Organic farming and semi-natural habitats for multifunctional agriculture: a case study in hedgerow landscapes of Brittany

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ECOBIO (Ecosystèmes, Biodiversité, Evolution), Univ Rennes, CNRS, France
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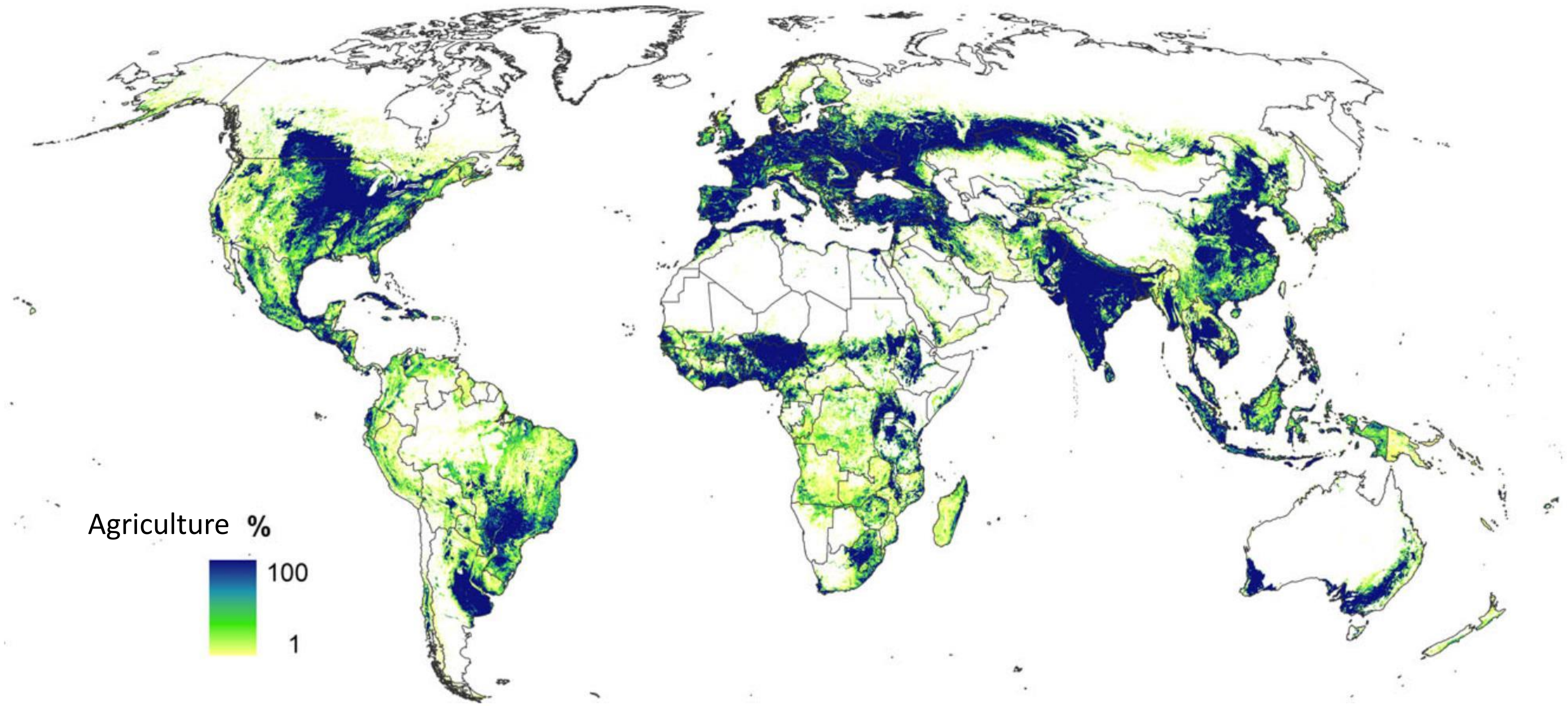
18th Congress of the European Society for Agronomy in Rennes, France

Introduction

Agriculture covers about 40% of the Earth's terrestrial area



Fritz et al. 2015

Reducing agrochemical input and diversifying landscapes for multifunctional agriculture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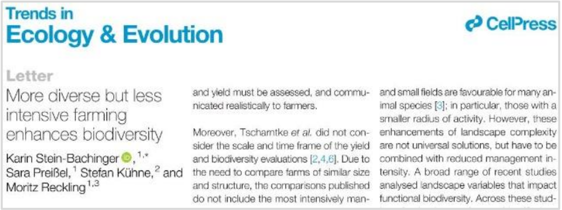
Opinion

Beyond organic farming – harnessing biodiversity-friendly landscapes

Teja Tscharntke,[1,*] Ingo Grass,[2] Thomas C. Wanger,[3,4,5,*] Catrin Westphal,[6] and Péter Batáry[7]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Letter

More diverse but less intensive farming enhances biodiversity

Karin Stein-Bachinger,[1,*] Sara Preißel,[1] Stefan Kühne,[2] and Moritz Reckling[1,3]

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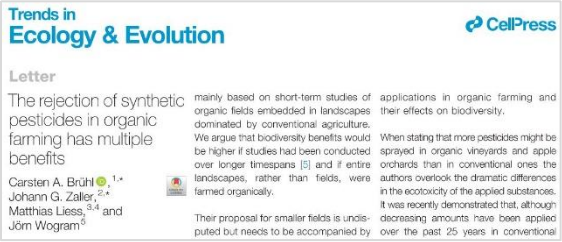
Moreover, Tscharntke *et al.* did not consider the scale and time frame of the yield and biodiversity evaluations [2,4,6]. Due to the need to compare farms of similar size and structure, the comparisons published do not include the most intensively man-

and small fields are favourable for many animal species [3]; in particular, those with a smaller radius of activity. However, these enhancements of landscape complexity are not universal solutions, but have to be combined with reduced management intensity. A broad range of recent studies analysed landscape variables that impact functional biodiversity. Across these stud-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Letter

The rejection of synthetic pesticides in organic farming has multiple benefits

Carsten A. Brühl,[1,*] Johann G. Zaller,[2,*] Matthias Liess,[3,4] and Jörn Wogram[5]

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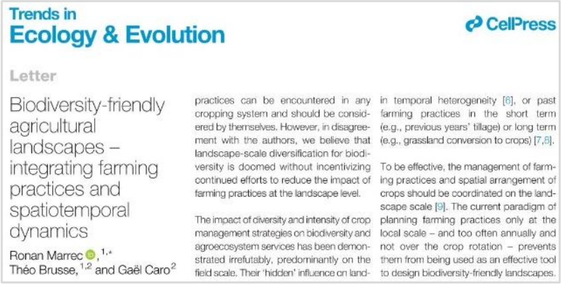
Their proposal for smaller fields is undisputed but needs to be accompanied by

applications in organic farming and their effects on biodiversity.

When stating that more pesticides might be sprayed in organic vineyards and apple orchards than in conventional ones the authors overlook the dramatic differences in the ecotoxicity of the applied substances. It was recently demonstrated that, although decreasing amounts have been applied over the past 25 years in conventional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Biodiversity-friendly agricultural landscapes – integrating farming practices and spatiotemporal dynamics

Ronan Marrec,[1,*] Théo Brusse,[1,2] and Gaël Caro[2]

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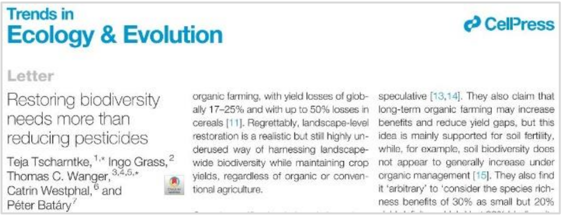
The impact of diversity and intensity of crop management strategies on biodiversity and agroecosystem services has been demonstrated irrefutably, predominantly on the field scale. Their 'hidden' influence on land-

in temporal heterogeneity [6], or past farming practices in the short term (e.g., previous years' tillage) or long term (e.g., grassland conversion to crops) [7,8].

To be effective, the management of farming practices and spatial arrangement of crops should be coordinated on the landscape scale [9]. The current paradigm of planning farming practices only at the local scale – and too often annually and not over the crop rotation – prevents them from being used as an effective tool to design biodiversity-friendly landscapes.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Restoring biodiversity needs more than reducing pesticides

Teja Tscharntke,[1,*] Ingo Grass,[2] Thomas C. Wanger,[3,4,5,*] Catrin Westphal,[6] and Péter Batáry[7]

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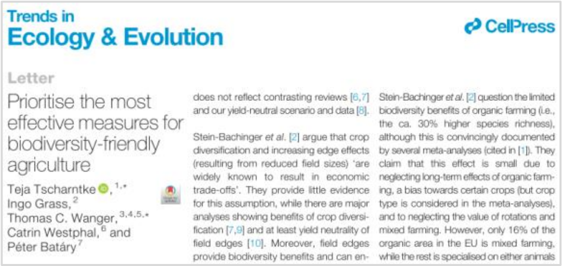
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Prioritise the most effective measures for biodiversity-friendly agriculture

Teja Tscharntke,[1,*] Ingo Grass,[2] Thomas C. Wanger,[3,4,5,*] Catrin Westphal,[6] and Péter Batáry[7]

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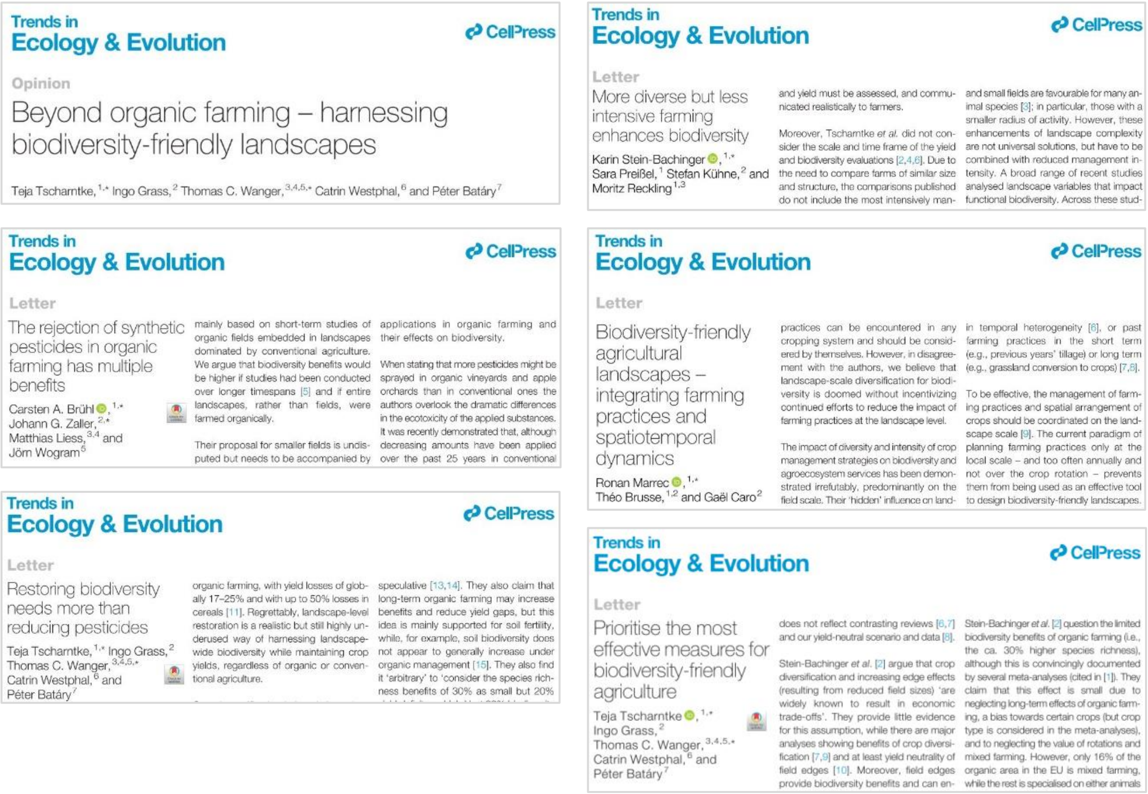
- **Sustainable Use Regulation:** reduce pesticide use by 50% in 2030
- **Nature Restoration Law:** restore 20% of Europe's marine and terrestrial territory by 2030

Reducing agrochemical input and diversifying landscapes for multifunctional agriculture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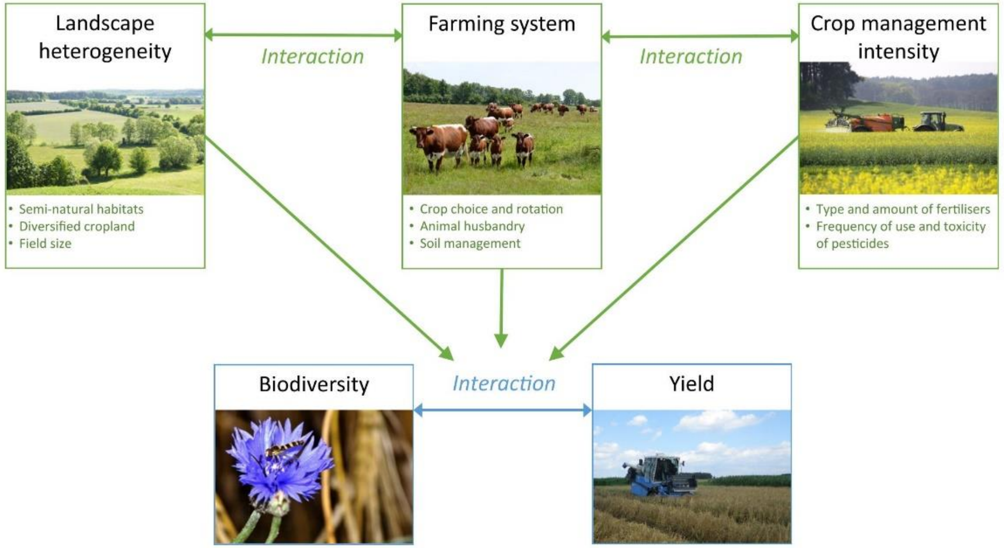

Stein-Bachinger et al. 2020

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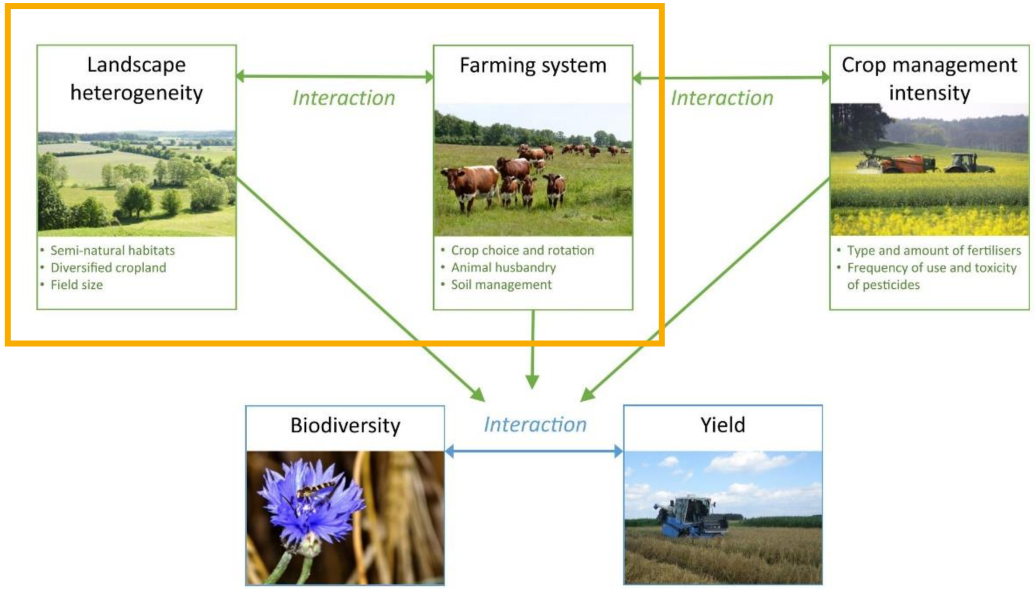

Stein-Bachinger et al. 2020

Combining organic farming and hedgerow preservation to promote multifunctional agriculture?

HEDGEROW FUNCTIONING

1. **Habitat provision**
→ survival/growth *(Stamps & Linit 1998)*

2. **Habitat connectivity**
→ dispersal *(Blitzer et al. 2012)*

3. **Environmental heterogeneity**
→ coexistence *(Stein et al. 2014)*

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INTERACTION WITH FARMING SYSTEM

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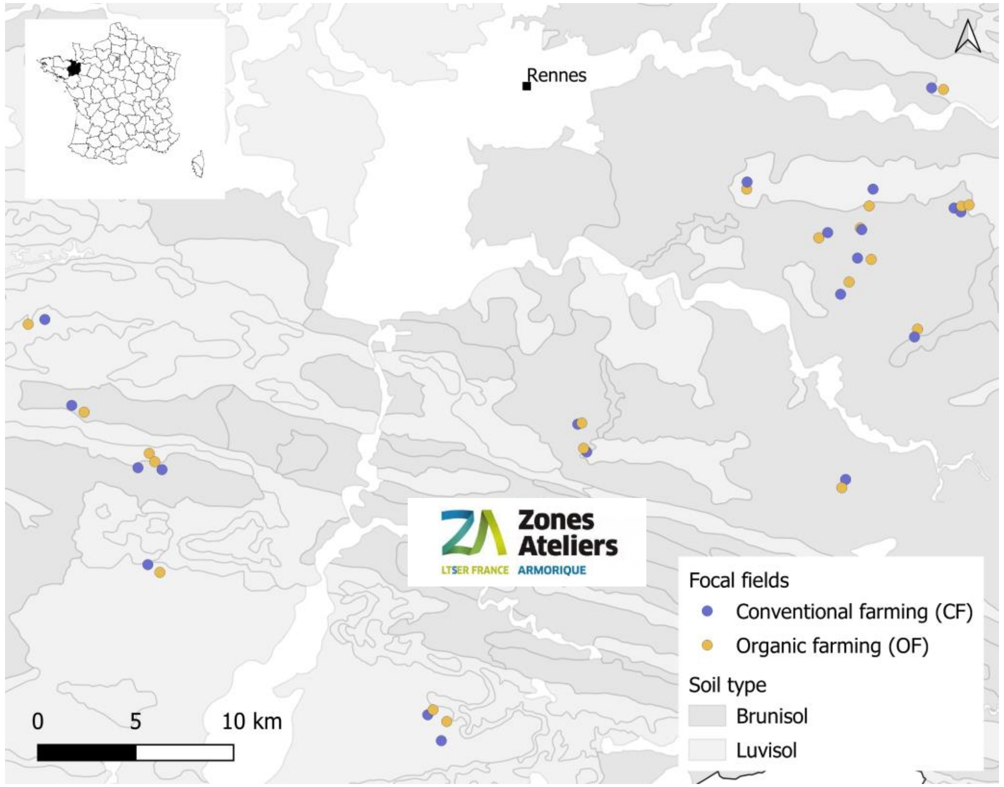
INTERACTION WITH FARMING SYSTEM

Antagonistic effect: agrochemical disturbances (conventional farming) undermine the beneficial effects of hedgerows *(Madin & Nelson 2023)*

Methods

Study site



N = 40 cereal fields along a gradient of hedgerow density in the landscape

→ field work in 2019 in the centre of cereal fields

Estimating multifunctionality

Indicators	Agroecosystem goods
Bacterial diversity	**1. Biodiversity conservation**
Fungal diversity	
Earthworm diversity	
Weed diversity	
Carabid diversity	

Byrnes et al. 2023

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Soil enzyme activities	**2. Nutrient cycling and soil structure**
% symbio- and saprotrophic fungi	
Earthworm abundance	
SOC:clay ratio	
C:N ratio	

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Granivorous carabid abundance	3. Pest and disease regulation
Carnivorous carabid abundance	
Staphylinid abundance	
Spider abundance	
Aphid parasitism rate	
Weed abundance*	
Aphid abundance*	
Septoria tritici abundance*	

Byrnes et al. 2023

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Grain yield	**4. Food production**

Byrnes et al. 2023

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Duration of interventions*	**5. Socio-economic performance**
Semi-net margin	

Byrnes et al. 2023

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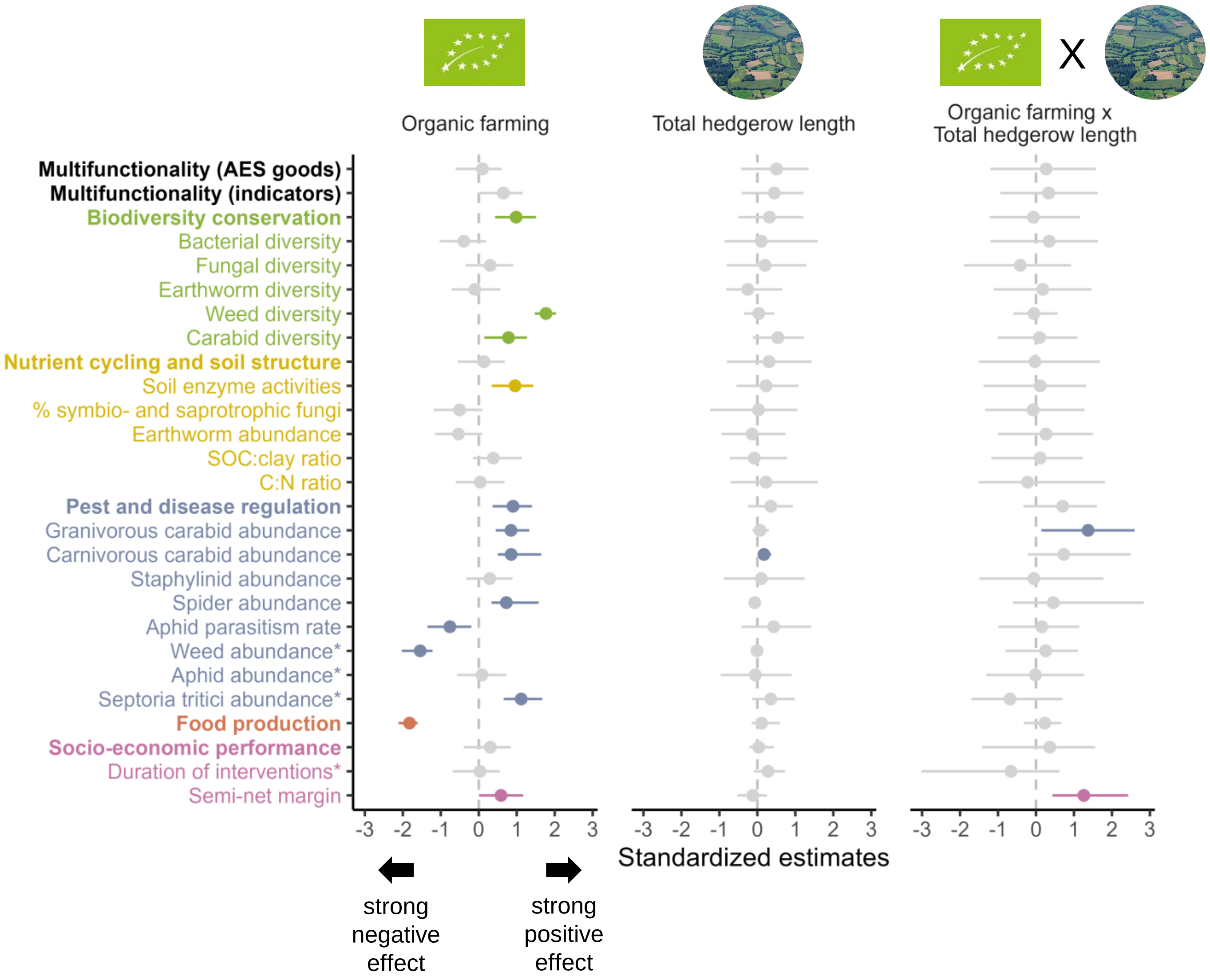
Semi-net margin	
Multifunctionality (indicators)	**Multifunctionality (AES goods)**

Byrnes et al. 2023

Results and discussion

Major positive influence of organic farming on many indicators



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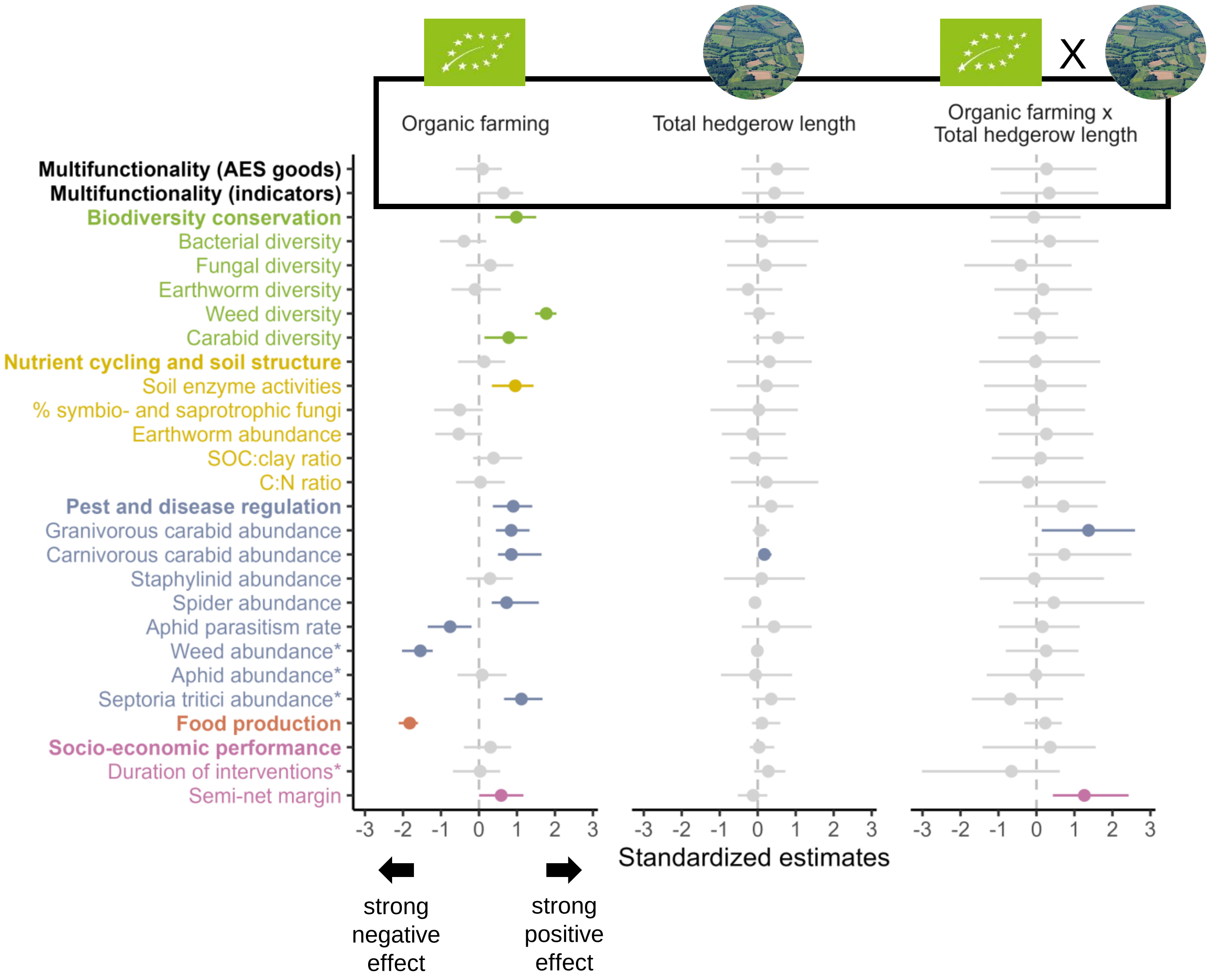

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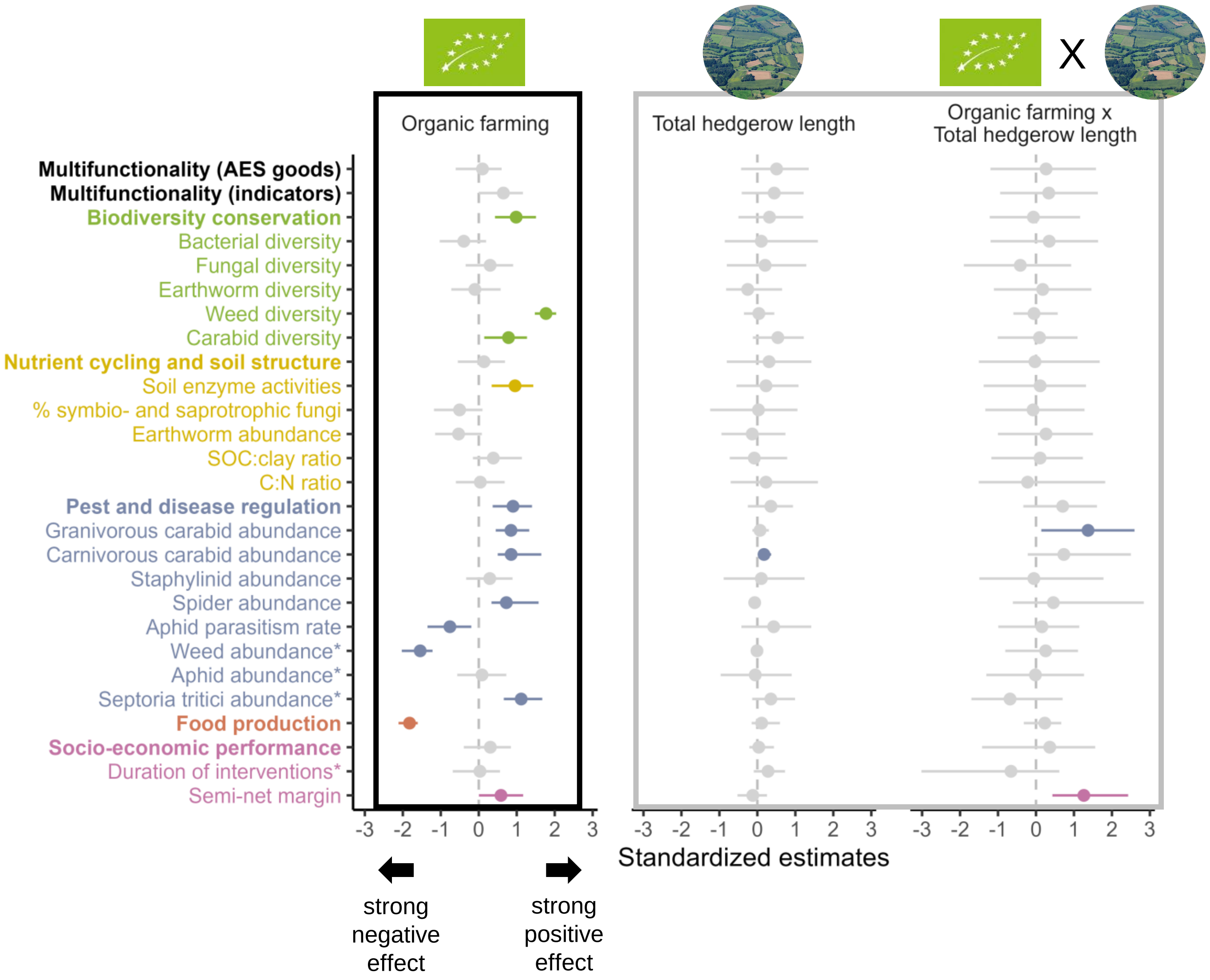

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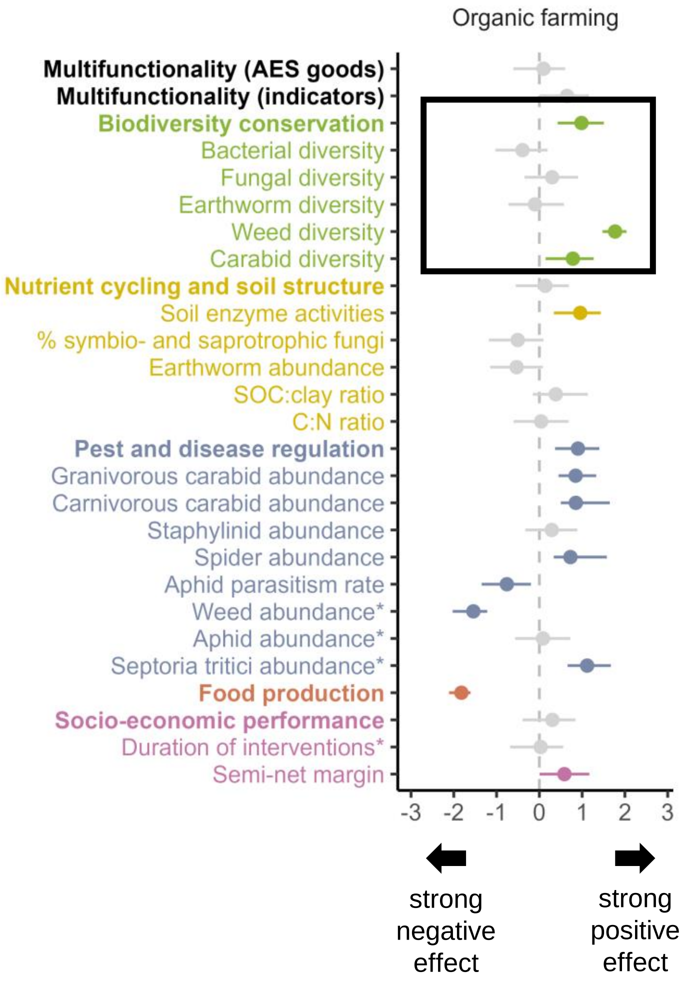


RESULTS

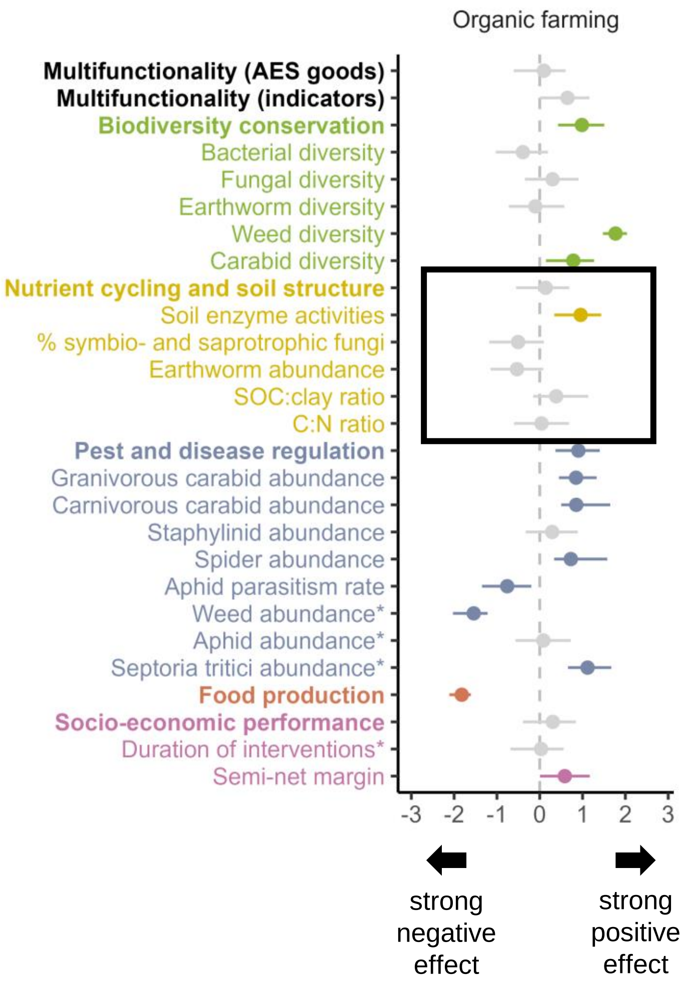
↗ biodiversity conservation (aboveground)

+24 weed species / field

INTERPRETATIONS

Absence of agrochemical disturbances (weeds) and increase in resources (carabids) *(Diehl et al. 2012; Storkey et al. 2012)*

Major positive influence of organic farming on many indicators



RESULTS

Weak influence on soil functioning

INTERPRETATIONS

Intense tillage to control weeds offsets the benefits of pesticide-free farming, organic amendments, and complex crop rotations for soil biota *(Tamburini et al. 2016)*

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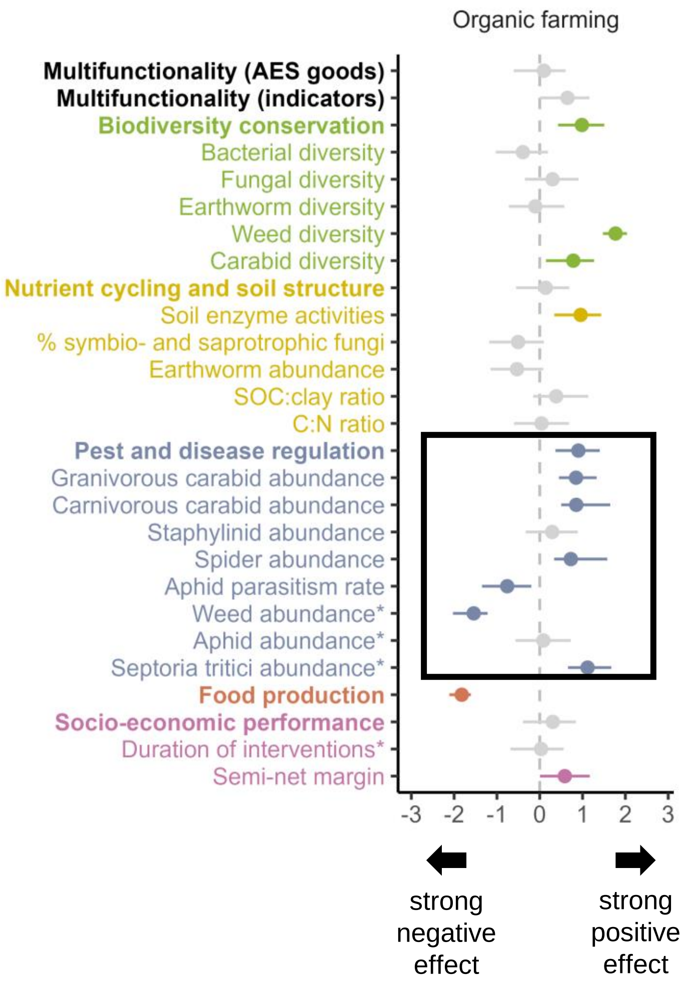


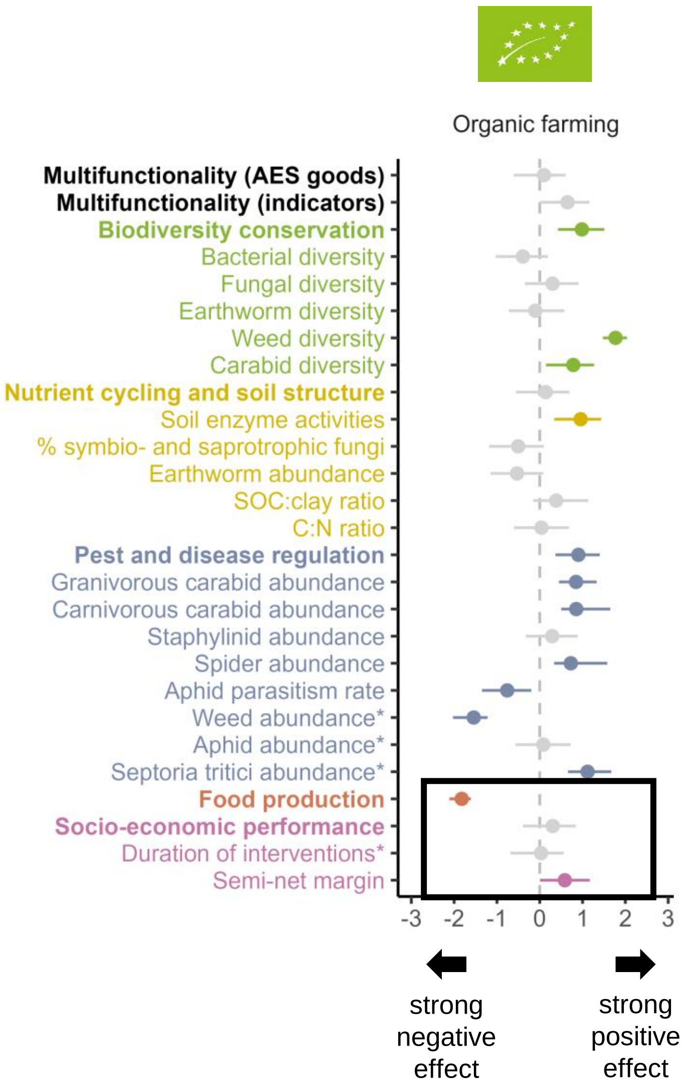
RESULTS

↗ pest and disease regulation
+26 carnivorous carabid and +42 spider individuals / pair of pitfall traps

INTERPRETATIONS

Increased resources promote the growth of (generalist) natural enemy populations, and absence of synthetic fertilizers reduces plant diseases *(Précigout et al. 2017)*

Major positive influence of organic farming on many indicators



RESULTS

↘ food production *(-42q/ha)*
↗ semi-net margin *(+248€/ha)*

INTERPRETATIONS

Crop-weed competition reduces yields *(Oerke 2006)*
Lower costs and higher selling prices increase profitability

Arable weeds: a central role in agroecosystem multifunctionality

WEED RESEARCH An International Journal of Weed Biology, Ecology and Vegetation Management

DOI: 10.1111/wre.12310

INSIGHTS

What good is weed diversity?

J STORKEY & P NEVE
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ARTICLES
https://doi.org/10.1038/s41893-019-0415-y
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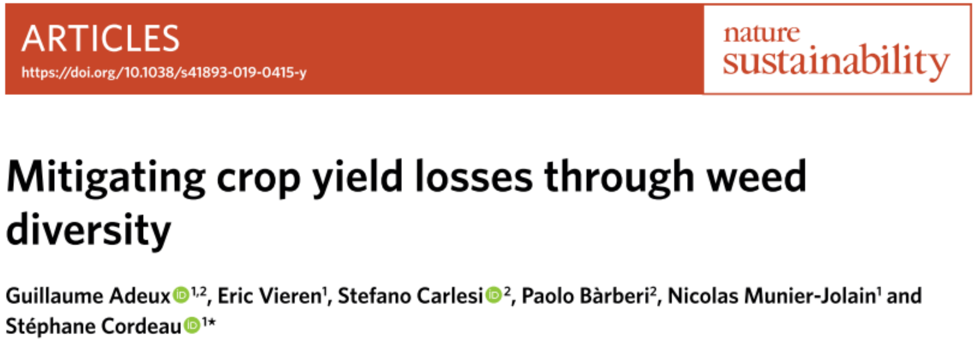
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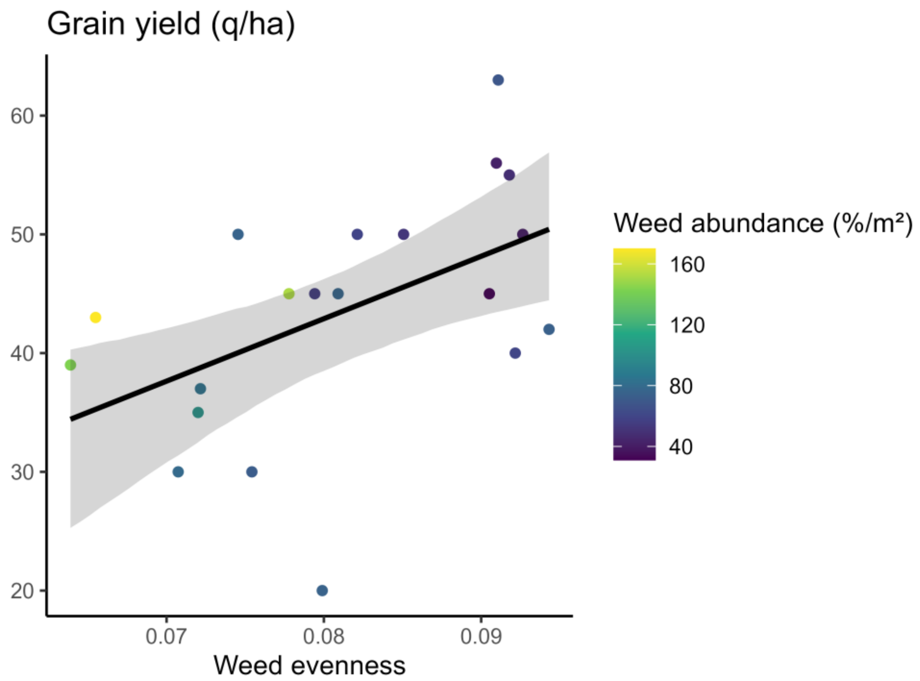
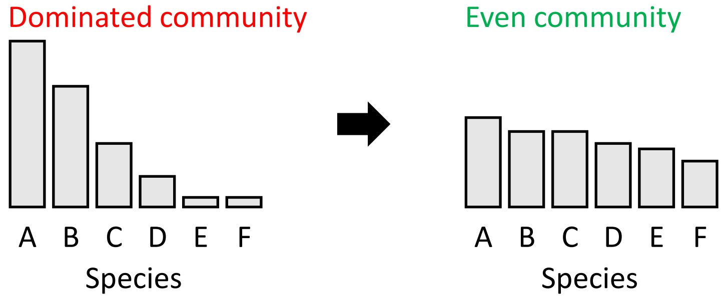
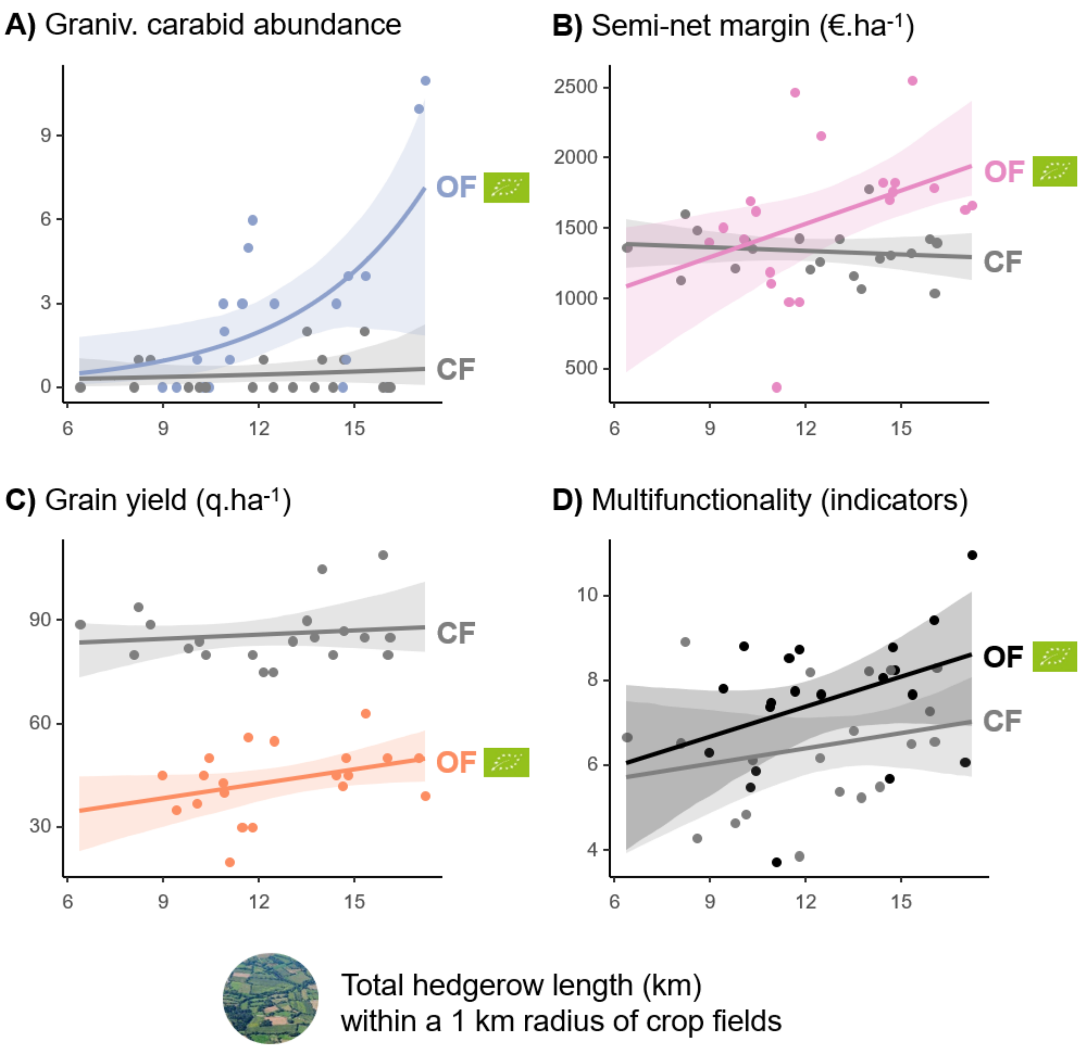




Combining organic farming and hedgerows is possible/preferable



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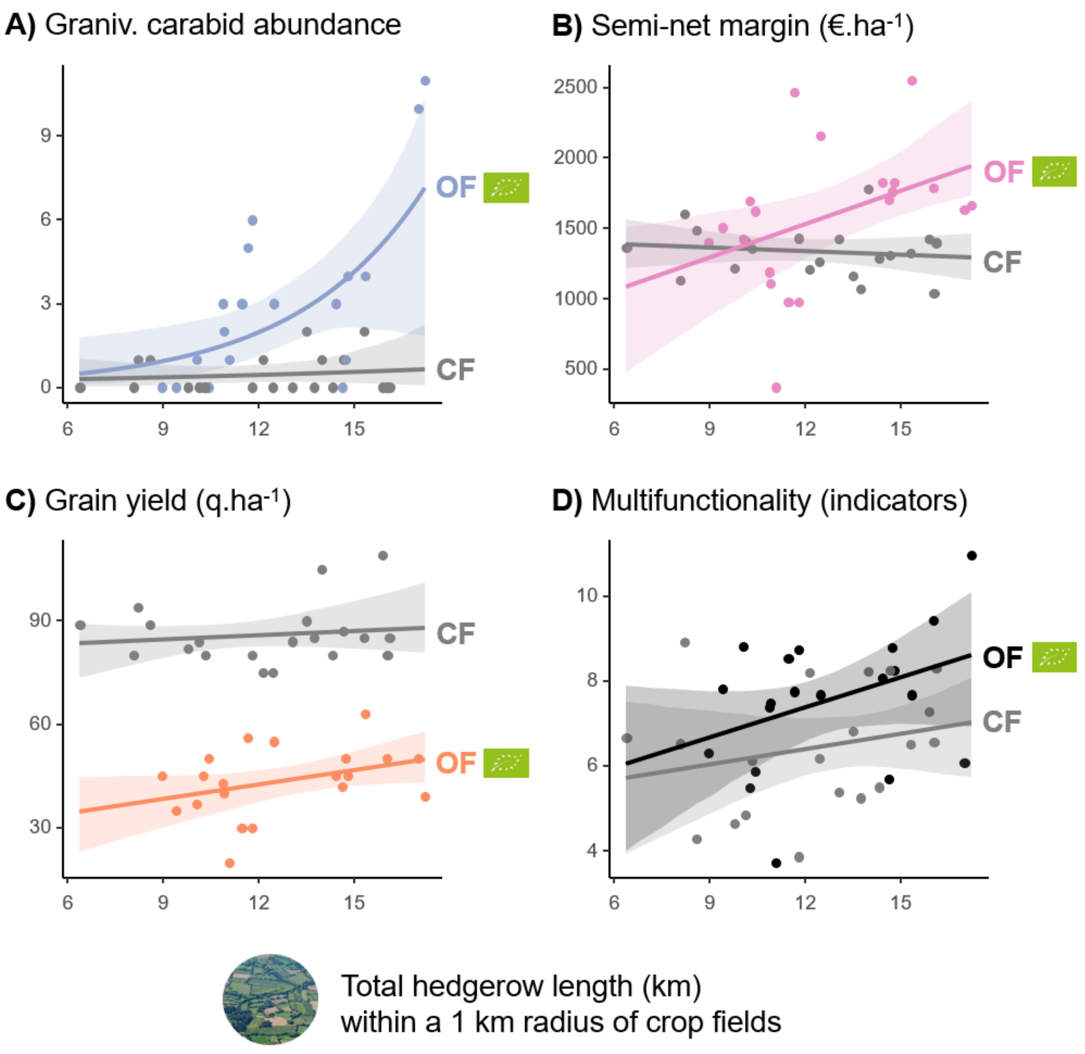

INTERPRETATIONS

- Hedgerows = overwintering habitats, and organic farming = trophic resources (weeds) for granivorous carabids *(Boinot et al. 2020; Madin et al. 2023)*

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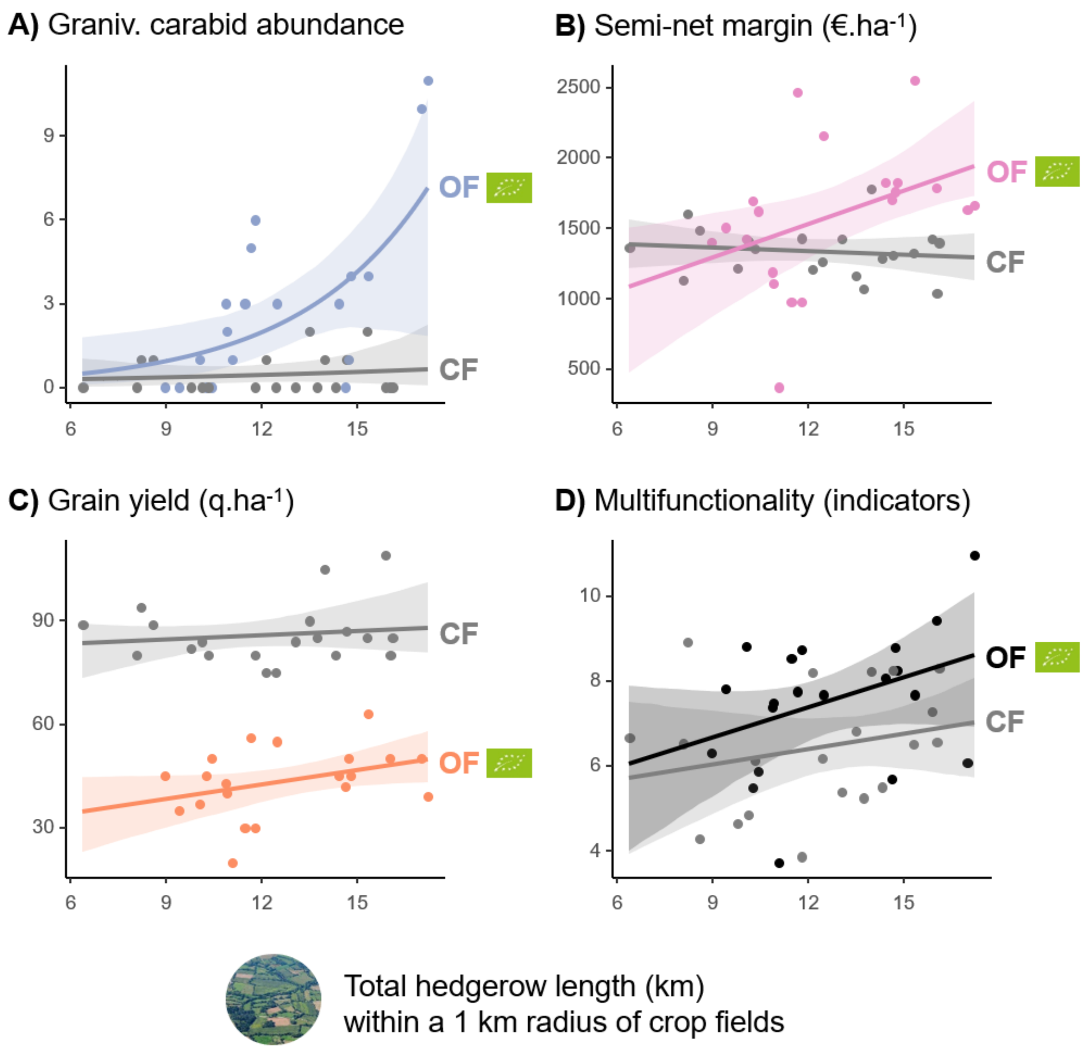
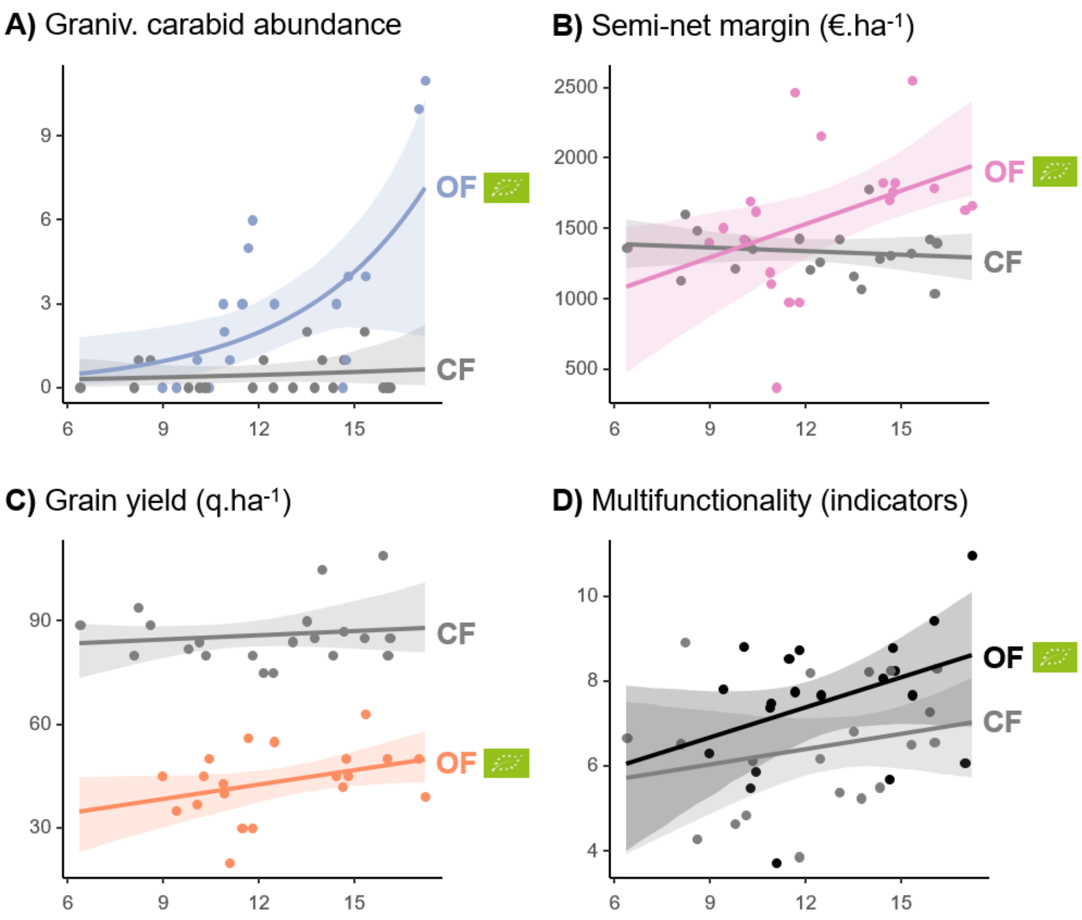


INTERPRETATIONS

- Hedgerows = overwintering habitats, and organic farming = trophic resources (weeds) for granivorous carabids *(Boinot et al. 2020; Madin et al. 2023)*

- Increase in yields and semi-net margin owing to ecological intensification ? (farming practices were constant along the hedgerow gradient) *(Abson et al. 2013; Dainese et al. 2019)*

Combining organic farming and hedgerows is possible/preferable



Total hedgerow length (km)
within a 1 km radius of crop fields

INTERPRETATIONS

- Hedgerows = overwintering habitats, and organic farming = trophic resources (weeds) for granivorous carabids *(Boinot et al. 2020; Madin et al. 2023)*
- Increase in yields and semi-net margin owing to ecological intensification ? (farming practices were constant along the hedgerow gradient) *(Abson et al. 2013; Dainese et al. 2019)*

→ Hedgerows are not sources of weeds and do not decrease yields *(Boinot et al. 2019; Boinot et al. 2022)*

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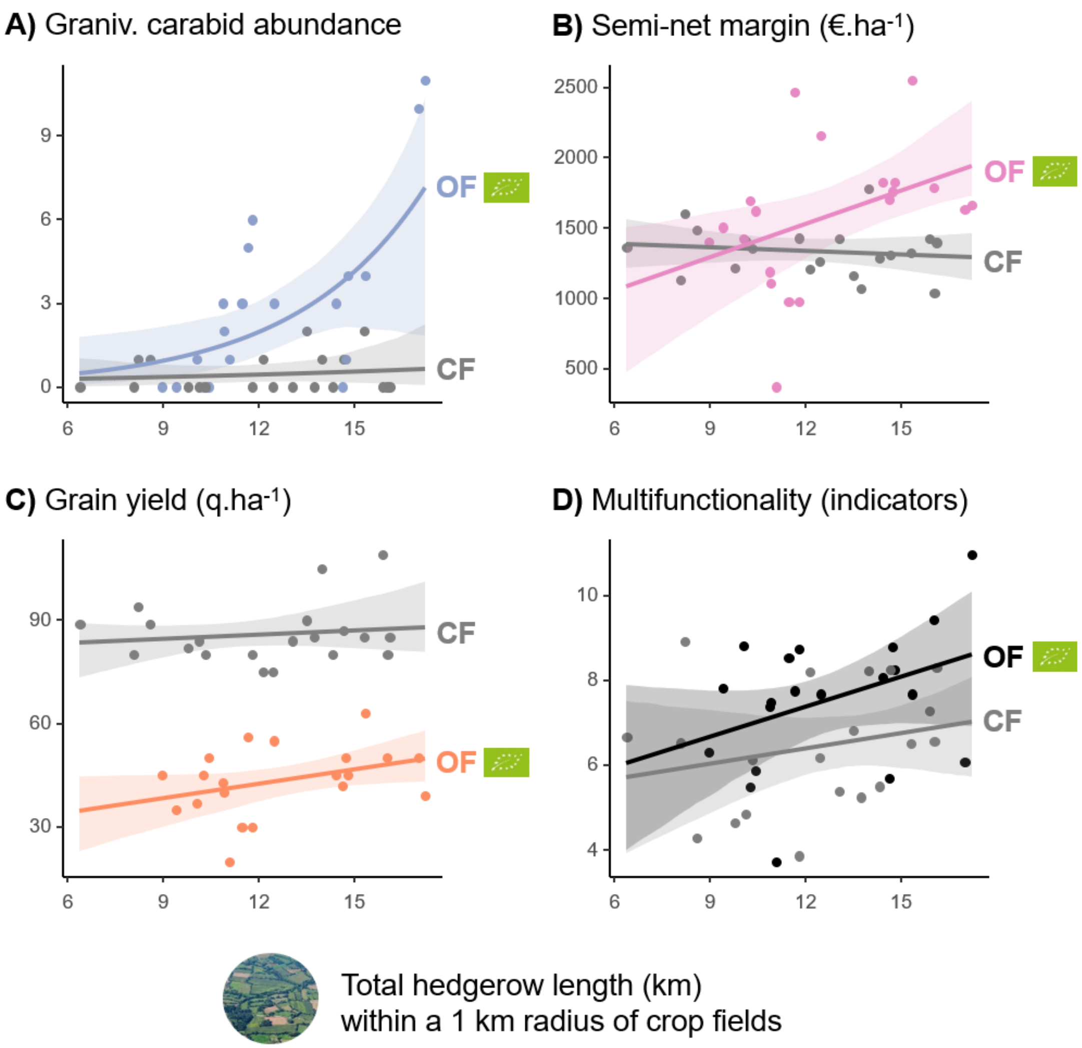

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→ Evidence of antagonistic effects: landscape studies should go beyond the context of conventional farming, which is not conducive to ecological intensification

Conclusion and future research

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- **Yields are one aspect of food security → reducing poverty/inequalities, food waste and malnutrition, and increasing stability of agricultural production** ***(Holt-Giménez et al. 2012; Benton & Bailey 2019; Pe'er et al. 2023)***

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→ Hedgerow landscapes may promote the stability of agroecosystem functioning (including production) by favouring biodiversity, providing refugia, and buffering extreme events, which require longer-term observations ***(Garibaldi et al. 2011; Abson et al. 2013; Redhead et al. 2020; Nelson et al. 2022)***

Thank you for your attention

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Field data collection

	Soil parameters and enzyme activities	Soil micro-organisms	Earthworms	Weeds	Crop disease severity	Aphids and mummies	Carabids, spiders and staphylinids
Sampling date (2019)	April–May	May	April	June–July	March–May	May–June	May
Number of sessions	1	1	1	1	2	2	1
Sample type	Soil auger	Bulk soil sample	Quadrat	Quadrat	Plant leaf	Plant individual	Pitfall trap (four days)
Dimension of samples	5 cm Ø	5 × 10 cm	40 × 40 cm	1 × 1 m	_	_	9.5 cm Ø
Sampling effort per field and per sessions	5	6	3	10	12–20 plant individual and 3 leaves / individual	25	2
Sampling design	Four corners + center	Distance gradient	Distance gradient	Distance gradient + center	Distance gradient	Random	Center
Distance from nearest field margin (m)	5 (min)	10-20-30	15-30-45	10-20-30-50	5-15-25-35	10-50	50
Minimal distance between samples (m)	>50	10	20	10	10	5	20
Soil depth (cm)	0-20	0-10					

OIKOS

Forum

Understandable multifunctionality measures using Hill numbers

Jarrett E. K. Byrnes[1], Fabian Roger[2,4] and Robert Bagchi[3]

entropies and species richness (Jost 2006) and more. All can be expressed as generalized entropies that can be converted to an effective number of species of 'order' q which specifies the weighting of proportional abundances. The general formula for the diversity of order q for S species is the following:

$$^{q}D = \left(\sum_{i=1}^{S} p_i^q\right)^{1/(1-q)} \tag{1}$$

Here, p_i is the relative abundance of the ith species and q is the weight given to the species' relative abundances. Species richness, the effective number of species based on Shannon entropy, the effective number of species based on the Simpson index, and the Berger–Parker dominance index are all effective numbers of species of order $q=0$, 1, 2 and ∞, respectively. (Note that the formula is undefined for $q=1$, but its

To define the effective number of functions, we begin with a set of measurements on k functions (Table 1) that have been standardized to a common scale (i.e. between 0 and 1 where 0 means no function and 1 means maximum level of function). Let F_i, $i \in 1, 2, \ldots K$ show the level of function for function i (Table 1). The relative proportion a function contributes to the whole is defined as

$$p_i = \frac{F_i}{\sum F_i} \tag{2}$$

We can now substitute the relative proportion into the formula for the effective number of types given in Eq. 1

$$^{q}N = \left(\sum_{i=1}^{K} p_i^q\right)^{1/(1-q)} \tag{3}$$

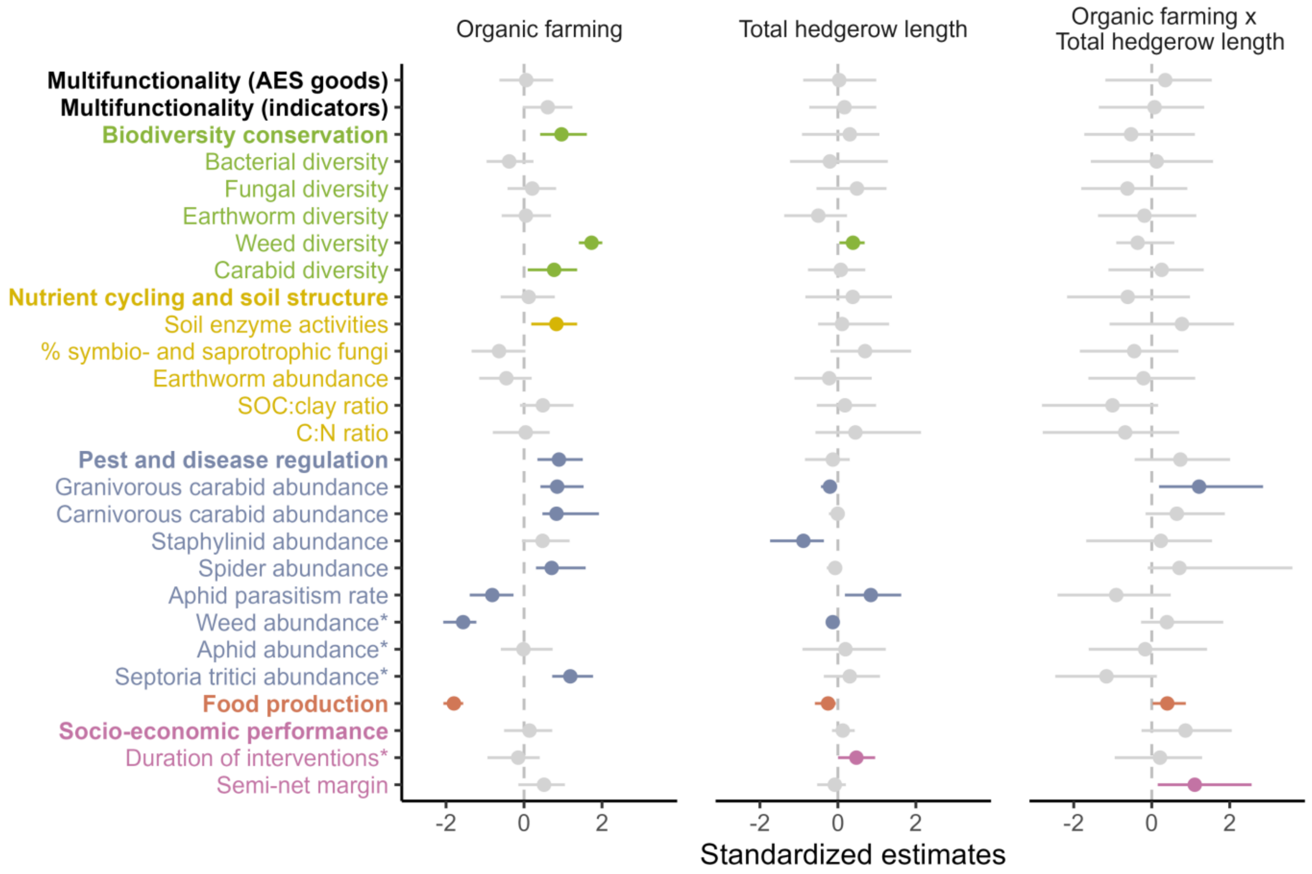
where ^{q}N is the effective number of functions for some order q (Table 1). The effective number of functions here translates to the equivalent number of functions were all functions provided at the same level. Effective number of functions tells us nothing about total level of functioning. Average function can be low or high (see below and Fig. 1). Rather, ^{q}N tells us how many functions we would see in an equivalent system where all functions were performing at the same level. This effective number of functions can actually drop. To achieve the translation to a metric of multifunctionality, we need to take into account the level at which the functions are performed: the arithmetic mean of the function values standardized to a common scale, which we define as A (Table 1). As we are using standardized values as before, A will range from 0 to 1.

We can then calculate effective multifunctionality of order q (Table 1) as the product of both terms. We remind readers that A is an expected value – it provides information on the expected level of one function sampled at random from the cluster of functions. Scaling A by ^{q}N gives a metric of multifunction summed across the suite of functions – the cumulative performance of the system were it composed of functions all performing at equal levels

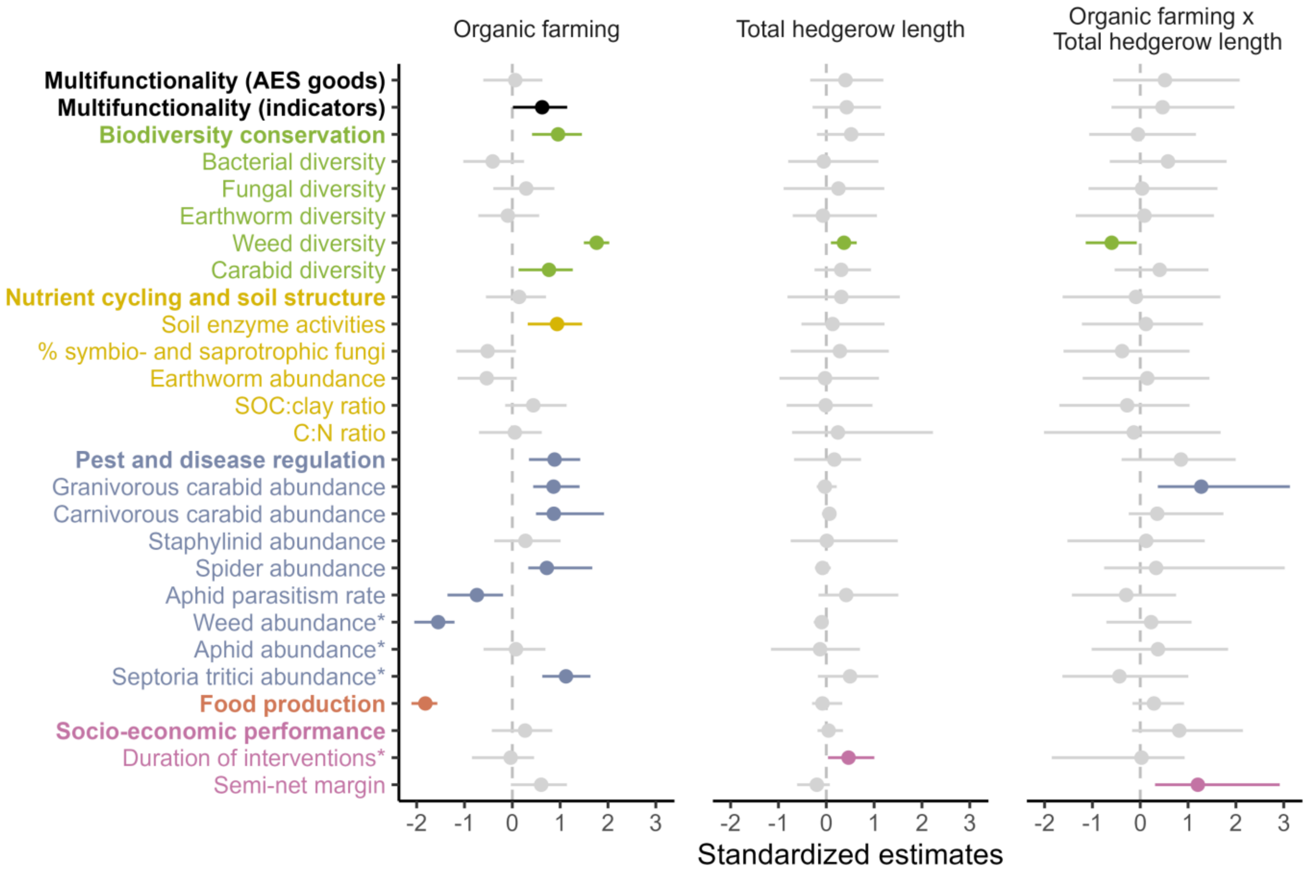
$$^{q}M_{ef} = {}^{q}NA \tag{4}$$

This metric, where $^{q}M_{ef}$ is effective multifunctionality for order q, will have a maximum value of K, the total number of functions measured in the system, as maximum performance is all functions performing at a standardized level of 1. Alternatively, we can standardize by the total number of

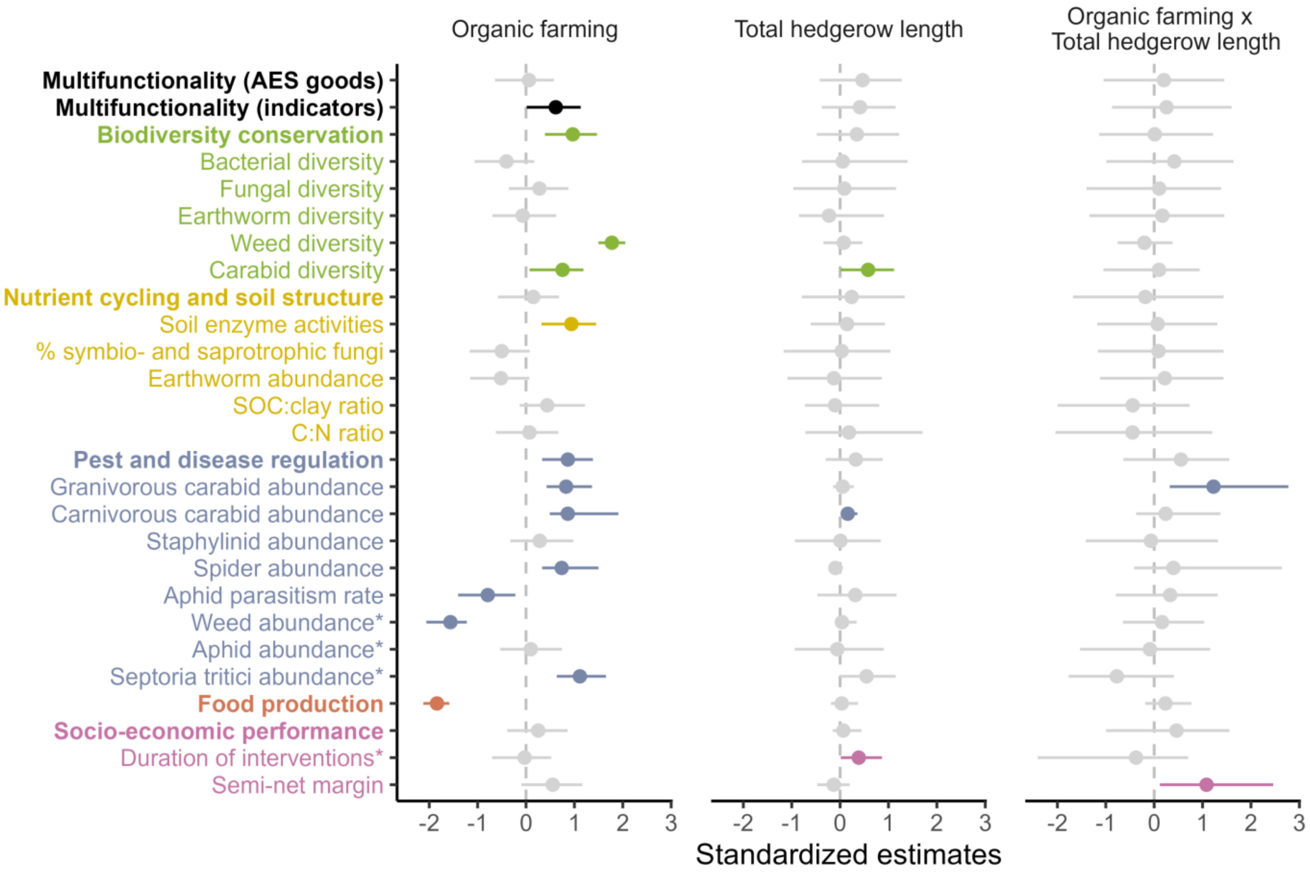
Buffer radius = 250 m



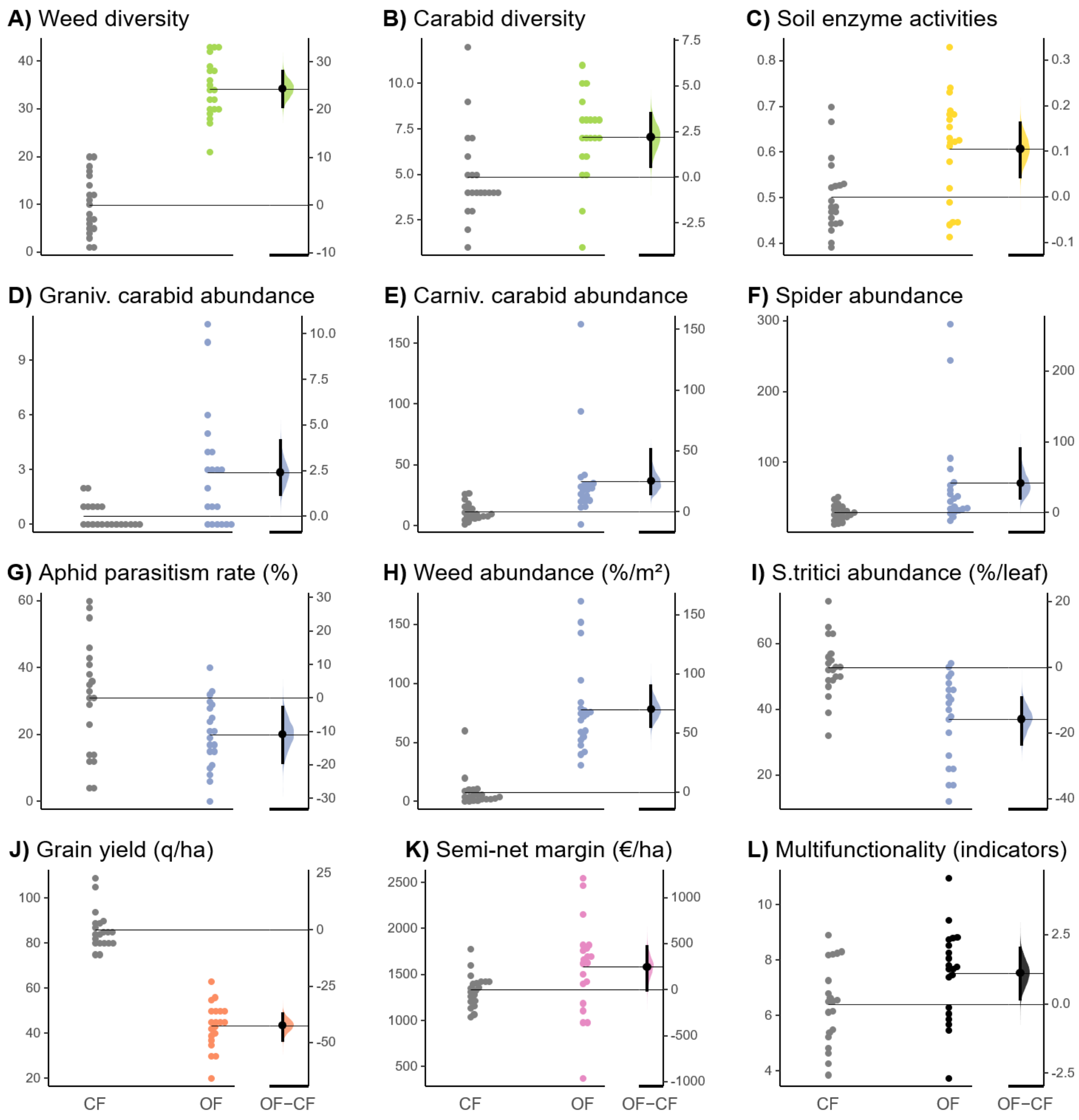
Buffer radius = 500 m



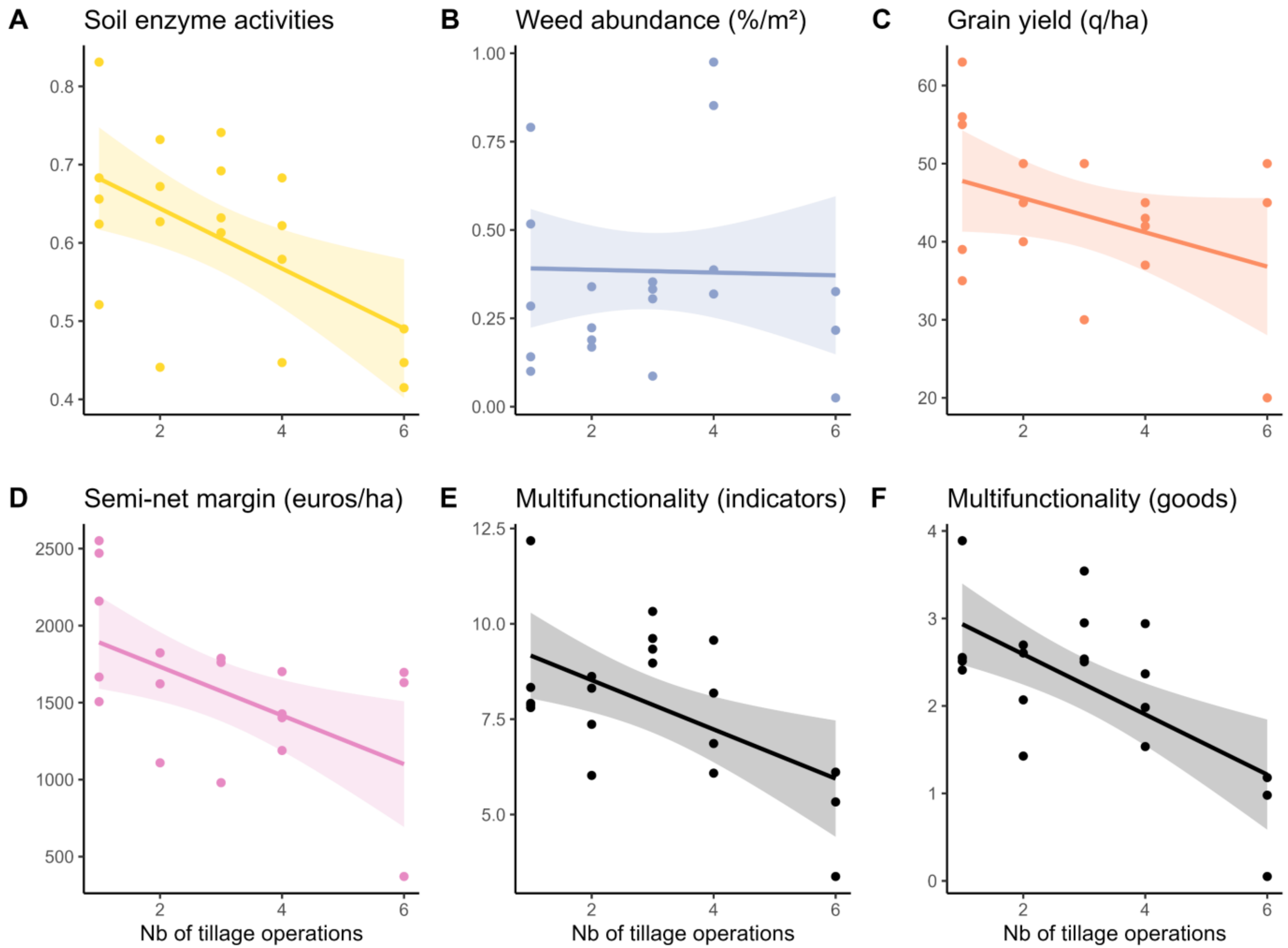
Buffer radius = 750 m



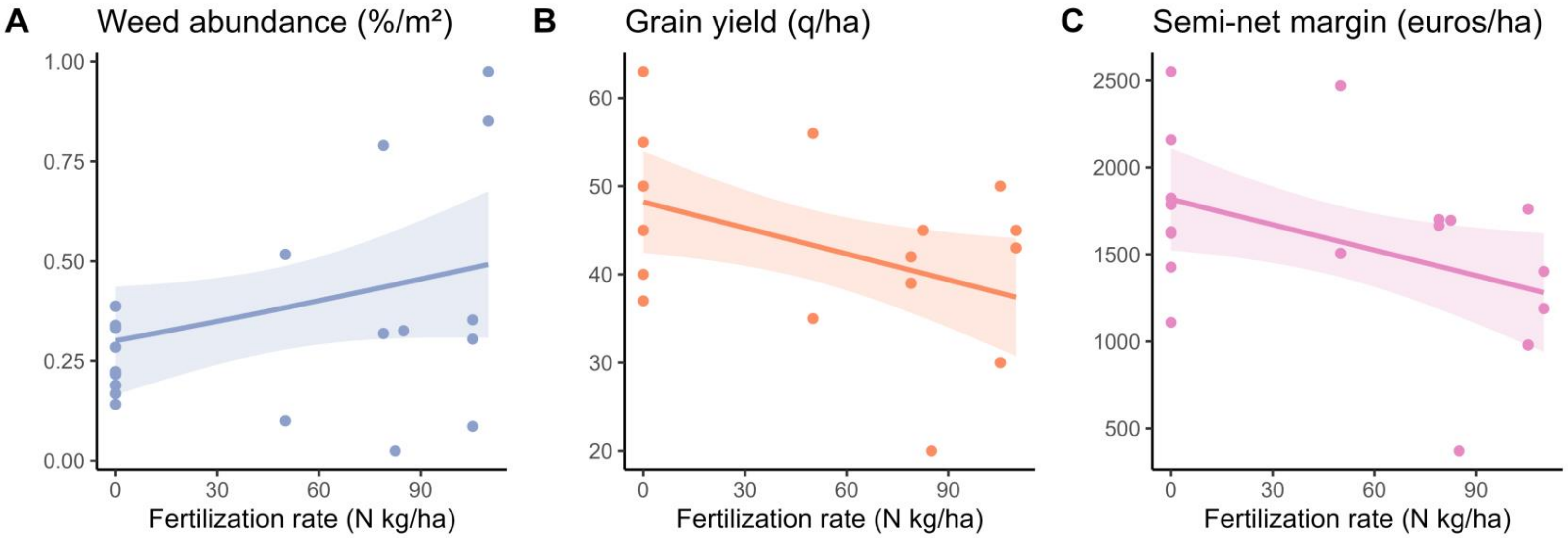
Indicator values between conventional (CF) and organic (OF) systems



Tillage in organic farming systems

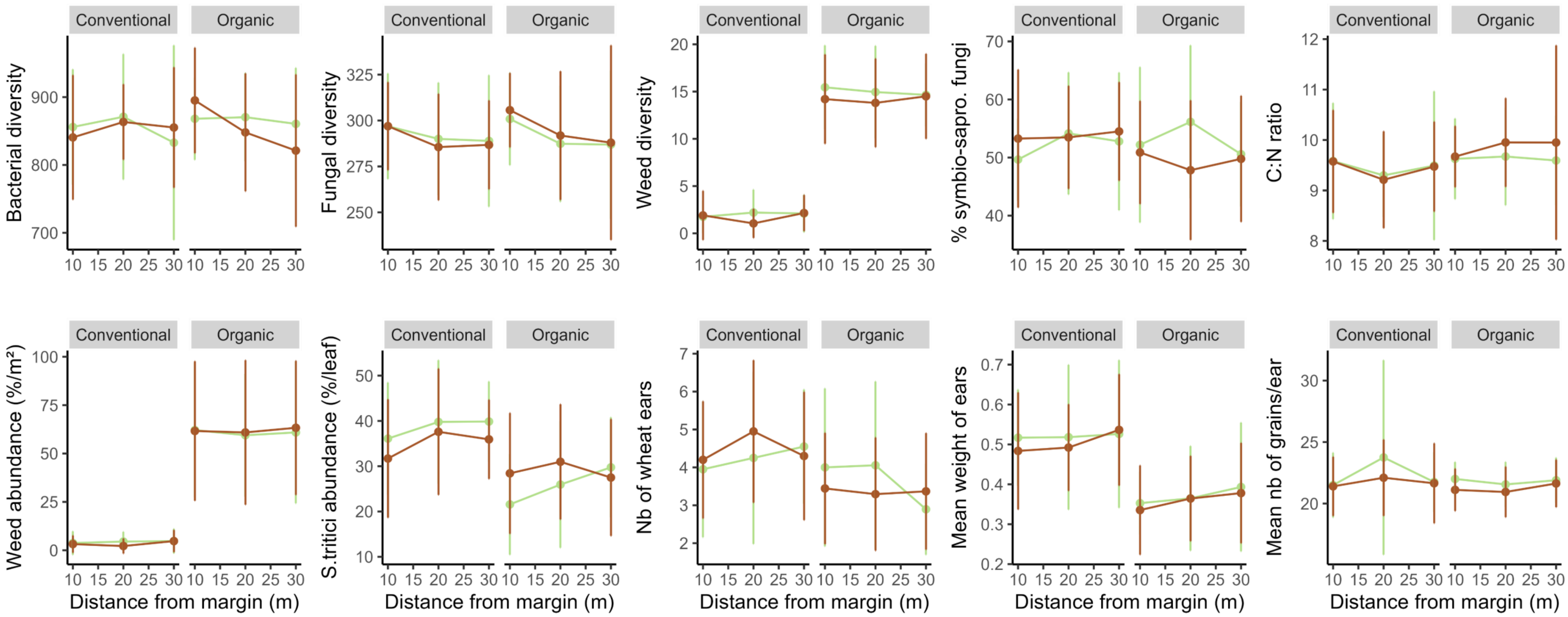


Fertilization in organic farming systems

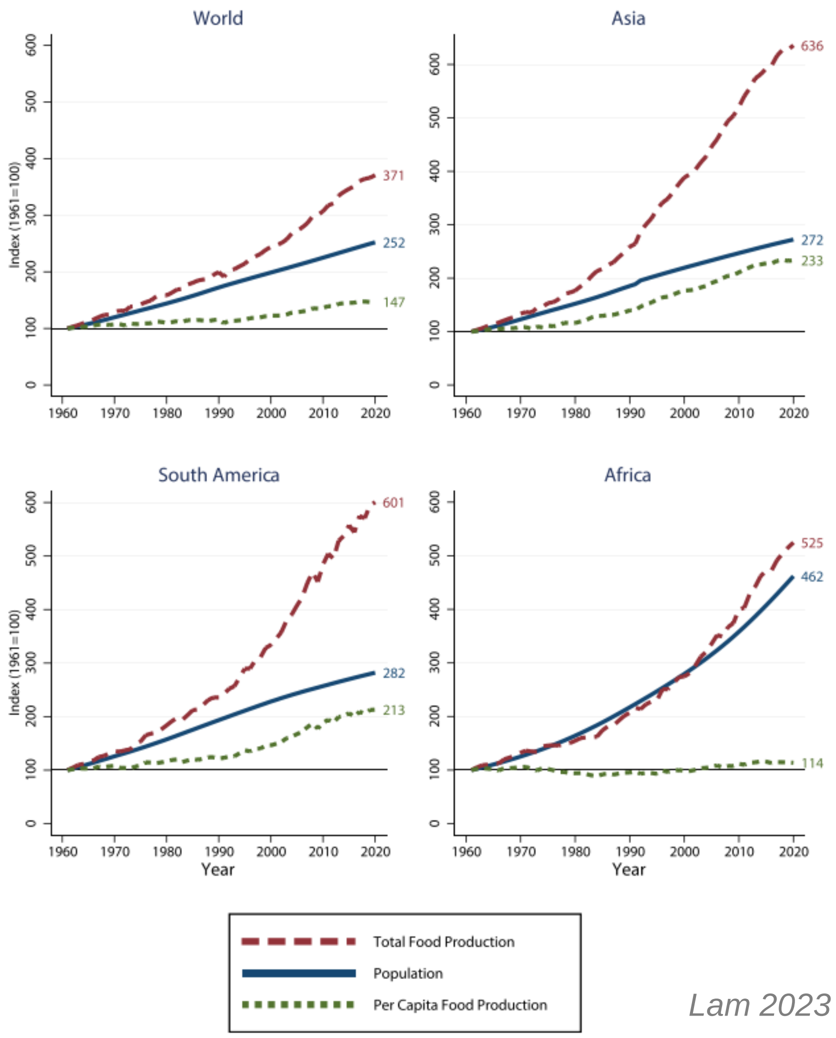


Adjacent margin type

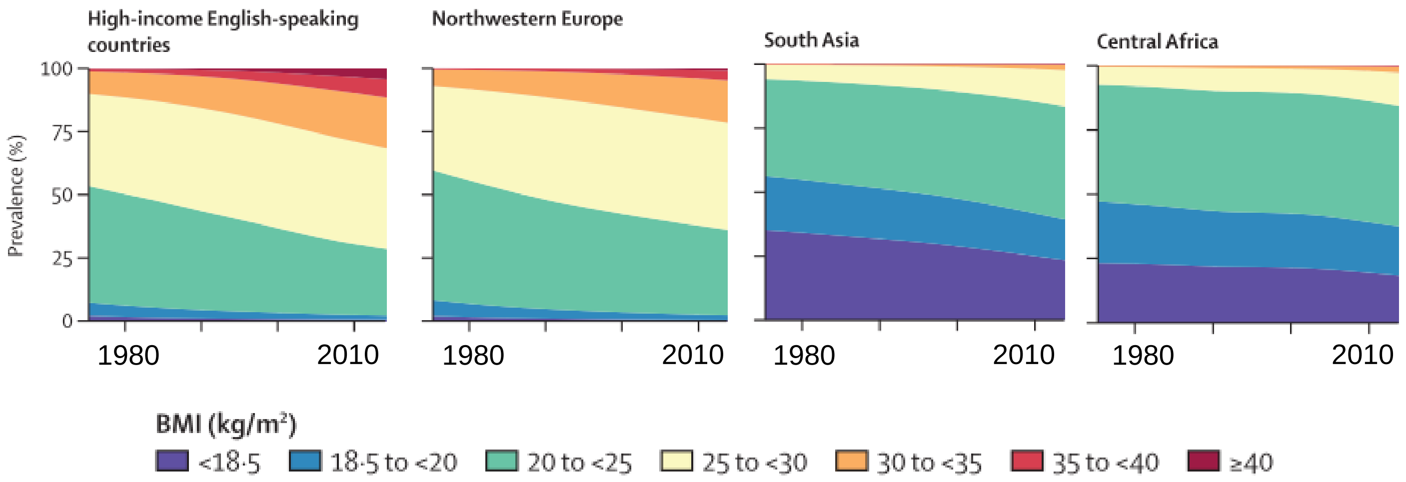
- Herbaceous strip
- Hedgerow



Food production and waste, unhealthy diets



Lam 2023



- **828 million** people were affected by hunger in 2021
- **3.1 billion** people do not have access to a healthy diet (more obese than underweight people today)
- **14%** of world food is lost before being harvested or reaching shops
- **17%** are further wasted by consumers (58 million tonnes / year)
- **1.26 billion** people could be fed with this lost/wasted food (1.05 billion tonnes / year)

NCD-RisC 2016
FAO 2022
European Commission 2024