Trends in
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Opinion

Beyond organic farming – harnessing biodiversity-friendly landscapes

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We challenge the widespread appraisal that organic farming is the fundamental alternative to conventional farming for harnessing biodiversity in agricultural landscapes. Certification of organic production is largely restricted to banning synthetic agrochemicals, resulting in limited benefits for biodiversity but high yield losses despite ongoing intensification and specialisation. In contrast, successful agricultural measures to enhance biodiversity include diversifying cropland and reducing field size, which can multiply biodiversity while sustaining high yields in both conventional and organic systems. Achieving a landscape-level mosaic of natural habitat patches and fine-grained cropland diversification in both conventional and organic agriculture is key for promoting large-scale biodiversity. This needs to be urgently acknowledged by policy makers for an agricultural paradigm shift.

Highlights

Biodiversity continues to decline rapidly, despite decades of repeated national and international policy efforts. Agricultural intensification is a major driver of biodiversity losses, while conversion to organic farming has been suggested as a key technique to halt or reverse this trend.

In contrast to this widespread view, certified organic agriculture raises local richness of widespread species by just a third when compared to conventional farming. This is achieved through waiving synthetic agrochemicals, but leads to considerable yield losses, requiring the conversion of more land to agriculture to obtain similar yields.

Diversifying cropland and reducing field size on a landscape level can multiply biodiversity in both organic and conventional agriculture without reducing cropland productivity.

Complementing such increases in cropland heterogeneity with at least 20% seminatural habitat per landscape should be a key recommendation in current biodiversity frameworks.

Adjusting expectations from organic farming

Biodiversity continues to decline, despite the repeated implementation of international conservation conventions, such as the Convention on Biological Diversity (1992), the UN Decade of Biodiversity (2011–2020), and many other biodiversity conservation schemes, which had little success [1,2]. Agriculture is considered the main cause of global biodiversity decline [3–5], but conservation objectives still collide with FAO calls for higher crop production to feed the world [6].

The current model of agricultural intensification, based on agrochemical inputs, large monocultures and landscape homogenisation, has successfully increased yields, but is associated with severe losses of biodiversity and ecosystem services, even in neighbouring nature reserves [3,5–7]. Current trends can only be reversed by a concerted effort to fundamentally redesign farming systems and agricultural landscapes [8–10]; that is, a paradigm shift in agriculture. Certified organic farming, that is, banning synthetic agrochemicals [11] to achieve sustainability in agricultural systems in general and biodiversity conservation in particular, is often claimed to be the fundamental alternative to conventional farming [12–14]. However, the contribution of certified organic agriculture to stop the losses in biodiversity appears to be exaggerated in the public perception [15,16]. In fact, switching from conventional to organic practices increases local species richness by just a third [17], but leads to considerable yield losses, so that more land is needed to produce the same amount of food [11,18]. Surprisingly, a wealth of biodiversity-friendly measures that can enhance biodiversity and can be implemented in conventional agriculture, have so far been poorly adopted in current agricultural systems [19–23].

Here, we challenge the widespread appraisal that organic farming is the fundamental alternative to conventional farming for promoting or restoring biodiversity in agricultural landscapes. After considering measures essential for biodiversity-friendly farming, we propose more effective solutions towards biodiversity friendly landscapes and ways to integrate local and landscape scales in existing organic and conventional farming systems as well as in agricultural policies.

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Benefits and limitations of organic farming for biodiversity conservation

Certified organic farming can enhance biodiversity when compared to conventional farming. On average, organic farming across the world's crops increases local species richness by ~34% and abundance by ~50% [17,24,25], with plants and bees benefitting most and other arthropods and birds to a smaller degree [11]. Benefits also vary with crop type and landscape context [17]. Organic farming strives for environmental benefits, sustaining soil fertility and biodiversity, and prohibits synthetic fertilisers, synthetic pesticides, and genetically modified organisms [11,12,26]. In particular, the replacement of herbicides by mechanical weeding is important for biodiversity conservation, because higher weed cover benefits many organisms [27–30]. Practices such as crop diversification, small fields, green manure, low fertiliser input, and restoration of natural landscape elements are often recommended by organic food organisations and can be more prevalent on organic than conventional farms [31,32], but they are not formal part of certification regulations [33]. Mainstreaming of organic agriculture in the public, pushed by green policies and NGO activities, continues to play an important role in its success, promoting empathy for and trust in organic certification schemes. Lastly, organic products are more profitable for farmers, while consumers, not governments, pay for most of the premium prices [11,25,30,34].

However, there are also important limitations to the biodiversity benefits of organic farming, resulting from reduced yields, misconceptions about pesticide use, taxon-specific benefits, and commercial intensification of production. While reducing food waste and meat consumption are important for global food security [6,18], lower crop yields and the additional land needed for similar yields are major obstacles for organic farming to benefit biodiversity conservation [35]. When biodiversity benefits are measured per unit of land necessary for a defined agricultural output or yield (e.g., number of kilograms of wheat produced) and not simply per unit of agricultural land (e.g., a hectare of wheat), the biodiversity benefits of organic farming can disappear [10,18,36]. Globally and across all major crops, organic farming yields are lower by 19–25% [18]. Vegetables and cereals show the highest yield gaps [37], with up to 50% yield decrease in wheat [30,35]; however, yields of fruits and oilseed crops are not lower [37].

Moreover, it is a myth that organic farms principally waive pesticides. Pesticides are allowed under organic labels as long as they are derived from natural substances rather than synthetic ones [11]. Widespread insecticides used in organic farming include natural pyrethrin, derived from chrysanthemum, and azadirachtin from the Asian neem tree. Copper sulfate is often applied to cope with fungal and bacterial diseases, for example, in vineyards, orchards, and vegetables [38], but is persistent and accumulates in soils [39]. Natural pesticides can do as much damage as synthetic pesticides [40]. While the vast majority of organic arable crops are rarely treated with pesticides, potatoes, vegetables, hops, grapes, and other fruits are regularly and heavily treated with natural pesticides. For instance, spraying in organic grapes or apples has been shown to be just 20% less but can also be more than in conventional fields [38,39]. Overall, this suggests that smart application strategies for pesticide use (e.g., Integrated Pest and Pollinator Management techniques) are needed regardless of organic or conventional agricultural systems [14,41,42]. Similarly, harmful overfertilisation occurs not only with mineral fertilisers, but also with manure [43].

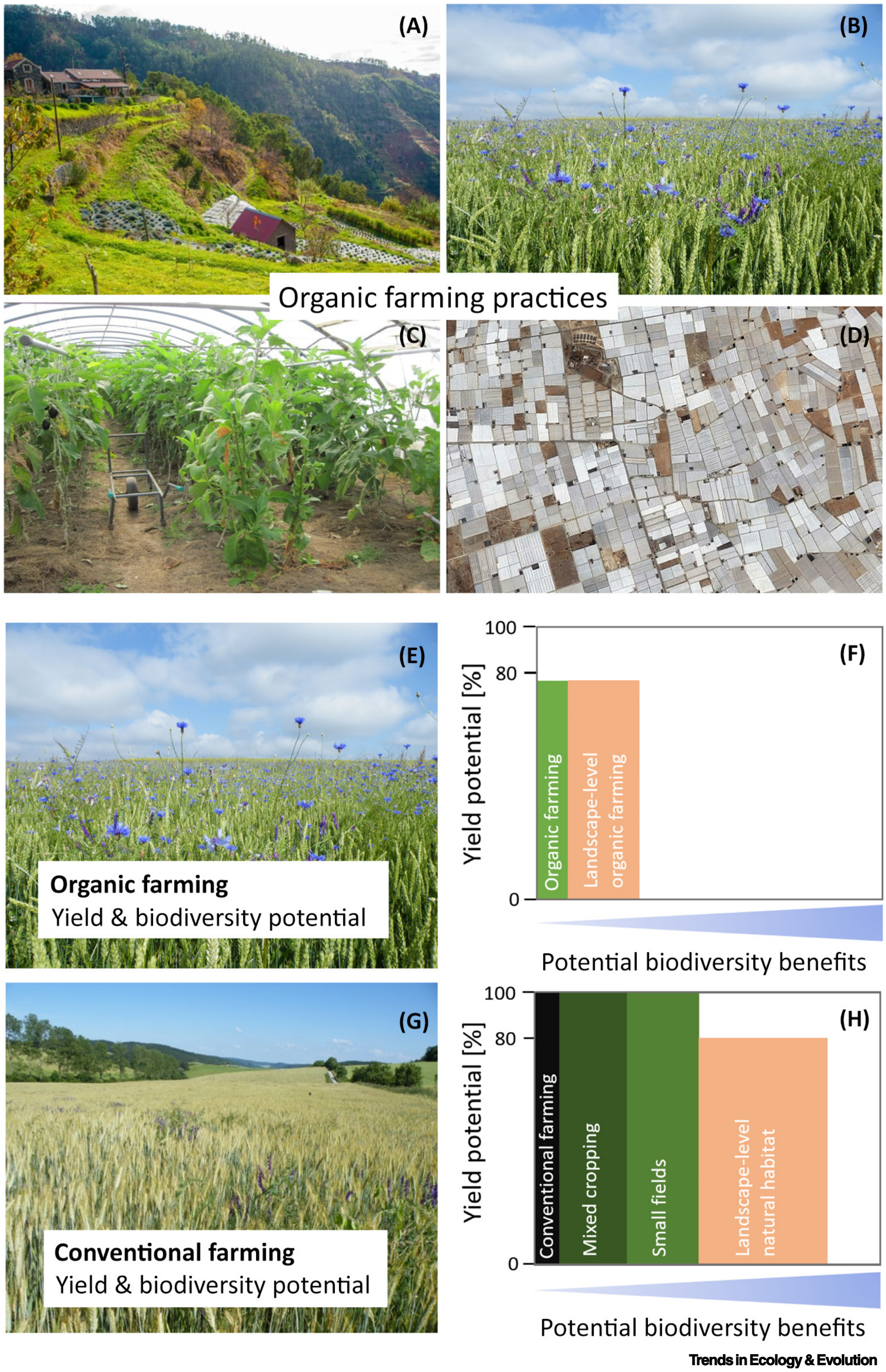
Importantly, organic farming enhances only a limited spectrum of species [5,44]. In particular, noncrop plants benefit due to missing herbicides, whereas more mobile, landscape-dependent insect populations benefit less [31]. Furthermore, reduced applications of agrochemicals enhance common insect species associated with agriculture, but not the less common species associated with a great diversity of seminatural habitats. These seminatural habitats include hedges, herbaceous field boundaries, and traditional, uneconomic agroecosystems such as calcareous grasslands and orchard meadows [21,45]. In fact, a meta-analysis of agrienvironment schemes found that off-field measures, such as field margins and hedgerows, are more than twice as effective in promoting biodiversity as in-field measures such as organic management [46]. For example, higher farmland habitat diversity, but not conversion to organic farming, increases butterfly diversity on farms by ~50% [45]. Increasing hedge length per field by 250 m raises bird diversity from one to 12 species, whereas conversion from conventional to organic farming increased species richness by only 50% [21].

Lastly, current organic production is increasingly intensified, specialised, and often far away from the idealism and enthusiasm of the original organic movement (Figure 1). In contrast to the small and diversified family farms that characterised the beginning of the organic movement, modern organic arable fields can be huge monocultures, resembling conventional fields. Organic vegetables often come from sterile greenhouse blocks or large-scale cultures under plastic sheets, covering entire landscapes. The Almeria Province (Spain) is the heart of Europe's intensive agriculture, where >50% of fruits and vegetables are grown under plastic sheets, with the proportion of organic farming increasing over the last decade from 1.4% to 10.3% [47]. Further examples of landscape-damaging practices of organic production include vegetables that are produced in greenhouse blocks, favourably doubling yields by intensification and extending growing seasons, but at high cost for biodiversity [48]. Overall, pesticide use, limited species benefits, and the above intensification suggest that certified organic production is not the silver bullet for current biodiversity conservation and agricultural production.

Local and farm scale biodiversity-friendly land-use practices

Diversifying agricultural systems is key for the restoration of biodiversity and associated ecosystem services, such as pollination, and biological pest and weed control [5,49,50] (Table 1 and Table 2). Agricultural land, in particular in Europe and North America, is increasingly shaped by large monocultures and short crop rotations to simplify production techniques and to specialise on the best-selling products. Diverse crop rotations are increasingly missing or dominated by just one crop (e.g., wheat after wheat or maize after maize), or only up to three crop species (e.g., standard conventional crop sequences with wheat, barley, and oilseed rape [51,52]). These simplified crop rotations deplete soils, and promote pest infestations, resistance through repeated pesticide applications, and the risk of resource bottlenecks for pollinators and biocontrol agents [53]; all of which also increase the risk of yield declines [52]. In contrast, resource continuity provided by a mixed pattern of crops, alone or combined with land-sharing practices, such as wildflower strips, effectively increases the stability of ecosystem services, such as pollination and biological pest control [53–55]. Globally, crop rotations are only 15% longer in organic than conventional farming (4.5 instead of 3.8 years). Still, organic farms have on average 48% higher crop species richness [56]. Diversification of organic farming by multicropping and diversified crop rotations may reduce the yield gap to just 8–9% [57]. However, crop rotations could be longer, for example, over at least a 7-year period [26], but there is little uptake in both organic and conventional agriculture [58]. Instead, the current trend in organic farming is, similar to conventional agriculture, to specialise and intensify [48,59].

Hence, measures to enhance biodiversity include temporal and spatial crop diversification, as reported from both temperate and tropical regions [60–62], but also cover crops or green manure, agroforestry, that is, combining trees and crops [63,64], or crop–livestock systems [65] and other biodiversity-friendly measures [49] (Table 1). Seminatural habitats adjacent to croplands may include linear or patchy landscape elements, such as hedges and woody or herbaceous patches [23,49], facilitate spillover to small fields and enhance on-farm biodiversity [66,67]. However, targeted on-farm measures to restore biodiversity are not mandatory in any organic certification scheme [33].



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Landscape-scale diversification for biodiversity

We emphasise the key role of landscape-level species pools and suggest two major biodiversity-friendly measures at the landscape scale that are missing in organic certification [33] and agrienvironmental EU policies. Landscape changes often provide much larger biodiversity benefits than the incentivised changes of local management [30,68]. First, we provide evidence for the need to restore seminatural habitats in simplified landscapes. Second, we focus on augmenting landscape heterogeneity through small and diversified crop fields.

Restoring simplified landscapes with seminatural habitat

Local field or farm biodiversity is determined by the available pool of populations and species in the surrounding landscapes. In structurally poor, simplified landscapes, biodiversity is reduced so that only few species can be locally expected – independent of the type of local management (Table 1). For example, current dramatic insect declines in German grasslands (67% of the biomass, 34% of the species within 10 years, 2008–2017) were mainly observed in simplified landscapes dominated by annual crops, irrespective of the local intensification level [4]. This spatial-scale mismatch, that is, the usual focus on local management instead of managing landscapes and their species pools, needs to be addressed for successfully redesigning organic certification schemes [33] and policy instruments for biodiversity conservation [69].

Landscape complexity, that is, the amount of seminatural habitats in the agricultural landscape, is well known to increase species pools, linking resources and populations of cropland and natural area [1,67,70], although effects are variable and taxon specific [41,71]. For example, wild bee richness in standardised field margin strips doubles when landscape-wide habitat increases from 10% to 40% [72] (Figure 2B and Table 1). Complex landscapes also enhance local availability of key predators and parasitoids for pest control [73–75], including a tenfold increase in parasitism of the pollen beetle, halving oilseed rape damage [76]. Interestingly, 29% of the local species richness in protected calcareous grasslands, which are among the most species rich habitats in Central Europe, is lost when the percentage of arable land in the surrounding landscape increases from 10% to 80% (Figure 2A,C) [7]. Complex landscapes support a broader range of resources and microclimates, thereby counteracting biotic homogenisation [70] and promoting stability of population dynamics [77].

There is evidence that a 20% threshold level of seminatural habitat in agricultural landscapes is key to biodiversity maintenance [76,78–80]. According to percolation theory [81], habitat loss below 20% causes disproportionally high losses in patch connectivity. This can disrupt exchange of organisms across the landscape, and therefore, their survival probability. Connectivity loss may be also counterbalanced by reduced field sizes per landscape as well as crop diversification, but quantification

Figure 1. Examples of organic farming practices (A–D) and a conceptual figure pointing to yield versus biodiversity potentials of certified organic (E, F) and diversified conventional farming (G, H). Photos illustrating the multifaceted forms of organic agriculture: (A) traditional small-scale farming (organic farm in Madeira, photo licensed under CC BY-NC-ND 2.0); (B) large-scale cereal monocultures (winter wheat, photo: Silvia Fusaro); (C) greenhouse production (biological vegetable production in Austria; photo by Mario Sedlak, licensed under CC BY 3.0); and (D) fields covered by plastic foil across entire landscapes (in Almeria, Spain) [105,106]. Yield and biodiversity potentials in certified organic versus diversified conventional farming (E–H). In this scenario, the benefits of certified organic farming (F) consider only the mandatory regulations for organic certification (largely waiving synthetic agrochemicals) and do not consider any potential diversification measures. In contrast, we consider diversification measures for conventional farming to illustrate their potential for enhancing biodiversity (H). However, diversification practices may also greatly benefit organic farming [57,107]. Yield is reduced by 22% (19–25%) in organic farming, based on three meta-analyses [18], while yield in conventional farming may be also reduced by 22% when setting aside 22% seminatural habitat [78,79]. In this scenario, conventional farming with mixed cropping and small fields keeps the high (100%) yield level, but with higher biodiversity benefits than certified organic farming alone. Landscape-wide expansion of organic farming may at least double biodiversity benefits [29], but landscape-wide diversification of conventional cropland (mixed cropping, small fields) and 22% restoration of seminatural habitat leads to altogether much higher biodiversity benefits [20,84]. (Photos E, G: Silvia Fusaro; study fields of Batary *et al*. [30]).

Table 1. Biodiversity benefits through increasing heterogeneity at local and landscape scales, illustrated by meta-analyses and syntheses showing quantified estimates

Measures	Quantified findings	Refs
Local and farm scale		
Off-field vs in-field measures	Measures at off-field areas, such as field margins and hedgerows, are roughly twice as effective at enhancing species richness as those aimed at in-field, such as organic farming.	Three global meta-analyses [46]
Crop diversity	Biocontrol effect is 36% higher in organic polycultures compared to organic monocultures	Global meta-analysis [98]
Crop diversity	Diversification practices in cropping systems enhances biodiversity by 40%, pollination by 32%, and pest control by 23%, while yield remains on a similar level.	Review of 98 meta-analyses [50]
Flower strips	Number of sown plant species in flower strips is linearly positively correlated with species richness of pollinators, with around tenfold increased richness compared to control strips	Meta-analysis of European studies [99]
Nitrogen input	Extensively managed fields (<30 kg N/ha/year) support more than twice the species richness of intensively managed fields (>200 kg N/ha/year)	Synthesis across six EU countries [1,100]
Landscape scale		
Field size	Decrease from 6 to 1 ha per landscape means ~6 times increase in species richness (7 taxa, 435 landscapes, 8 regions), which was as strong as the effect of increasing seminatural cover from 0 to 35%. Reducing field size from 5 to 2.8 ha is as effective as increasing seminatural habitat from 0.5 to 11%.	Synthesis across eight regions (Europe, North America) [20,85]
Field border density	Increasing field border density (m per ha) from 100 to 600 m enhances wild bee abundance fivefold.	Synthesis across four EU countries [84]
Field perimeter	Increasing field perimeter up to 6 km per landscape in conventional (or organic) fields means increasing species richness from 50 to 100 (or 60 to 130) in large-scale, but to 150 (or 210) in small-scale landscapes, i.e., more species in conventional small-scale than in organic large-scale landscapes.	Covering 2 EU regions, 4 taxa [30]
Crop diversity	Increasing the number of crop types sampled can double landscape-level multitrophic diversity, if the amount of seminatural cover exceeds 11%	Synthesis across eight regions (Europe, North America) [20]
Crop diversity	Doubling crop diversity results in ~6 times higher pollinator (but not spider and carabid) diversity if the landscape shares 30% seminatural habitat, and ~4 times more if seminatural habitat is 10%	Synthesis of seven Swedish studies [101]
Crop diversity	High landscape crop diversity leads to 8–33% higher biological aphid control, to tripling of bumblebee densities, and to higher pollen diversity, linked to threefold increase in bumblebee colony weight compared to landscapes with low crop diversity	Three EU studies [88,93,102]
Landscape complexity	Increasing percent seminatural habitat in the landscape up to 40% doubles bee species richness and enhances parasitism of rape pollen beetles tenfold, thereby halving oilseed rape damage	Two EU studies [67,76]
Landscape complexity	Natural enemy diversity is ~50% higher in complex than simple landscapes	Meta-analysis [103]
Landscape complexity	Landscape complexity enhances social bee richness by >4 times, while solitary bee richness by ~50%.	Global synthesis [104]
Landscape complexity	A simplification of the landscape from 2% to 100% of cultivated land reduces the level of aphid control by 46%	Synthesis across Europe [73]

Table 1. (continued)

Measures	Quantified findings	Refs
Landscape complexity	In landscapes with high edge density, 70% of the pollinator species and 44% of the natural enemy species reach highest abundances, while pollination and pest control improve 1.7-fold and 1.4-fold, respectively	Synthesis across Europe [71]
Diversified farming system and organic farming	Diversified farming systems enhance local arthropod richness by 23% (29% in complex, 11% in simple landscapes) and organic farming by 18% (26% in complex, 9% in simple landscapes), benefitting in particular pollinators and predators	Global synthesis [5]

of these effects needs further research. In Europe, maintaining landscape complexity with seminatural habitats needs to consider the traditional, uneconomic agroecosystems that are threatened from agricultural intensification or abandonment, such as orchard meadows and dry grasslands [2,82,83].

Promoting landscape-wide cropland heterogeneity for biodiversity

Although increasing the amount of seminatural habitat in the landscape can mitigate biodiversity loss, rising land prices make seminatural habitat an expensive good that is difficult to maintain, yet alone to increase [10]. Consequently, the idea has gained momentum that raising landscape-wide heterogeneity of the crop mosaic (i.e., cropland heterogeneity) may also exhibit major positive effects on biodiversity, without compromising the availability of agricultural land [84,85] (Figure 1).

A recent study, based on 435 landscapes across eight regions, showed that increasing configurational cropland heterogeneity by decreasing field size can be even as beneficial for multitrophic diversity (plants, birds, bees, butterflies, carabid beetles, spiders, and syrphid flies) as increasing seminatural habitat [20] (Figure 2F,G and Table 1) [20,85,86]. Reducing size of crop fields from 5 to 2.8 ha (or from 6 to 1 ha) enhanced as many species as increasing seminatural habitat from 0.5 to 11% (or from 0 to 35%). This was not just due to the increase in common grassy field margin strips along crop fields, as there was also a positive effect of increasing crop edges *per se*. Higher field edge densities can result in up to five times the number of wild bees and higher fruit set in an agricultural landscape [84] and also reduces pest infestation [71,87,88]. These patterns have been quantified in the mosaic landscapes of Europe, but the situation may be different in large-scale regions with large fields and farms, for example, found in North America or Brazil [8].

Batáry *et al.* [30] found also high biodiversity benefits of small-scale over large-scale agriculture, which are on par or even higher than the biodiversity benefits from converting conventional to organic agriculture (Figure 2D,E). Independent of field size, organic farming increased biodiversity, but also halved cereal yield levels, compared to conventional farms [30]. However, profit per farmland area was 50% higher on 20-ha than 3-ha fields, due to the lower costs (e.g., working time) for managing large fields [30]. The higher costs for managing small fields include also higher risks for compacted soil, higher crop damage, and growth heterogeneity due to the increase of edges and headland (where machines turn around) [85]. However, conversion to long, narrow fields can minimise headland, while biodiversity enhancement is optimised through long margins [85], promoting ecosystem services through spillover of crop pollinators as well as predators and parasitoids in temperate and tropical regions [71,89]. Furthermore, small fields allow better adaptation of crop diversification to local heterogeneity, for example in soil quality [49], and may reduce the risk of pest outbreaks, typical for large areas of monocultures [90–92]. Increasing the number of crop types had also a positive effect on landscape-level biodiversity, but only in landscapes with >11% of seminatural habitat [20]. Pest densities are typically lower in landscapes with higher crop diversity [71,87,88], while monocultural, maize-dominated landscape are of little value for pollinators [93].

Table 2. Major biodiversity-friendly measures on the local (field and farm) and landscape scale. Photo: Tibor Hartel.

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Local scale	Landscape scale
• Diversify crops, consider resource continuity across the season [49,53,108] • Restore semi-natural habitat (field boundaries, hedges, ponds, trees) to increase land-use diversity [5,49,108] • Maintain traditional, species-rich but uneconomic land-use systems [2,82] • Minimize pesticide use by synthetic and natural pesticides [14,40,42,109] • Improve yield with ecological intensification and new crop varieties suitable for diversification [19,57,110,111,112] • Stop overfertilization by organic and mineral fertilizers [43,113]	• Increase landscape complexity by restoring >20% of semi-natural habitat [10,78,79] • Prioritize restoration of simple landscapes [1,67,114] • Spread habitat patches across landscapes to increase beta diversity [68,79,115,116] • Augment crop diversity per landscape while keeping >11% semi-natural habitat [20,87] • Certify crops when grown with landscape-wide biodiversity-friendly measures [33] • Reduce mean field size per landscape below 6 ha [20,30,85] • Increase length of semi-natural edge habitats (field margin strips) per landscape [20,84] • Promote collaboration of farmers with other stakeholders to design biodiversity-friendly landscapes [8,97,117]

Outstanding questions

What is the best combination of organic farming, field size, crop diversification, and natural habitat to restore biodiversity in agricultural landscapes?

How do regionally adapted measures for biodiversity-friendly landscapes differ between small-scale mosaic landscapes (e.g., most of Europe) and large-scale landscapes (e.g., most of USA)?

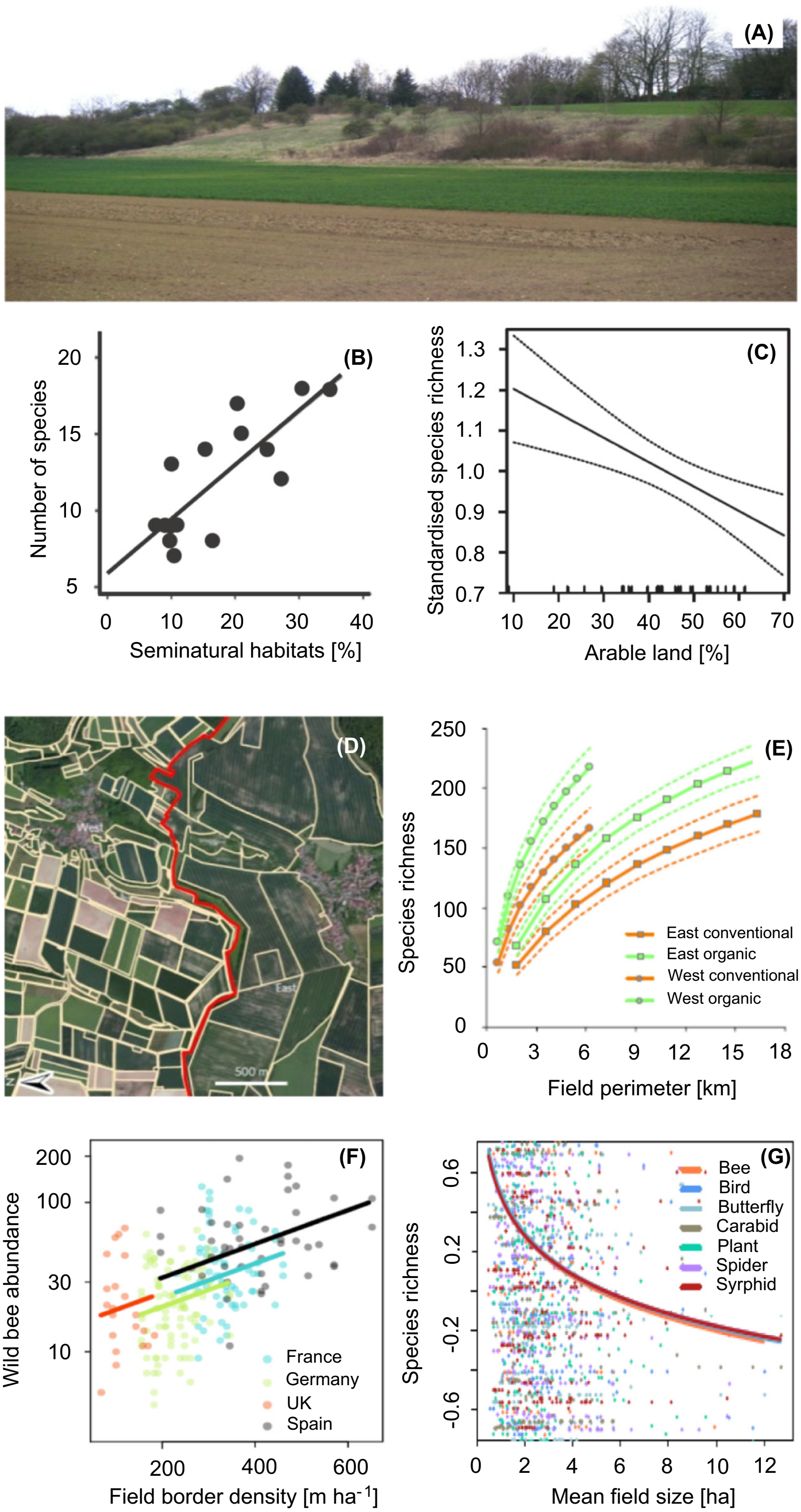
Are successful agri-environmental, biodiversity-friendly schemes in the Global North a prototype for the Global South?

How can we incentivise switching to small-scale and diversified farming practices in a sustainable way?

Concluding remarks: biodiversity-friendly landscape measures

In conclusion, organic farming contributes more to biodiversity conservation than conventional agriculture, but these benefits are small and come at the cost of high yield deficits (Figure 1). Crop diversification, small fields, and promotion of seminatural habitat patches can have greater effects on biodiversity than organic certification [20,30]. These biodiversity-friendly measures can be applied in both organic and conventional agriculture, thereby improving a larger area of the agricultural landscapes. Even under the EU Green Deal goal to achieve 25% organic farming by 2030, there is a need to target the 75% conventional agriculture shaping most landscapes. Keeping and restoring natural habitat in agricultural landscapes is not the only solution for higher landscape-wide biodiversity. Landscape-wide promotion of cropland heterogeneity can compensate for losses in natural habitat, mainly through smaller fields but also by increasing the number of crop species.

Figure 2. Landscape-wide seminatural habitat (landscape complexity) and cropland heterogeneity (small fields and high field edge density) is shaping local species richness. (A) Calcareous grassland embedded in annual cropland (Photo: Verena Rösch). (B) Wild bee species visiting a standardised set of flowering herbs planted in grassy field margin strips along wheat fields, increasing with percent seminatural habitats in the surrounding landscape [67]. (C) Standardised species richness of nine plant and insect taxa on small calcareous grassland fragments in relation to percent arable land in the surrounding agricultural landscape [7]. (D) Map showing the field-size differences between former West Germany (Lower Saxony) and former East Germany (Thuringia) along the former Iron Curtain (red line). East Germany farms are ~20 ha, West German farms ~3 ha [30]. (E) Effects of region (small-scale farming in the West and large-scale farming in the East of Germany) and organic versus conventional management on accumulated species richness of plants, carabid beetles, spiders, and rove beetles. Accumulated field perimeter (sample-based rarefaction curves standardized for perimeter per field; n = 36 fields; dashed lines represent 95% confidence intervals [30]). (F) Effects of field border density (i.e., configurational cropland heterogeneity) on wild bee abundance sampled in crop fields of four EU countries. Abundances are shown on a log10 scale [84]. (G) Effects of mean field size per landscape on the landscape-level species richness (standardised multidiversity) of seven taxonomic groups. Data from eight regions of Europe and Canada with altogether 435 fields [20].



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There is a need for improving landscape connectivity with habitat mosaics that are highly permeable for dispersing organisms across landscapes [9,94,95]. Functional landscape connectivity is a major landscape feature [96], as common extinctions due to climatic extremes, disturbance, or random extinctions and genetic drift in small populations [79] can only be countered by colonisation [95]. Connectivity between environmentally friendly managed and protected areas allows spillover of populations, including ecosystem service providers, from habitat patches or field boundaries to agroecosystems, but also to spared natural habitat remnants [9,10].

Incentives and regulations for biodiversity-friendly measures should come with a new focus on cropland diversification (i.e., small fields, high edge density), which is more important than organic farming for supporting biodiversity on farmland. Whereas current policies target local management, future measures must be broadened to the landscape level, with small-scale and diversified agriculture embedded in at least 20% seminatural habitat. Optimising landscape design needs governmental schemes as well as collaboration of farmers with other groups of stakeholders [8,97]. Biodiversity conservation as part of multifunctional agricultural landscapes, balancing socioeconomic and ecological goods, needs a realistic roadmap towards a much-needed paradigm shift in agriculture (see Outstanding questions).

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