4. Discussion

Creating field margins helps to maintain populations of wild bees and other pollinator insects and ensure their viability (Königslöw *et al.*, 2021). In our studies, the diversity of species composition and phenological development of annual flowering plants attracted more pollinators. The abundance of flowers is a key factor for the diversity of wild bees. Species belong to the Hymenoptera and Diptera families are considered as a very efficient pollinators (Ouvrard *et al.*, 2018). In order to preserve native, rarer plant species, these species are included in flowering margins plant compositions (Königslöw *et al.*, 2021). Flower field margins are for increasing SOC stocks, optimize pest abundance, that has multiple benefits for agroecosystems (Harbo *et al.*, 2023).

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Comprehensive assessment of agricultural nutrient management policy mix in a watershed region (Poster #27)

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Keywords: policy mix; crop choice; fertilizer use; manure substitution; nutrient loss

Many nutrient management policy combinations have been implemented to reduce the influx of agricultural nitrogen (N) and phosphorus (P) into watersheds in China and elsewhere. These policy combinations not only consist of measures that directly control nutrient input but also comprise other conservation measures, such as crop selection regulations. However, the combined and separate impacts of combined policies are not well-understood, which hinders the improvement of nutrient management policy design. To gain a clearer insight into policy effects, we take a policy mix implemented in Eryuan County, a watershed region in southwest China, as a case study. The policy aimed at reducing the agricultural N and P pollution entering the downstream Erhai Lake through the control of nutrient input and the regulation of crop choice. We examined the impacts of this policy mix by applying a fixed-effects model to farmer panel survey data for the years 2017 and 2021. Our findings indicate that the policy mix was insufficient to achieve its target, but substantially reduced farmers' benefit by 65.1%. It effectively reduced N surplus, but the two policy instruments had opposite on the use of P and as a result did not significantly change P surplus. Given these findings, we recommend that more precise fertilization regimes should be developed, along with the promotion of new farming models to effectively reduce N and P losses simultaneously. Furthermore, policymakers should pay more attention to addressing the trade-offs between environmental gains and farmer benefits of nutrient management policies.

Phenotypic differentiation and plasticity of arable and urban populations of the grass weed *Vulpia myuros* (Poster #266)

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Keywords: rattail fescue; intraspecific variability

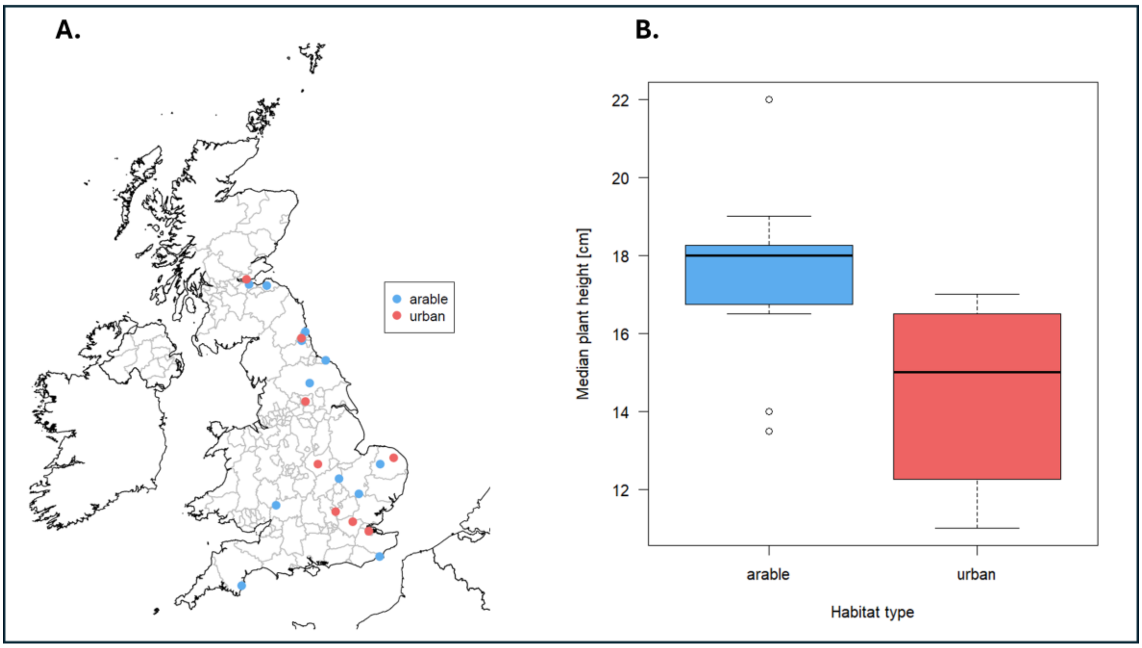

Figure 1: A. Locations of the populations analysed, B. Median plant height after 78 days in arable and urban habitats

1. Introduction

Weeds represent a major global constraint to crop production, leading to ~10% yield losses annually, across crops and regions (Oerke, 2006). *Vulpia myuros* (rattail fescue) is an annual grass species with an almost worldwide presence. In recent years, *V. myuros* has been increasingly observed as a weed in arable crops in Europe and northern America, in particular in crops under reduced tillage practices (Akhter *et al.*, 2020; Büchi *et al.*, 2020). These reduced tillage practices are increasingly followed to conserve soil and reduce time and energy inputs, but these may favour infestation by *V. myuros*. *V. myuros* is adapted to dry conditions and could therefore also be favoured by future climates, as most climate change scenarios for Europe predict increasing occurrences of drought. In Europe, *V. myuros* distribution has increased in the past century, first in semi-natural habitats, and later as an arable weed. It is now widely found in disturbed urban habitats, such as pavement cracks, walls, car parks, green roofs and increasingly in arable fields. However, what is not known is if the arable populations come from opportunistic invasion from those semi-natural populations, or if a particular arable weed ecotype is spreading independently from the semi natural populations. The objective of this current study is to phenotype in uniform conditions 20 populations of *V. myuros* coming from semi-natural and arable habitats, to assess the amount of phenotypic differentiation between those populations.

2. Materials and Methods

In summer 2023, we collected seeds from semi-natural and urban populations of *V. myuros* in the United Kingdom, spanning from the south of England to Scotland. Farmers with *V. myuros* infestations also contributed to the collection by sending seeds. From those arable and non-arable populations, we selected 20 populations (12 arable, 8 from urban habitats, Figure 1) to run a set of five phenotyping experiments: E1: seed germination, E2. plant development, E3. vernalisation requirements, E4. herbicide response, E5. competitiveness in a gradient of soil fertility (*i.e.* from pure topsoil to pure sand, with three intermediate mixtures). The data were subjected to uni- and multi-variate analyses, to assess the phenotypic diversity of the different populations, and if the habitats (arable *vs* non-arable) or the climate of origin played a role in shaping the characteristics of the individuals.

3. Results and Discussion

We observed significant differences between the 20 populations of *V. myuros* in terms of seed weight (from in situ collection), number of leaves and height (when grown in topsoil). Seeds coming from urban populations were lighter than arable ones, and the plants were shorter (Figure 1); no significant difference in leaf number was however observed between the two habitat types. No differences in number of leaves between plants grown in soils of different fertility were observed, except for a strong reduction in leaf production in pure sand (60% of the number of leaves produced in the other soils).

We observed differentiation in the phenotype of *V. myuros* populations of different origins when grown in uniform conditions, but less than what is observed in situ, indicating the presence of phenotypic plasticity for the traits measured here. Genetic analyses are now needed to unravel the evolutionary pathway driving the expansion of *Vulpia myuros* populations.

N.B. The remaining data are still being collected and analysed but will be ready for presentation during the conference in August.

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VIKING: validating the introduction of kernza in the Nordic-Baltic region (Poster #227)

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Presenter: Mailiis Korge (mailiis.korge@emu.ee)

Keywords: environment; forage; grain; intermediate wheatgrass; management

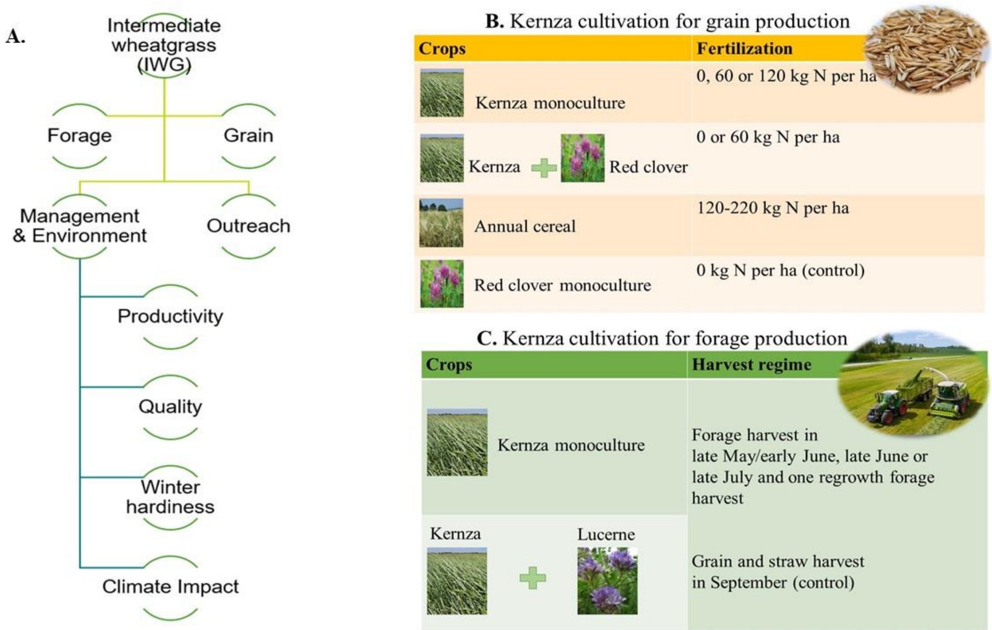

Figure 1. A. Schematic overview of the VIKING project; B. Treatments in the full-scale Kernza® grain production trials; C. Treatments in the full-scale Kernza® forage production trials

Food production globally relies on monocultures of annual crop species, which require replanting every year and external inputs, causing soil erosion, climate change, water pollution, and biodiversity loss, and are vulnerable to climate extremes like drought. Perennials provide continuous soil cover and roots, which fix carbon, protect soil health, retain nutrients, reduce inputs, and are more resilient to droughts. Developing perennial grain and forage systems can transform the relationship between humans and the environment by providing food and ecosystem services.

Kernza (Intermediate wheatgrass, *Thinopyrum intermedium*) is a perennial grass relative of wheat and recently domesticated as a perennial grain and forage crop in North America. Demand for perennial grain food products, like Kernza beer and baked goods, is increasing. In addition, dairy and beef farmers are interested in the high forage production potential from Kernza. As a perennial deep-rooted plant, Kernza is both drought and cold tolerant, which makes it an attractive crop adapted to future Nordic-Baltic conditions under climate change. Several environmental and ecological benefits have been confirmed for Kernza, such as increased soil carbon content (Culman *et al.*, 2013), higher soil community complexity

(Sprunger *et al.*, 2019), root biomass (Duchene *et al.*, 2020) and reduced nitrate leaching (Jungers *et al.*, 2019). Previously reported grain yields (Dimitrova Mårtensson *et al.*, 2022) do not contribute sufficiently to farmers' income, while the large total biomass utilised for feed and forage have potential to add to the economy of the production (Franco *et al.*, 2021).

Kernza has been tested at farms in Sweden, which has pioneered this research in Northern Europe. However, little is known about the productivity of this novel crop at the Nordic and Baltic countries, as well as which agronomic management practices may optimize the grain and forage production. The main objective of this research is to strengthen research collaboration between Sweden, Norway, Finland, Estonia, Lithuania, and Denmark to explore the adaptation and potential of grain and forage production and quality of Kernza across the Nordic and Baltic region. Our research will test a range of agronomic management questions including optimal N fertilization, benefits of intercropping with legumes, optimal harvest schedule for forage, soil health benefits, and carbon budget. We will engage an international network of diverse stakeholders including farmers, food industry, advisors, and policy makers to explore the feasibility of this new crop in the region. The productivity and management requirements will be used to assess the climate impact of Kernza production systems as compared to annual cereal production systems, both in terms of grain and forage production, to evaluate the Kernza production systems potential contribution to climate mitigation within the agricultural primary production in the Nordic region of Europe (Figure 1).

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The effect of silicate, carbonate, and sulphate calcium amendments on the mineralizability and persistence of soil organic carbon: a comparative study (Poster #102)

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Keywords: enhanced rock weathering; liming; microbial metabolite; soil organic carbon; soil organic matter mineralizability

Soils account for the largest reservoir of terrestrial organic carbon [1]. However, soil organic carbon (SOC) losses associated with cropland cultivation are substantial [2,3] and expected to increase with global warming [4,5]. Major implications of SOC losses include the exacerbation of climate change (as CO_2 is released to the atmosphere) and the decline of soil health [6]. To circumvent these losses, the adoption of climate-smart crop practices promoting SOC accrual, such as Enhanced Rock Weathering (ERW, which consists of amending soils with crushed fast-reacting magnesium or calcium-rich silicate rocks, *e.g.*, wollastonite) are key [7]. By capturing and converting CO_2 from the atmosphere to soil dissolved inorganic carbon and supplying essential cations to roots, ERW can provide multiple benefits to cropping systems [7]. Nevertheless, as wollastonite application raises soil pH it may favour microbial activity and the deprotonation of organic compounds, thereby contributing to SOC mineralization, which partially offsets ERW benefits [8]. The extent to which SOC is mineralized depends, among other things, on the carbon use efficiency (CUE) of microbes and the persistence of SOC in the different soil pools, comprised of particulate (POM), dissolved (DOM) and mineral associated (MAOM) organic matter – the latest being considered as the most persistent physical fraction [9]. In non-acidic soils, calcium (Ca) supply in the form of $CaCl_2$ can increase microbial CUE [10]. A proposed mechanism of improvement is that Ca favours the colonization of mineral surface by metabolically efficient organic matter decomposers, such as Actinomycetes (a group of bacteria characterized by the formation of hyphae), which deposit their metabolic byproducts on mineral surfaces, enhancing the MAOM pool [10]. Hence, we hypothesized that the supply of wollastonite will foster mineral surface colonization by hypha-forming bacteria, which will slow down SOC mineralization in non-acidic soils, resulting in SOC accrual, particularly in the MAOM. To test this hypothesis, we carried out an incubation experiment where we compared the supply of wollastonite with $CaCl_2$, in addition to two widely used Ca soil amendments, a seashell calcium carbonate and gypsum. The experiment lasted 90 days and the mineralizability of Ca-treated soils of different textures was assessed with KOH traps. Dynamic combustion and loss on ignition (LOI) analyses were performed to quantify total organic and inorganic carbon content in the POM and MAOM fractions separated using a combined size and density fractionation method, which provided insights on the effect of Ca amendments chemically different on the accumulation and persistence of SOC in non-acidic soils of contrasting texture. The use of optical microscopy techniques enabled comparisons of hypha-forming bacteria abundance between treatments, thereby elucidating the involvement of Ca in microbial transformation of soil organic matter.

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The impact of different fungicide product combinations on malting barley, yield, quality, and profitability in the Western Cape of South Africa (Poster #108)

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Keywords: barley; fungicide; disease management; agronomic performance; economics

Effective foliar disease management in barley (*Hordeum vulgare*) is crucial for ensuring high crop yields and meeting quality standards demanded by maltsters. However, the extensive use of fungicides in cereal crop production, particularly in the Western Cape Province of South Africa, raises concerns regarding its impact on yield, quality, and potential development of resistance. This study aims to comprehensively evaluate the impact of fungicide treatments on the agronomic performance of malting barley varieties in the region.

The increasing demand for malting barley, particularly driven by major buyers like Anheuser-Busch InBev, has led to a rapid expansion of barley hectares planted in the Western Cape Province. However, this growth has prompted growers to compromise on good crop rotation strategies, favoring consecutive barley planting which undermines Integrated Pest Management (IPM) principles. This, coupled with prevalent no-tillage practices, contributes to higher disease pressure during the growing season.

The study encompasses four main parts:

Barley Passport Analysis: Analysis of the barley passport data spanning four years (2019–2022) will provide insights into growers' fungicide usage patterns and inform field trial actions.

Field Trial: A field trial will assess the responses of biomass yield, seed yield, and quality to various fungicide treatment programs across four malting barley varieties in South Africa.

Fungicide Resistance Evaluation: This part aims to measure and quantify fungicide resistance, particularly focusing on the Succinate Dehydrogenase Inhibitor (SDHI) group of fungicides registered on barley varieties.

Economic Evaluation: The economic value of each fungicide treatment program from the field trial will be determined, identifying the most financially viable options for growers across different locations and barley varieties.

The findings of this study will provide crucial insights into optimizing disease management strategies, preserving crop yields and quality, and mitigating the risk of fungicide resistance in the malting barley industry of the Western Cape Province. Ultimately, this research aims to enhance sustainability and profitability for barley growers while meeting the stringent demands of the maltsters.

Scenario labs and integrated assessment modelling for bioeconomy and agroecology development (Poster #15)

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Keywords: carbon neutrality; integrated assessment and modelling; living lab; agroecology

1. Introduction

To achieve carbon neutrality by 2050, development of a bioeconomy, in which the production and processing of foods and non-food products is balanced with the conservation of natural resources, is a key target of public policies (Wohlfahrt *et al.*, 2019). Regional approaches that combine diverse strategies, including agroecological systems, optimised resource use, collective action, and virtuous circles of interactions (*e.g.*, circular economies, stronger rural-urban links) is a well-recognized strategy to develop territorial bioeconomic systems (Axelos *et al.*, 2020). Development and application of Integrated assessment model (IAM) is a powerful approach that stakeholders can use when designing such socioeconomic territorial organisations (Allain *et al.*, 2020). These models aims to integrate generic multidisciplinary knowledge together with the empirical knowledge of local stakeholders (Hamilton *et al.*, 2015). They are then used to simulate and evaluate ex ante scenarios in which regional structures undergo endogenous or exogenous changes as climate change (Dardonville *et al.*, 2023).

2. Objectives

The SLAM-B project (2023-208, 6,5 M€) aims to group and structure French researchers developing and applying IAMs to collaboratively design a sustainable bioeconomy based on agroecology. SLAM-B will examine the influences of different bioeconomic forces, including the diversity of production systems, raw materials and finished products, biorefineries, recycling loops, and industry architecture. SLAM-B aims to tackle major scientific challenges *via* three specific actions: (i) developing generic IAM approaches for designing and assessing bioeconomy and agroecology transitions; (ii) demonstrating their practical utility in living labs; and (iii) producing tailored knowledge for French and European policymakers.

3. Procedure

SLAM-B is organised into three interconnected work packages (WPs). WP1 aims to amplify functionalities of the MAELIA platform (maelia-platform.inra.fr). Specifically, it will integrate a range of new capacities for modelling and simulations of very contrasted livestock systems and environmental biorefineries, optimisation of spatial allocation of biomass plants, spatialised and territorial life cycle analysis, and local planetary boundaries assessment. To provide proof of concept for MAELIA-based IAMs, WP2 will establish and run seven living labs: 4 in France metropole (Armorique, Vosges, Vaucluse, Greater Reims), and three outside (Réunion and Guadeloupe islands, and Northern Senegal). These labs cover a vast range of pedoclimatic, agricultural, forestry, urban, and socioeconomic conditions. Finally, WP3 aims to create and apply IAMs at national and European scales. The objective is three-fold: quantify biomass available to different bioeconomy chains issued from agroecological and well-managed forestry systems considering potential organic waste recycling, evaluate biogas production potential and energy efficiency of bioeconomic systems based on agroecology.

4. Conclusion

SLAM-B will rely on the expertise of about 120 researchers from INRAE, IRD, CIRAD, CNRS, and a variety of French universities. Their work covers an array of topics: agronomy, social-ecological system analysis and modelling, chemical and bioprocess engineering, sustainability assessment and decision-making, political science, economics, and informatics. SLAM-B's aims at enhancing the visibility of French researchers working on IAM approaches to design transitional pathways towards a sustainable bioeconomy based on agroecological systems.

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Agronomic strategies for sustainable cereal production in the Mediterranean area (Poster #93)

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Keywords: cover crop; irrigated maize; nitrogen use efficiency; organic fertilizer; winter cereal

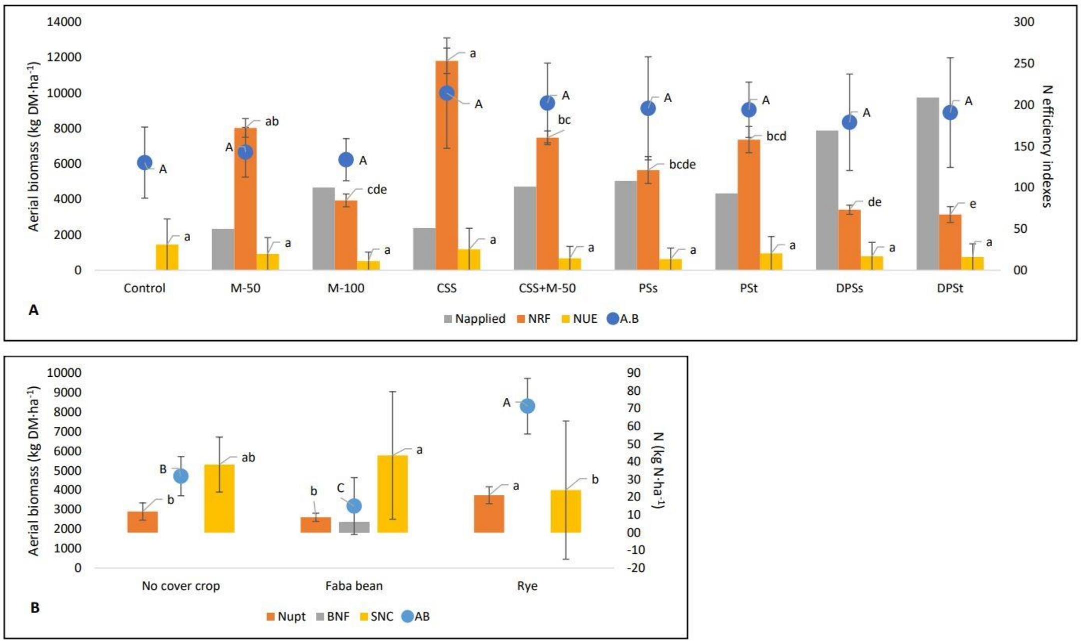

Figure 1. A) Aerial biomass at end of flowering (A.B, kg DM ha^{-1}), yearly N applied (kg ha^{-1} year^{-1}), N apparent recovery fraction (NRF) and N use efficiency (NUE) for the 2023 cropping season in RCS. M-50 and M-100: mineral N at 50 and 100 kg ha^{-1}, respectively, CSS: composted sewage sludge, CSS+M-50: composted sewage sludge plus mineral 50 kg ha^{-1}, PSs: pig slurry at sowing, PSt: pig slurry at top-dressing, DPSs: digested pig slurry at sowing and DPSt: digested pig slurry at top dressing. B) Aerial biomass in ICS (A.B, kg DM ha^{-1}), N uptake (Nupt, kg N ha^{-1}), soil nitrate content (SNC, kg N-NO3^{-} ha^{-1}) (0-60 cm), BNF (biological N fixation for faba bean, kg N ha^{-1}). Vertical bars indicate the standard deviation of the mean. For a given variable, means with different letters indicate treatment differences at p<0.05 (upper-case letters correspond to A.B)

In Mediterranean areas, irrigated maize systems are based on winter bare soil periods and synthetic N fertilizer is split in a maximum of three applications leading to a low nitrogen use efficiency (NUE). Spain is one of the largest pig producers worldwide, which leads to an important availability of organic sources. Therefore, application of organic fertilizers is usual in cereals. Moreover, the Spanish biogas sector is under development. Therefore, it is necessary to study organic fertilizer strategies allowing a NUE optimization leading to synchrony between N availability and crop demand. The aim of this work is to assess different strategies to enhance NUE, on irrigated maize (*Zea mays* L.) and rainfed cereal systems in the Ebro Valley (NE Spain).

Two on-farm field experiments were established in 2022. A rainfed cropping systems (RCS) one in Agramunt (Lleida, NE Spain) and an irrigated one (ICS) in Sucs (Lleida, NE Spain). In RCS the factors evaluated were: (i) use of different fertilizers and (ii) their application date (either pre-sowing or top-dressing). For factor (i) a control, mineral N (50 and 100 kg N·ha^{-1}, M-50 and M-100, respectively), pig slurry (PS) and digested pig slurry (DPS) at 125 kg N·ha^{-1} (either at sowing, -s, or top-dressing, -t) and composted sewage sludge at pre-sowing (125 kg N·ha^{-1}) top-dressed with (CSS+M-50) or without 50 kg mineral N ha^{-1} (CSS). For some treatments was not feasible to apply the target rate with the commercial machinery. The effective N rates applied are shown in Figure 1A. The experimental design is based on randomized blocks with 3 replications. In 2023 triticale (Triticosecale Wittm.) was harvested at the end of flowering for forage. In ICS the factors assessed were: (i) fertigation with liquid fraction of sow slurry (control and fertigation), (ii) the use of cover crops (control, rye (*Secale cereale* L.), faba bean (*Vicia faba* L.)) and, (iii) top-dressed urea-ammonium nitrate (0, 50, 100 and 150 kg N·ha^{-1}). The experiment was based on a split-split plot design with 4 replications. The 2023 season was extraordinarily dry and maize could not be planted. Nitrogen efficiency indexes were defined as follows: (i) nitrogen apparent recovery fraction (NRF, %) as the increment of crop aboveground N uptake to applied N, (ii) nitrogen use efficiency (NUE, kg kg^{-1}) as the ratio of forage yield to N supply. Nitrogen supply includes the total N applied as fertilizer and the initial soil nitrate content (SNC). Three for RCS and two for ICS observations of aerial biomass samples for each plot were taken at flowering in RCS and before cover crops termination in ICS, to determine dry matter and N content. In addition, biological nitrogen fixation (BNF) for faba bean was also determined, using the natural abundance method of the 15N isotope (Unkovich *et al.*, 2008). SNC was determined either just before sowing and after crop termination for 0-90 cm in RCS and for 0-60 cm for ICS.

In ICS no differences were found between treatments on forage yield (Figure 1A), although a trend of higher values was observed when using organic fertilizers compared to M-50 and M-100. CSS applied at around 50 kg N·ha^{-1} in such a dry year (280 mm, of which 15.5 mm fell from March to May) lead to the highest NRF. The additional application of 50 kg N·ha^{-1} of mineral fertilizer didn't improve either efficiency N indices and yield. The application of PS independently of the date, led to the same NRF than the use of mineral N (M-100, C-M-50). In a dry season such as the studied, 50 kg N ha^{-1} applied with organic fertilizers were enough to reach the highest yields without differences between treatments. In ICS rye achieved the greatest aerial biomass and faba bean the lowest with intermediate values of the control due to spontaneous vegetation (Figure 1B). N uptake the highest in rye (21 *vs* 10.5 kg N ha^{-1}). In faba bean BNF accounted for 69% of N acquired (Figure 1B). Rye showed its ability to mitigate nitrate leaching. However, more research is needed to assess the fate of cover crops nitrogen decomposition.

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Combining methods and knowledges for monitoring environmental policies on a territorial scale: spatial disaggregation of pesticides sales through land use data, reglementary information and expert knowledges (Poster #351)

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Keywords: pesticides; public policies; regional scale; land use

1. Introduction

Understanding the pesticide uses across a region is crucial for evaluating environmental policy effectiveness, guiding environmental monitoring, and implementing targeted actions (Martin *et al.*, 2023). However, when detailed on-the-ground data on phytosanitary practices and pollutant measurements are scarce or unavailable, the use of appropriate indicators with suitable spatial and temporal resolutions becomes imperative.

We present a method for allocating the annual sales of plant protection products on a territorial scale according to agricultural land use. This method provides a spatial and temporal estimate of the application of plant protection products, and is primarily intended for use by local authorities needing to carry out temporal and spatial diagnoses. The method draws upon a nationwide approach proposed by Martin *et al.* (2023) and Lungarska *et al.* (2024) in France, aiming to enhance and implement it locally.

2. Materials and Methods

The method is based on the disaggregation of sales declaration information at the postal code level (BNV-d), based on the detailed land use information at the agricultural parcel scale (more than 350 different crops) provided by the Land Parcel Identification System (LPIS), and the registered uses of products (*i.e.*, the target crops and the registered doses) from the authorisation marketing database (E-phy). This disaggregation encompasses the consideration of infrastructures in non-agricultural zones that could potentially be treated with these products, agricultural practices such as organic farming, and the evolution of legislation concerning the application of pesticides. As some pesticides have several registered uses per crop (*i.e.*, different targets), a reference dose per pesticide and per crop type is calculated with the median of all the uses.

Users can interact with the method to refine information on phytosanitary practices within the investigated area. This enables the mobilisation of local expertise, which allows for the adjustment of the target crops and the reference doses applied per plant protection product. The objective is to reflect the actual phytosanitary practices in the studied area accurately.

Subsequently, the refined disaggregated information is reaggregated into a comprehensive territorial-scale resolution. This resolution provides the user with relevant information, such as the quantity of active ingredients, to monitor pesticides over time and land use category (*e.g.*, by crop, by non-agricultural land uses). Furthermore, data disaggregated at the plot level within the territory can be used to trace pressures that vary from one point to another for a given substance. The data employed by this method are freely accessible, with records available from 2015 onwards, typically with a maximum lag of two years.

3. Results and Discussion

The method was implemented in a number of different territories across France, each characterised by varying land uses, geomorphological features, and phytosanitary challenges. The implementation process engaged a range of local stakeholders, including government agencies and local organisations, underlining the collaborative nature of the method.

The method is undergoing further developments, specifically focusing on refining the spatial units associated with the administrative postal code of pesticide sales (*i.e.*, the parcels to which products sold in a postal area are effectively applied). Additionally, including real data on pesticide applications obtained from farmers' notebooks is being considered. This will lead to a significant improvement in the results produced by the method.

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Greater diversification and the use of a decision tool allow a significant reduction in mineral nitrogen application in durum wheat without compromising yield and quality (Poster #172)

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Keywords: rotation extension; legumes; multi-services over crop; CHN crop model

In 2021, the agricultural sector accounted for 18.4 % of French GHG emissions in which 29 % was associated with crop fertilization (Citepa, 2023). Consequently, the reduction of synthetic fertilizers is a key element to lower agricultural emissions.

In south-western France, durum wheat (*Triticum durum*) is an important crop both in terms of area and contribution to the economic performance of local arable farms. In conventional farming, durum wheat is fertilized at a relatively high rate to maximize yield and guarantee quality, mainly linked to grain protein content. Agroecological approaches relying more on ecosystem services like diversification with longer rotations including legumes crops and multi-services cover crop (MSCC), were tested in the Syppre network to lower mineral nitrogen rates and associated GHG emissions (Longis *et al.*, 2024). We hypothesized that these levers, combined with the use of a decision-tool (CHN) capable of considering the benefits of diversification for the fertilization recommendations, would make it possible to significantly reduce mineral nitrogen rates on durum wheat without reducing yield or quality.

A 7-year field experiment was carried out at the Syppre experimental platform of Lauragais in southwestern France from 2017 to 2023 (Longis *et al.*, 2024). This study compares the durum wheat of two modalities:

- Reference cropping system (2-year rotation): durum wheat – sunflower, without any cover crop, representative of the dominant crop rotation in Lauragais, with optimized cropping practices to ensure high technical and economic performance.

- Innovative cropping system (8-year rotation): MSCC and chickpea – oilseed rape intercropped with MSCC – durum wheat – MSCC and sorghum – winter pea and buckwheat (as cash crop or MSCC according to biomass produced) – durum wheat – MSCC and sunflower – winter wheat.

N fertilizer rates were calculated using the balance method for the reference durum wheat and using the CHN crop model (Soenen *et al.*, 2019), whose aim is to simulate crop growth in real time to better adapt fertilizer doses, for the durum wheats in the innovative system.

On average of all years, mineral nitrogen available at the end of winter in innovative durum wheats was superior to the reference (21 kg N ha^{-1}, $P < 0.15$) ; Durum wheat N fertilisation was reduced by 69 kg N ha^{-1} ($P < 0.05$) in the innovative system compared to the reference ; Grain yields were non significantly different with 6.5 and 6.7 t ha^{-1} for the innovative and reference durum wheats respectively; grain protein content were always equal or above the quality threshold for both modalities.

Mineral fertilizer costs were significantly reduced in the innovative system, but this did not offset the costs of MSCC-certified seed and increased herbicide costs we also observed.

Our results show that greater diversification can help to significantly reduce nitrogen fertilization and the associated risks of pollution and illustrate the importance of using decision tools to make the most of the benefits of diversification.

The presentation will detail the analyses on mineralisation rates between the two modalities, the effect of climate on the indicators observed, the change in herbicide use and discuss the appropriation of the results by local farmers.

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Coevolution of herd and its feed resources for transforming dairy farming towards an agrecological and resilient system face to climate crisis (Poster #74)

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Keywords: coevolution; dairy farming; transformation; agroecology; resilience

Farming systems are both impacted and responsible of climate change, due to a major cause of greenhouse gas emission and consequences on farmers' productions. In response to these challenges, innovative farming systems based on agroecological principles emerged. Their development transform specialised and input dependent farming systems. Agroecological transformations have not been documented extensively, but it is necessary to understand them for generalising their processes. In this study, we described coevolution of herd and its feed resources during agroecological transformations of the on-station farming system Oasys (INRAE, Lusignan, France). During this work, we rebuilt the evolution of practices on cows, crops and pastures management. Thanks to archives with details on the design, the system establishment and team's discussions we were able to trace trajectories of crops, pastures and animals for identifying the main phases and practice changes over time. Then, we analysed dynamics of agronomic, breeding, economic and environmental performance of the system. The results showed time synchronisations between trajectories and trend changes of performance. For example, in 2018 the start of a phase with deeper changes occurs with trend changes in feeding and production of herd: decrease in concentrates intake, early start of the grazing seasons, increase of milk solids contents, *etc.* The adapter with shifts in perspectives, new learnings and new decisions will be analysed in a future study.

Climate change mitigation along the plant production chain – an overview on agronomic research supporting climate neutrality in Germany (Poster #319)

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Keywords: crop production; climate change mitigation; soil organic carbon; nitrogen use efficiency

Germany aims to become climate-neutral by 2045. The German government set this target in the amended Federal Climate Change Act of 2021. On this path, greenhouse gas (GHG) emissions must be reduced by 65% by 2030 compared to 1990. This requires special efforts in the agricultural sector, which is currently responsible for around 8% of total GHG emissions in Germany.

The agricultural sector faces the challenge of being both part of the problem and part of the solution. Current reports show that German agriculture has the potential to substantially reduce its emissions, although food production will always be linked with emissions. At the same time, in association with the LULUCF sector, agriculture can be part of the solution if vegetation and soils are effectively and sustainably utilized as carbon sinks.

It is crucial that the implementation of new measures to mitigate climate change remain viable and profitable to ensure that German agriculture can stay competitive on the global market under changing climatic conditions. Policy-makers and researchers have a responsibility to provide the best possible support for agricultural practice and identify measures that can be implemented fast in order to achieve the German government's climate change mitigation targets and reverse current negative trends.

"RessortForschtKlima" is a network of over 20 projects that are carried out by the departmental research institutes assigned to the German Federal Ministry of Food and Agriculture. They are intended to support the achievement of the 2030 climate protection targets in the areas of food, agriculture and forests - inter alia through new climate change mitigation measures as well as solutions for climate reporting, impact assessment and socio-economic issues. For this purpose, the departmental research institutions received funding from the Federal Ministry of Food and Agriculture as part of the German Climate Protection Programme 2022.

As part of RessortForschtKlima initiative, the Julius Kühn Institute, which is the Federal Research Centre for Cultivated Plants is researching and developing innovative solutions for the effective reduction of GHG emissions in plant production and development of carbon sequestration potentials in 18 projects. The research activities cover the entire plant production chain in the fields of increasing carbon sequestration potentials, improving resource use efficiency, including the reduction of nitrogen surpluses, sustainable reduction of GHG emissions, including the development and implementation of alternative utilisation concepts and methods, and improving biodiversity as a contribution to climate change mitigation. In addition, the joint projects are supported by the Networking and Coordination Project (VKP), which acts as a link between research and policymakers.

The overall objective of the RessortForschtKlima research projects is to provide a significant contribution to the reduction of GHG emissions in agriculture in Germany, whereby the measures developed must be implemented near-term and easily in agricultural practice and their effects must be quantifiable. The results should help to achieve overarching climate change mitigation measures and targets more effectively.

The VKP aims to strengthen communication between researchers across institutes and fields in RessortForschtKlima in order to identify synergies in research and development and to discuss possible contributions to effective climate change mitigation. By creating overview articles on agricultural climate change mitigation measures in Germany and bundling and processing the research results of all RessortForschtKlima projects in a targeted manner, the VKP aims to ensure a comprehensive summary for political decision-makers, climate reporting, farmers and the general public. Based on the findings, recommendations for action can be derived and published in the form of policy briefs or synthesis reports in order to create an evidence-based foundation for future steps in the field of climate change mitigation in agriculture.

This contribution provides a structured overview on major research objectives, relevant research approaches and an impression of the potential conclusions that can be drawn from the 18 research projects. It further highlights important challenges and respective trajectories for effective climate change mitigation along the plant production chain.

Development of on-farm and experimental cereal yields in Germany under climate change (Poster #346)

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Keywords: yield gap assessment; on-farm yields; experimental yields; genetic trend; non-genetic trend

Crop yields are determined by the selected genotypes (G), the applied crop management (M) and the environmental conditions (E) the crop is exposed to, *i.e.*, especially the local soil and seasonal weather conditions. After decades of continuous yield increases in European and German crop production systems, a plateauing of on-farm crop yields is reported in several studies for different regions in recent years. As genotypes, management and weather conditions change simultaneously over time it is difficult to clearly attribute yield changes to one or the other factor including climate change. However, to be able to develop effective climate change adaptation strategies, it is crucial to understand the underlying causes and disentangle the yield effects of changes in G × E × M.

Cereals are highly relevant for agricultural production and food security covering about 50% of European and German cropland. In this study, we hence utilize German-wide yield data to assess trends of on-farm and experimental cereal yields over the last three decade. We assess yield developments of the major cereal crops winter wheat (*Triticum aestivum* L.), winter triticale (×*Triticosecale*), winter rye (*Secale cereale*) hybrid and population varieties as well as spring barley and winter barley (*Hordeum vulgare*) two-row and six-row varieties. We build on the value for cultivation and use (VCU) trial data, provided by the federal plant variety office. In these trials, each variety is tested for three years for its (additional) VCU at multiple sites throughout Germany before being released to the European market. We further utilize on-farm yield data from the official national census. We apply trend analysis to comparatively assess yield development under experimental *vs.* on-farm conditions. We further use mixed linear models including regression components for dissecting genetic and non-genetic trends. In this way the contribution of new varieties can be separated from other non-genetic effects, especially changes in management and environment, *i.e.*, climate.

We find that on-farm yields of all major cereals are leveling-off in recent years, with triticale yields showing the most negative trend development and barleys showing the least downturned trend. Comparing these trends to the experimental yields we find a widening yield gap between practical on-farm yields and experimental attainable yields. Dissecting the genetic and non-genetic component of the yield trend, we find no plateau for the genetic yield trend, highlighting the continuous increase in genetic yield potential in cereals. However, we find a strong negative downturn of the non-genetic trend of cereal yield development in the last 10 to 15 years. As crop management in the experimental VCU trials was constant over the past decades, this negative non-genetic trend clearly depicts the strongly negative effect of changes in environmental conditions, *i.e.*, weather conditions, in the last decade.

This study provides novel insights on recent G × E × M developments and their effect on cereal yield trends in Germany. While breeding progress per-sists, climatic conditions acted increasingly negative on cereal yield development in Germany during the last decade.

Drivers for cropping decisions and predicting crop rotational patterns for Central Europe using machine learning (Poster #265)

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Keywords: crop rotation; machine learning; agricultural decision making; crop modelling

1. Introduction

Growing different crops in a repeating sequence on the same field - frequently referred to as crop rotation - has various benefits over monoculture. These include improved control of weeds and soil-borne pests and diseases, enhanced resource use efficiency, and an increase in crop yield overall. Agronomic theory behind crop rotational planning is well-established, and respective planning tools are abundantly available. Software like ROTOR, ROTAT, and Fruchtfolge have been designed to generate best-suited crop sequences for specific fields. Although these optimization approaches promise mathematical clarity with logically convincing rule sets and best-practice assumptions, real-world sequential cropping may not follow those agronomic rules exclusively. In addition to environmental growing conditions, farmers' preferences, market prices, and agro-political decisions are expected to play a decisive role in driving operational cropping decision (Jänicke *et al.*, 2022; Notz *et al.*, 2023; Stein and Steinmann, 2018). A comprehensive analysis of the drivers determining sequential cropping and consequently rotational patterns is however missing so far.

2. Materials and Methods

Therefore, we conducted a data-driven analysis to reveal practically relevant information using large observational datasets over Central Europe. Based on field-level data from the Integrated Administration and Control System (IACS) for Germany (eight federal states included), Austria, and the Czech Republic, we collected observations of individual crop sequences over the past 18 years. Across the three countries, our study area covered more than five million and 17 different crop types (excluding grassland and perennial crops). We used an unsupervised K-means clustering approach *via* Principal Component Analysis (PCA) of soil and climate characteristics at 1 km resolution to create clusters of fields with similar growing conditions. We used these cluster and a field-level cropping history from the past five years, market price developments, agronomic best-practice rules, subsidy payments, county-level animal density data, and information on cropping decisions of neighbouring fields to train a random forest (RF) machine learning model to detect and predict the crop type grown at each field for the upcoming year. All the above predictors were defined dynamic in time such that *e.g.* changes in climatic conditions would result in changes of the resulting cluster or changes in individual cropping decisions affected neighbouring fields. RF training included spatio-temporal cross-validation and forward feature selection.

3. Results and Discussion

Preliminary results revealed the importance of the individual cropping history (with regional differences), agricultural subsidies such as the Diversification of Crop production promoting grain legumes through the Common Agricultural Policy of the EU, and prices of high-revenue products, especially for oilseed crops. When designing economic and agronomic scenarios for adapting crop production to a changing climate at a higher level, these results point to the importance of economic incentives to move away from habitual sequential patterns, while agronomic rules for best-practice crop rotations play a secondary role.

In the next step, we will use the trained RF to project crop rotational patterns until 2070 across the German grid at 5 km resolution. This outlook will be based on climatic projections from the German core ensemble of the German Weather Service (DWD) to inform the process-based crop model MONICA (Nendel, 2014) to simulate long-term climate change outlooks considering the projected rotational management for each simulation unit. To advance from a one-crop-covers-all approach will allow for a more realistic representation of the agricultural landscape when simulating crop production, greenhouse gas emissions, or carbon sequestration potentials over large areas and timespans.

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Space-LUOPS: mapping carbon sequestration potential to inform for Carbon Farming investments in Queensland (Australia) (Poster #256)

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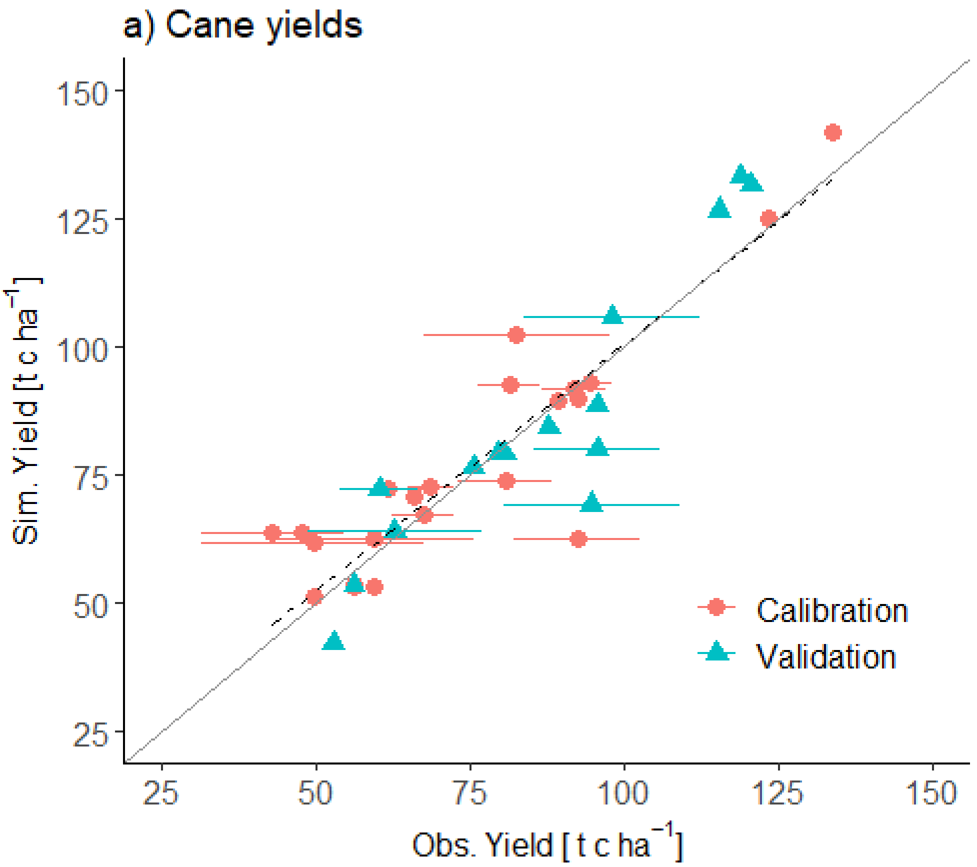
Keywords: land use change; decision support system; future climatic conditions



1. Introduction

Global warming is a pressing issue for all countries and especially their primary producers. The carbon (C) farming industry is an integral part of Europe's and Australia's transition to address the threat of global warming.

Prior to designing C farming projects, proponents, policy makers and government agencies need to identify where it is most effective to invest to sequester C. The scientific literature has abundantly demonstrated that the C sequestration potential varies significantly across the landscape, depending on the agricultural management practices, the physico-chemical properties of the soil itself and the characteristics of the local climate (Li *et al.*, 2020). Moreover, it is unclear whether the strategies proposed today to sequester C in specific regions will be effective under future climatic conditions.

This project aims therefore to use state-of-the-art technology to develop, for the first time, a high-resolution, publicly available online decision support system displaying the C sequestration potential across the entire State of Queensland in Australia, under current and future climate change scenarios.

2. Materials and Methods

Through a collaboration between the Queensland Department of Environment, Science and Innovation, and INRAE (French National Research Institute for Agriculture, Food, and Environment), this ongoing study assesses the potential of sequestering C in the soil and woody vegetation components by simulating three land use change scenarios: converting land from i) cropland to grassland, ii) from cropland to forest, and iii) from grassland to forest. Each land use change scenario is simulated for a duration of either 25 or 100 years (the two possible permanence periods prescribed by the Australian Clean Energy Regulator) under current and future climatic conditions.

The C sequestration potential is assessed using the newly released DayCent-CABBI biogeochemical model, which incorporates microbial-explicit processes and a refined perennial plant submodule. The model is parameterised using publicly available spatial datasets regarding soil, weather and land use information, as well as local expert knowledge to determine region-specific vegetation management data (*e.g.*, common crop rotations, sowing densities, planting and harvesting dates, fertiliser and irrigation rates, *etc.*).

3. Results and Discussion

To date there are no tools that allow C farming project proponents, policymakers and government agencies to visualise where, across different regions and landscapes, there is the highest C sequestration potential under current and future climatic conditions.

To date, the initial model calibration and validation phase has focused on sugarcane cropping systems, showing promising results (Figure 1). On average, the model provided reliable simulations of soil water and nitrogen dynamics, which resulted in a good agreement between observed and simulated yields, with RRMSE and Modelling Efficiency values of 11.1 % and 0.79, respectively.

This project uses Queensland as a case study to set up a modelling framework, which will provide a regularly updatable and transparent state-of-the-art platform to support science-based decision making in C farming projects. Importantly, the framework is designed to incorporate other features, such as the ability to simulate the impact of different crop management practices and the full suite of greenhouse gas emissions (carbon dioxide, methane and nitrous oxide) across land uses and climatic scenarios. The methodology established will be available to develop soil C sequestration potential maps of other statutory bodies (*e.g.* Australia and France), refining the approach used by Launay *et al.* (2021) and Martin *et al.* (2021) by allowing to test the agronomic and environmental performances of current and innovative cropping systems (including different crop rotations under conservation and organic agriculture) under climate change.

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Crop plasticity in the face of climate change – will CO_2 offset the effects of high temperature and water deficit on wheat? (Poster #224)

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Keywords: plasticity; climate change; wheat; elevated CO2; high temperature

1. Introduction

Future crop production depends on plant plasticity to the increase in atmospheric CO_2 concomitant to an increase in mean temperatures as well as more frequent and intense events of heat waves and droughts (Zscheischler *et al.*, 2018; Wang *et al.*, 2023). Thus, it is necessary to better understand the effects of these different climatic variables and their interactions on crops, particularly wheat. These climatic effects have been studied experimentally using different types of facilities, but few studies have focused on the interactions between elevated CO_2 (eCO_2), warming and water deficit. Indeed, the outcome of these interactions is uncertain as these three variables have opposite effects on two main processes: photosynthesis is increased by elevated CO_2 but decreased by high temperatures and water deficit while stomatal conductance (and hence transpiration) is reduced by elevated CO_2 and water deficit but increased by high temperatures (Kadam *et al.*, 2014). We thus aimed to synthesize current experimental knowledge on the effects of combined stress under eCO_2 on production and water related traits.

2. Materials and Methods

A literature search was carried out to identify 63 experiments quantifying the interaction effects between these variables. Based on this data, we studied the evolution of wheat production and water related traits between current non-limiting conditions (ambient CO_2 and temperature, no stress) and the future stressed conditions tested in experiments (eCO_2, warming and water deficit). We also studied the hypothesis according to which the fertilizing effect of elevated CO_2 on crop production is stronger under dry than wet conditions. Relative reaction norms have been used to summarize the available data as far as possible.

3. Results

Highly variable trends were observed, especially for crop production, due to the heterogeneity of the experimental protocols applied. Despite this variability, crop production tends to decrease under future conditions, despite the fertilizing effect of increased CO_2 and this decrease is emphasized by the intensity of water deficit, the increase in temperature and the duration of heat wave events. Conversely, water consumption also tends to decrease under these conditions despite the antagonist effect of high temperatures. We also tested the hypothesis that the fertilizing effect of CO_2 on yield is greater under drought conditions and on the basis of the data collected, this hypothesis was only verified in 56% of cases.

4. Discussion

The studied experimental results mostly show that the fertilizing effect of elevated CO_2 on wheat crop performance is not able to offset the negative effects of high temperatures and water deficit. Water consumption is another key aspect of plant functioning under climate change with contrasted plastic responses to the different climatic variables. However, the effects of elevated CO_2 and water deficit are predominant over warming, resulting in a decreasing trend under future climatic conditions. Indeed, experiments combining interactions between CO_2, temperature and water deficit are not numerous enough and very heterogeneous, mainly because of the diversity in experimental protocols. Besides, a better characterization of stress factors could be achieved with the conception of ecoclimatic indices (Caubel *et al.*, 2015) which would enable better inter-comparison of existing heterogeneous experiments, and the design of future experiments that better represent future multiple stresses. The acquisition of experimental data under future climatic conditions is all the more important as the calibration and validation of crop models depend on them and their range of validity should be more thoroughly tested under interacting climatic variables.

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Agronomic and environmental effects of legumes as pre-crop to winter wheat (Poster #349)

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Keywords: pulses; pre-crop effect; nitrous oxide; GHG emissions; nitrogen losses

1. Introduction

Climate change and the overloaded nitrogen (N) cycle are among the greatest challenges in agriculture (Rockström *et al.*, 2009). Therefore, crop production must increasingly focus on environmental and climate impacts. Legume-based cropping systems are known to be particularly environmentally friendly and have several benefits for farmers and the environment (Zander *et al.*, 2016). Through biological N fixation, mineral N fertilizers can be saved and thus the greenhouse gas balance of crop rotations can be improved (Nemecek *et al.*, 2008). However, there is limited knowledge about the agronomic and environmental effects of legumes under Central European conditions, and in particular climate-relevant nitrous oxide emissions have rarely been investigated (Binacchi *et al.*, 2023).

2. Materials and Methods

For this reason, two similar field trials were set up in the north (Kiel) and south (Munich) of Germany in 2022/2023 as part of the "ISLAND" research project to analyze the processes in the N cycle of legume-based cropping systems. In the field trial in southern Germany, the pre-crop effect of soybean and a grass-legume mixture is compared with non-fixing reference crops (spring wheat without and with N fertilization, field grass). In the following year, winter wheat is grown and fertilized with five N rates ranging from 0 to 320 kg per ha. The investigations comprise soil and plant analyses, including yield formation, estimation of N fixation, measurement of soil N dynamics and nitrous oxide emissions, multispectral reflectance measurements as well as root investigations and greenhouse gas balances.

3. Results

The results of the first year show that soybeans can achieve a high grain yield of 4.7 Mg per ha at this site. The spring wheat fertilized with 160 kg N per ha produced a grain yield of 6.7 Mg per ha, which was significantly higher than the unfertilized spring wheat with a yield of only 3.1 Mg per ha. At 16.9 Mg per ha, the dry matter yield of the grass-legume mixture was considerably higher than that of the unfertilized field grass at 7.1 Mg per ha. Fertilized spring wheat had the highest direct cumulative nitrous oxide emissions of 2.09 kg per ha within eight months and the highest soil mineral N stocks in autumn. The nitrous oxide emissions from spring wheat are primarily due to high post-harvest emissions and less to N fertilization. In contrast, the grass-legume mixture and the field grass had extremely low nitrous oxide emissions of 0.03 and -0.06 kg per ha respectively. Nitrous oxide emissions from soybeans were intermediate at 1.39 kg per ha, with the highest fluxes occurring in June and July and in the fall after sowing winter wheat.

4. Discussion

The results indicate that spring wheat has the highest N loss potential in the form of nitrous oxide emissions and nitrate leaching. Interestingly, the grass-legume mixture had very low nitrous oxide emissions despite high dry matter yield, suggesting that biological N fixation per se does not stimulate nitrous oxide production. However, to make a complete assessment of the environmental and climate impact, multi-year data from multiple sites is required. Additionally, the effect on the subsequent crop must be taken into account.

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Evaluating the impact of soil uncertainty on N_2O emissions from winter oilseed rape cultivation in Germany using large-scale crop model simulations (Poster #272)

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Keywords: winter oilseed rape; DSSAT CROPGRO model; bayesian calibration; N2O emissions; soil uncertainty

Agricultural soils are a primary source of anthropogenic N_2O, a potent greenhouse gas (GHG). It is emitted from the cultivation of crops, especially those with low nitrogen (N) use efficiency such as winter oilseed rape (WOSR) wherein high amounts of N fertilizer are added to soils to ensure high crop productivity. WOSR is an important crop cultivated for fuel, food and fodder in Germany. In order to reduce N_2O emissions from its cultivation, N inputs must be optimized and suitable cultivars need to be developed with better N use efficiency (Stahl *et al.*, 2017). N_2O fluxes also depend on soil texture, weather and N availability (Ruser *et al.*, 2017) which are assessed using agroecosystem models to develop management strategies for low emissions and high yields. Soils, in particular, influence plant N availability, leaching *etc.*, which depends on soil-specific characteristics. They exhibit spatial heterogeneity and their properties are uncertain at regional scales (Folberth *et al.*, 2016). Not accounting for their uncertainty leads to unreliable model predictions. Bayesian inference is used to account for difference sources of uncertainty including those in model inputs such as soils. In this study, we aim to account for soil uncertainty while using Bayesian inference to calibrate a crop model to observations of WOSR grown in Germany in order to improve crop model predictions and obtain representative uncertainty estimates of N_2O emissions.

We use observations from 5 most extensively grown WOSR varieties in the official variety trials performed by the Federal Plant Variety Office (Bundessortenamt), from 9 sites across Germany between 2009 and 2020. For each variety, 30 growing seasons are used for calibrating the DSSAT CROPGRO model to phenology, seed yield as well as seed oil and protein content. The considered site-specific soil profiles and respective horizon-wise properties, which are model inputs, are based on the BUEK200 soil map (Bundesanstalt für Geowissenschaften und Rohstoffe). The map includes soil profile descriptions along with a percentage of their areal coverage in each spatial unit. For each trial site, three profiles with the highest areal coverage are chosen. The percentage of areal coverage are interpreted as prior information about their probability of occurrence at the given site and are assigned as prior weights for each profile. During Bayesian calibration of the model to observations, these weights are updated along with the crop model parameters. The resultant posterior soil profile weights indicate which soil profile is more likely to occur at the trial sites, given the crop observations. To assess the impact of accounting for soil uncertainty, results from this calibration scenario are compared with those in which only the crop model parameters are estimated: one with a single soil profile per site and the other with top three soils weighted as per their areal coverage in the BUEK200. The resultant model output variables of crop yield and N_2O are expressed as probability distributions.

The prior uncertainty in soil profiles at each site is constrained by calibrating the model to data from multiple varieties grown at the same set of trial sites. This study could provide relevant insights into the importance of soil type on yield and N_2O simulations. Furthermore, accounting for soil uncertainty could also result in a more representative estimate of crop model parameters, which would otherwise compensate for errors in soil inputs. Bayesian calibration is used to account for uncertainties in soil input, model parameters and observations, resulting in improved estimates of uncertainties in yield and N_2O emissions. These results could feed into life cycle assessment-based GHG accounting studies.

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Soil conservation: what is the real importance of soil organisms in soil aggregate stability? (Poster #336)

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Keywords: soil; aggregate stability; microorganisms; earthworms; international

Soil structural stability is a key indicator of soil health, particularly its resistance to erosion caused by wind and rain. It is assessed by studying aggregate stability, which depends on various physical, chemical, and biological factors, whether internal (specific to the soil) or external (dependent on climate and land use). Among these factors, it is widely recognized that soil organisms, especially soil macrofauna (earthworms) and microorganisms (fungi and bacteria), play an important role in maintaining soil structural stability. However, their exact contribution is unclear and requires further research.

In this context, MINAUTOR project (EJP-Soil European program), involving eight countries, aims to i) map and model soil biodiversity at European level and ii) identify the relationships between soil biodiversity, function and ecosystem services (ecological production functions, EPF), in order to assess soil vulnerability to climate change and sensitivity to management practices. One of the objectives is to assess the contribution of soil biodiversity to soil structural stability. Through collaboration with numerous European researchers, networks, and programs, extensive soil biodiversity and aggregate stability datasets have been collected, covering different land uses, soil types, and climatic regions.

The main challenges in the database construction process include the heterogeneous nature of the data concerning the method of assessing aggregate stability, as well as the sometimes lack of metadata regarding organism sampling methodology, agricultural activities, soil properties, and climate at study sites. Thus, preliminary findings from our analysis highlight (i) the need for data harmonization and (ii) the inclusion of a minimal set of metadata to examine factors influencing aggregate stability in agricultural systems. Following a rigorous data harmonization process, we will analyze our data to determine which factors have the highest impact on soil structural stability and assess the importance of soil biodiversity. This information allows for a better understanding of structural stability within agroecosystems, and the promotion of strategies to enhance soil protection and organism biodiversity on an international scale.

Agronomic resilience of grain legumes to drought stress using rainout shelters (Poster #229)

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Keywords: grain legumes; drought stress; rainout shelter

1. Introduction

Spring crops and especially grain legumes are expected to be vulnerable to increasing drought due to climate change in Europe (Nendel *et al.*, 2023). The magnitude of climatic changes on yield variability remain unclear, particularly under different exposure periods during plant growth stages. For this purpose, we carried out an experiment to simulate the effect of drought using rainout shelters on five common and novel grain legume species grown under standard cultivation practices in Germany. The research objects were, (i) to investigate the responses of grain legume crops to imposed reductions in precipitation (drought stress) under field condition, by measuring grain yield and yield components, (ii) to assess the effect of timing of this drought stress during flowering and pod-filling.

2. Methods

The factors in the experiment were, (i) plant species (soybean, chickpea, field pea, yellow lupine and white lupine) and, (ii) water availability (irrigated, rainfed, rainfed with drought stress during flowering stage, and rainfed with drought stress during pod-filling stage). Number of pods per plant, biomass, TKW and grain yield were determined. The 1 m^2 harvested plots were in the middle of the shelter area for treatments with rainout shelters.

3. Results

Reducing the rain during the pod-filling phase of yellow lupin decreased the number of pods by 0.4 pods per plants, the biomass by 46% and the grain yield by 0.52 t ha^{-1}, while irrigating yellow lupine with additional 35 mm increased the number of pods by 1.34 pods per plants, the biomass by 30% and the grain yield by 0.31 t ha^{-1} compared to the rainfed treatment. In chickpea, the variety Irenka and Castor were both affected by drought during flowering, decreasing the number of pods by 1.34 and 3.7 pods per plant, the biomass by 18% and 37%, and the grain yield by 0.15 and 0.37 t ha^{-1}, respectively. On the other hand, drought during pod filling did not affect chickpea yield structure, and rather increased the grain yield slightly. No significant reduction or increase in the yield and yield structure of white lupin was detected by the different treatments during both stages. There was also no effect observed for field pea that was much earlier in growth and already affected by drought before the rainout shelters were implemented. For soybean, the variety Tofina was not affected by the reduction of rain during flowering, however drought during pod filling decreased the biomass by 15 % and the grain yield by 0.97 t ha^{-1}. On the other hand, irrigating soybean with additional 85 mm in the drought periods, increased the number of pods by 1.35 pods per plant, biomass by 12 % and the yield by 0.35 t ha^{-1}.

We conclude that grain legumes exhibit varying responses to drought at different growth stages. Chickpeas were notably susceptible to drought stress during flowering, while soybean and yellow lupin was affected by drought during pod filling. On the other hand, white lupin showed minimal impact under drought conditions. Further research will investigate the effect of drought on the grain quality characteristics.

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Pseudomonas chlororaphis as a potential Plant Growth Promoting Rhizobacteria for enhancing barley performance under drought stress (Poster #286)

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Keywords: plant growth promoting rhizobacteria (PGPR); *Pseudomonas chlororaphis*; drought stress; barley; sustainable agriculture

Drought is one of the major abiotic stresses affecting crops. Traditional breeding and genetic approach are applied to mitigate the effects of the drought. However, crop tolerance to abiotic stresses involves quantitative traits and many genes, therefore the plant adaptation to stresses should be improved by various sustainable strategies (Ali *et al.*, 2022). Sustainability in agriculture without affecting the yield of the crops is one of the main areas of research in recent years. Plant growth promoting rhizobacteria (PGPR) could very well achieve this goal as they are excellent plant biostimulants. Due to their diverse nature and activity on the plants, PGPR can play an important role in improving the growth of plants, the yield, and crop tolerance to abiotic stress events, such as long period of drought (Ferioun *et al.*, 2023), whose frequency is increasing due to climate change. The aim of the present study was to evaluate the interaction between *Pseudomonas chlororaphis* subspecies *aureofaciens* inoculation and six genotypes of barley in controlled condition under drought stress. The selected genotypes of barley involved facultative (Lunet and Pamina), spring (Tremois and Morex), and winter (Nure and Ponente) growing habit. A randomized complete design was used with six genotypes, two treatments (inoculated and non-inoculated) and two irrigation regimes (soil moisture at 20% as stress and soil moisture at 40% as control). Twelve biological replicates were considered. Seeds of barley were inoculated with *Pseudomonas chlororaphis* subspecies *aureofaciens* (1 × 109 CFU/mL) at sowing. The pots (12 cm x 14 cm) were kept at control conditions (16 h / 8 h day/ night; 24 °C day and 19 °C night). Drought stress was applied fourteen days after sowing. The growth of seedlings was monitored, and morphological and physiological parameters were recorded. Two weeks after the application of drought stress the plants were destroyed for biomass evaluation.

Various morphological and physiological parameters showed that bacterial application significantly (P <0.05) improved height (+3.6%), leaf chlorophyll (+17.5%), and plant fresh (+37%) and dry weight (+28.8%) and root fresh (+63.8%) and dry weight (61%) under drought in comparison with untreated plants. Significant interactions among variables (Genotype, Stress and Treatment) were observed in some parameters (height, root, shoot and total dry and fresh weight and Water use efficiency). Considering the dry weight of plants the best results were achieved by inoculated plants without drought stress followed by plant without inoculation and without emphasized textdrought stress, inoculated plants under drought stress and plant without inoculation and under drought stress. Considering water use efficiency, Pamina was the genotype that showed the highest values when inoculated with *Pseudomonas chlororaphis* subspecies *aureofaciens* whereas Ponente showed the highest results without inoculation.

Conclusively, our results showed that *Pseudomonas chlororaphis* subspecies *aureofaciens* has the potential to ameliorate drought tolerance in barley, however, other genotypes should be evaluated considered the interactions between genotype and treatment observed and the effect of PGPR should be also checked in field condition.

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Weed seed predation by carabids can help to regulate weeds in arable cropping systems (Poster #37)

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Keywords: biological regulation; weeds; mechanistic model; model validation; weed seed predation

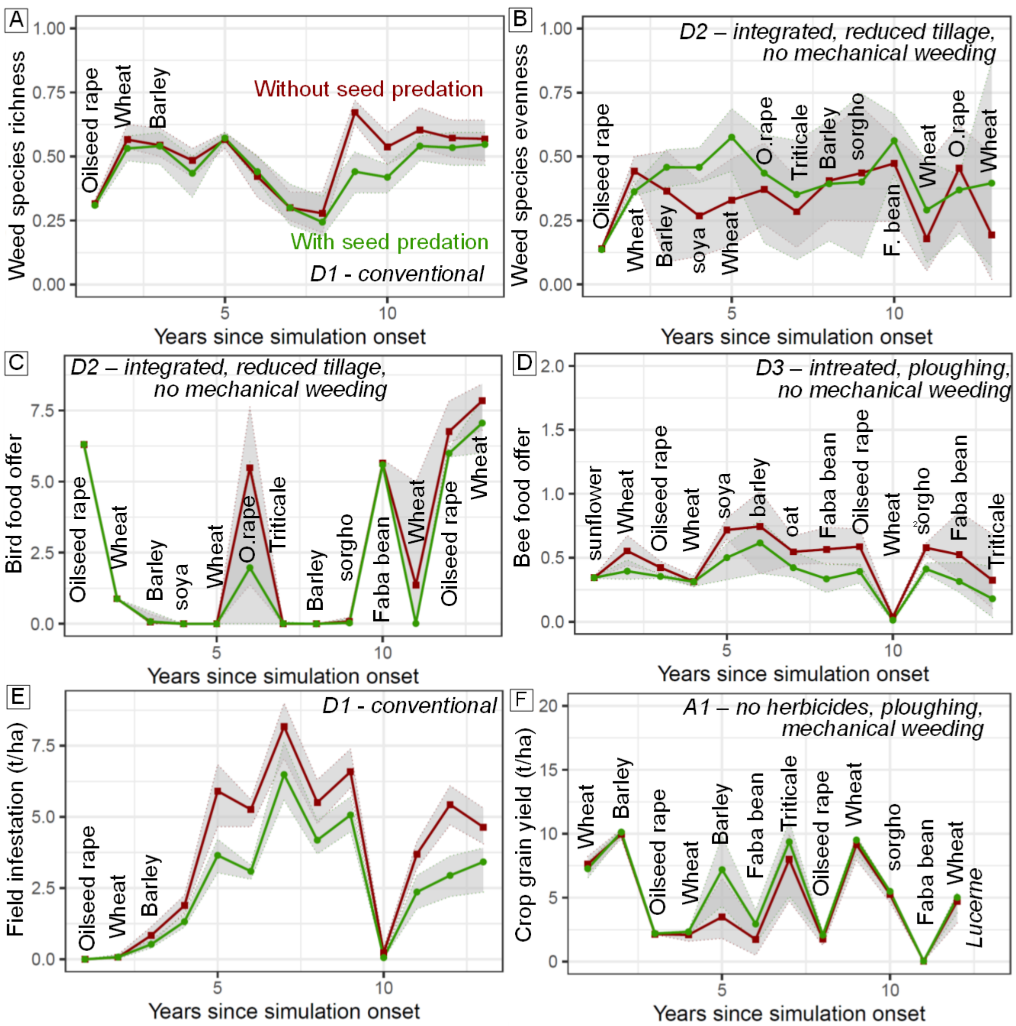

Figure 1. Effect of weed seed predation on crop yield and weed impacts on crop production and biodiversity simulated with FLORSYS. For each weed impact, the cropping system (among the 10 simulated systems) with the largest difference between simulations with (green dots) and without predation (red squares) was shown. Grey shades show 90%-confidence intervals resulting from stochastic repetitions. Crop names show crop succession (with spring/summer crops in lower case)

1. Introduction

To reduce herbicide use, different avenues of biological weed regulation are currently investigated. Among these, weed seed predation by carabid beetles appears promising.

Though observed in different cropping systems and conditions in fields, there has been to date no demonstration that this process actually influences weed dynamics over time and reduces weed harmfulness for crop production. Consequently, the objective of the present paper was to (1) model the impact of cropping system, field margin and pedoclimate on weed seed predation by carabids to complete the FLORSYS model, which simulates weed dynamics and crop production from cropping systems, soil and weather, (2) evaluate whether including seed predation is needed to correctly predict weed dynamics in different cropping systems, (3) determine which components of the seed predation submodel are the most influential.

2. Modelling weed seed predation

The new seed-predation submodel (Perthame *et al.*, 2023) calculates the daily predation rate for each weed species from seed traits, weather data, canopy state variables and management operations. In FLORSYS, this predation rate is applied to the newly shed weed seeds on the soil surface. The equations and parameters were based on past publications from our team and other literature. Then, simulations were run with FLORSYS over 13 years, with and without the seed predation submodel, using weather data and management operations from 10 fields from the INRAE Dijon-Epoisses experimental station. The resulting output in terms of weed and crop state variables (plant density, biomass, seed bank, yield) were compared to measurements from the 10 fields, showing that including weed seed predation in the simulations improved the model's prediction quality, by reducing the overestimation in weed-variable predictions.

3. The factors influencing weed seed predation

A sensitivity analysis to the components of the predation submodel was run, by repeating the simulations after successively switching off individual components of the submodel. This showed that daily incident radiation, light interception by plant canopy, harvest, carabid reproduction and daily temperature had the most influence on seed predation rates.

In addition, the simulations showed that weed seed predation by carabids can contribute to managing weeds, by reducing field infestation and improving crop yields, but with large variations among crops (Figure 1). In average over all tested cropping systems, years and repetitions, seed predation slightly decreased species richness (from 59% of possible species to 57%). The effect took several years to become noticeable, even in the most affected cropping system, and the difference between years and crops was more important (Figure 1A). Predation had no significant effect on species evenness in average but could improve evenness in some crops and years (Figure 1B). Both bird and bee food offer tended to be lower in the presence of seed predation (-6% and -23%, respectively) but the differences were very small compared to the variations due to crops and years (Figure 1C and D).

The effect of predation on field infestation and crop yield was much more important, with roughly a 50%-decrease in field infestation and a 7%-increase in yield in average. These variations were even larger in the cropping systems with the largest impact (Figure 1E and F), though the effect of crops and years remained more influential, even for field infestation.

4. Conclusion and perspectives

The present model-based approach is one of the rare studies to demonstrate the actual effect of weed seed predation on weed dynamics and crop production. The simulations with FLORSYS showed that weed seed predation can indeed contribute to managing weeds, by reducing field infestation, increasing weed-flora evenness and improving crop yields. To determine which cropping systems and field margins favour weed seed predation enough to noticeably contribute to biological weed regulation, more and more diverse cropping systems and weather series must be explored by simulation.

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Prediction model for N_2O emissions related to fertilization and rain events over a 3-year period (Poster #206)

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Keywords: N_2O fluxes; crop model; soil; fertilizer type; greenhouse gas emissions

Agriculture stands as a fundamental pillar of human sustenance, meeting the growing global demand for food, feed and fiber. Within this context, the use of fertilizers, especially nitrogen (N) based, has been pivotal in enhancing crop productivity. However, excess usage of nitrogen not only leads to economic losses but also has negative environmental consequences, such as the emission of greenhouse gases. Among these gases, the nitrous oxide (N_2O) stands out as a direct derivate of the use of N fertilizers. N_2O is a long-lasting anthropogenic greenhouse gas (IPCC 2019) and has a global warming potential (GWP) of 298 times higher than carbon dioxide (CO_2). Emissions are highly variable in space and time and depend on biological (microbial activity), physical (rainfall) or environmental (frost-thaw cycles) factors as well as the availability of N (Ito *et al.* 2018). Since the dynamics of N is a central piece in crop models, these can be an appropriate tool to integrate multiple environmental factors and management practices to understand N_2O fluxes in agricultural systems. In this study, the model HERMES was tested in its ability to simulate N_2O production in an experiment with varying fertilizer types.

The experiment was planned as an on-farm strip design spanning three consecutive crop rotations (maize, wheat, barley) in NE Germany (Uckermark Region, "53°18'54.2"N, 13°40'15.2"E"). The mineral N fertilizer used was ammonium sulfate urea (AS-HS; 33%N 12%S) and tested in combination with a urease inhibitor (UI) and a nitrification inhibitor (NI). The on-farm field trial was divided into four equal stripes, with the following treatments: 1) Control (non-fertilized); 2) mineral N fertilizer (AS-HS); 3) fertilizer with urease inhibitor (AS-HS+UI); and 4) fertilizer with urease and nitrification inhibitor (AS-HS+UI+NI), respectively. N_2O (and CH_4) emissions were measured using NFT-NSS opaque chambers, evacuated glass vials for sampling and subsequent gas chromatography analyses (Shimadzu GC-14B with ECD and FID detectors). Experimental conditions were reproduced in the model HERMES, which combines a series of basic modules (soil, crop, field management, N cycle), to simulate yield, biomass and, among other outputs, N_2O production (Kersebaum 2019). Model results were compared with field measurements.

The model was able to predict most of the N_2O emission events (peaks) and showed a high sensitivity to the effect of rain events on N_2O production. Fertilization events played a relatively lower role in the production of N_2O, indicating that the model might need adjustments in this respect. Crop and soil parameter calibration is currently being carried out to adjust the simulations to fit additional measurements. Preliminary results of this study also showed the need to adjust the fertilizer parameterization to accurately discriminate between fertilizer types.

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Risk management in agriculture and crop insurance: implementation of a method for estimating reference yields in organic field crops in France (Poster #320)

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Keywords: risk management; crop insurance; yield determinants; reference yield; modeling

1. Introduction

Agriculture in France is subject to numerous constraints, notably increasing meteorological risks in recent years due to climate change. Faced with natural disasters and pressure from bio-aggressors, farmers in both conventional and organic production are confronted with a multitude of risk factors leading to variability in their agricultural yields (Arora 2019; Malhi *et al.*, 2021). Consequently, risk management is a key issue for the sustainability of agricultural activities. Crop insurance is considered an essential tool for safeguarding against these various risks and securing farmers' income (Folus *et al.* 2020; Frascarelli *et al.*, 2021; Koenig *et al.*, 2022). The objective of this study is to develop a method for estimating reference yields in large-scale crops (winter wheat, maize, spring barley) in organic agriculture, using statistical models, in order to determine the conditions and parameters to be considered for crop insurance pricing and the contractualization of Groupama Paris Val de Loire (GPVL) members.

2. Materials and Methods

To determine the reference yield, the first step is to study the determinants of yield in large-scale crops (winter wheat, spring barley, maize grain) to identify the factors that impact yield (Ponisio *et al.* 2015; Ben Zekri *et al.*, 2019). Then, statistical regression analysis was used to explain the variability of yields among members based on the factors determining yield. These factors primarily include climate, soil type, pressure from bio-aggressors, crop rotation, technical itinerary of the crop, as well as the farmer's expertise and landscape factors.

3. Résultats

The analysis of yield variability based on yield determinants has enabled the development of a method for estimating reference yields in organic agriculture using regression and prediction models such as Generalized Linear Regression (GLM), Partial Least Squares (PLS), Random Forest, and Gradient Boosting. The latter two models are the most effective and suitable for yield estimation, as determined through comparison using metrics and criteria such as R^2 and RMSE.

The yield estimation model was applied to predict the yields of insured members of Groupama Paris Val de Loire based on their location and the spatial intrinsic characteristics of the plots. The estimated average yield in organic farming for winter wheat ranges from 5.45 t/ha to 9.33 t/ha, spring barley ranges from 4.25 t/ha to 6.43 t/ha, while maize grain varies from 4.44 t/ha to 8.83 t/ha. This approach will facilitate a better assessment of risk factors and more precise crop insurance pricing, thereby helping to support farmers in the face of increasing uncertainty resulting from current climatic, agronomic, and environmental challenges.

4. Discussion

Each factor has its limitations and leads to a lack of precision regarding results. Several other factors have not been studied and may impact yields, including sowing date, bio-aggressor management, nitrogen management, soil cover, varieties used, and rotation duration.

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Adapting FLORSYS for climate change: implementing plant-plant competition for water in a 3D mechanistic model for predicting future crop/weed interactions and their consequences in arable cropping systems (Poster #95)

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Keywords: model; weed/crop water competition; climate change; arable cropping systems; sustainable crop production

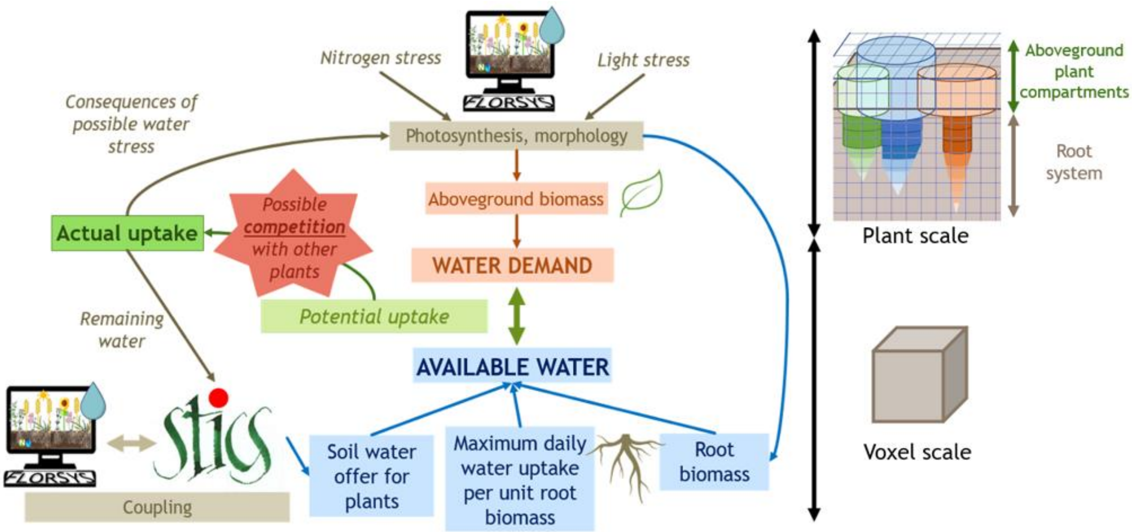

Figure 1. Two-scale organization (voxel, plant) of the water competition submodel of FLORSYS

1. Introduction

Weeds compete with crops for light, minerals and water, and weed-related yield losses will probably increase with climate change (drought, heat waves), under the influence of competitive weeds, in particular for increasingly scarcer water resources (Storkey *et al.*, 2021). Thus, cropping systems must be redesigned to make weed management low-input and climate-resilient. FLORSYS is a 3D mechanistic model (Colbach *et al.*, 2021) that can be used to investigate such issues. It simulates the multi-annual dynamics of weeds and their harmfulness (*e.g.* yield losses) and benefits (*e.g.* trophic supply for crop auxiliaries) from cropping system (rotation, cultivars, cropping techniques) and pedoclimate. However, FLORSYS does not include all mechanisms relevant to climate change, in particular plant-plant competition for water. To better forecast future weed dynamics in arable cropping systems, this work aimed at developing a water competition submodel for FLORSYS.

2. Materials and Methods

The submodel was customised for FLORSYS and connected to other submodels (*e.g.* growth and phenology, light and nitrogen competition). When possible, it reused existing formalisms. The submodel was designed to be generic across crop and weed species, with few parameters.

3. Results

As in Aschehoug *et al.* (2016), the submodel modelled: (1) water availability, demand, competition and uptake at the voxel (3D pixel) scale, as for light and nitrogen competitions (Munier-Jolain *et al.*, 2013; Moreau *et al.*, 2021) and (2) the consequences of water stress on photosynthesis and morphology at the plant scale (Figure 1).

The potential water uptake of a plant in each voxel occupied by its roots is the minimum of (1) its water demand in the voxel, downscaled from total plant demand according to soil water distribution (formalisms from 'Virtual Grassland', Louarn and Faverjon (2018)), (2) the amount of water available to plants in the voxel (linked with the STICS soil submodel, Brisson *et al.* (2008)) and (3) the maximum amount of water roots can take up (experiment of Cournault *et al.* (2024)). Competition among plants with roots in the voxel only occurs if the available water is insufficient to meet their potential uptakes. After completing the loop across soil voxels, it is possible that some plants did not take up enough water to fulfil their demands in some voxels, while water remains in other occupied voxels. Thus, a second uptake loop is run across voxels to compensate for the initial insufficient uptake.

The plant's total water uptake is the sum of water uptakes over all occupied voxels. For each plant, a daily water stress index is computed as "1 - the ratio of water uptake to water demand". To account for past stresses, the daily indexes are combined into a relative linear combination over the plant life (since emergence), with a greater weight for recent stresses. Together with shading and nitrogen stress indexes, the water stress index can affect photosynthesis (according to DSSAT/APSIM formalisms, Ritchie (1998)), and plant morphology (new formalisms from Cournault *et al.* (2024), first presentation in this congress).

4. Discussion

FLORSYS becomes the first crop-weed model to account for light, water and nitrogen competitions, with new formalisms accounting for maximum root water uptake and water-stress effects on plant morphology. The new submodel includes only 7 new parameters, in line with FLORSYS' spirit. It disregards daily lateral soil water flows, but this is consistent with FLORSYS' focus on multiannual cropping system evaluation (Colbach *et al.*, 2021).

5. Conclusion

The new FLORSYS version is expected to improve the credibility of flora projections in the context of climate change. Once the model has been evaluated with field observations, it will be used in simulation studies and participatory workshops with farmers and crop advisors, to design sustainable low-input and climate-resilient cropping systems.

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Exploring the use of naturalized Bradyrhizobia populations for increasing soybean productivity in Northern Germany (Poster #235)

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Keywords: Bradyrhizobia; protein; soybean; inoculation; yield variability

Grain legume production in Europe remains low, despite their numerous benefits. On average, they occupy less than 2% of European acreage. For instance, soybean, a highly valued grain legume, accounts for a small proportion of total arable land in Central Europe, despite its potential. Commercial inoculants are commonly used to inoculate field-grown soybeans in Europe. However, nodulation efficiency has been continually low (Schmidt *et al.* 2015), necessitating the need to explore strategies to increase its growth and productivity. The objectives of this study were: (i) to evaluate the ability of naturalized Bradyrhizobium strain(s) to maximize soybean grain protein content, grain yields, and protein yields in field conditions (ii) to evaluate the extent to which the symbiotic performance of the strains is impacted by soil moisture.

The experiments were carried out in three consecutive seasons (2020–2022) at the experimental station of the Leibniz Centre for Agricultural Landscape Research (ZALF), Müncheberg. Treatments were laid out in a slit-plot design with three factors, namely soybean cultivar, inoculant strain, and water supply. The three soybean cvs. were: Merlin, maturity group (MG) 000; Sultana, MG 000; and Siroca, MG 00. The inoculant strain consisted of three promising Bradyrhizobium strains (GMF14; GMM36; GEM96), previously isolated from Northern Germany. The water supply had two treatments, namely irrigated and rainfed. The isolates, as well as a reference strain (*Bradyrhizobium diazoefficiens* USDA110) and a noninoculated control, were tested in combination with the soybean cultivars.

Inoculation with the local isolates resulted in significant increases in grain yield compared to the commercial USDA110 strain. However, there were no statistical differences in grain protein or protein yields. While irrigation did not significantly affect crude protein content, it resulted in a 27% and 16% increase in grain and protein yields, respectively. Although irrigation increased grain and protein yield in all strains, it had a greater effect on the commercial USDA110 strain than on GMF14 or GEM96. This implies that GMF14 and GEM96 are more adaptable to the drought conditions in Northeast Germany than the standard USDA110. Inoculation with these promising local isolates of superior soybean cultivars has the potential to create a more resilient soybean cropping system in northeast Germany.

Comparative analysis of crop phenotypes to assess cropping system diversification potential by introducing improved accessions of *Thinopyrum intermedium* in fields (Poster #13)

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Keywords: diversification; functional traits; phenotype; grain and forage crops; perennial grain;

1. Introduction

Thinopyrum intermedium (*Th. int.*) accessions are currently under breeding for better grain productivity (Bajgain *et al.*, 2022). Their introduction into the fields aims at diversifying cropping systems by proposing a crop enabling grain production while ensuring a range of services typically offered by perennial forages, namely fodder production and soil and nutrient conservation (Ryan *et al.*, 2018). However, few data are available to characterize *Th. int.* phenotypes and plant functional traits (PFT) compared to other grass crops. Such a comparison can help to unravel the potential differences between this new crop and the well-known crops grown in temperate European cropping systems.

2. Materials and Methods

We measured morphological, phenological and chemical traits (above-belowground) mainly linked to plant resource use strategies and reproductive efforts of 22 accessions of forage and grain crops corresponding to 14 different species. The plants were sown in autumn 2022 in individual soil columns, watered with drip irrigation, fertilized with ammo-nitrate in spring, and harvested in the summer 2023. For each treatment, 4 replicates were carried out, each being duplicated to have a plant available for analysis and destructive sampling in the spring and another for final measurements at maturity. The spring samples allowed measurements of functional traits (root and leaf morphology and nutrient content) at the vegetative stage. The summer samples were used to obtain performance traits in terms of root, above-ground, and seed biomass production.

3. Results

The accessions of *Th. int.* had lower seed mass than the other cereals (p-value < 0.001) and produced a wide range of shoot biomass, including the highest and the lowest values among cereals. Their root biomass was higher compared to other cereals (p-value < 0.001) and more like forage grasses. When examining leaf and root traits in spring, plants were mainly spread across a two-dimensional space mainly structured by gradients of tissue thinness, nutrient content in leaves (P, K, N, S), and unit mass of the seeds. The clustering separated most of the *Th. int.* individuals from other forage grasses and cereals. *Th. int.* individuals generally had lower specific leaf area (SLA) and specific root length (SRL) values compared to forage grasses, and higher root diameter (RD) values compared to forage and grain crops (p-value $<$ 0.001). *Th. int.* accessions had intermediate levels of silicon (Si) between cereals and forage grasses.

4. Discussion

A diversification strategy with *Th. int.* currently requires considering much lower grain production than with annual cereals on a plant basis. Furthermore, despite shoot and root biomass production close to other forage grasses, *Th. int.* leaf and root traits differed. *Th. int.* accessions appeared to express a trait syndrome (higher RD & Si content in leaves, lower SRL & SLA) identified in the literature about plants adapted to stressful conditions (Laughlin, 2023). This syndrome may help in harsh conditions but can be detrimental to productivity, resource use efficiency in peak season, and to fodder values for animal feed. Also, a higher average root diameter is likely to influence the dynamics of carbon storage in soil, soil exploration, and the mycorrhizal symbiosis (Bergmann *et al.*, 2020; Kim *et al.*, 2022). Future attempts to diversify cropping systems will need to align plant growth strategies with farmers' objectives in terms of production, soil functioning and input use.

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Genotype-Environment Interactions in pre-harvest sprouting of wheat (Poster #6)

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Keywords: alpha-amylase; dormancy; falling number; *Triticum aestivum* L.

1. Introduction

Pre-harvest sprouting (PHS) is the untimely germination of the seed while intact to the plant at or before harvesting occurring in a multitude of crops including wheat (*Triticum aestivum* L.). The incidence of PHS is influenced by the conditions of rainfall, temperature, and humidity as well as a lack of genetic dormancy, a quantitative genetic trait, during these conditions. This results in the synthesis of the hydrolytic enzyme alpha-amylase which, in turn, decreases falling number, thereby reducing grain yields and quality with an associated decrease in grain price. Given the ongoing changes in climate patterns and the complexity of PHS, gaining an understanding of the genotype x environment interaction, resulting in PHS, has become imperative. The aim of this study is to evaluate the influence of the environment, genotype and their interaction on PHS of wheat cultivars.

2. Materials and Methods

Trials were conducted in 2021, 2022 and 2023 at two sites in the Eastern Cape province, South Africa, and in 2022 and 2023, nine additional locations in the Western Cape province were included. A total of 40 commercial wheat cultivars were planted in 2021 while 15 commercial wheat cultivars were planted in 2022 in the Eastern Cape, with three replications. In 2022 and 2023 in the Western Cape, 17 commercial South African cultivars were planted with four replications. At anthesis 10 spikes per plot were labelled and later hand-harvested during harvest. Harvested spikes were subjected to simulated conducive conditions for 72 hours in a rainfall simulator and assessed for PHS using a scoring matrix of one to eight where one had no sprouting and eight was fully sprouted. Falling number and alpha-amylase activity were analysed on harvested grain. Statistical analyses, including mixed models, Additive Main Effects and Multiplicative Interaction (AMMI) analyses and correlations were, performed using R.

3. Results

Genotype x environment interactions ($P<0.05$) were present in the Eastern Cape in 2021 and 2023 for all assessments, however, no interaction ($P>0.05$) was present in 2022. In the Western Cape in 2022 and 2023, G x E interactions ($P<0.05$) were present for visual score and alpha-amylase activity, however, no interaction was present for falling number ($P>0.05$). Correlations between weather conditions during the season and PHS assessments indicated that weather conditions, including minimum and maximum temperature, minimum and maximum relative humidity, and rainfall during August, September and October are influential in PHS susceptibility and not only the conditions during harvesting.

4. Discussion

Since the cultivar and environment play a key role in the incidence of PHS, identifying a cultivar that is most suited to a particular environment is imperative. In the Western Cape, a significant proportion of variation was explained by the AMMI analysis identifying that specific cultivars were better suited to particular environments in terms of visual assessment, falling number and alpha-amylase, while some cultivars were moderately stable and adapted to all environments. A similar result was present in the Eastern Cape, where environmental factors influenced the expression of PHS in terms of visual score, falling number and alpha-amylase assay. Additionally, the correlogram correlations indicated that PHS is influenced by weather conditions during critical growth stages in months before harvesting, not only during the harvesting period. The level of seed dormancy experienced during harvest is linked to environmental conditions throughout the season. Therefore, the risk of PHS can be associated with conditions during critical growth phases. Additional research is essential to determine the precise weather conditions affecting PHS susceptibility during specific critical growth phases. By identifying the weather conditions that are most influential in maintaining seed dormancy during different critical growth stages, while linking this to a specific cultivar, the risk of PHS may be reduced.

Distinct and interactive effects of low light and *Alternaria alternata* infection on grain yield of sorghum (Poster #166)

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Keywords: agroforestry; *Alternaria alternata* (fr.) keiss; dead mulch; grain yield; light; *Sorghum bicolorr* L. Moench.

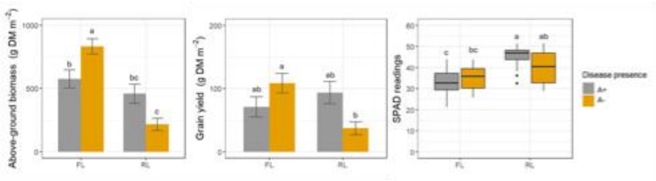

Figure 1. Average values of above-ground biomass, grain yield and SPAD readings of sorghum as affected by shade x disease interaction. Vertical bars indicate standard error of the mean. SPAD readings were graphically reported as boxplots, where the main body of the boxplots shows the interquartile range (IQR), and the central line the median. Bars represent Q1-1.15 IQR (lower) and Q3 + 1.5 IQR (upper), with dots to indicate outliers. Bars with the same letters are not significantly different at $p \leq 0.05$ (Tukey's HSD test). FL= Full Light; RL= Reduced Light; A+= Alternaria infection; A-= Alternaria absence

1. Introduction

Sorghum (*Sorghum bicolor* L. Moench) is a summer crop rainfed in Mediterranean areas for its rusticity and drought tolerance. Hairy vetch (*Vicia villosa* Roth) is often used as a winter cover crop before cereal cultivation to control weeds, increase soil nitrogen availability, and protect soil and water. Sorghum can also be cultivated with poplar in narrow alleys in agroforestry [1]. However, sorghum is a C4 plant, not tolerant to light reduction [2] and shaded and humid conditions commonly increase the risk of sorghum diseases, such as leaf spot caused by *Alternaria alternata* (Fr.) Keissl. Anyway, a clear understanding of the effects of agroforestry practices on plant diseases is far from being obtained. Here, we investigated the singular and interactive effects of simulated tree shading and Alternaria infection on grain yield of sorghum cultivated after a vetch cover crop.

2. Materials and Methods

The field experiment was established at Center for Agri-environmental Research "Enrico Avanzi", University of Pisa, Italy (43.674460 °N, 10.318331 °E) on a loam soil with pH 7.9 and 1.9 % w/w organic matter. Following a randomized complete block design with 4 replications, S. bicolor cv PR89Y79 was grown under full light (FL) or potential light availability reduced by 50% (RL); at flowering, the crop was fully sprayed with *A. alternata* suspensions (strains A214 and A216) with final concentrations of 0 (A-) or 2 (A+) × 108 CFU mL^{-1}. Vetch was sown in December and mechanically terminated in May using a Crimper Roller, then sorghum was sown on dead mulch. Shading was simulated on half of the plots using plastic slats fixed on iron structures, N-S oriented (2.0 x 2.0 m). Soil water content at two depths (*i.e.*, 0-10 and 10-30 cm) and SPAD, were assessed at three growth stages (*i.e.*, 5-6 leaves unfolded, flowering, and soft dough), and above ground and grain biomass measures were carried out at maturity.

Moreover, one month after inoculation, hyperspectral data were collected at both leaf and canopy levels (1 m above the canopy, nadir).

3. Results

Results show that above-ground biomass of sorghum was the highest in the control without shading and disease, followed by infected plants irrespectively in shaded and full light conditions (Figure 1). Grain yield of A- more than halved when grown with RL, while it did not differ between FL and RL in A- and A+ plants.

SPAD values decreased more in RL than FL plants when infected than when not-infected (by 27 and 14% respectively). Similarly, a significant shading x disease interaction was observed for four spectral vegetation indices (*i.e.*, color rendering index 1 and 2, normalized difference nitrogen index, and normalized difference lignin index). Soil water content was not significantly chaged by treatments but decreased along the crop cycle and was higher at the lowest profile.

4. Discussion

A close relationship between sorghum production and light availability was found by [3], but here we revealed that the decreased plant biomass of RL plants was not due to photosynthetic impairments (SPAD values did not drop) but likely to weed pressure (weed biomass was about 130 g m^{-2}) competing for resources. The impacts of agroforestry on diseases have shown context-dependent results [1]; in our research, the lowest biomass and grain production of the shaded and infected plants were consistent with leaf spectral signatures highlighting their potential in assessing crop disturbances by abiotic and/or biotic stress in a timely and cost-effective manner.

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SuMoQuality: a crop growth model to predict seed yield and quality under recurring heat waves (Poster #5)

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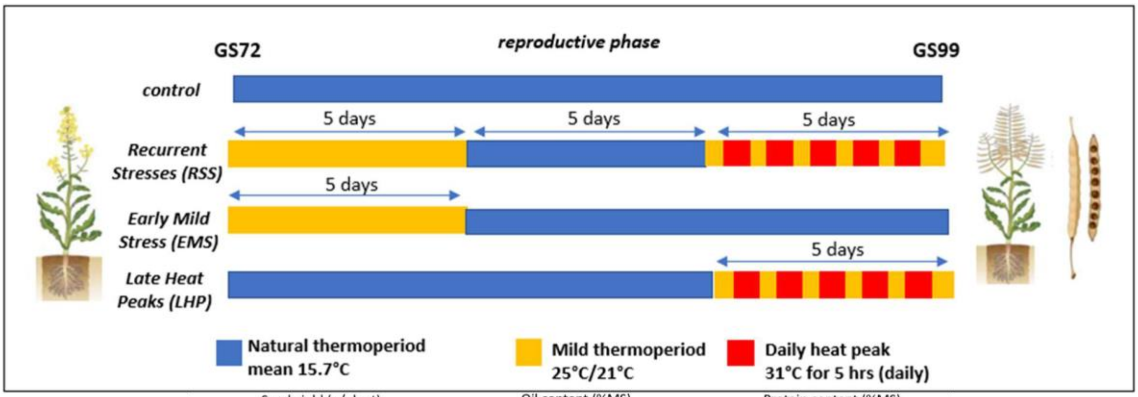
Keywords: modelling; heat stress; oilseed rape; stress memory; crop model



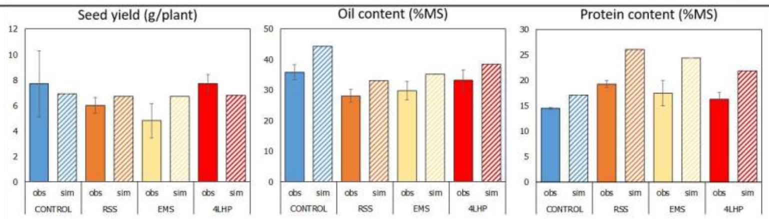


Figure 1. Heat stress sequences tested with the SuMoQuality model (Magno *et al.* 2022a)

Figure 2. Observation (plain) and simulation (dashed) of seed yield, oil and protein contents with SuMoQuality (Magno *et al.* 2022b)

1. Introduction

Among climate change's features, the recurrence of spring heat waves has become a growing threat to winter crops that complete their reproductive phase over the spring and early summer period (IPCC, 2021) such as winter oilseed rape (WOSR). Modelling approaches to predict and to help anticipating risks of heat stress over crop sensitive stages (*e.g.* using early or late flowering varieties) could be reliable decision-making tools. The SuMoToRI crop model was previously designed to predict the effects of sulfur (S) availability in WOSR which is a high S-demanding crop (Brunel-Muguet *et al.* 2015, Poisson *et al.* 2018). Recent developments have focused on testing the robustness of the model production under repeated heat stresses. Experimental results have shown that successive heat stresses can either amplify the negative effects of late stresses or alleviate these late effects (the so-called 'priming effect' of first stress exposure) as a consequence of stress memory-triggered processes (Magno *et al.* 2022ab, Hilker 2019). The objective was to test whether crop model such as SuMoToRI was able to predict such non-additive effects of recurring heat stresses without additional modification of the model.

2. Materials and Methods

Firstly, the initial version of the model (SuMoToRI, Brunel-Muguet *et al.* 2015) was implemented to predict seed yield and quality criteria *i.e.* seed oil and protein contents (SuMoQuality, Magno *et al.* 2022b). The extension of the period of prediction required to (i) consider the pods for the equations related to light interception and carbon assimilation, as they act as the main photosynthetic organ throughout the seed filling and maturation phases and (ii) define two periods (in thermal time) that distinguish pods' heterotrophy from pods' autotrophy. The seed oil content was estimated as a function of the post flowering intercepted Photosynthetically Active Radiation (PARi, Aguirrezabal *et al.* 2015) and the seed protein content was negatively correlated to the seed oil content (Hammac 2017).

Secondly, the SuMoQuality model was tested with different heat stress sequences previously used in an in a greenhouse assay (Figure 1, Magno *et al.* 2022a). These sequences were initially designed to observe any effect of an early mild stress (EMS) on the magnitude of the effect of later heat peaks (LHP).

3. Results

For each variable, the simulation values were of the same order of magnitude as the observations' values (Figure 2). The model was able to predict the non-additive effects of repeated heat stresses. Indeed, the observed data indicated that seed yield was reduced by 22.1% under RSS and by -37.7% under EMS and its was similar to the control under 4LPH which highlighted that the individual effects of EMS and LHP were not additive. Similarly, the simulation output indicated a reduction of 2.9% under RSS, 2.9% under EMS and 1.4% under LHP, which also pointed out non-additive effects of the individual stresses (EMS and LHP). The same conclusions were drawn for oil and protein contents. However, while the decrease in oil concentration under RSS was correctly predicted under RSS (-22% for the observations *vs.* -25% for the simulations), the increase in protein contents was not with almost to a two-fold difference (+33% for the observations *vs.* + 53% for the simulations).

4. Discussion

These exploratory results indicated that the SuMoQuality model was able to predict seed yield and main quality criteria in oilseed rape although the seed oil content was slightly overestimated in the control condition. Under heat stress, trends (increase or decrease) were nicely represented but the model tend to fail simulating correct increase in protein content under repeated heat stresses. These conclusions indicate that no additional equations nor structural changes were needed to predict the effects of repeated stresses. The prediction quality is likely to be improved with additional datasets to better calibrate oil and protein content related-parameters.

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How multi-species cover and perennial forages mitigate the impact of repeated heatwaves in a context of Sulphur deficiency (Poster #151)

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Keywords: heatwave; forage; experimentation; sulphur; acclimation

Research on forage production to secure livestock feed is essential to face the challenges posed by global change. An overlooked aspect of climate change is how repeated heatwaves impact forage production (Breshears *et al.*, 2021). Likewise, the role of species diversity and Sulphur (S) availability in mitigating their effects is poorly understood. Soil S availability has significantly decreased over the last decades(Scherer, 2001), making it particularly relevant to study plant's responses to heatwaves, as S plays a major role in stress responses(Rausch and Wachter, 2005). However, there is a lack of research on how species with different S requirements respond to heatwaves. Resistance to heatwaves has been widely demonstrated among forage species(De Boeck *et al.*, 2011). Because some species have the ability to recover (Langworthy *et al.*, 2020), research has primarily focused on immediate responses to heatwaves but very little on longer-term responses. Plants are capable of storing and retrieving information from previous exposures to improve future responses(Liu *et al.*, 2022). This mechanism should be considered in grassland management, as a grassland plant previously exposed to stresses is likely to better cope with repeated heatwaves. Multi-species grasslands would also have a greater potential to ensure production than monospecific crops, as diversity not only ensures at least some successful responses(Isbell *et al.*, 2015) since resistance and resilience strategies are species-dependent, but it also promotes species complementarity (Chen *et al.*, 2022). A 36-week experiment was conducted to simulate repeated heatwaves, S soil availability and mowing practices. The experiment included monocultures of four species (*Lolium perenne*, *Lotus corniculatus*, *Plantago lanceolata*, *Festuca rubra*), a mixed culture of *L. perenne* and *L. corniculatus*, and a mixed culture of the four species. The experiment was carried out to test the effects four thermoprotocols: a control, a spring heatwave, a summer heatwave, and of a combined sequence with one spring and one summer heatwave to simulate stress recurrence. Plants were grown over a 7-month cycle in order to take into account harvests after regrowth. We hypothesise better resistance of stress-tolerant species like *F. rubra* and *L. corniculatus* and a better resilience of *L. perenne* and *P. lanceolata*. We hypothesise then acclimated responses during the summer heatwaves following a spring heatwave of *P. lanceolata* and *L. perenne* due to their ability to produce new leaves. Our third hypothesis is that high S availability improves production, resistance, and resilience, especially for *L. corniculatus*, as a Fabaceae species. We also expect an enhanced production in mixed cultures than in monospecific ones. Our study, by highlighting the afterward responses, the species diversity and S availability as nature-based solutions to face heatwaves in a context of sulphur deficiency, aims at enhancing forage production management.

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The secrets of shading for thriving cocoa (Poster #180)

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Keywords: agroforestry; shading; associated trees; cocoa farming and sustainable production.

1. Faced with the looming threat of climate change and the spread of the Cocoa Swollen Shoot Virus, the sustainability of cocoa cultivation in Côte d'Ivoire is at stake. In this context, agroforestry emerges as a beacon of hope for sustainable cocoa production. However, the quest for optimal shading in these agroforestry systems remains a major challenge. This study aims to unveil the secrets of ideal shading by characterizing a shading system through a thorough analysis of the functional and morphological traits of associated trees, correlated with the agromorphological characteristics of cocoa trees.

2. To achieve this, a rigorous methodology was employed, involving the installation of 4 agroforestry plots, each measuring 1000 m^2. Morphological characteristics such as height, diameter at breast height (DBH), and crown diameter were meticulously measured on shading trees within the plots. Concurrently, the productivity, vegetative state, and health status of cocoa trees were assessed.

3. The results highlight the crucial role of DBH, basal area, crown height, and crown diameter of a tree as the main determinants of shading. Heavily shaded plots were more susceptible to brown rot attacks and less productive. Furthermore, this study demonstrates that variability in shading significantly influences the agronomic traits of cocoa trees, particularly in their architecture due to tropism movements in search of light. In conclusion, these findings shed valuable light on how to preserve and optimize cocoa production in the face of climate change and increasing pathogenic pressure.

Intensification of crop rotation by growing multi-species mixtures for green manure (Poster #365)

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Keywords: mixtures; green manure; soil mineral N; dry matter yield

The green manure provides environmental benefits, mainly related to improved soil properties and increased flora and fauna diversity. Incorporated plant biomass with green manure crops aims to replace the insufficient application of livestock manure, increase soil organic matter content, and provide mineral nitrogen (N) for main cash crops in the crop rotation. This study aims to analyze the impact of incorporating pure stands and multi-species mixtures for green manure in four growth stages on soil mineral N content.

A field trial was established in the spring of 2022, at the experimental station Rimski Šančevi, in the vicinity of Novi Sad, in the northern part of Serbia. The trial was conducted as a random block design in three replications and included a pure stand of field pea (P), common vetch (CV), berseem clover (BC), fodder kale (FK), oilseed radish (OR), spring oat (O), spring barley (B), phacelia (F) and mixtures of 2C (two components) (CV+B), 3C (2C+FK), 4C (3C+F), 5C (4C+P), 6C (5C+OR), 7C (6C+O), and 8C (7C+BC). The dry matter yield was measured before the crops were incorporated into the soil. The termination was done in the four periods of crop growth,starting from one month and a halffrom sowing, and each seven days after that. The soil mineral N content (kg N ha^{-1}) was measured at the time of crop termination and two weeks after. The soil analysis was done from two soil layers, 0-30 cm, and 30-60 cm.

The amount and distribution of precipitation significantly differed from the long-term average and affected crop growth and nitrogen content. The yield of dry matter in all treatments was the highest in the fourth period of termination when the crops were in full bloom or grain filling, where the highest yield was measured in the treatment with spring barley (4,5 t ha^{-1}), and the soil nitrogen content was low in this period as well as two weeks after termination due to intensive plant growth. The third period of incorporation (beginning of flowering and flowering) showed the most favorable effects in the obtained dry matter yield and enriching the soil with mineral N, especially in legume treatments and mixtures with more components.

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Stakeholders' evaluation of vegetation and its management in railway environments (Poster #136)

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Keywords: weed control; railway environment; diagnosis of uses; glyphosate

Vegetation management in railway networks is a multifaceted challenge, dealing with numerous risks and considerations. The unchecked vegetation growth along railway tracks poses various hazards, from obstructing access paths and hindering visibility to creating operational hazards such as fire risks and track destabilization (Pietras-Couffignal 2021; Braschi 2016; UIC 2003). Historically, the RATP has employed glyphosate-based treatments to manage vegetation across its network. However, with growing concerns over environmental and health impacts, the decision was made in May 2019 to discontinue glyphosate, instead opting for alternative methods such as mowing and uprooting campaigns. Despite this shift, vegetation management at RATP has remained unchanged, with an objective of eradication rather than integration. Our study focuses on stakeholders' perceptions of vegetation and its management within the railway environment. Through a series of 30 interviews with key stakeholders from both the RATP and the Ile-de-France region, we aimed to explore the diverse perspectives and priorities shaping attitudes towards vegetation, following a “diagnosis of uses” method (Cerf *et al.* 2012; Clerino *et al.* 2023). The interviewed stakeholders ranged from operational agents to environmental engineers and community representatives. Our analysis revealed a spectrum of stakeholder perspectives, highlighting varying criteria in evaluating vegetation and its management. While some stakeholders emphasized the need for rigorous vegetation control to ensure safety and operational efficiency, others advocated for a more balanced approach that considers ecological sustainability and biodiversity preservation. We identified distinct groups of stakeholders with differing viewpoints and priorities. By delineating these perspectives, we gained valuable insights into the complexities of vegetation management within the railway context. These findings serve as a foundation for designing inclusive and sustainable vegetation management solutions that align with stakeholders' diverse needs and values. RATP's decision to stop using glyphosate presents an opportune moment to reimagine its approach to vegetation management, moving towards more sustainable and ecological practices.

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A short-season, early-vigorous wheat ideotype for adaptation to a changing global climate (Poster #118)

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Keywords: wheat; short-season; vigour; australian ideotype

The changing global climate of more variable rainfall patterns and increasing temperatures is a severe threat to worldwide food security. There is need for adaptive technologies, agronomy, and crop varieties that will be capable of meeting and exceeding the projected demands of an increasing human population in the changing climate. An increase in average temperatures will result in crop cycles shortening and as such the vigour of varieties will need to increase to ensure optimum production occurs (Malhi *et al.* 2021). With up to ~20% of all calories consumed coming from wheat grain, it is therefore a vital component of food security and a focus for yield improvement (Erenstein *et al.* 2022). A proposed new wheat ideotype, of a highly early vigorous plant with a shortened lifecycle has been tested in Australian conditions, and has applicability on a global scale.

Australia is one of the largest wheat exporters, and is essential to worldwide food security. In the southern Australian wheatbelt, wheat is traditionally sown in the autumn to be grown over winter, flower in spring and then be harvested in early summer. With water availability the greatest limiter to yield, this allows for sufficient time for moisture to be harvested by the crop, and develop enough biomass before anthesis for conversion to grain yield (Richards *et al.* 2014). The timing of sowing in the autumn is crucial as it enables the plant's phenological requirements of vernalisation, photoperiod, and earliness per se to be met over winter. This results in anthesis occurring in spring when the relative risks of frost and heat and drought stress are at their lowest. Mistimed flowering results in the sensitive floral parts being damaged, and a resultant drop in grain yield (Flohr *et al.* 2017). However, the timing of sowing in autumn, to ensure correct timing of anthesis, is often dictated by the colloquially termed autumn break. This is a flush of rainfall that growers will wait for until they sow. The autumn break provides good soil moisture, ensuring consistent and even germination of the crop. The changing climate has reduced the reliability of this rainfall and so many growers are being forced to sow into dry soil, and are encountering issues with poor germination, emergence, and crop stand establishment (Unkovich 2010). The proposed ideotype tested here negates the need for the autumn rainfall by delaying sowing into mid-winter into near guaranteed moisture. This delay in sowing requires the ideotype to have exceptionally high early vigour for biomass development, as well as hastened phenology to still time anthesis in the optimum flowering window in the spring (Chen *et al.* 2020). This paper covers a definition of the ideotype drawing upon global literature of short season, highly vigorous wheat varieties in addition to a multi-trait multi-environment analysis of short season wheats in Australian conditions.

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WS-CI: a web service for predicting the biomass and nitrogen uptake of intercropping cover crops (Poster #308)

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Keywords: cover crops; biomass; nitrogen uptake; web portal; interoperability; wms and wfs protocols

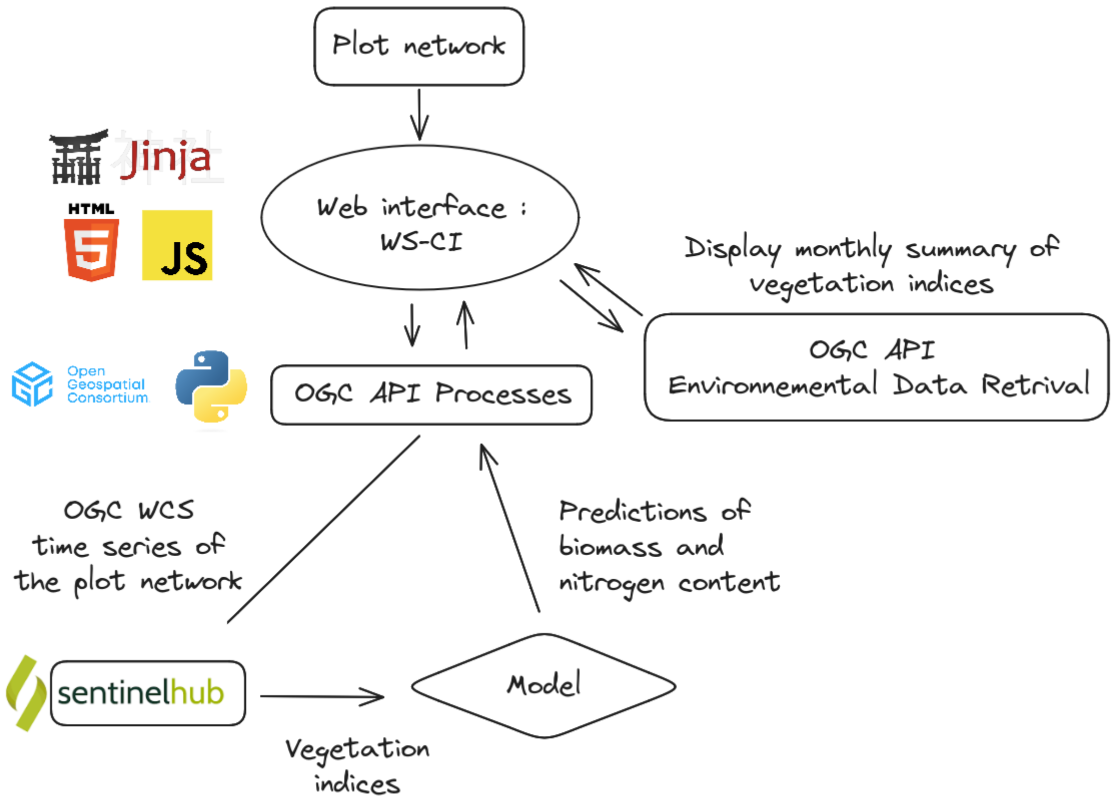

Figure 1. Architecture and technology of the web service

1. Introduction

Cover crops are an effective tool for decreasing nitrogen leaching in agrosystems, and their biodegradation after destruction provides nitrogen for the following crop, but in highly variable amounts depending on their biomass and the amount of nitrogen that they took up. Remote sensing data from Sentinel-2 satellites show great potential for addressing this variability through the development of predictive models based on vegetation indices and parameterised using field measurements of variables of agronomic interest (Dusseux *et al.*, 2022). These perspectives led the mixed research unit SAS of INRAE (France) to initiate a project, in partnership with the Chambers of Agriculture of Brittany, to develop a web service (WS-CI) designed for farmers and agricultural advisors to characterise the development dynamics of cover crops and help predict their biomass and nitrogen (N) uptake. Developing this tool required setting up an experiment on a network of plots in which the biomass and N of the canopies were measured in elementary sampling units (ESUs), which consisted of homogeneous 20 m × 20 m areas (Verrelst *et al.*, 2015). Here, we present the results obtained from this network and the design and features of the WS-CI web service.

2. Materials and Methods

2.1. Data used

We took field measurements from 277 ESUs in Brittany during the autumn/winter of 2022-2023 and 2023-2024. In each ESU, we collected five georeferenced samples of above-ground biomass in a 1 m^2 quadrat from each vertices and centre zones of the ESU. A composite sample from each ESU was sent to the laboratory for analysis of dry matter and N content. The data were carefully characterized based on several criteria.

Images from Sentinel-2 satellites were used to calculate vegetation indices. The satellite data for each sample were determined by intersecting the sample's coordinates with pixels in the image and then averaging the values of each pixel to obtain one value per band for index calculation.

2.2. Selection of the best indices and modelling approach

We calculated 152 vegetation indices selected from the literature. The 20 best spectral bands or indices were selected based on a correlation test with field data, and then all possible pairs of the 20 bands or indices with different combinations were assessed using several modelling approaches (*i.e.* statistical and machine learning) (Verrelst *et al.*, 2015) to determine which approach was most appropriate for the web service.

2.3. Web service

The WS-CI web service was designed using interoperable standards and free and open-source technology (Bera *et al.*, 2015) (Figure 1).

3. Results and Discussion

We selected parametric regression to parameterise the models because it is highly accurate and simple to implement. We integrated into the web service the most accurate model, which combined GEMI (Pinty *et al.*, 1991) and NIRV (Grayson *et al.*, 2017) (RMSE = 6.53 kg N/ha) and the vegetation index that had the strongest correlation with the amount of fresh biomass (MCARIOSAVI705, Chaoyang *et al.*, 2008) to visualize the development of canopies on a map.

The web service, based on open-source technology, enables users to easily view the development of cover crops over time and the maximum amount of N that they take up at the plot scale. It is now in production and already helping to improve advice on N fertilisation.

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Nitrogen performances of pesticide-free system experiments of INRAE (Poster #306)

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Keywords: nitrogen; cropping systems; low input trials; efficiency; modeling

1. Introduction

Since the 2000’s, innovative cropping systems have been designed and tested at INRAE in "system experiments", with the constraint of drastically limiting or even eliminating the use of pesticides. To this end, these systems are based on the principles of agroecology, mobilizing – in conjunction with a variety of cropping techniques – the services provided by increased biological diversity, which is mainly expected to result in biological regulation of pests and diseases. Although multi-performance was generally sought in these system experiments, high nitrogen (N) performance was not a central objective in their design. In NExSys research project, we therefore hypothesize that the nitrogen performance of these systems can be improved, both in terms of plant nutrition and environmental impacts. One step to test this assumption is the assessment of the N efficiency and N losses in these systems.

2. Materials and Methods

In about 10 system experiments, we collected different types of data: crop sequences and cropping techniques (sowing and harvest dates, mineral and organic fertilization, tillage interventions), soil characteristics and meteorological data. We also collected measurements as soil mineral N and plant N at different dates.

We then applied several tools to the cropping systems according to our different purposes:

- SyNE (Godinot *et al.*, 2014) to assess the N efficiency
- SyNB to assess the global N balance
- Syst’N® (Parnaudeau *et al.,* 2012, Bedu *et al.*, 2023) to assess and make the diagnosis of N losses towards environment

3. Results and Discussion

The first results were methodological, as expected. SyNE results showed that for systems with low inputs and outputs (low production), the efficiency was very uncertain and sometimes aberrant because of the uncertainty associated to the calculation of the stocks of soil organic N. In systems with higher N fluxes, SyNE and SyNB allowed identifying soil N mining situations. Syst’N® results were correct when compared to N measurements in plant and soil for simple systems (without intercrops in particular). In systems with high N organic restitutions (manure application and pastures), soil N mineralization had to be calibrated to provide good results. In diversified systems with no or shallow tillage systems, Syst’N® still requires additional calibration or even modifications to take account of the complexity of the processes influencing N losses.

Work is ongoing and more detailed results will be presented in the poster.

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A comparison of plant sap and plant dry tissue analysis in winter wheat using three interpretation approaches and their correlation with yield (Poster #285)

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Keywords: nutrient management; DRIS; CND; sap analysis; plant sampling

Balanced nutrient management is critical for both long-term sustainability and productivity of farming systems.

Plant analyses such as dry matter (DM) and sap analysis are tools to identify nutrient imbalances at plant level. They can indicate nutritional challenges within the season, while fertilizer application is still effective. DM analysis reflects the total concentration of nutrients in the plants, while sap analysis reflects the nutrients which are readily available for plant development (Esteves *et al.*, 2021).

The commonly used interpretation method is the univariate Critical Value (CV) approach. It is based on sufficiency ranges established through fertilizer experiments and is simple to use, but does not account for nutrient interactions or climatic variabilities (Sumner, 1990). The bivariate Diagnosis and Recommendation Integrated System (DRIS) (Beaufils, 1973) evaluates the nutritional status based on dual ratios rather than absolute values. Its main advantage is the insensitivity to crop age, variety and nutrient accumulation or dilution effects. The multivariate Compositional Nutrient Diagnosis (CND) (Parent and Dafir, 1992) originates in the compositional data analysis. As it accounts for all possible nutrient interactions, it has been suggested to be superior to the DRIS.

Fertilizer guidelines commonly use CV based on DM samples, but the usage of sap analysis is increasing. However, no standardized sampling and interpretation protocols exist. The DRIS and CND might be especially suited for interpretation due to their insensitivity to absolute values. Here, we wanted to test whether DRIS and CND can be used to estimate the nutritional status in arable crops, and to assess which sampling (DM or sap) or interpretation (CV, DRIS or CND) method is more suitable as fertilizer recommendations.

In June 2023, before flowering, we took DM and sap samples of winter wheat grown on loamy soils in Western Switzerland. 15 fields of exemplary farms and 12 reference fields of a research station were sampled. The references represented N limited, PK limited and sufficient fertilization (Blanchet *et al.*, 2016). The youngest, fully developed and the oldest, still functioning leaf (whole leaf, without petiole) were sampled per plant. DM and sap samples were analyzed for N, P, K, Ca, Mg, S, Cu, Zn, Fe, Mo and Mn, using ICP-OES and CNS analyzer for DM samples, and a commercial lab for the sap analysis. The results were interpreted using CV ranges (Richner *et al.*, 2017 for DM; ranges suggested by the sap analysis lab), as well as interpreted through the calculation of DRIS and CND indices.

Nutrients in DM and sap were significantly correlated (except Fe). However, preliminary results suggest that the nutritional status indicated by the three different interpretations does not align. Only Nitrogen was clearly identified as limited by all methods. Overall, DRIS indices (DM and sap) suggested stronger nutrient imbalances than CND indices. The indices of sap and DM correlated for CND, but not for DRIS. Opposingly, yield was correlated to the DRIS indices for DM and sap, but not to CND indices.

The in-depth analysis of soil and plant nutrients will continue and the methods will be further assessed in a field trial in 2024/2025.

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Model-based exploration of sustainable cropping systems by integrating crop rotation diversification with management practice optimization (Poster #56)

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Keywords: multi-attribute agricultural sustainability; cropping system redesign; trade-offs; synergies; ROTAT model

1. Introduction

Sustainable cropping systems are deemed multifunctional, *i.e.*, supplying sufficient agricultural products while maximizing eco-environmental and socio-economic benefits. Researchers have made considerable efforts to develop cropping systems towards multi-attribute sustainability either by diversifying crop rotations (Liang *et al.*, 2023) or ameliorating management practices (Chen *et al.*, 2014). However, few studies investigate the sustainability benefits of cropping systems by integrating these two approaches, leaving the potential scope for improvement across multiple sustainability objectives unknown. To fill this gap, we proposed a model-aided method for designing and evaluating all agronomically feasible crop rotations furnished with the optimal management regime for specific agricultural regions, which enables stakeholders to grasp the whole picture of improvement potential and possible trade-offs across farming sustainability objectives.

2. Methods

Our modelling framework for designing sustainable cropping systems comprises four parts: 1) Rotation generation module, 2) Yield estimation module, 3) Management optimization module, and 4) Indicator assessment module. Initially, the model generates all feasible rotations based on a predefined list of candidate crops and rotation rules (Dogliotti *et al.*, 2004). Next, it calculates the yield of each crop in the rotations, considering the attainable yield level and crop succession-induced yield-reducing factors. An optimal management regime is then devised for each crop to close the yield gap associated with crop management with more efficient resource use, incorporating three advanced agronomic strategies including the integrated soil-crop system management (Chen *et al.*, 2014), the steady-state N balance fertilization (Yin *et al.*, 2021), and manure substitution. With crop input-output data obtained from above steps, the model quantifies the sustainability indicator performance of rotations in socio-economic, human-nutrition, eco-environmental terms. We illustrate this framework by exploring promising cropping systems in terms of 11 sustainability objectives for the North China Plain where cropland is predominantly covered by the highly intensified wheat-maize double cropping.

3. Results

Relative to the currently dominant intensified wheat-maize system, optimized management can increase gross margin by 47%, and dietary energy and zinc yield by 19% while mitigating groundwater depletion, aquatic eutrophication, and greenhouse gas emission by 45-75% albeit with a 12% increase in economic risk. However, this cereal-based system did not produce vitamin C and had low agrobiodiversity. The model generated 3,684 optimally managed alternative rotations, of which 2801 (76%) are Pareto-optimal in terms of 11 objectives. Although no single alternative outperformed the intensified wheat-maize in all objectives simultaneously particularly due to higher labor use and economic risks, these rotations presented considerable benefits in gross margin, vitamin C output and eco-environmental indicators. On average, Pareto-optimal rotations had more than twice the gross margin and agrobiodiversity, and 36-64% lower groundwater depletion, aquatic eutrophication and greenhouse gas emission compared to the intensified wheat-maize system, while 405, 612 and 2421 (16%, 22% and 86%) of them supplied more dietary energy, zinc, and vitamin C than the wheat-maize respectively. On the other hand, trade-offs were evident between gross margin and economic risks/labor use, and between gross margin/dietary energy yield and eco-environmental benefits.

4. Discussion

Combining rotation diversification and management optimization holds promise for improving multi-attribute sustainability. While optimizing management alone for the dominant wheat-maize system could deliver multiple wins in productivity, profitability and eco-environmental performance, it failed to address objectives that require the inclusion of non-cereal species, *e.g.*, vitamin C production and agrobiodiversity. Moreover, optimally managed diversified rotations could offer opportunities to further enhance the benefit for each sustainability objective compared to the wheat-maize system. Given that no single rotation performed best across all objectives, implementing various promising rotations with the optimized wheat-maize system in the future farming landscapes could better reconcile stakeholders' sustainability demands. This modeling framework is flexible for application in other agricultural regions with appropriate adaptations.

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