A portfolio of biodiversity-based options and solutions integrating biodiversity and farming synergistically

Deliverable D3.2

31 July 2024

SHOWCASE

SHOWCASing synergies between agriculture, biodiversity and Ecosystem services to help farmers capitalising on native biodiversity

This project receives funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 862480.

Prepared under contract from the European Commission
Grant agreement No. 862480
EU Horizon 2020 Research and Innovation action

Project acronym:	**SHOWCASE**
Project full title:	**SHOWCASing synergies between agriculture, biodiversity and Ecosystem services to help farmers capitalising on native biodiversity**
Start of the project:	November 2020
Duration:	60 months
Project coordinator:	Prof. David Kleijn Wageningen University
Deliverable title:	[Validated methods for testing reliability of landscape metrics based biodiversity indicators]
Deliverable n°:	D3.2
Nature of the deliverable:	Report
Dissemination level:	Public
WP responsible:	D3.2
Lead beneficiary:	CNRS
Citation:	Bretagnolle, V, Melts, I, Martinez, MR, Hood, A, Mauchline, A, Potts, S, Ganz, M, Herzog, F, Jeanneret, P, Vajna, F, Baldi, A, Bodea, F, Herera, JM, Velado, E, Bartomeus, I, Öckinger, E, Segre, H, Bishop, G, Kleijn, D, Gaba, S. (2024). A portfolio of biodiversity-based options and solutions integrating biodiversity and farming synergistically. Deliverable D3.2 EU Horizon 2020 SHOWCASE Project, Grant agreement No 862480.
Due date of deliverable:	M45
Actual submission date:	31 July 2024
Deliverable status:	

Version	Status	Date	Author(s)
1.0	First Draft	1/12/23	Vincent Bretagnolle, Sabrina Gaba
2.0	Second Draft	1/7/24	Vincent Bretagnolle, Sabrina Gaba, with inputs from Indrek Melts, Mylene R. Martinez, Amelia Hood, Simon Potts, Maura Ganz, Felix Herzog, Philippe Jeanneret, Flora Vajna, Andras Baldi, Flaviu Bodea, Jose M Herera, Elena Velado, Ignasi Bartomeus, Erik Öckinger, Hila Segre, Gabrielle Bishop, David Kleijn
2.1	Final	25/7/24	Vincent Bretagnolle, Indrek Melts, Mylene R. Martinez, Amelia Hood, Alice Mauchline, Simon Potts, Maura Ganz, Felix Herzog, Philippe Jeanneret, Flora Vajna, Andras Baldi, Flaviu Bodea, Jose M Herera, Elena Velado, Ignasi Bartomeus, Erik Öckinger, Hila Segre, Gabriella Bishop, David Kleijn, Sabrina Gaba

3.1	Revised	1/4/25	Vincent Bretagnolle, Indrek Melts, Mylene R. Martinez, Amelia Hood, Alice Mauchline, Simon Potts, Maura Ganz, Felix Herzog, Philippe Jeanneret, Flora Vajna, Andras Baldi, Flaviu Bodea, Jose M Herera, Elena Velado, Ignasi Bartomeus, Erik Öckinger, Hila Segre, Gabriella Bishop, David Kleijn, Sabrina Gaba
3.2	Revised	20/5/25	Vincent Bretagnolle, Indrek Melts, Mylene R. Martinez, Amelia Hood, Alice Mauchline, Simon Potts, Maura Ganz, Felix Herzog, Philippe Jeanneret, Flora Vajna, Andras Baldi, Flaviu Bodea, Jose M Herera, Elena Velado, Ignasi Bartomeus, Erik Öckinger, Hila Segre, Gabriella Bishop, David Kleijn, Sabrina Gaba

The content of this deliverable does not necessarily reflect the official opinions of the European Commission or other institutions of the European Union.

Summary

Combining data from WP2 and WP3, **Task 3.2** in WP3 was specifically targeted at empirically testing, together with stakeholders, the ecological and socio-economic effects of biodiversity innovations within the local context of each EBA. Implementation of the farm interventions was realized, as planned in the proposal, in all EBAs over 2021-2023, and the effects of biodiversity innovations on biodiversity, provision of ecosystem services and yield were quantified during two years using the standardized protocols established in Task 1.2 and the specific indicators selected in Task 1.3. This deliverable 3.2 aims at presenting a synthesis and analysis of the biodiversity-based solutions explored in the SHOWCASE project. In particular, the analysis focuses on solutions for synergistically promoting agricultural production and biodiversity.

In each EBA, biodiversity interventions were designed with farmers, albeit to varying degrees. The proposed interventions at farm or field level have thus been discussed with, and even in a few cases, proposed by farmers. Broadly speaking, farm interventions can be grouped into four meta-components: 1/ **soil biodiversity** improvement (reduction of plough/tillage, cover crop) for fertility, crop health and water storage; 2/ **crop management** in order to improve its resilience to climate extremes and enemies (under sowing, intercropping, pesticide reduction); 3/ **ecological restoration** (mowing, grazing or tree/shrub removal in grasslands, alternative crops in arable land); 4/ increasing **semi-natural elements** to improve functional biodiversity at landscape or local scales (hedgerows, flower strips, grasslands). In all EBAs, whether a full co-design, a mixed or a pure scientist/manager approaches were used, the choice of farm interventions involved meetings with 15-25 farmers, and in most cases, one-on-one meetings in order to establish detailed protocols. Biodiversity itself was seldom the main target of the farm intervention (except in the Netherland, Hungary, Romania and Estonia); more often, agroecological targets, which include both agronomic, economic and ecological (i.e., biodiversity) aims, were discussed. As for the farmer first contacts and selection, there was a large diversity in the type of interventions discussed, then implemented. This ranged from a very standardized (and to some extent, academic) way of doing research, to very open and flexible strategy in terms of design and protocols.

Although detailed analyses are still ongoing, several findings are worth highlighting, some of which are already published. In most EBAs, biodiversity was improved by the intervention, which is not surprising because they were mainly aimed at this goal. In the meantime, in regard to yield, a decrease in yield was only found in a few cases, sometimes rather strong (Estonia, NL1, Romania in first year), in other cases moderate (Switzerland, France). Overall in many EBAs, the effect on yield was neutral (UK, Switzerland, Sweden, France though in the latter there was a non-significant decrease by about 2-5%). Interestingly, these are all arable systems. In orchards, yield was not modified in one of the two experiments, in Spain, while in Portugal the outcome is not yet known. If, overall, there is not much difference in yield, this would indicate there is a win/win situation, not between biodiversity and yield, but between biodiversity and income. This was the case in France and Switzerland, and possibly in Sweden. Indeed, one can expect an increase of income when no yield effect was found and when the intervention was at no or reduced costs (e.g. pesticide/nitrogen reduction). In the Netherland, the UK, Hungary and Spain, the outcome depends on the actual cost of implementing the intervention. These results obtained with a range of interventions are encouraging. It would be interesting to quantitatively evaluate the effect on income; which was outside the scope of Task 3.2. It would also be of interest to evaluate the outcome of the intervention on the mid-term because the effect of biodiversity increase on the agroecosystem functioning could be time lagged or because it could buffer the negative effects of disturbances and extreme events.

1 Introduction

Over the last 25 years, scientific evidence has accumulated that biodiversity conservation could coexist with farmland production, and our knowledge on such “win-win” situations has progressively improved (Marja et al. 2024). Several studies have now demonstrated that farming practices can improve biodiversity, thus delivering of ecosystem services (Pywell et al. 2015), while allowing yields or income to be maintained at sustainable levels (Catarino et al. 2019a, Catarino et al. 2019b). Theoretical and experimental work at the field (or plot within field) scale suggests that ecosystem functioning, service delivery and stability are positively related to species and habitat diversity (Isbell et al. 2015). Meta-analyses have provided support for these relationships in real-world farming systems and demonstrated positive relationships between landscape complexity, biodiversity and ecosystem services (Dainese et al. 2019, Jeanneret et al. 2021, Perrot et al. 2023). Increased abundance and diversity of species such as pollinators and natural enemies through targeted local biodiversity management improves the delivery of pollination and natural pest control services in focal fields and nearby crops (Tschumi et al. 2015, Perrot et al. 2023).

However, several challenges remain, such as understanding key drivers at different spatial scales of success or failure in delivering services and yield benefits (Sirami et al. 2019), including more stable yields over time (Senapathi et al. 2021), or better understanding costs and benefits of different practices. Furthermore, we need a better understanding of how the effects or combinations of different practices, both on- and off-field, add up to farm or landscape level effects and how we can promote synergies and reduce trade-offs by smart combinations and spatial designs of practices (Schneider et al. 2015, Klebl et al. 2024). In addition, despite many such studies have allowed a deep or at least clear understanding of ecological basis underlying such solutions, adoption of biodiversity management by the farmers at a large scale (i.e., sufficient for significant biodiversity benefits), has remained elusive to the least (Kleijn et al. 2019). This has clearly resulted in a science-policy, or research converted into action gap.

Indeed, while scientists are increasingly highlighting the benefits of integrating biodiversity management into farming practices and public policies promoting the implementation of biodiversity and ecosystem based practices for safe food and health, apart from subsidized management practices such as agri-environment-climate schemes, very few farmers currently integrate effective biodiversity management into farming practices, even in organic farming (Brown et al. 2019). One reason is that research has largely focused on ecological processes and consequences associated with biodiversity decline, and have more or less ignored incentives, economic and social aspects underlying the willingness to adopt environmentally-friendly practices (Kleijn et al. 2019, Klebl et al. 2024). We thus need to better understand the motivation of farmers to integrate biodiversity into daily farm management, which may be economic, social, or related to farmers’ health (Klebl et al. 2024). In addition, we need more evidence on how farmers can actually benefit from biodiversity-based approaches. Indeed, few studies have investigated economic (yield and margins) outcomes of biodiversity based farming, either at field, rotation or farm scale (Kleijn et al. 2019).

Achieving sustainable farmland biodiversity into farming practices and businesses is the critical task SHOWCASE has targeted. Using a multi-actor approach, SHOWCASE has first established Experimental Biodiversity Areas (EBAs; WP1). EBAs are ideal sets up to examine with local stakeholders the drivers of farmland biodiversity and its associated services from field to farm, regional and European scales, and from cropping seasons to multi-year crop rotations. This original tool has been used in

SHOWCASE through farm interventions to identify which management actions at which spatial scales (field, farm) impact a panel of response variables (i.e. yield, economic benefits, farmland biodiversity, social acceptance). In each EBA, SHOWCASE partners have selected, together with farmers, the most promising novel (combinations of) biodiversity management practices (i.e. biodiversity innovations). In the first part of this document, we present the biodiversity innovations that have been studied on each EBA, and discuss their pros and cons.

In WP1, SHOWCASE tested under real-world conditions a fundamental ecological hypothesis: i) biodiversity may enhance ecosystem functions through the implementation of effective farming practices; and ii) this can stabilize productivity and buffer it against environmental variability through enhanced system resistance and resilience (WP3.4). The first part of this document reviews farming practices that may allow enhancing ecosystem functions, as a portfolio. In each EBA, we then evaluated the effectiveness of these practices, accounted for the factors influencing the outcomes of on-site experiments and the determinants of the farmers' willingness to adopt these practices into farm management. We used face-to-face surveys, meetings and indicators to measure impacts on the response variables of interest (Séchaud et al. 2021). This constitutes the second part of this document.

WP3 – Increasing the evidence base for synergies between agriculture and biodiversity – aimed at synthesizing state-of-the-art knowledge of synergies and trade-offs between agricultural management and biodiversity in various socio-economic contexts and a diversity of farming systems [1]. WP3 has also tests various public and private benefits of innovative biodiversity management practices, and a series of knowledge gaps where evidence for potential biodiversity benefits was lacking. In particular, WP3 aimed at analysing empirically and experimentally relationships between farmland biodiversity and stability of agricultural production under real-world conditions, as a potential way to mitigate effects of biodiversity to consequences of climate change and/or economic stochasticity.

Combining data from WP2 and WP3, **Task 3.2** in WP3 was specifically targeted at empirically testing, together with stakeholders, the ecological and socio-economic effects of biodiversity innovations within the local context of each EBA. Once the EBA network was established in WP1.1 (Bretagnolle et al. 2022) during the first year of SHOWCASE, the specific innovations to be implemented in this task were set up by the outcome of W1.2 (Bretagnolle et al. 2021). This was done either by farmer learning-by-doing schemes where farmers design their own biodiversity enhancing management and monitor impacts by means of specially designed toolkits (CH), farmers performing agro-ecological experiments in their own fields, by reducing pesticide inputs, improving biodiversity, maintaining their yield and improving their income (FR), biodiversity labelling schemes where farm products are certified based on biodiversity standards (UK), collective schemes where biodiversity management is implemented by groups of farmers in coordination with local conservation groups to optimize impact (ES), collaborative approaches where in a specific area novel biodiversity management by seven different stakeholders (farmers' collectives, three nature conservation organizations, water board and two municipalities) is spatially and temporally coordinated (NL). The level of complexity of the biodiversity innovations among EBA is related to the level of experience with biodiversity management within the local communities (i.e. in some EBAs, stakeholders had never managed for biodiversity

[1] WP3 has also examined relationships between agricultural landscapes and genetic diversity, how existing citizen science schemes can be used or improved to evaluate the conservation and ecosystem service effects of integrating biodiversity in farm management, and trade-offs between farming and biodiversity conservation using the case of large carnivores. This will not be covered in this report.

before).

Implementation of the farm interventions was realized, as planned in the proposal, in all EBAs over 2021-2023 (Bretagnolle et al. 2022), and the effects of biodiversity innovations on biodiversity, provision of ecosystem services and yield were quantified during two years using the standardized protocols established in Task 1.2 and the specific indicators selected in Task 1.3 (Bretagnolle et al. 2021, Séchaud et al. 2021). Over-arching analyses across all EBAs to derive general conclusions and significant advances in our understanding of key drivers of impacts on biodiversity, provision of ecosystem services, agricultural productivity and socio-economic factors, are now underway. This deliverable 3.2 aims at presenting a synthesis and analysis of the biodiversity-based solutions explored in the SHOWCASE project. In particular, the analysis focuses on solutions for synergistically promoting agricultural production and biodiversity.

2 Rationale behind the farm interventions and typology of biodiversity experiments

2.1. Types of farming systems

EBAs have been located in a wide range of agro-ecosystems, which best represent farming systems in Europe, those undergoing intensification as well as agricultural abandonment. Rather than creating new networks, EBAs have been developed mostly from existing collaborations between scientists and practitioners. However most evidence to date for benefits of practices on biodiversity and associated ecosystem services comes from intensive farming systems (Batáry et al. 2011), neglecting relationships between agriculture, practices and biodiversity in moderate intensively managed farming systems and systems in which biodiversity is threatened by abandonment rather than intensification of agricultural management. Therefore synergies between agriculture and biodiversity in low-input farming systems, though self-evident, were studied in SHOWCASE as well. These latter farming systems form the bulk of Europe's High Nature Value (HNV) farming regions, which are threatened by rural depopulation and abandonment due to low profitability, harsh living conditions and more attractive job opportunities in urban areas, are now mostly restricted to agriculturally marginal areas in the Mediterranean, Alpine or Boreal regions.

In SHOWCASE we have thus deliberately chosen to improve our understanding of the complex interactions between agricultural management and biodiversity at the European scale, for the European major farm types (grassland, arable, horticulture) and farming systems (conventional, integrated production (IP), organic), thus accounting for the variability of the European farming sector in terms of natural conditions, production intensity and socio-economic context. We have paid particular attention to differences in drivers, processes and consequences of biodiversity decline in areas where farmland biodiversity is primarily threatened by agricultural intensification (EBAs in UK, France, the Netherlands, Spain, Portugal, Hungary) or agricultural abandonment (Romania, Hungary, Estonia) and included countries where both processes occur simultaneously in different regions (Sweden, Switzerland). In arable, we set up EBA in pure arable (Sweden), mixed farming systems dominated by arable (UK, Switzerland) or equilibrated (France, the Netherlands), farming systems dominated by grasslands (Hungary) or exclusively grassland (Estonia, Romania), and finally, orchard (Portugal, Spain). Some farming systems were indeed not, or very poorly covered (vineyards, rice, steppe and pseudo-steppe, alpine grasslands), though present in Europe and of high nature value.

2.2. Generalities about EBAs

An EBA gathers growers and researchers that work together to design, implement and test innovative interventions to promote biodiversity while maintaining or increasing production. It is also a platform for performing a wide range of experiments to explore ecological, economic and social processes within an inter-disciplinary consortium. Within SHOWCASE, EBAs are the units for knowledge exchange, demonstration and dissemination. EBAs are also intended to bring together a wide set of stakeholders (e.g. NGOs, other land owners, nature conservation authority). The 10 countries with EBAs (CH, EE, ES, FR, HU, NL, RO, PT, SW, UK) have identified the most appropriate existing local or regional multi-stakeholder initiatives as a basis to build upon the SHOWCASE EBA network in agricultural landscapes. One country has 2 EBAS with different farming systems (Hungary, HU-1 and HU-2), one country had two distinct and distant sites (Romania) and one country had distinct interventions (The Netherlands, NL-1, NL-2).

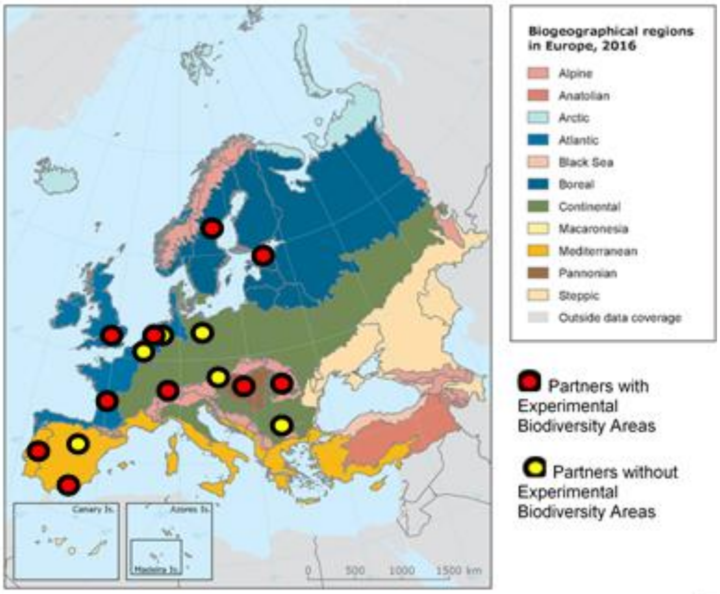

Fig. 1. A Map of Europe showing the location of the EBAs (red dots).

The network of EBAs represents a gradient of farming systems (types and intensification) that range from intensive pure (almost) arable crops (CH, UK), intensive arable with some livestock/grasslands or forests (FR, SW, HU-2), mixed (arable crops and livestock) such as in the NL, grassland with some arable crops (HU-1), pure grassland (EE, RO-DCE, RO-STM) and finally, orchards (PT, ES; Fig. 1). There is also a huge variety of Region sizes (from highly packed, e.g. HU-1, to very large, e.g. UK), and of number of farms (from 1 to about 100). There is finally a diversity of history, with some EBAs being established since 15-20 years (FR), while some started along this project (ES, PT). Among the 12 EBAs, 9 EBA leaders have co-designed its implementation. Most interventions have been be performed at the field scale (10 over 12) in landscapes generally characterised by land use change because of intensification (8 over 12). EBAs not only engaged with farmers in SHOWCASE, but also farmer organisation and other stakeholders (citizens, NGOs ...) were involved.

2.3. An overview of the literature on selected and major types of intervention

Traditional approaches to farming innovations, such as linear technology transfer approaches, can lead to slow progress, simplistic problem solving, low adoption rates and lack of trust in research (Duru et al. 2015). This shortfall is being recognised with a shift moving away from the traditional model of science providing solutions for practice, towards more collaborative approaches where expertise from both science and practice is valued equally (Lang et al. 2012). The use of the multi-actor approach has been increasingly applied in the sustainable agriculture sector over the last decade, with successful innovations documented for improving cereal diversity (Chateil et al. 2013, Sacchi et al. 2018) or biodiversity conservation (Berthet et al. 2019).

In arable farming, pesticides have a major negative impact on biodiversity, hence many studies have been carried out to show that improving biodiversity can reduce the use of pesticides for pest control (Lechenet et al. 2014, Möhring et al. 2020). Indeed a promising alternative to the use of pesticides is the use of natural pest and weed enemies (Maas et al. 2013, Bengtsson 2015, Schneider et al. 2015, Ali et al. 2018), which can provide similar efficacy to synthetic pesticides (Ratto et al. 2022) at a lower cost (Losey and Vaughan 2006). However, the abundance of natural enemies in agricultural landscapes depends on resources provided by semi-natural habitats, such as grasslands (Dainese et al. 2019, Sirami et al. 2019, Perrot et al. 2023) and woodlands (Costa et al. 2020, Herrera et al. 2021, Herrera et al. 2024). Though, the amount of semi-natural habitat has been declined in most of the agricultural regions of the world in the recent decades (Benton et al. 2003), especially in European countries that have received little support from the Common Agricultural Policy (Pe'er et al. 2014, Morales et al. 2022). This reduction in semi-natural elements has been shown to reduce biological pest control by an average of 46% (Rusch et al. 2016). Furthermore, it is not only the amount of semi-natural habitat needed to ensure for natural pest control, but also the distance from the crop at which natural regulation must occur has also been shown to be a key factor (Alignier et al. 2014, Perrot et al. 2021). Indeed, the ability of semi-natural habitats to provide effective pest or weed control is highly variable (Bianchi et al. 2006, Karp et al. 2018, Albrecht et al. 2020), mainly because natural pest control relies not only on the presence of natural enemies, but also on encounters between natural enemies and their pests or weeds, which can occur in crop or in non-crop habitats. Therefore, for natural pest control services to be efficient and sustainable, we need to design farming systems or landscapes that favour both natural enemies and their encounter rates with insect pests or weeds.

In each EBA, biodiversity interventions were designed with farmers, albeit to varying degrees. The proposed interventions at farm or field level have thus been discussed with, and even in a few cases, proposed by farmer. Despite a fairly restricted number of sites (EBAs) and a wide diversity of agricultural and farming systems, the interventions tested in SHOWCASE cover a very wide range of the possible experiments and management options already identified in such farming systems for reconciling biodiversity and farming, as can be seen below. In the following, we list the interventions that have been tested in SHOWCASE, and place them in the context of the general scientific literature investigating relationships between farming practices and biodiversity or ecosystem functions. Broadly speaking, farm interventions can be grouped into four meta-components: 1/ **soil biodiversity** improvement (reduction of plough/tillage, cover crop) for fertility, crop health and water storage; 2/ **crop management** in order to improve its resilience to climate and enemies (under sowing, intercropping, pesticide reduction); 3/ **ecological restoration** (mowing, grazing or tree/shrub removal in grasslands, alternative crops in arable land); 4/ increasing **semi-natural elements** to improve functional biodiversity at landscape or local scales (hedgerows, flower strips, grasslands). The following section does not aim to review all possible interventions, nor does it aim to provide a full scientific literature review on the subject. Rather, the aim here is to present the results of fruitful discussions with farmers, resulting in proposals for feasible interventions (from their point of view), and a selected set of literature that support discussions and final choice for a given range of farm interventions in each EBA.

2.3.1. Improving soil health and quality

Cover crops

EBAs in which this intervention was tested: UK

Winter cover crops are planted within arable rotations between summer harvest (e.g., typically July-August in the UK) and spring planting (typically February-March). Cover crops can provide environmental and economic benefits, for example by reducing nutrient run off and soil erosion, and promoting water infiltration, biodiversity, soil nutrient content, and subsequent crop yields. Their potential benefits are gaining recognition amongst farmers and other agricultural stakeholders, partly due to their status within the growing "Regenerative agriculture" movement, which centres around soil health. This movement also discourages soil disturbance, such as ploughing, and as such most cover crops in the UK (estimated 81% here) are removed by spraying the harmful herbicide glyphosate. Careful selection of cover crop plant traits may reduce the level of herbicide application needed to remove cover crops, and in SHOWCASE we investigated the ecological and crop production impacts of frost tolerant vs. frost sensitive cover crops. Our hypothesis is that frost-sensitive cover crop species will die off during the winter, reducing the need for chemical removal and strain on planting machinery. In addition, we hypothesise that they will promote soil health and nutrients via the gradual release of organic matter as the cover crop decomposes. In UK, four treatments were applied experimentally with farmers: a frost-tolerant cover crop mix, a frost-sensitive cover crop mix, an intermediary mix, and a control (no cover crop planting).

Supporting literature:

Storr T, Simmons RW, Hannam JA. A UK survey of the use and management of cover crops. Ann Appl Biol. 2019;174: 179–189. doi:10.1111/aab.12488

Shackelford GE, Kelsey R, Dicks L V. Effects of cover crops on multiple ecosystem services: Ten meta-analyses of data from arable farmland in California and the Mediterranean. Land use policy. 2019;88: 104204. doi:10.1016/j.landusepol.2019.104204

Dicks L V., Rose DC, Ang F, Aston S, Birch ANE, Boatman N, et al. What agricultural practices are most likely to deliver "sustainable intensification" in the UK? Food Energy Secur. 2019;8: 1–15. doi:10.1002/fes3.148

Rehberger E, West PC, Spillane C, McKeown PC. What climate and environmental benefits of regenerative agriculture practices? an evidence review. Environ Res Commun. 2023;5. doi:10.1088/2515-7620/acd6dc

Reducing soil work (ploughing, mechanical weeding) and improved soil management

EBAs in which this intervention was tested: FR, and to a lesser extent, PT and ES

Soil is a key target of EU policy. Soil quality is very important for agricultural productivity and its sustainability. Plant biodiversity and the biodiversity of the entire trophic chain of decomposers are critical to ensure optimal nutrient recycling. Apart from the agricultural work done on the soil, the biological activity of the soil is the main parameter that determines its structure and therefore its quality. In temperate environments, the structure and porosity of soils are improved by the presence and abundance of earthworms which dig galleries consolidated by their mucus and excrete organic and mineral matter, forming more or less stable aggregates. Earthworms also contribute directly to soil formation by accumulating of castings in the upper horizons (+0.4 cm/year based on 13 studies). Earthworm activity favours the transfer and accumulation of organic matter throughout the soil profile, and in temperate environments, improves water infiltration into the soil reducing the risk of crop anoxia during wet periods, as well as the water retention capacity of the soil and therefore the useful water reserve for crops. Finally, earthworms can play a role in climate regulation through carbon sequestration and emissions (although the impact varies with agricultural practices); and they can play a role in remediating soil pollution. The critical role that microorganisms play (10 grams of soil can contain up to 10 billion microorganisms) in many essential ecosystem functions related to soil fertility, water and environmental quality is also widely recognized. However, soil belowground biodiversity is impacted by farming. In particular in organic farming, the herbicide ban is expected to lead to an increase in soil work (tillage, mechanical weeding) to enable weed management. Organic farmers also plough fields before sowing, and often plough superficially after harvest to elicit weed germination). All this soil work contributes to reducing soil biodiversity, especially macrofauna. In the French EBA, organic farmers were strongly motivated to reduce soil work, in particular in wheat crops. In the Spanish and Portuguese EBAs, farmers were suggested to replace ploughing between rows of trees with flower strips or herbaceous strips, hence reducing soil work (see below "inter-row crop management").

Supporting literature:

Blouin et al. (2013) 'A review of earthworm impact on soil function and ecosystem services', *European Journal of Soil Science*, 64(2), pp. 161–182.

Minasny et al. (2017) 'Soil carbon 4 per mille', *Geoderma*, 292, pp. 59–86.

Rabot et al. (2018) 'Soil structure as an indicator of soil functions: A review', *Geoderma*, 314, pp. 122–137.

Rutgers et al. (2012) 'A method to assess ecosystem services developed from soil attributes with stakeholders and data of four arable farms', *Science of the Total Environment*, 415, pp. 39–48.

2.3.2. Crop management to improve resilience

Undersowing (mixed crops and inter-row cropping)

EBAs in which this intervention was tested: CH, SW and to a lesser extent, FR, HU-2

Undersowing consists of sowing a second crop within the main crop such that they both develop at the same time (e.g. clover mixed with a cereal). This intervention is part of the package of measures applied in the fields of the Swiss EBA. Farmers wanted to implement it to protect their soil, reduce nitrogen leaching, control weeds and increase productivity. Undersowing also has a number of possible effects on pest natural control. The architecture of the plant or canopy acts as a barrier to the dispersal of weed seeds, aerial or telluric pathogens (via the architecture of the root profile) and passive-flying insects. It also restricts access to resources for pests, such as access to light, which slows down the growth of weeds, or access to egg-laying sites, which regulates the reproduction of herbivorous insects. Indirectly, it modifies the microclimate and the structural complexity of the habitat for both pests and their natural enemies. In the Swiss EBA, interventions were carried out in fields as part of a Swiss project (www.pestired.ch) aimed at reducing the use of chemical pesticides (-75%) through alternative crop protection measures over the course of a well-defined crop rotation, while maintaining productivity (max. -10 % yield). For SHOWCASE, three crops (oilseed rape, winter wheat and barley) were selected on a total of 22 fields located in the canton of Solothurn. The fields in Solothurn are located on a total area of approximately 700km². In Sweden, inter-cropping has also been tested experimentally. The rationale for using intercropping as an intervention was partly driven by farmers' preferences, i.e. several of them were interested in this intervention, and wanted to know if it had any positive effects on biodiversity. There were also sound ecological reasons to believe that intercropping can be a win-win situation in terms of both yield and biodiversity. For instance, intercropping cereals with nitrogen-fixing legumes can improve soil nitrogen status, at least if legumes are used as green manure rather than being harvested. Intercropping with undersown legumes such as clover can also suppress weeds, and if the legume species is also allowed to flower, it can also benefit pollinating insects. In another farming system, oversowing fallows was done in HU-2 EBA, with a seed mixture containing locally occurring native, non-protected plant species, with a wide diversity according to season, flower morphology and taxonomy, though with a dominance of Fabaceae species, which are known for improving soil properties. Soil properties were thus analysed over the years (within Super-G project). Soil management through oversowing was expected to improve both biodiversity and hay yield.

Supporting literature:

Bedoussac, L., Journet, E.-P., Hauggaard-Nielsen, H., Naudin, C., Corre-Hellou, G., Jensen, E. S., Prieur, L., & Justes, E. (2015). Ecological principles underlying the increase of productivity achieved by cereal-grain legume intercrops in organic farming. A Review. Agronomy for Sustainable Development, 35, 911–935.

Boetzl, F. A., Douhan Sundahl, A., Friberg, H., Viketoft, M., Bergkvist, G., & Lundin, O. (2023). Undersowing oats with clovers supports pollinators and suppresses arable weeds without reducing yields. Journal of Applied Ecology, 60, 614–623. https://doi.org/10.1111/1365-2664.14361

Brooker, R.W., Bennett, A.E., Cong, W.-F., Daniell, T.J., George, T.S., Hallett, P.D., Hawes, C., Iannetta, P.P.M., Jones, H.G., Karley, A.J., Li, L., McKenzie, B.M., Pakeman, R.J., Paterson, E., Schöb, C., Shen, J., Squire, G., Watson, C.A., Zhang, C., Zhang, F., Zhang, J. and White, P.J. (2015), Improving intercropping: a synthesis of research in agronomy, plant physiology and ecology. New Phytol, 206: 107-117. https://doi.org/10.1111/nph.13132

Gu, C., Bastiaans, L., Anten, N. P. R., Makowski, D., & van der Werf, W. (2021). Annual intercropping suppresses weeds: A meta-analysis. Agriculture, Ecosystems & Environment, 322, 107658.

Isbell, F., Adler, P. R., Eisenhauer, N., Fornara, D., Kimmel, K., Kremen, C., Letourneau, D. K., Liebman, M., Polley, H. W., Quijas, S., & Scherer-Lorenzen, M. (2017). Benefits of increasing plant diversity in sustainable agroecosystems. Journal of Ecology, 105, 871–879.

Inter-row improved management in perennial crops

EBAs in which this intervention was tested: PT, ES

In olives groves, vineyards and orchards through Europe, one of the main management options for the inter-row area (i.e., between rows of trees or grape) has been soil ploughing, sometimes in combination with herbicide application, with the idea that removing herbs and weeds would allow a higher proportion of water to be available for the crop and reduced pest population abundance. However, there is increasing evidence that inter-row vegetation can have ecological and agricultural benefits. One of the main objectives of the intervention in SHOWCASE for orchard system was to test the effect of a green cover with selected plant species on biodiversity, when implemented under real production conditions of stone fruit orchards in Guadalquivida (ES). The rationale for our intervention was that the presence of herbaceous vegetation will benefit biodiversity without compromising crop production. This is largely because herbaceous vegetation will provide key resources for pollinators and natural enemies including food and shelter (. Green covers are still a poorly integrated agroecological practices in Mediterranean orchards, although having several benefits. Green covers can improve soil quality, prevent soil erosion, promote the presence of beneficial fauna that contribute to pest control and limit their presence and have a rapid positive impact on on-farm biodiversity.

The intensification of arboreal crop production is widely reported to significantly reduce spontaneous vegetation cover within farms, with associated impacts on biodiversity. This is the case with the intensification of the olive production. It is often reported that herbaceous vegetation that typically grows between the rows of olive trees is deliberately eliminated. The main goal of the Portuguese EBA, EBAlentejo, was to determine the role of the non-crop herbaceous vegetation occurring between the rows of olive trees in promoting biodiversity, i.e., bees and spiders. To achieve this goal, diversity and abundance of bees and spiders between experimental sites which were artificially sown with a mixture of plant species and control sites with no herbaceous vegetation and no sowing treatment applied were compared.

Supporting literature:

Fernández-Ugalde, O., & López-Piñeiro, J. L. (2020). Impact of Tillage Practices on Soil Quality, Crop Yield, and Economic Performance in Olive Groves: A Review. Agronomy, 10(4), 580. 10.3390/agronomy10040580

Fernández-Ugalde, O., Plaza, C., García-Díaz, J. A., & Alfaro-Martínez, M. M. (2020). Soil organic carbon and mineralization as affected by tillage and irrigation in an olive grove under editerranean climate. Soil & Tillage Research, 196, 104896. 10.1016/j.still.2020.104896

Fernández-Ugalde, O., Soane, B., Barreiro, D., & Plaza, C. (2015). Soil tillage and irrigation effects on soil aggregation, organic carbon storage, and greenhouse gas emissions in a Mediterranean olive grove. Soil & Tillage Research, 152, 53-59.

García-Díaz, J. A., & Castillo, C. (2019). Soil quality and ecosystem services in olive groves under different tillage practices. Agricultural Ecosystems & Environment, 269, 1-10. 10.1016/j.agee.2019.03.007

García-Díaz, J. A., & Castillo, C. (2019). Tillage effects on aggregate stability and soil organic matter in an irrigated olive grove under Mediterranean climate. Catena, 173, 17-23. 10.1016/j.catena.2019.104352

Gómez-Brandón, M., & Llanderal-Méndez, C. (2021). Organic farming in olive groves: A review of crop yield, soil quality, and environmental benefits. Environmental Science and Pollution Research, 27(1), 440-455. https://doi.org/10.1007/s10531-021-02338-w

Gómez-Brandón, M., Díaz-Villacorta, V., & Llanderal-Méndez, C. (2019). Effect of tillage on the arthropod community of an olive grove agroecosystem. Biological Control, 136, 104066. 10.1016/j.biocontrol.2019.104066

Herrera JM, Silva B, Jiménez-Navarro G, Barreiro S, Melguizo-Ruiz N, Moreira F, Vasconcelos S, Morgado R, Rodríguez-Pérez J (2021) A food web approach reveals the vulnerability of biocontrol services by birds and bats to landscape modification at regional scale. *Scientific Reports* 11, 23662. https://doi.org/10.1038/s41598-021-02768-0

Ministerio de Agricultura, Pesca y Alimentación 2023. Plan Estratégico de la PAC 2023-2027 ; Ministerio de Agricultura, Pesca y Alimentación: https://www.mapa.gob.es/es/pac/pac-2023-2027/plan-estrategico-v21_tcm30-659518.pdf

Outhwaite, CL, McCann P, Newbold T (2022) Agriculture and climate change are reshaping insect biodiversity worldwide Nature 605, 97. https://doi.org/10.1038/s41586-022-04644-x

Rey, P.J., Manzaneda, A.J., Valera, F., Alcántara, J.M., Tarifa, R., Isla, J., Molina-Pardo, J.L., Calvo, G., Salido, T., Gutiérrez, J.E. and Ruiz, C., 2019. Landscape-moderated biodiversity effects of ground herb cover in olive groves: Implications for regional biodiversity conservation. Agriculture, Ecosystems & Environment, 277, pp.61-73.

Vasconcelos S, Pina S, Herrera JM, Silva B, Sousa P, Porto M, Melguizo-Ruiz N, Jiménez-Navarro G, Ferreira S, Moreira F, Beja P. (2022) Drivers of canopy arthropod declines along a gradient of olive farming intensification. Scientific Reports 12:17273. https://doi.org/10.1038/s41598-022-21480-1

Pesticide reduction in arable crops

EBAs in which this intervention was tested: FR and CH

One of the most important features of the Green Revolution has been the provision of efficient tools for pest and weed control, such as pesticides. However, while their use has helped ensure food security, they also threaten human and ecosystem health, and ecosystem functioning to the extent that alternative methods of pest control have become important political and societal goals. Understanding whether reducing the use of pesticides without compromising food production and quality, increasing farmers' work load and favouring pests and weeds outbreaks remains a main challenge. The choice of resistant cultivars, diversified crop successions, crop mixtures, careful selection of cover crop plant traits … are part of agronomic levers that were shown to reduce the level of pesticide application during cropping season or when removing cover crops. One of the main goal in SHOWCASE was to evaluate the effect of a strong pesticide reduction (typically 50% in France but up to 75% in Switzerland), alongside a similar reduction in Nitrogen or not, on Biodiversity in the plots or field level, as well as yield (or subsequently, margin). Such experiments have been conducted in France over the last 10 years (in various crops and plot sizes) as well as in Switzerland. Here the goal was to work at field size scale.

Supporting literature:

Badenhausser, I., Gross, N., Mornet, V., Roncoroni, M., Saintilan, A., Rusch, A., 2020, Increasing amount and quality of green infrastructures at different scales promotes biological control in agricultural landscapes, Agriculture" Ecosystems and Environment**, pp. 106735. DOI:10.1016=j.agee.2019.106735

Catarino, R., V. Bretagnolle, T. Perrot, F. Vialloux, and S. Gaba. 2019a. Bee pollination outperforms pesticides for oilseed crop production and profitability. Proceedings of the Royal Society B 286:20191550.

Catarino, R., S. Gaba, and V. Bretagnolle. 2019b. Experimental and empirical evidence shows that reducing weed control in winter cereal fields is a viable strategy for farmers. Sci Rep 9:9004.

Crochard, L., Julliard, R., Gaba, S., Bretagnolle, V., Baude, M., & Fontaine, C. (2022). Weeds from non-flowering crops as potential contributors to oilseed rape pollination. Agriculture, Ecosystems & Environment, 336, 108026

Gaba S., Bretagnolle V**.** *Chapter 14.* Designing multifunctional and resilient agricultural landscapes: lessons from long-term monitoring of biodiversity and land use. *In:* C. Hurford et al. (eds.), The Changing Status of Arable Habitats in Europe**.** Springer Nature Switzerland AG 2020. 2021, 203-224

Lechenet, M., V. Bretagnolle, C. Bockstaller, F. Boissinot, M. S. Petit, S. Petit, and N. M. Munier-Jolain. 2014. Reconciling pesticide reduction with economic and environmental sustainability in arable farming. PLoS One 9:e97922.

Möhring, N., K. Ingold, P. Kudsk, F. Martin-Laurent, U. Niggli, M. Siegrist, B. Studer, A. Walter, and R. Finger. 2020. Pathways for advancing pesticide policies. Nature food 1:535-540.

Mostafalou, S., and M. Abdollahi. 2017. Pesticides: an update of human exposure and toxicity. Archives of toxicology 91:549-599.

2.3.3. Ecological restoration

Alternative crops

EBAs in which this intervention was tested: NL-1

Plant proteins have a substantially lower carbon footprint compared to animal products. Lupin (*Lupinus* spp.) is a particularly rich plant protein (up to 40 %), making it an attractive option to contribute to the increase in local plant protein production called for under the European protein strategy. As a mass-flowering leguminous crop, lupin can be beneficial to insect pollinators and contribute to soil quality. When in flower, cultivated lupin species are highly visited by bumblebees (*Bombus* spp.) for pollen, which is essential to bee reproduction. Mass-flowering crops can benefit bee populations in arable landscapes that otherwise might not provide abundant floral resources. Lupin blooms at a time period that represents a natural dip in floral resource availability so it could be a good candidate for adding a large amount of floral resources to support pollinators in agricultural areas.

Supporting literature:

Beyer, N., Kirsch, F., Gabriel, D. et al. Identity of mass-flowering crops moderates functional trait composition of pollinator communities. Landscape Ecol 36, 2657–2671 (2021). https://doi-org.ezproxy.library.wur.nl/10.1007/s10980-021-01261-3

European Parliament. 2023. Regulation (EU) 2015/2283 of the European Parliament and of the Council of 25 November 2015 on novel foods, amending Regulation (EU) No 1169/2011 of the European Parliament and of the Council and repealing Regulation (EC) No 258/97 of the European Parliament and of the Council and Commission Regulation (EC) No 1852/2001.

Fijen, T.P.M., Morra, E., Kleijn, D. (2021) Pollination increases white and narrow-leaved lupin protein yields but not all crop visitors contribute to pollination Agriculture, Ecosystems & Environment 313. https://doi.org/10.1016/j.agee.2021.107386.

Holzschuh, A., Dormann, C.F., Tscharntke, T. et al. Mass-flowering crops enhance wild bee abundance. Oecologia 172, 477–484 (2013). https://doi-org.ezproxy.library.wur.nl/10.1007/s00442-012-2515-5

Lucas, M.M., F.L. Stoddard, P. Annicchiarico, J. Frias, C. Martinez-Villaluenga, D. Sussmann, M. Duranti, A. Seger, P.M. Zander, J.J. Pueyo. The future of lupin as a protein crop in Europe. Front. Plant Sci., 6 (2015), p. 705

Nemecek, T., J.-S. von Richthofen, G. Dubois, P. Casta, R. Charles, H. Pahl. Environmental impacts of introducing grain legumes into European crop rotations. Eur. J. Agron., 28 (2008), pp. 380-393

Timberlake, T.P., Vaughan, I.P., Memmott, J., 2019. Phenology of farmland floral resources reveals seasonal gaps in nectar availability for bumblebees. J Appl Ecol 56, 1585–1596. https://doi.org/10.1111/1365-2664.13403

Willett, W. J. Rockström, B. Loken, M. Springmann, T. Lang, S. Vermeulen, T. Garnett, D. Tilman, F. DeClerck, A. Wood, M. Jonell, M. Clark, L.J. Gordon, J. Fanzo, C. Hawkes, R. Zurayk, J.A. Rivera, W. De Vries, L. Majele Sibanda, A. Afshin, A. Chaudhary, M. Herrero, R. Agustina, F. Branca, A. Lartey, S. Fan, B. Crona, E. Fox, V. Bignet, M. Troell, T. Lindahl, S. Singh, S.E. Cornell, K. Srinath Reddy, S. Narain, S. Nishtar, C.J.L. Murray.

Food in the Anthropocene: the EAT–lancet Commission on healthy diets from sustainable food systems. Lancet, 393 (2019), pp. 447-492

Permanent grassland restoration and grassland management for biodiversity

EBAs in which this intervention was tested: RO, EE and to a lesser extent, HU-2

In many parts of Europe, seminatural grasslands are part of the traditional landscape and cultural heritage. They are formed and shaped by long-term extensive management, such as mowing and grazing, and are characterised by high biodiversity. In addition to biodiversity, such grasslands play an important role in providing various ecosystem benefits and services. These grasslands are an integral part of productive landscapes used for animal husbandry to produce meat, dairy and other products. Unfortunately, the area of these seminatural grasslands has declined significantly from the middle of last century.

The rationale behind the interventions in SHOWCASE lies in the understanding that agricultural landscapes can play an important role in supporting biodiversity. The first hypothesis underlying the biodiversity-based options is ecological : opening habitats by removing shrubs can enhance biodiversity by creating more favorable conditions for a variety of plant and animal species. This intervention aims to increase light availability, promote diverse vegetation, and create niches for different species to thrive. The second hypothesis is socio-economical- compensatory schemes for farmers, administered through paying agencies, are designed to align ecological goals with the economic interests of farmers. By providing financial incentives, these schemes aim to encourage environmentally friendly practices, such as habitat preservation or restoration, minimizing the impact of agricultural activities on biodiversity (GAEC, Common Agricultural Policy). In addition, due to population aging (especially) from rural areas, most of the traditional agricultural activities are gradually abandoned in some areas of Europe. As a direct consequence, there are changes in land use. Many such abandoned areas are grazed by sheep, others are integrated in arable monoculture. In Romania, the number of sheep in “Dealurile Clujului Est” has increased considerably in the past few years. For examples, in Apahida the number of sheep and goats has increased by 64%, in Bonţida by 65%, in Dăbâca has doubled (116%), and in Vultureni tripled (197%). It can be noticed that even in the cases where sheep and goat flocks have been reduced or maintained compared to 2007, the pressure on meadows is still high, and Livestock Units/ha exceed the value of 0.5, being 5-9 within the ”Dealurile Clujului Est”, while it is generally admitted that 0.5 over a 135-day grazing in semi-natural meadows should be the target value. Another problem is winter grazing. When snow layer is lacking, sheep grazing occurs, a trend that will increase with climate change. The Management Plan of the ”Dealurile Clujului Est” includes conservation measures for each protected species/habitat that has been identified on the site. Strategy for the conservation of biodiversity in the “Dealurile Clujului Est” is equivalent to implementing the Management Plan and Regulations of the Natura 2000 site. The Management Plan for the site is accepted by the Ministry of Environment but it is not in published yet. No Natura 2000 compensatory payments for farmers, only the AE *Maculinea* sp. package.

In Estonia, such changes in land use and management practices have led to a decline in species and degradation of ecosystem services and functions. Therefore, it is important to focus on the management efforts needed to maintain semi-natural grasslands and to protect the overall biodiversity in the era of global changes. In SHOWCASE, various forms of grassland management have been experimented to restore grassland functioning, biodiversity, and use by farmers. In Estonia, it consisted in grazing pastures while in Romania, old permanent grasslands were restored by scrub and tree removal; finally, in Hungary, over-seeding was experimented to improve the agronomic value of old grasslands while maintaining biodiversity.

Supporting literature:

Bengtsson, J., Bullock, J.M., Egoh, B., Everson, C., Everson, T., O'Connor, T., O'Farrell, P.J., Smith, H.G., Lindborg, R. (2019) Grasslands—more important for ecosystem services than you might think. Ecosphere 10(2), e02582. https://doi.org/10.1002/ecs2.2582

Billeter, R., Liira, J., Bailey, D., Bugter, R., Arens, P., Augenstein, I., Aviron, S., Baudry, J., Bukacek, R., Burel, F., Cerny, M., De Blust, G., De Cock, R., Diekötter, T., Dietz, H., Dirksen, J., Dormann, C., Durka, W., Frenzel, M., Hamersky, R., Hendrickx, F., Herzog, F., Klotz, S., Koolstra, B., Lausch, A., Le Coeur, D., Maelfait, J.P., Opdam, P., Roubalova, M., Schermann, A., Schermann, N., Schmidt, T., Schweiger, O., Smulders, M.J.M., Speelmans, M., Simova, P., Verboom, J., Van Wingerden, W.K.R.E., Zobel, M., Edwards, P.J. (2008), Indicators for biodiversity in agricultural landscapes: a pan-European study. Journal of Applied Ecology 45, 141-150. https://doi.org/10.1111/j.1365-2664.2007.01393.x

Hansson, M., Fogelfors, H. (2000). Management of a Semi-Natural Grassland; Results from a 15-Year-Old Experiment in Southern Sweden. Journal of Vegetation Science 11(1), 31–38. https://doi.org/10.2307/3236772

Heinsoo, K., Sammul, M., Kukk, T., Kull, T., Melts, I. (2020). The long-term recovery of a moderately fertilised semi-natural grassland. Agriculture Ecosystems & Environment 289, 106744. https://doi.org/10.1016/j.agee.2019.1067

Hejcman, M., Hejcmanová, P., Pavlů, V., Beneš, J. (2013) Origin and history of grasslands in Central Europe – a review. Grass and Forage Science 68, 345-363. https://doi.org/10.1111/gfs.12066

Kull, K., Zobel, M. (1991). High Species Richness in an Estonian Wooded Meadow. Journal of Vegetation Science *2*(5), 715–718. https://doi.org/10.2307/3236182

Prangel, E., Kasari-Toussaint, L., Neuenkamp, L., Noreika, N., Karise, R., Marja, R., Ingerpuu, N., Kupper, T., Keerberg, L., Oja, E., Meriste, M., Tiitsaar, A., Ivask, M., Helm, A. (2023) Afforestation and abandonment of semi-natural grasslands lead to biodiversity loss and a decline in ecosystem services and functions. Journal of Applied Ecology 60, 825–836. https://doi.org/10.1111/1365-2664.14375

Sammet, K., Martinez, M.R., Tali, K., Melts, I. (2023) New records of arthropods from the priority Natura 2000 habitats in Estonian coastal areas. Check List 19 (6), 1–20. https://doi.org/10.15560/19.6.1

Squires, V., Dengler, J., Feng, H., Hua, L. (2018) Grasslands of the world: diversity, management and conservation. CRC Press, Taylor & Francis Group: Boca Raton 10.1201/9781498796262.

Vessby, K., Söderström, B., Glimskär, A., Svensson, B. (2002) Species-Richness Correlations of Six Different Taxa in Swedish Seminatural Grasslands. Conservation Biology 16, 430-439. https://doi.org/10.1046/j.1523-1739.2002.00198.x

2.3.4. Landscape infrastructures

Semi natural elements to improve pest control and pollination: Flower strips, hedgerows and grasslands

EBAs in which this intervention was tested: CH, NL-2, HU-1

The European Union’s Biodiversity Strategy and the Nature Restoration Law proposal pave the way to promote farmland biodiversity via ecosystem restoration. The implementation of semi-natural elements, such as flower strips, hedgerows and grasslands, in the agricultural landscape has a two-fold purpose. First, areas with non-crop plants diversify ecological niche provision for other organisms compared to crops. This improves the biodiversity condition in the agricultural landscapes. Second, beyond restoration of farmland biodiversity in general, an explicit goal of such areas is to foster biodiversity-based ecosystem services, such as crop pollination and natural pest control services. In case of the biocontrol of pests by natural enemies, the biodiversity-based option is expected to reduce the use of chemical-synthetic pesticides.

In Switzerland, the impact of flower strips on biodiversity and crop yield was assessed by comparing biodiversity and yield in fields with and without flower strips. In the Netherlands, we assessed multiple interventions of varying quality. Two types of hedges (simple shaved hedgerows, which are mown yearly, and complex thicket hedgerows, which are mown every 5-7 years), herb-rich grasslands and road verges as control, were compared. The simple hedges are highly implemented by farmers since they are well paid for and simple to manage. The other two interventions have lower uptake, although payment for them is higher. All three interventions are off-field natural habitats that have been shown to benefit biodiversity. However, thicket hedges and grasslands are richer in floral resources than shaved hedges, which can benefit biodiversity, especially pollinator diversity. We hypothesized that the effect size on biodiversity and pest control services would be correlated with the quality of the intervention (road verges, shaved hedges, thicket hedges, grasslands).

Ecosystem restoration via semi-natural elements can also take the form of semi-natural grasslands, because of their high biodiversity value and rapid success potential. Grassland restoration promotes plant species richness and composition over time, which in turn is beneficial for both aboveground and belowground biodiversity. Long-term results and effects are highly valuable for further projects, policy and decision-making. It is a common premise that the restoration of a species-rich plant community will ultimately result in a diverse arthropod assemblage both in terms of species and functional groups. The primary producers, i.e., plants, are largely established because of direct seeding or emerge from the seed bank and create habitat for other taxa. In Hungary, the aim was to compare sown wildflower fields with permanent road verges and adjacent crop fields.

Supporting literature:

Albrecht, M., Kleijn, D., Williams, N., Tschumi, M., Blaauw, B., Bommarco, R., Campbell, A., Dainese, M., Drummond, F., Entling, M., Ganser, D., De Groot, A., Goulson, D., Grab, H., Hamilton, H., Herzog, F., Isaacs, R., Jacot, K., Jeanneret, P., … Sutter, L. (2020). Global synthesis of the effectiveness of flower strips and hedgerows on pest control, pollination services and crop yield. Ecology Letters, 23, 1488–1498. DOI10.1111/ele.13576

Albrecht, M., Kleijn, D., Williams, N.M., Tschumi, M., Blaauw, B.R., Bommarco, R., Campbell, A.J., Dainese, M., Drummond, F.A., Entling, M.H., Ganser, D., Arjen de Groot, G., Goulson, D., Grab, H., Hamilton, H., Herzog, F., Isaacs, R., Jacot, K., Jeanneret, P., Jonsson, M., Knop, E., Kremen, C., Landis, D.A., Loeb, G.M., Marini, L., McKerchar, M., Morandin, L., Pfister, S.C., Potts, S.G., Rundlöf, M., Sardiñas, H., Sciligo, A., Thies, C., Tscharntke, T., Venturini, E., Veromann, E., Vollhardt, I.M.G., Wäckers, F., Ward, K., Wilby, A., Woltz, M., Wratten, S., Sutter, L., 2020. The effectiveness of flower strips and hedgerows on pest control, pollination services and crop yield: a quantitative synthesis. Ecology Letters 23, 1488–1498. https://doi.org/10.1111/ele.13576

Báldi, A., Pellaton, R., Bihaly, Á. D., Szigeti, V., Lellei-Kovács, E., Máté, A., Sárospataki, M., Soltész, Z., Somay, L., & Kovács-Hostyánszki, A. (2022). Improving ecosystem services in farmlands: beginning of a long-term ecological study with restored flower-rich grasslands. Ecosystem Health and Sustainability, 8(1). https://doi.org/10.1080/20964129.2022.2090449

Balzan, M. V., Bocci, G., & Moonen, A. C. (2014). Augmenting flower trait diversity in wildflower strips to optimise the conservation of arthropod functional groups for multiple agroecosystem services. Journal of Insect Conservation, 18(4), 713–728. https://doi.org/10.1007/s10841-014-9680-2

Bedoussac, L., Journet, E.-P., Hauggaard-Nielsen, H., Naudin, C., Corre-Hellou, G., Jensen, E. S., Prieur, L., & Justes, E. (2015). Ecological principles underlying the increase of productivity achieved by cereal-grain legume intercrops in organic farming. A Review. Agronomy for Sustainable Development, 35, 911–935.

Bihaly Á.D., Piross I.S., Pellaton R., Szigeti V., Somay L., Vajna F., Soltész Z., Báldi A., Sárospataki M., Kovács-Hostyánszki A. (2024). Landscape-wide floral resource deficit enhances the importance of diverse wildflower plantings for pollinators in farmlands. Agriculture Ecosystems & Environment, 367 Paper: 108984. https://doi.org/10.1016/j.agee.2024.108984

Boetzl, F. A., Douhan Sundahl, A., Friberg, H., Viketoft, M., Bergkvist, G., & Lundin, O. (2023). Undersowing oats with clovers supports pollinators and suppresses arable weeds without reducing yields. Journal of Applied Ecology, 60, 614–623. https://doi.org/10.1111/1365-2664.14361

Boetzl, F.A., Krauss, J., Heinze, J., Hoffmann, H., Juffa, J., König, S., Krimmer, E., Prante, M., Martin, E.A., Holzschuh, A., Steffan-Dewenter, I., 2021. A multitaxa assessment of the effectiveness of agri-environmental schemes for biodiversity management. Proceedings of the National Academy of Sciences of the United States of America 118, e2016038118. https://doi.org/10.1073/pnas.2016038118

Bossuyt, B., & Honnay, O. (2008). Can the seed bank be used for ecological restoration? An overview of seed bank characteristics in European communities. Journal of Vegetation Science, 19(6), 875–884. https://doi.org/10.3170/2008-8-18462

Dolezal, A. J., Esch, E. H., & MacDougall, A. S. (2022). Restored marginal farmland benefits arthropod diversity at multiple scales. Restoration Ecology, 30(1). https://doi.org/10.1111/rec.13485
Gu, C., Bastiaans, L., Anten, N. P. R., Makowski, D., & van der Werf, W. (2021). Annual intercropping suppresses weeds: A meta-analysis. Agriculture, Ecosystems & Environment, 322, 107658.
Habel, J. C., Dengler, J., Janišová, M., Török, P., Wellstein, C., & Wiezik, M. (2013). European grassland ecosystems: Threatened hotspots of biodiversity. Biodiversity and Conservation, 22(10), 2131–2138. https://doi.org/10.1007/s10531-013-0537-x
Hermoso, V., Carvalho, S. B., Giakoumi, S., Goldsborough, D., Katsanevakis, S., Leontiou, S., Markantonatou, V., Rumes, B., Vogiatzakis, I. N., & Yates, K. L. (2022). The EU Biodiversity Strategy for 2030: opportunities and challenges on the path towards biodiversity recovery. Environmental Science and Policy, 127, 263–271.
Hyvönen, T., Huusela, E., Kuussaari, M., Niemi, M., Uusitalo, R., & Nuutinen, V. (2021). Aboveground and belowground biodiversity responses to seed mixtures and mowing in a long-term set-aside experiment. Agriculture, Ecosystems & Environment, 322(September), 107656. https://doi.org/10.1016/j.agee.2021.107656
Isbell, F., Adler, P. R., Eisenhauer, N., Fornara, D., Kimmel, K., Kremen, C., Letourneau, D. K., Liebman, M., Polley, H. W., Quijas, S., & Scherer-Lorenzen, M. (2017). Benefits of increasing plant diversity in sustainable agroecosystems. Journal of Ecology, 105, 871–879.
Kiehl, K., Kirmer, A., Donath, T. W., Rasran, L., & Hölzel, N. (2010). Species introduction in restoration projects – Evaluation of different techniques for the establishment of semi-natural grasslands in Central and Northwestern Europe. Basic and Applied Ecology, 11, 285–299. https://doi.org/10.1016/j.baae.2009.09.002
Segre, H., Kleijn, D., Bartomeus, I., WallisDeVries, M. F., de Jong, M., van der Schee, M. F., ... & Fijen, T. P. (2023). Butterflies are not a robust bioindicator for assessing pollinator communities, but floral resources offer a promising way forward. Ecological Indicators, 154, 110842.
Török, P., Vida, E., Deák, B., Lengyel, S., & Tóthmérész, B. (2011). Grassland restoration on former croplands in Europe: An assessment of applicability of techniques and costs. In Biodiversity and Conservation (Vol. 20, Issue 11, pp. 2311–2332). https://doi.org/10.1007/s10531-011-9992-4
Van Buskirk, J. & Willi, Y. (2004) Enhancement of Farmland Biodiversity within Set-Aside Land. Conservation Biology. 18(4), 987-994. https://doi.org/10.1111/j.1523-1739.2004.00359.x

3 Methods

3.1. Description of the EBAs

UK EBA

The UK EBA (Fig. 2) is dispersed across Southern England, within an area of ~17,000 km². It consists of 16 farms (marked in red in the map below), each of which volunteered to participate in Showcase. Many of them have an existing relationship with project-partners LEAF (Linking Environment and Farming), and were recruited via their member network. These 16 farms are predominantly arable, but some are mixed. The most common arable crops are wheat, oilseed rape, barley, and oats. The farms vary in size from large estates to small local businesses, and the intensity of farming also varies, but most are intensive. Overall, a typical group of farmers with many particularly interested in sustainability (including biodiversity, soil health, and carbon-capture) and some that are LEAF Mark Certified.

Fig. 2. Location of the farms in the UK EBA

All farms are participating in some agri-environment schemes. The co-design method to start the EBA took eight months and many one-to-one and group meetings, but thereafter one meeting per year was organized. The research aims to identify whether winter cover crop frost tolerance affects biodiversity in UK arable farming, and included three cover crop treatments and one control (non-cropped area). The expectation is that cover crops with lower frost tolerance will die off gradually throughout the winter causing the gradual addition of organic matter to the soil and the formation of pores to improve infiltration. Less plant matter in spring could reduce glyphosate application and strain on machinery caused by planting through biomass. We used a randomized complete block design across 11 farms (originally 16, but many exited due to drought). The cover crops established well, despite a severe summer drought that delayed planting and an intense frost that killed off some of the species selected for high frost tolerance. The control areas had lowest plant cover during cover cropping, and the cover cropped areas had similar levels of plant cover. There was greater dead biomass in the frost sensitive mix in the spring indicating that the treatments were effective. We measured the impacts of the treatments before, during (twice) and after the treatments were in using biodiversity (plants, spiders, beetles, earthworms) and ecosystem functioning (decomposition, soil structure, soil nutrients, soil organic matter, yield) indicators.

French EBA

The French EBA (Fig. 3) is located within the *Nouvelle Aquitaine Region*, Centre West of France. The site size is about 450 km² with more than 13 000 agricultural fields belonging to almost 450 farms. The EBA is situated just south of the City of Niort, and around the Chizé Forest (see map; the blue line contour shows the EBA). More than 90% of the 450 km² are farmed. Agricultural systems are equally shared between mixed farming (50%) and pure arable (50%), though over the last 25 years, mixed farms have strongly decreased from c.80% to 50%, as well as the overall number of farms (650 in 1994). Our team is currently working with ~100 farmers per year, 250 over the last 5-6 years. Of the 450 farms, 70 are currently organically farmed, and > 100 have contracted AES (Agri-environmental measures), because half of the study area is a NATURA2000 site.

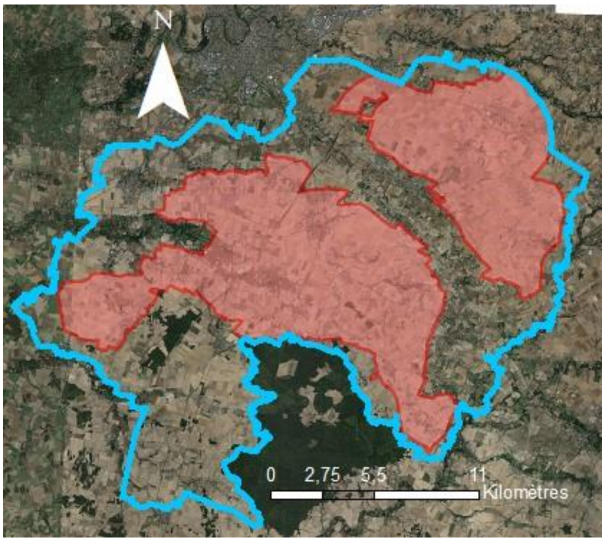

Fig. 3. The LTSER Zone Atelier Plaine & Val de Sèvre, French EBA, delineated in blue. The red are is the NATURA 2000 site.

The EBA is a typical lowland intensive farmland, with 8% forests, 8% urban, many hedges, 3% permanent grasslands (aged >10yrs). Semi natural elements include mainly hedges, small forest fragments (about 400 patches), stone walls, isolated trees and small vineyards. The EBA is a research platform with long-term monitoring of weeds, insect pollinators and birds. The biodiversity intervention is to extensify crop production in wheat by 33 to 55 percent. This has been achieved by (a combination of) reducing nitrogen and pesticide use in conventional farming, reducing tillage from several times per year to no plough and 1-2 times mechanical weeding. In 2022, 16 farmers participated with 20 fields and in 2023 12 farmers with 20 fields. Ten farmers participated in both years. The exact interventions were agreed upon in face-to-face meetings in co-design with individual farmers so the exact nature of the interventions differs between fields. For organic farmers the assumption was that sowing high densities can reduce weeds, thus reducing mechanical weeding.

Hungarian EBA

The **EBA HU-1** is located in Central Hungary (Fig. 4a), in the Kiskunság area. One large farm, which has c. ten-thousand ha of crops and low intensity pastures; crops: cereal, maize, oilseed rape, sunflower; animal breeding: pig, sheep, poultry, but only sheep graze the pastures. The landscape is characterised by vast conventionally managed (ca. 100 kg N/ha on average) agricultural fields; arable land amounted to more than 40% of every landscape circle. Mainly arable landscapes composed of large fields, and semi-natural grasslands. There are tree lines, small woodlots, wetlands scattered in the landscape. The Hungarian intervention was the creation of wildflower fields. The aim of the study is to show that wildflower fields can enhance pollination and pest control. Road verges were used as control, seminatural habitats. The road verges in the area either consist of tree hedgerows or grassy margins. Plants, insect pollinators via various techniques (transect walk), yield of neighbouring arable fields, were sampled. For SHOWCASE project, we surveyed vegetation, bees and hoverflies, spiders and cereal yield.

Fig. 4a. Location of the fields in the Hungarian EBA 1

The **EBA HU-2** is located in Central Hungary (Fig. 4b), in the Kiskunság area. In the EBA there is 88% livestock and semi-natural grassland (including those under Natura 2000 protection), 10% arable land, 2% other. The EBA hosts c. 80 farms, belonging to an informal network, of which the SHOWCASE team works with 20, via a farmer advisory hub. There is some certified organic farming, and many farmers take up agri-environmental schemes (AES). The questions addressed are co-designed with the stakeholder, the farmers and nature conseervation authority. The goal was to improving soil quality and increasing invertebrate species diversity in abandoned arable fields, by overseeding with seed mixture of 11 plant species, containing locally occurring native, non-protected plant species, with a wide diversity according to season, flower morphology and taxonomy, but with a dominance of Fabaceae species, which are known for improving soil properties.This EBA was primarily used for WP2 surveys. Farmers could be contacted through the farm/agricultural-advisor, or, directly.

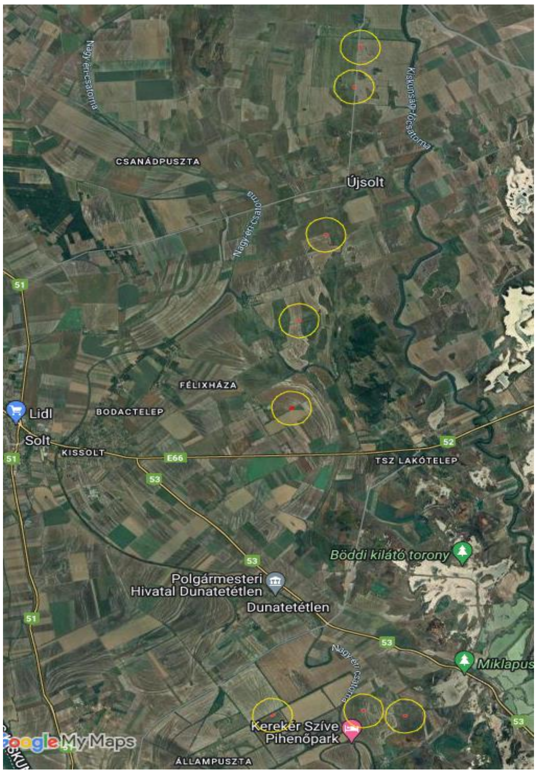

Fig. 4b. Location of the fields in the Hungarian EBA 2

Romanian EBA

”Dealurile Clujului Est” Natura 2000 site is situated in the north of Cluj-Napoca (Transylvania), the second largest city in Romania (Fig. 5). The main part of the protected area is situated in four communes: Borşa, Vultureni, Chinteni, Dăbâca. The commune of Borşa extends over an area of 62 km², and has about 1550 inhabitants in 4 villages (data for 2011). The commune of Vultureni has about 1500 inhabitans in 6 villages and covers an area of 71 km² (data for 2011). The commune of Chinteni has 2900 inhabitants in 9 villages and covers an area of 96 km² (data for 2011). The commune of Dăbâca has 1500 inhabitants in 3 villages and covers an area of 50 km² (data for 2011). Geographically, the area belongs to the so-called “Hills of Cluj”, the south-eastern part of the Someş Plateau, which borders on the Transylvanian Depression. As the name implies, the region is characterised by hill chains with average heights of between 450 and 550 m (max. is ”Dealul Nucului” with 667m), whereas the valleys of the left bank tributaries to the “Someșul Mic” are between 250 and 400 m high. In the research area, the valleys are orientated NW-SE, leading often to distinctive characters on the north and south facing slopes. The soils belong (most of its) to chernozemic soils (CZ) with its related subtypes: CZ ca, CZ ca gl. Landslide phenomena can be observed in the area – both so called “slumping hills” characteristic of Transylvania and active superficial landslides on some slopes. A particularity of the area is the presence of volcanic tuff “tuful de Dej” (in some places even at surface of the earth). As a cultural feature, most of the old houses are built with volcanic tufa. The mean annual temperature is 7-10°C, with average temperatures of 19-21°C in July and -1 or -2°C in January. The annual mean precipitation reaches 600-700 mm, with great fluctuations between years. The agriculture is characterised by subsistence and semi-subsistence holdings (3-4ha), which in general own several small arable and grassland plots scattered over the commune. As well as arable farming, sheep and cattle keeping are carried out. One of the great problems in the studied area, as well as in most of the rural area of Romania, is the aging of the population. In the region there are Agri-environment measures with a package on the conservation *Maculinea* sp. with late cutting date.

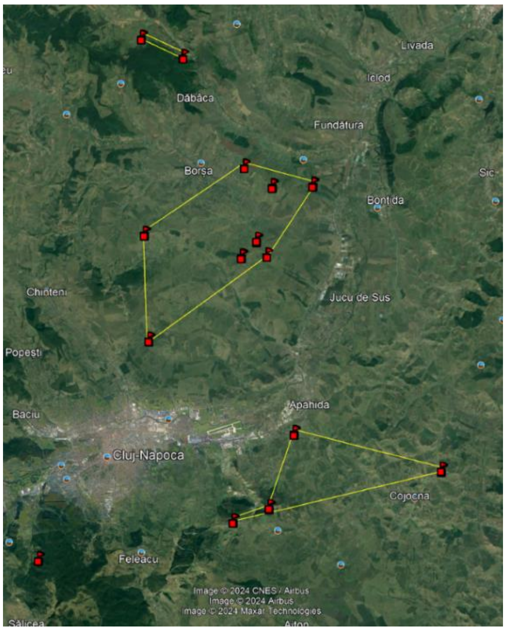

Fig. 5. The Romanian EBA with all experimental and control fields (red dots).

Dutch EBA

The Dutch EBA (Fig. 6) is located in the southern tip of the Netherlands, in the southern half of the province of Limburg. The area is centred around the Living Lab Boshommellandschap Geuldal (https://www.boshommellandschap-geuldal.nl) where WU has implemented a landscape-level multi-stakeholder project for bee conservation (yellow area in the figure below). The SHOWCASE experimental work and social interactions are taking place in a larger area south of the city of Heerlen and bordered on all other sides by Belgium and Germany. Farming in the area consists of a mix of dairy, orchard and arable farming, which are all very intensively managed. Many farms participate in agri-environment schemes (AES). We thus collaborated intensively with the agricultural nature conservation cooperative that coordinates AES implementation. The number of organic farmers is limited, as approximately 3% of the agricultural land use of the province is organic, which is primarily grassland for dairy farming. The EBA is located on a plateau of loess soils in which a number of small rivers have eroded a range of valleys into the limestone substrate. Intensive arable farming and orchards dominate the plateau and dairy farming dominates the valleys. A significant proportion of the valleys furthermore consists of N2000 areas as the slopes in particular support species-rich calcareous grasslands. The management of most of these protected areas is subcontracted to farmers under strict guidelines set out by conservation organizations. The key economic sector of the area is however recreation (popular region for vacations, outings or cycling trips).

Fig. 6. Locations of fields studied for hedgerow and grassland interventions in south Limburg, the Netherlands

Two biodiversity interventions were studied in the Dutch EBA. Intervention one is growing lupin with cereals as control (**NL-1**). In 2021 6 fields, in 2022 14 fields, and in 2023 6 fields were studied, so in total 26 fields (13 interventions and 13 control). All fields were organic or extensively managed. Core biodiversity indicators were collected and identified. Yield was not considered because only two of the farmers harvested the crops, and not in every year, due to cultivation difficulties. The second biodiversity intervention was managing natural elements (two types of hedgerows and herb-rich grasslands) in a biodiversity-friendly way (**NL-2**). In 2021 data was collected in 26 cereal fields (8 control and 18 interventions), and 2022 in 21 fields (7 control and 14 interventions). Core biodiversity indicators have been collected and identified. Yield and pest control indicators were collected. A third study aimed to quantify the relation between biodiversity and a range of ecosystem services and productivity in grasslands. Forty-one grasslands were sampled in a gradient from low intensity to high intensity. Plants, bees, earthworms and a number of ecosystem services and functions were measured. Management and agronomic data were collected to calculate gross margins.

Swiss EBA

The EBA is on the Swiss plateau in the canton of Solothurn between Bern and Basel (Fig. 7). It is part of a project running in a larger area consisting of 5 small regions of 20 km² each, 1 near Geneva (8 farms), 3 in the canton of Vaud (38) and the EBA in the Solothurn region (11 of a total of 19 farms). Farming systems consist of arable farming (cereals, oilseed rape, maize, sugar beet, potatoes), but also mix arable/diary, with sown grasslands being part of the rotation. Most of the farms have cows. There are no organic farms in the set of farms involved. The agricultural landscape is mixed, arable, pastures and semi natural elements, such as hedgerows, grasslands, traditional orchards and sown wild flower strips. Agricultural production fields are interspersed with woodlots. The region is mainly flat with few gentle slopes. Soils are mainly very highly to highly productive for Switzerland. The Swiss intervention aimed to reduce the use of chemical pesticides by 75 per cent and not reduce yield by more than 10 per cent. For the EBA, the interventions consist of implementing wildflower strips and undersowing (as main agronomic practice) on 11 so called agroecological fields and 11 control fields in 2022 and 2023, respectively. Crops were oil seed rape, winter wheat and barley. Differences in pesticide applications were observed but were not too very pronounced (e.g. no insecticides on both treatments and controls). Fertilizer use was similar on the two treatments. Biodiversity indicators bees, spiders, vascular plants were measured, yield was assessed and habitat mapping was done. Hardly any bees were found in most crops and only some in oil seed rape.

Off-field there was clearly higher bee species richness in the intervention treatments. Spider species richness seemed to be higher in the agroecological management compared to control in oil seed rape and wheat but not in barley. Vascular plant species richness was significantly increased in agroecological fields.

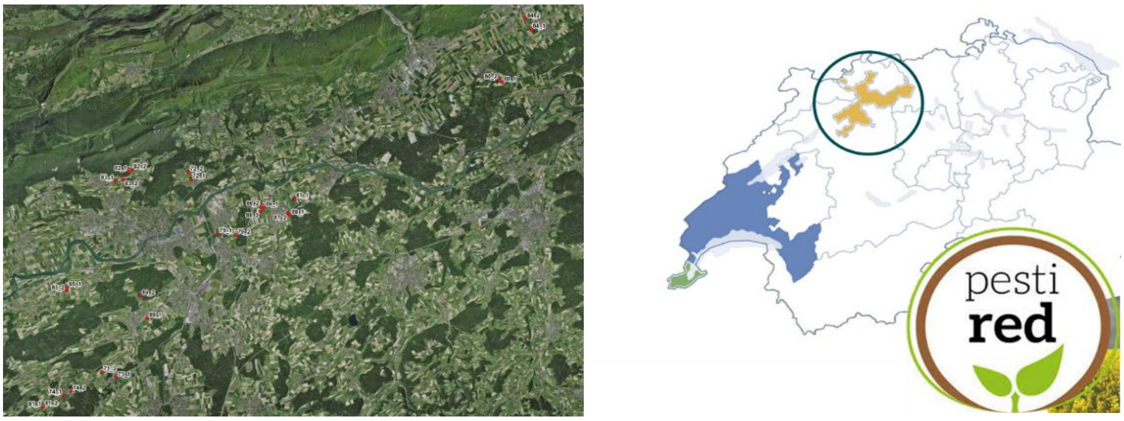

Fig. 7. Locations of fields studied in Swiss EBA, with the general area of PestiRed shown on right.

Portuguese EBA

The Portuguese EBA, EBAlentejo (Fig. 8), is located in Alentejo in southernPortugal, being the largest natural region in the country. It has an area of 26158 km2, which corresponds to about 29% of the country's total surface. It is divided into three large areas, Alto Alentejo, Central Alentejo and Baixo Alentejo. Alentejo is bordered on the north by the Tejo River, on the east by Spain, on the south by the Algarve and on the west by the Atlantic Ocean. The region's relief is characterized by the great uniformity of peneplains, where low altitude mountainous masses stand out, disperse and far apart, with the exception of the São Mamede (1025m) and Mãrvao (865m) mountains. The climate is temperate Mediterranean, with hot, dry summers and mild, rainy winters.

Fig. 8. General location of Portigese EBA (blue) and fields studied (red dots).

The decrease in maritime influence makes the inland areas of the Alentejo particularly hot in summer and relatively cold in winter. Natural and semi-natural vegetation occurs in the form of extensive savanna-like forests mainly composed of cork (*Quercus suber* L.) and holm-oak (*Q. rotundifolia* L.) trees in varying densities, the characteristic Portuguese montado, which is considered a High Nature Value Farming System according to the European Environmental Agency. The agricultural characterization of the area encompasses a useful agricultural surface of 582,190ha being represented by a wide variety of crops. During the last decade, .however, olive groves have become a major crop in the region. The annual production of olive oil in Alentejo has increased by more than 1,000 percent in less than 20 years, mainly driven by the ever-increasing cropland area devoted to this crop and the intensification of farming practices. Portugal is, in fact, the fourth largest olive oil producer in Europe and the sixth largest producer in the world, with a record harvest of 140,000 tons reached in 2021.

Spanish EBA

The Spanish EBA (Fig. 9) is called Guadalquivida (https://www.beeproject.science/eba.html). It consists of a new pilot community of stone fruits producers and is located in the agricultural Guadalquivir valley, in the Vega del Guadalquivir county in Seville province. This EBA was newly created during the SHOWCASE proposal phase and its finally assembled by two farmers cooperatives, two companies, a scientific partner and collaborates with local ngo's. Farming in the Spanish EBA initially consisted of stone fruit conventional orchards with a traditional intensive use of pesticides and labour. The experimental work has been developed in 15 fields located in San José de la Rinconada, Alcalá del Río, Esquivel, Cantillana, Alcolea del Río and Burguillos village. The community includes farmers, agricultural technicians, scientists and other sector stakeholders. The field community participated in the co-design that was successfully implemented in 15 fields over 2 years, and there was sporadic contact with the broad community, with key informants interested in knowledge transfer. Spanish EBA is in an area where the stone fruit sector has suffered a restructuring due to economic and socio-political factors. During the last decade, the number of stone fruit fields has significantly decreased in favour of citric orchards. Also, field management has intensified. The participant farmers are those remaining after the sector restructuring and are interested in pro-biodiversity managements facing new market demands and policy requirements. However, they are openly warring against organic farming. Our route to assemble the EBA has been through telephone calls to different cooperatives and companies.

Fig. 9. Locations of fields studied in Spanish EBA (fields in blue).

Swedish EBA

The Swedish EBA (Fig. 10) is located in the Uppland region, centred around Uppsala, and north of Stockholm in eastern south-central Sweden. The EBA consists of farms distributed over the entire region, rather than being one contiguous area. Arable farming is dominating in the area, but there are also livestock farming (mainly cattle, for meet), and few dairy farms. Cereals are the dominating crop type, with oilseed rape and ley (grass, clover etc.) also typically being part of the crop rotation. Both organic and conventional farms are represented in the EBA. Average farm size within the EBA is highly variable and in some cases, the farming is only a part-time occupation. The landscape in the region is dominated by a mix of production forest and agricultural land. In addition to arable land, there are fragments of permanent, semi-natural, grasslands. Arable land is typically situated on post-glacial clay deposits, while forest and semi-natural grasslands are typically on moraine or outcrops.

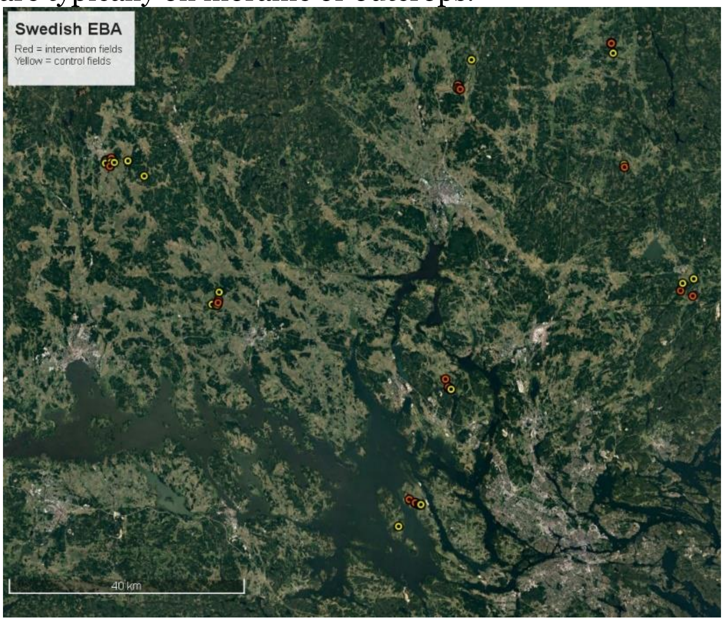

Fig. 10. Map of Swedish EBA fields 2022-2023. Intervention fileds are shown in red and control fields in yellow. N.B.: Some fields located close to each other might not be visible at this scale because symbols or on top of each other.

Estonian EBA (EE)

The SHOWCASE EBA in Estonia (EE) is located in the western and south-western coastal lowlands next to Baltic Sea (except islands, see Fig 11 below). Study areas are situated in two counties (Pärnu and Lääne county). The study area encompasses the West-Estonian Lowland and the Gulf of Riga Coastal Lowland (landscape regions by Arold 2005; see figure below) covered west coast of Estonian mainland. The West-Estonian Lowland is on limestone bedrock, while the Gulf of Riga Coastal Lowland lies mainly on Devonian sandstones. More precisely in two urban (Pärnu and Haapsalu cities) and three rural municipalities (Häädemeeste, Lääneranna and Lääne-Nigula) covering the coastline of about 300 km. Pärnu and Haapsalu cities cover 857.9 km^2 (population density 59. 0 inhabitants per km^2) and 271.8 km^2 (47.4 inhabitants per km^2), respectively (Statistics Estonia, 2021a). Häädemeeste, Lääneranna and Lääne-Nigula rural municipalities cover 494.3, 1,362.6 and 1,448.7 km^2 with population density 9.7, 4.0 and 4.8 inhabitants per km^2, respectively. The EE EBA consists of mix farming, and crop and/or livestock farming, managed both extensively and intensively. Many farmers manage coastal and other types of semi-natural grasslands by grazing and/or by mowing for nature conservation. Based on Statistics Estonia (2021b), the number of agricultural holdings having received area and animal-based European Union support is the biggest in Pärnu county with 1,305 holdings and comparable number is 383 holdings in Lääne county.

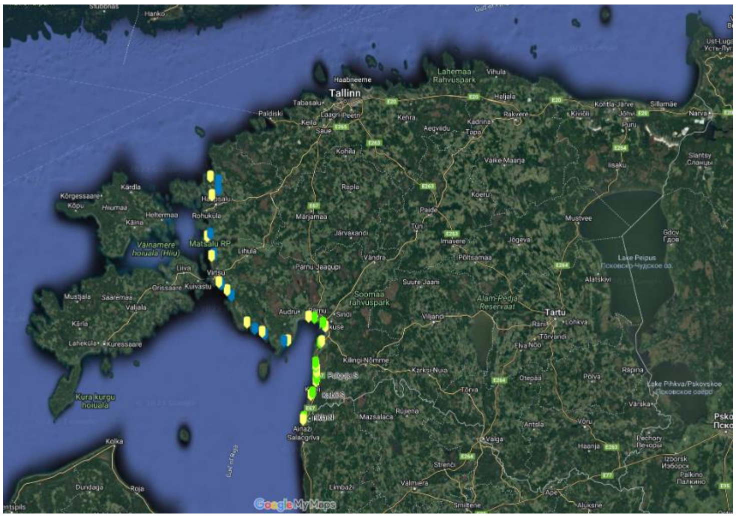

Fig. 11. Location of study fields in EE EBA in 2022. Yellow icon is control fields; green and blue icons are experimental fields managed by grazing and indicate to the two different landscape regions.

The number of agricultural holdings participating in agri-environmental schemes (AES) is 1,201 in Pärnu county and 366 in Lääne county. In Pärnu county you can find the biggest number of holdings with organic farming (221). Corresponding number is 83 holdings in Lääne County. Total number of holdings with organic farming in Estonia is 1,938. The EE EBA is located within coastline in Lääne County (population 20,208 (Statistics Estonia, 2021a)) and in Pärnu county (85,760). SHOWCASE project includes at least 16 farms that are strongly involved in land management in the coastal areas for nature conservation.

Fig. 12. Some pictures of the variety of landscapes across European EBAs

3.3. Farmer selection

Before establishing standardized protocols, we looked for local initiatives between SHOWCASE scientists and stakeholders, farmers or cooperatives. The way SHOWCASE scientists interacted with farmers to select the biodiversity interventions differed between each EBA. In the UK and Sweden, a full co-design approach was initiated late 2020 (UK) or spring/summer 2021 (Sweden) to identify together with farmers what biodiversity intervention to set up for. These latter two countries are the only one where such a full co-design approach has been used within SHOWCASE. Several meetings with farmers were organized in the UK before final acceptance. In Switzerland and France, a co-design approach was also used, but was initiated before SHOWCASE started. For instance, in France, scientists have been working with farmers to co-design Social-Ecological experiments since 2012. In Hungary, an experiment was designed with farmers (on their grasslands) before SHOWCASE started, but the discussions with a single large state-owned farm within SHOWCASE resulted in a new intervention related to wildflower strips implementation, an intervention which was suggested by the researchers. In the Netherlands, SHOWCASE scientists decided to work on existing interventions (hedges) and interacted with farmers to ask what kind of parameters/practices they were interested in and whether they would agree to work on their land. A similar situation was found in Estonia. In Spain and Portugal (Orchards), farm interventions were discussed with farmers, in a half co-designed process or top-down approach, i.e. scientists approached farmers and suggested options which were chosen and refined by farmers. Finally, in Romania, farm interventions were proposed by SHOWCASE scientists together with local managers. These are briefly summarized below, as a simple presentation. In-depth analyses of this process are the subject of several papers, which are in progress (UK and French lead).

In UK, Hungary and Switzerland, scientists relied on a farm organization. In the **UK**, the intervention was selected following a farmer-led co-design process that was conducted over eight months (Feb-September 2021). The farmers were recruited via a partner of the project, *Linking Environment and Farming* (LEAF), who is an internationally known farmer association focussing on integrated farm management. They recruited participants via their extensive farmer network (>26,000 followers on twitter) using twitter, their newsletter, emails, and phone calls. At least 3,000 farmers were reached. The farmers chose the intervention via an eight-month co-design process which included 11 online workshops, 2 surveys, 1 in-person meeting, 16 two hour in-person, face to face interviews, and tailored evidence synthesis of biodiversity interventions. After the intervention was chosen, the farmers selected the fields where to implement it. They were advised that they should select fields where soil type was relatively consistent throughout, if possible. Once the farmers chose the intervention (cover crops), cover crop experts were recruited from the University of Reading, the Royal Agricultural University, and a cover crop company (Oakbank) to help with the species selection. Oakbank provided the bespoke mixes that were designed with these stakeholders.

In **Switzerland**, farmers were similarly contacted through the project stakeholder IP-Suisse, a farmer association. Over 100 farmers were individually contacted. Fields were selected by the farmers after initial workshops during which rules have been defined including the minimum distance (> 500 m) between fields of the same pair – with and without interventions –, and first crop has to fit to the design of the crop rotation decided. The interventions – flower strips and undersowing – were part of the PestiRed design from the beginning on before SHOWCASE. The farmers and the extension services have been fully involved in the selection of the PestiRed agroecological practices that have been implemented. In **Hungary**, a single farm was involved in **HU-**

1 EBA, which was a large agricultural company. The company was approached as the selected sampling landscapes are managed by them. For the second site (**HU-2 EBA**), farmers were approached via a farm/agricultural advisor, then were individually contacted, in face to face meetings, and one by one.

In three other countries, a cooperation was also organized with a structure belonging to the farm world, in the form of a cooperative (Netherland, Portugal, Spain). In **Portugal**, an agricultural cooperative of olive farmers was first contacted. The project was explained and a meeting upon request of and with olive farmers was set up. Then, on-line meeting was organised with the responsible of the agricultural cooperative and all olive farmers potentially interested in participating. Lastly, scientists visited all the olive farms belonging to farmers interested in participating and all those olive farms belonging to farmers interested in participating were included in SHOWCASE. In total, approximately 35 farmers were contacted. Fields were selected based on farm size and pest management strategy (i.e., only farms following a pest management strategy were included). All olive farmers were highly interested to participate in the project from the beginning. In the **Netherlands**, a farm cooperative was also involved. Approximately 30 farmers were individually contacted. For the lupin study, the farmers selected experimental fields. The control fields were selected to be arable grain crops grown by mostly the same farmers, minimum 1km from any other field involved in the study. Experimental and control fields were chosen to have a similar gradient in surrounding landscape complexity (500m, % semi-natural habitat). The farmers chose where to sow the crop and which variety to sow. For the hedgerows and grassland study, the scientists mapped the crops and interventions in the area, followed by visits to the area to validate our maps and contacting land owners. Suitable interventions were then filtered according to several criteria such as field size (avoiding non-typical sizes), minimal length and size of the interventions, distance between fields (to avoid spatial biases). A more top-down contacting process was carried out during the spring of year 2021 in **Spain**. All the stone fruit companies and cooperatives in the Vega del Guadalquivir region were contacted through their directives and managers. In those that were interested in participating in the project, agricultural technicians from sustainability departments were invited to the co-design process. In the case of companies, agricultural technicians identified those farms suitable for the project. In addition, some foreman workers were invited to the conversation. In the case of cooperatives, agricultural technicians identified those farmers more interested in farm sustainability and collaborating in a participatory research project. Sixteen different companies and cooperatives were initially contacted. An online introductory meeting with 2 companies and 4 cooperatives was organised in June 2021, and a kick-off meeting with 2 companies and 2 cooperatives in September 2021, to introduce the final group, present SHOWCASE aims and decide a working plan. During October 2021, an in-person diagnosis workshop with farmers and agricultural technicians was realised to identify farmers' needs and opportunities using different participatory dynamics. The mains need were to improve the knowledge on plant and insect biodiversity and the current status of these taxa within farms, and to test biodiversity enhancing measures aligned with future CAP policy. After this workshop the research team elaborated a portfolio with different potential interventions based on current scientific evidence, with 2 dominant work lines: farm hedges and flower strips. After several in-person and telephone meetings, green covers were selected as the most interesting intervention for farmers and companies. A total of 19 farms were included originally in the project and seeded, but finally only 16 were finally monitored.

In a single country, a cooperation with an organisation was also sought, but it was not a farm organisation, but an environmental organisation (Estonia). In **Estonia**, farmers were selected through a systematic process involving cooperation with the Environmental Board, which is responsible for nature conservation in Estonia, including the maintenance of semi-natural grasslands. Also e-mails with the cooperation offer were shared to potential interested farmers through the local farmers federation. The Environmental board was asked for potential fields and contact details of the farmers who could be interested partners. By combining recommendations from the Environmental Board with prior knowledge of coastal grasslands from other colleagues, potential pilot fields, contacts were identified, and farmers were contacted by phone. For control fields, permission for fieldwork was requested from landowners. This methodological approach ensured a thorough and strategic selection of farmers to participate in this project. In total, about 20 farmers for experimental fields and about 25 landowners for control fields were contacted. The Environmental Board and the expert were involved in pre-selection, but not in designing the interventions. Farmers did not give any direct input in the design of the intervention, but in general potential interventions in the coastal grasslands were discussed with them, especially since some farmers were aware of biodiversity values in their coastal grasslands. In general, farmers just agreed with the design of experiment as proposed by scientists.

In the last three countries, farmers were directly and individually contacted, but the co-design process was either collective (Sweden) or individual (France, Romania), bottom up in France and Sweden, more top down in Romania. In **Sweden**, a bottom-up approach to the selection of both farmers and interventions was chosen. Originally, farmers that have been involved in previous research projects and who had interest in biodiversity-related issues, were first contacted. University channels were also used to reach farmers in the region who could potentially be interested in participating. This resulted in a set of approximately 40 farmers who were interested in collaborating in some way. Among these farmers/farms, which were highly diverse, similarities in farming types were screened, and farmers were asked about potential interventions that they would find interesting to assess. Based on this, and during a workshop to which interested farmers were invited, intercropping with a mixture of cereal and leguminous crops was selected as the intervention. The ca. 40 farmers were contacted again to identify those who of them had already planned to, or would be interested in, participating in a field test of intercropping vs. monoculture. This resulted in the final set of farmers. The second year (2023), farmers were contacted again, and this resulted in a few more farmers (please add the number). The experimental fields were selected by the participating farmers, and monoculture control fields, either managed by the same farmers, or in a few cases on neighbouring farms, were finally selected. In **France**, contacts were taken mainly with farmers engaged in previous projects, though a few (3) were participating for the first time. But the intervention was co-designed with farmers, who were allowed to choose the width, position, and level/magnitude of pesticide and nitrate reduction to be applied in part of or all the field. Organic farmers also decided the intensity of which soil operations they wish to reduce, i.e. either ploughing, mechanical weeding or both. This resulted in quite complex designs. In total, about 20 farmers were contacted, and all agreed to be part of the experiment (most of them had already taken part of previous experimentations on the LTSER). All the process in France was individually based, no meeting with all farmers was organized during the experimental set up process. In **Romania**, farmers were selected based on those who were already knew, and whose lands were familiar with the EBA leads, i.e. they were already known to employed such type of interventions. Of the 7-8 farmers contacted, 4 agreed to participate. They precisely adhered to the methodology proposed in the project and cut the shrubs along the established transects.

In summary, a co-design approach was adopted in the majority of sites. However, it can be a challenge to produce generalized findings from co-designed experiments, as with most place-based research approaches, the outcomes are highly context specific and dependent on the local characteristics of the stakeholders, their practices and socio-economic characteristics of the farmers. Having said this we were still able to provide some general principles derived from a comparative study that included SHOWCASE sites as well as other sites worldwide (a paper is currently in review, Hood et al.: Ten steps to maximise benefits and reduce risks when co-producing social-ecological experiments). This paper provides 10 guiding principles derived from our study cases, that we believe are strong predictors of successful co design approach. These include: 1/ Critically assess whether co-production is the best approach for you; 2/ Learn from the existing evidence base and consider partnering with current co-production projects; 3/ Identify ways of measuring the co-production process itself; 4/ Recognise that there is uncertainty and you may benefit from a contingency plan; 5/ Select and train your facilitator(s) for your specific needs; 6/ Explore the option of using a trusted intermediary; 7/ Be inclusive: consider the role, expertise and demographics of your participants against the feasibility of engagement; 8/ Set shared objectives and expectations and evaluate them throughout; 9/ Identify potential co-benefits and be prepared to nurture them; 10/ Plan your strategy for dissemination and project legacy.

3.4. Types of interventions

In all EBAs, whether a full co-design, a mixed or a pure scientist/manager approaches were used, the choice of farm interventions involved meetings with 15-25 farmers, and in most cases, one-to one meeting in order to establish detailed protocols. Biodiversity itself was seldom the main target of the farm intervention (except in the Netherland, Hungary, Romania and Estonia); more often, agroecological targets, which include both agronomic, economic and ecological (i.e., biodiversity) aims, were discussed. Therefore, the links between farm interventions and biodiversity were as diverse as the farm interventions themselves. This diversity required additional meeting (numerous) between SHOWCASE scientists and EBAs PIs in order to elaborate standardized protocols.

3.4.1. Some definitions

Field. A field is an agricultural parcel, or plot. It can be an arable field, a grassland (or meadow), or an orchard. A field contains the core field, the field margin (i.e., typically the first meter or less, quite often without crop between the external border and the first sowed row). Next to the field there is in some countries a grassy margin, but sometimes there is nothing like in France, where the next crop starts.

Focal Field. The focal field is the field where surveys are being conducted. It can be the Biodiversity Intervention Field, but can also be a field next to an intervention.

Biodiversity Intervention "Field". The Intervention field is the very precise field or plot where the intervention is being conducted. Depending on the situations, it can be an entire field (excluding field margin in arable, including field margin in grasslands), part of a field, it can also be a grassy strip out of the field but next to it. Or some other boundary feature, so that hedges, ditches and other features can be included.

Control "Field". Each Biodiversity Intervention "Field" is paired with a Control "Field", except in cases with multiple interventions, where the fields without interventions are included but not in a pairwise fashion. Ideally, Intervention and Control were 1 km distant from each other, the same applying if two intervention fields were close to each other, to avoid spatial autocorrelation or confounding effects imputable to mobile organisms. At the same time, the basic abiotic conditions should be similar, i.e. similar elevation, exposition, soil type or climate. Selection of control field was made to ensure for no systematic bias between Intervention and Control (e.g. not to place all intervention fields in coastal edge and all control fields in the hinterland).

3.4.2. Design of farm interventions

As for the farmer first contacts and selection, there was a large diversity in the type of interventions discussed, then implemented. This ranged from a very standardized (and to some extent, academic) way of doing research, to very open and flexible strategy in terms of design and protocols. Below these are presented from most complex and standardized design to the most flexible and/or less complex ones.

In the **UK**, a randomised-before-after-control-impact (R-BACI) experimental design with most samples taken in four times throughout the study duration (Fig. 13): once pre-treatment, twice in-treatment, and once post-treatment. We have four treatments that were implemented across 11 arable farms in Southern England: a frost-tolerant cover crop mix (rye, clover, linseed, vetch), a frost-sensitive cover crop mix (oats, clover, buckwheat, vetch), an intermediary mix (all eight varieties/species), and a control (no cover crop planting). Plant species traits other than frost tolerance (e.g. plant height, N-fixing capacity) were matched between frost tolerant and sensitive mixes as much as possible. A within-field experimental design that ran along the tramlines was chosen. The plots were 24-46 m wide (depending on the farm machinery at each farm) and varied in length, but we sampled within the first 200m. Farmers and researchers together chose within field as many of the measures we were interested in related to the soil, and within field is more comparable due to changes in soil characteristics over close distances. Secondarily, it was cheaper and logistically easier for the farmers.

Fig. 13. The crops in place during the experiment and duration of cover cropping. Months are abbreviated to letters.

In the **Swiss** EBA, both between and within design interventions were opted to investigate the possible synergetic impact on natural pest control (Fig. 14). The figures below illustrate the reduced (chemical) management intensity on innovative fields. The flower strips have been designed to serve as an additional source of nectar and pollen for honey bees and wild bees, as well as to provide food and shelter for other beneficial insects. In addition, the flowering plants enrich the cultivated landscape. Flower strips are classified as 'BFF' areas (biodiversity promotion areas) in Switzerland and farmers are paid for them. They are annual crops. The cultivation period is at least 100 days. The species composition has been selected to attract mainly pest control agents for early (winter) crops and contains many native wild forms (*Anethum graveolens, Anthemis arvensis, Anthriscus cerefolium, Camelina sativa, Centaurea cyanus, Centaurea jacea, Coriandrum sativum, Crepis capillaris, Fagopyrum esculentum, Papaver rhoeas, Reseda lutea, Silene noctiflora, Sinapis arvensis, Valerianella dentata*). They have been sown to the field margin and should not take up more than 50 ares.

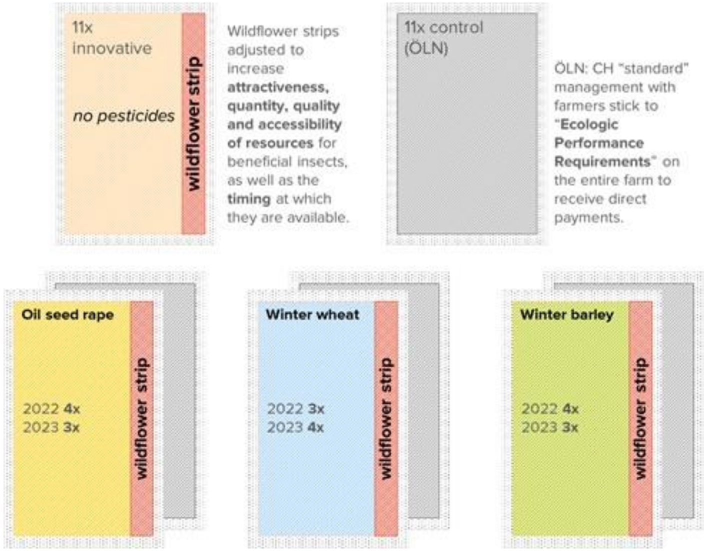

Fig. 14. The design of the experiments in the Swiss EBA. The upper figure shows the general design (paired experimental and control filed, with both filed experiment as well as wildflower strip), while the lower figure shows numbers and crop types in both years.

In **Hungary**, **HU-1**, we created new habitats, via establishing wildflower fields (WFF), as a first step to restore grasslands in the landscape. Such interventions are widespread in Europe, but not in our region. In addition, our WFFs are large (100x50m), and diverse seed mixtures were used for planting. A within-field design was chosen to avoid other influencing factors (e.g. different crop types, soil, management and land use history). Fields were selected within eight landscape circles (r = 500 m), each of which contains a 0.5 ha-sized (50 × 100 m) sown wildflower field (WFF) in the middle (Fig. 15). The distance between WFF and road verge habitats were ~ 100-200 m. The fields were sown in early 2020, on the edge of former crop fields with a seed mixture of 32 local insect-visited flowering plant species that provide food resources over the whole vegetation period and habitat for nesting, sleeping and mating for many animal taxa (Báldi et al., 2022). A detailed description of the study sites can be found in Báldi et al. (2022).

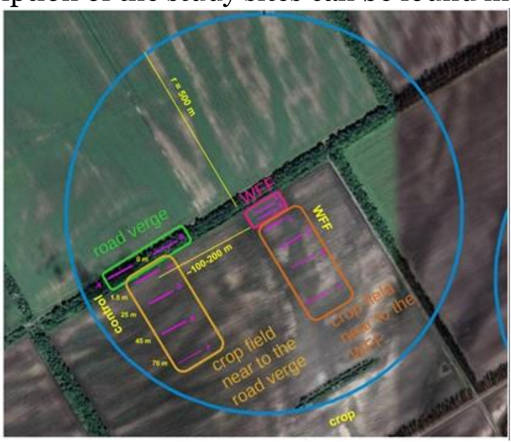

Fig. 15. HU-1 EBA sampling arrangement. WFF: newly established wildflower field in the crop field. Control is the road verge. Lines indicate transects where bee, hoverfly, and spider sampling were also performed. Asterics on the lines indicate botanical sampling locations.

Within the landscape circles, the research team sampled bees, hoverflies, spiders and the spontaneous vegetation within four habitat types, namely the WFF, the existing road verges and inside the crop field surrounding a given WFF and inside the crop field surrounding a given road verge. The research team also sampled alongside transects within WFFs and road verges, and inside the crop field 1.5, 25, 45 and 70 m away from the edge of WFF/ road verge. Cereal yield was sampled as well, 10. 20,... 90 m away from the edge of WFF/ road verge.

In **Sweden,** the intervention consisted of intercropping, i.e. in this case cereal crops combined with leguminous crops in the same field (i.e. sown together, not in separate rows or similar). Depending on what was possible for the involved farmers, there are several different combinations of cereal + leguminous crops (Fig. 16). The most common combination was oats + peas, but other combinations are also e.g. rye + peas, winter wheat + Medicago sp., etc.). We used a paired design, were each pair consist of one intervention field with intercropping, i.e. a cereal crop grown together with a leguminous crop on the same field, and one control field with the cereal crop in monoculture. As described above, there were different combinations of cereal and leguminous crops; in 2023 the most common combination was oats and peas; but the corresponding control field always had a monoculture of the same cereal crop as was grown in the intercropping, i.e. if the intercropping as oats and peas, then the control was oats in monoculture. In some cases, there was also a second control, with the leguminous crop in monoculture, i.e. in the example above, peas in monoculture. Both intervention and control were on entire fields.

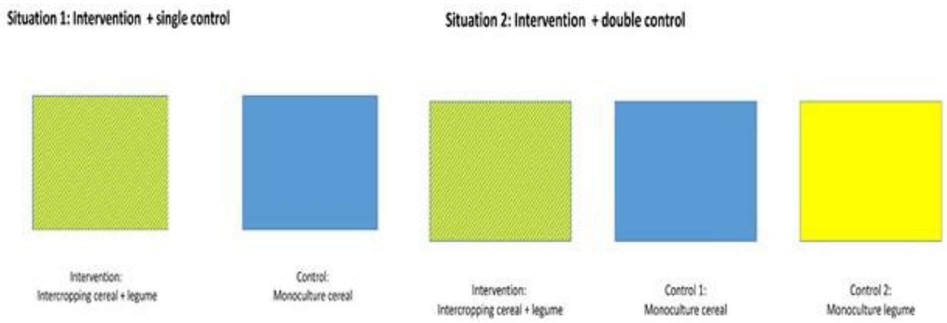

Fig. 16. Paired design with intercropping and control. B: Paired design with intercropping and double controls.

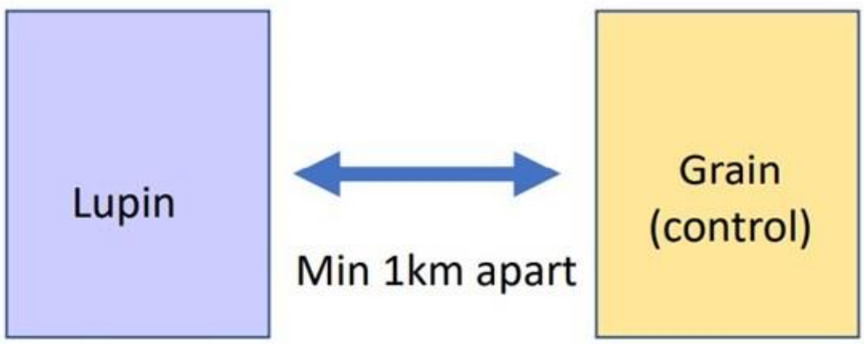

Fig. 17a Basic design of sowing lupin as an intervention within arable fields

In the **Netherlands**, in the first site, a between-field comparison was selected because the intervention was itself a crop. The intervention was sowing blue or white lupin as a crop in organic arable fields (Fig. 17a). The lupin fields were ~1ha in size. The experiment was performed in various locations in the province of Limburg.

In the **second Netherlands** site, a between-field intervention was adopted when farmers applied only one intervention per field, but for grasslands, which were always paired with a hedge, an off-field intervention was selected (Fig. 17b). The experiment was performed in various locations in the province of Limburg. Average field size was 0.5 ha and the length of the hedgerows was 200-500 m.

Fig. 17b. Types of interventions adjacent to arable fields and their sample sizes

In **France**, the design of the experiment was adapted to, and for each farmer, since they choose what they wanted to do. In the simplest, but quite rare case, farmers experimented at the whole field scale, resulting in between field experiments. This occurred both in 2022 and 2023, and both for conventional and organic farmers. More often, farmers decided to split their field into an experimental and a control part, a design actually preferred since it has the strongest statistical power because nothing else than the experiment differs between the two samples (see Fig. 18 for 3 examples).

The experimental plot was highly variable in size, from a band about 6m wide (to the length of the field) up to about 2ha. Within the experimental plot, the design was also highly variable, depending on the number of factors (and their levels) the farmer wanted to experiment. In the simplest case, there was a single factor (reducing, e.g. herbicides). But in most cases, two factors were involved (combination of one, often several pesticides reduction, and nitrogen input), hence the experiment was a two factorial design with the interaction (thus, four levels within the field), with in a number of situations, three levels. Experiments consisted overall in reducing the intensiveness of farming, thus in each experimental plot/field, farmers agreed to change their farming practices.

In **Portugal**, due to the large size that typically exhibit intensive olive farms, we opted for performing an in-farm design intervention (Fig. 19). This is, both control and experimental sites were placed within olive groves. Both types of sites consisted in four tree lines 75 m in length and 1.5 m wide. In the experimental sites, the space between these tree lines (four transects) was sowed with a seed mixture (8 plant species; 15-20 kg of seeds per ha). A paired design was used. This is, each experimental site was paired with a control site (spaced at least 250 meters from each other). In 2021, a total of 10 pairs of experimental and control sites were selected, while this number increased up to 12 in 2022.

Fig. 18. Three examples of experimental design in France (this shows actually the sheets that were given to farmers to recall them what was agreed, and providing the key to the colored flags that were put in their fields). Left, involving two adjacent fields and a two-factor design (herbicide halved, nitrogen halved). Right, a three-factorial design with an organic farmer, involving tillage instead of ploughing (yellow), no mechanical weeding (blue) and reduced inter sowing (12.5cm instead of 25cm; orange). Bottom: a two-factorial design.

Fig. 19. Picture showing an example of a study orchard. The yellow rectangle corresponds to the control site within the farm while the green rectangle corresponds to the intervention site.

In Spain, the experiment was carried out within highly intensive stone fruit orchards to test local effects of Green Covers (Fig. 20). In each farm, Green Covers were implemented as the intervention treatment. This intervention consisted in a surface of approximately halve hectare (a minimum of four adjacent alleys, i.e. the space between tree lines) located in the preferred area selected by each farmer. These alleys were sown with a seed mix for at least 150 meters long and 1.5 meters wide. Other four alleys within the same farm and the same dimensions were left for control treatment. Control alleys could consist in bare soil and/or pruning leftovers, spontaneous vegetation, or a grass-dominated cover. Control and intervention areas were separated by at least 2 alleys, and both treatments were placed at least one alley away from the plot border. As a result of the co-design agreement, farmers were allowed to do any business as usual practice in the experimental alleys, except by the use of herbicides in Intervention. For instance, farmers could choose to mow the Green Cover occasionally to avoid excessive plant height, or to use machinery to apply agrochemicals on the trees along the alleys. A density of 60 kg/ha was sown at a price of 7.2 €/kg. During the second year, the seed mix was enhanced by replacing plants deemed to tall by farmers for shorter alternatives.

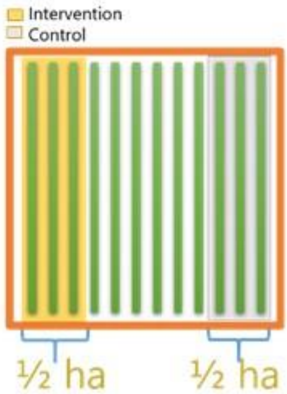

Fig. 20. Experimental set up of Guadalquivida green cover experiment.

In **Romania**, EBA biodiversity intervention was shrub removal in marginal grasslands. The intervention is part of the Romanian agri environment program that aims to maintain grasslands. Core indicators were surveyed as well as butterflies and hoverflies. The surveys in the controls were done next to the shrubs because shrubs were too dense and thorny. All plants and butterflies have been identified but the 2022 bee species still need to be identified and the 2023 spider and bee species need to be identified. Challenges were the sheep herds, and their aggressive dogs that prevented field work occasionally. Identifying who owns and manages what land is extremely difficult. Shrub removal was done by independent NGOs. The removal of shrubs was done mechanically - using machines. Regarding the removal of the shrubs: for the cutting of the shrubs the farmers use forestry cutters of different sizes. The big farmers have their own machines and they cut for themselves. The smaller farmers hire the big farmers to come and cut the shrubs on their plots. In this case the farmers are payed (600–700 euros/day). The farmers receive money for cutting the shrubs and maintaining the grasslands only after they cut. After they cut the shrubs they have to apply at the paying agency (APIA) for this measure. After they apply and are verified by APIA they receive 320 euro/ha of maintained grassland if they have less than 100 ha. Above, payment decreases, depending on the surface.

In **Estonia**, the study fields included Estonian coastal grasslands (Fig. 21). Those grasslands, one of the priority habitats in European level (Natura2000 network code 1630*), situated in flat, turfed geolittoral zones that are influenced by saline seawater.

The vegetation in coastal grasslands occurs in distinct zones, with saline vegetation closest to the sea. Historically, most coastal grasslands were utilised for grazing. The main goal of the intervention, grazing was to preserve the cultural heritage, the area of this habitat, maintaining vegetation at a minimal height while maximising the feed quality, fostering richness in vascular plant species and creating a suitable environment mainly for ground-nesting birds. In 2022 we conducted fieldworks in same fields (22/30), but we changed some and added new fields (14). Field sizes varied from 2 to 80 ha. Total number of experimental pairs was 18 in 2022. The main reason for changes was too short distance between fields and we needed min 500 m to minimise overlapping effects with birds' survey.

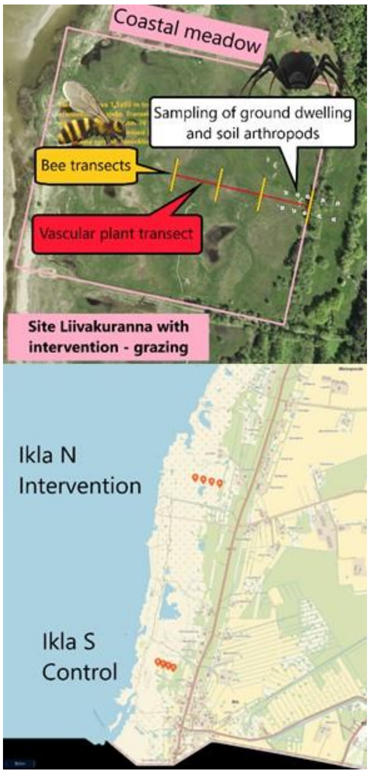

Fig. 21. Scheme of study field with intervention and location of plants` and pollinators` transects and sampling points on soil macro- and micrarthropods.

3.4.3. Which parameters have been surveyed

Core indicators (flora, bees and spiders) were monitored in all EBA, on experimental and control fields. Details of protocols and core indicators are provided in (Bretagnolle et al. 2021). In some of the EBAs, in addition to the core sampling biodiversity indicators, several other parameters (generally related to biodiversity) were surveyed. In some EBAs as well, some core indicators were not monitored. Below we first list biodiversity indicators, whether some core indicators were unsurveyed and why, as well as the additional biodiversity indicators that were monitored, and then we list the non-biodiversity indicators surveyed in some EBAs.

In the **UK**, other biodiversity indicators included quantifying Earthworm species and biomass (four times) to quantify the impact of the cover crop treatments on earthworms, which are an important indicator of soil biological health and are much easier for farmers to measure than other belowground biodiversity indicators (e.g. microbes or mesofauna); beetles to family level (four times) using the same vortis sampling as the core protocol for spiders; soil decomposition rates (twice) to determine whether the potential increase in belowground decomposers associated with cover crops, and frost sensitive mixes in particular, corresponded to increased ecosystem functioning. Bees were not surveyed because all intervention was carried out in winter, when there are no bees.

In **Switzerland**, bees, spiders, and vascular plants were monitored according to Showcase protocol (Fig. 22). Additional methods were used to sample spiders (pitfall traps, sweepnetting), carabids and staphylinds (pitfall traps), parasitoids (pan traps, PCR of pest larvae), pests (cereal leaf beetle and cabbage stem flea beetle sampled by pitfalltraps, damage counts, pest counts on tillers, Berlèse extraction from host plants).

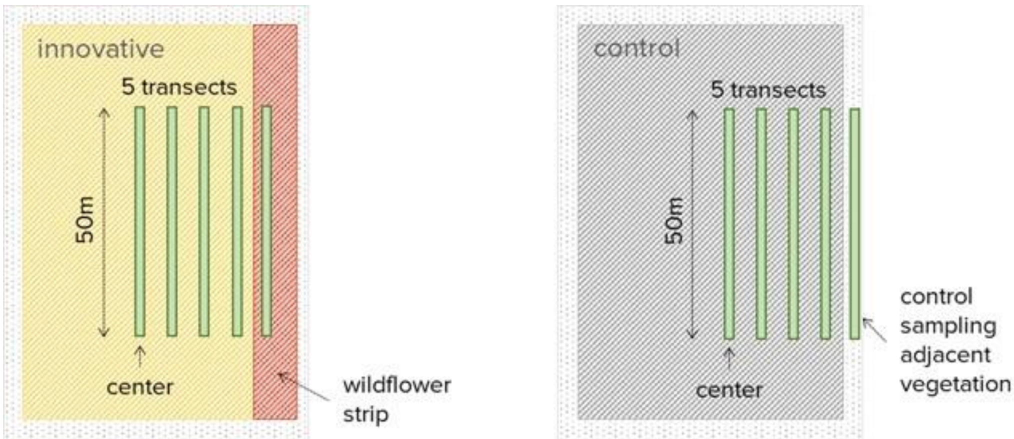

Fig. 22. Design of the sampling of biodiversity indicator in Swiss EBA.

In the **Netherlands**, bees outside of the fields themselves were also monitored because we expected the largest biodiversity impact to be on bees in the wider landscape. In the second study, pest control using aphid prey sentinel cards, natural enemies, pests, and pest damage were additionally monitored. Farmers are concerned that the hedges may introduce pests into the fields. Conversely, we expected the hedges to promote suitable habitats for natural enemies.

In **Hungary**, additionally to the core biodiversity indicators, hoverflies, simultaneously with sampling bees were monitored, since hoverflies are important pollinators and pest control agents.

In **Sweden**, carabid beetles were surveyed as an indicator group for ground-dwelling arthropods (along with spiders, which is one of the core indicators). In addition to the core protocol, spiders were also sampled using an additional method, i.e. pitfall traps.

In **Estonia**, macroarthropods (spiders and ground beetles) and soil microarthropods were surveyed using a modified protocol of SHOWCASE: ground beetles and spiders were captured using pitfall traps and soil microarthropods were collected by soil sampling in 15 experimental pairs (control field and field with intervention). Ten pitfall traps were placed in the suprasaline zone in each study field. Four of the pitfall traps were situated in the open grassland, two on the margin, and four of them in the forest or under trees (see scheme below). The pitfall traps were left in the studied field for four effective days and collected in one round in July–August 2021. Together with pitfall traps emplacement in 2021, topsoil (the top 10 cm at most) samples of approximately 200 ml were taken from each point and packed into pre-marked plastic mini-grip bags. Soil microarthropods were extracted into 70% ethanol using standard Tullgren-Berlese funnels. In addition, bees, butterflies and birds were also surveyed using the same abovementioned protocol. Monitoring of various taxa from different trophic level in coastal grasslands is grounded in the recognition of these organisms as integral components of a complex and interconnected coastal ecosystem: birds are indicator species of this habitat (e.g. waders in open and managed coastal grasslands, warbles in reed, natural coastal grasslands). The comprehensive monitoring of different taxa in coastal grasslands is essential for a nuanced understanding of its ecology.

In **France**, additional indicators were birds (all over the LTSER), butterflies and syrphids (using sweep netting, along as sweep netting for bees), and spiders and carabid beetles in pitfalls traps. This monitoring in experimental fields is done annually since 1995 for the oldest ones (Bretagnolle et al. 2018a, b).

In **Romania**, monitoring of biodiversity focused on butterflies, because they serve as excellent bioindicators.

In regard to non-biodiversity indicators, other parameters surveyed included the following.

In the **UK**, soil parameters of primary interest to the farmers were surveyed: soil texture (once) to characterise the plots and aid interpretation of between-farm trends; soil structure, compaction, and moisture (four times) to determine whether plant cover positively impacted soil physical properties due to the higher abundance of roots, and potential increase in belowground biodiversity; soil nitrogen content (four times) to determine the impact of the cover crop treatments on soil nutrient content, hypothesising that it will be greater in the cover crop treatments, and in frost sensitive mixes in particular; and soil organic matter (twice) to determine the impact of the cover crop treatments on soil organic matter.

In **Switzerland**, yield and additional agronomic and economic parameters have been monitored in 5 transects in 2022 and 2023 according to SHOWCASE protocol.

In the **Netherlands**, some impact on soil properties were expected because lupin is a nitrogen-fixing leguminous crop. For this reason, organic matter decomposition was surveyed with the tea bag index and N leaching with resin bags. In the second study, crop yields were also measured.

In **France**, additional indicators were soil variables, tea bags, predation cards with aphids, and crop yield.

In **Spain**, farmers were particularly worried about pests, and hence, we included sticky traps to monitor wider insect biodiversity in the farms, especially pests.

In **Sweden**, soil temperature and water holding capacity (using data loggers) and decomposition (using the tea bag index) were monitored. The rationale was that we mainly expect the intervention to influence properties in the soil and on the ground surface. Intercropping leads to more structurally varied vegetation, and at least in some cases more ground cover (less bare soil). We were interested in testing if this, together with any potential effects on soil structure, would affect the water holding capacity of the soil. In addition, we also collected soil samples, and have collected and stored cereal grains from the yield samples, for potential future analyses of nitrogen contents (in the soil and in the crop).

In **Hungary**, cereal yield was sampled at 0, 10, 20 ... 90 m away from the edge of WFF and road verge. We sampled biodiversity and yield according to the protocol.

3.4.4. Synthesis

The Table below summarizes all the descriptors of the farm interventions as they were performed in the EBAs. As can be seen, there was a high variability (as expected) between countries and sites, depending on farming systems, farmers' types and other parameters. In total, over the three years, 464 fields have been surveyed.

EBA	Country	Farming	Years			Number of farms	N of fields (/year)	Total (number of fields)	Design			Including organic
			2021	2022	2023	Year1/Year2			Within	Between	Off field	
	UK	Arable	Prep	X	Survey	11	11	11	X			No
Pestired	Switzerland	Mixed		X	X	11	22	44		X	X	No
NL-1, Zuid Limburg	The Netherlands	Arable	X	X	X	6	3/7/3	26		X		Y (100%)
NL-2, Zuid Limburg	NL-2	Mixed	X	X		26	26	47			X	Y (7%)
HU1	Hungary	Mixed		X	X	1	8	16	X		X	No
HU2	Hungary	Grassland		X	X	9	9	18	X			No
EBAlentejo	Portugal	Orchard	X	X		10/12	10/12	44	X	X		No
SW	Sweden	Arable		X	X	9/12	12/12	48		X		Y (75%)
Pärnu and Lääne county	Estonia	Grassland	X	X	X	14/15/8	15/18/9	84	X	X		Y (35%)
Guadalquivida	Spain	Orchard		X	X	15/12	16/16	32	X			No
LTSER ZA-PVS	France	Mixed		X	X	15/14	21/23	44	X	X		Y (40%)
UBB Transylvania	Romania	Grassland	X	Survey	Survey	4	20/30	50		X		No

4 Results

4.1. General information on the biodiversity interventions

In this section, we describe how the intervention and fieldwork were carried out, and provide some pictures of the fields under study.

In the **UK**, due to severe weather in 2022, a few farmers dropped out from the protocol. Other fields were farmed according to protocol (Fig. 23)

Fig. 23a. A photo showing the winter-tolerant cover crop (left) vs the control (no cover crop planted – right).

Fig. 23b. A photo showing the winter-tolerant cover crop (front), the winter sensitive cover crop (middle) and the control (no cover crop planted – behind).

In the **Swiss** EBA, interventions in wheat, barley and oilseed rape fields were studied in 2022 and 2023 for a total of 44 fields, of which some were part of the monitoring in both years (i.e. 14) and others only one of the two years(i.e. 16) (28+16=44 cropping seasons). The fields were located on a total area of approximately 700 km² in the canton of Solothurn. The fields are part of a crop rotation system, where winter wheat is followed by oilseed rape, then winter barley, followed by maize, artificial meadow, or potato. Theoretically, each farmer manages two fields of the same culture in spatial proximity of two different treatment: a) the agroecological treatment is free from pesticide (i.e. fungicide, insecticide, herbicide, adjuvants and growth regulators) and includes 18 measures such as undersowing and mechanical weeding to regulate weeds, and the sowing of WFS at field margins to support natural pest regulation, and b) the control treatment with fields conventionally managed. However, some farmers deviated from the protocol (e.g. wrong WFS mixture, WFS not on margin but in the middle of the field, 1 farmer also sew a WFS on control field) and in some cases (11 were judged as "bad", at least 3 with wrong mix), flower strips did not grow well.

In **Hungary, EBA 1**, the intervention was creating wildflower fields integrated into agricultural landscapes (Fig. 24). We studied the 8 wildflower fields (WFF), the surrounding crop habitats and the road verges near to them. We monitored vegetation, bees and hoverflies, spiders, and cereal yield according to the protocol. In 2022 (two years after the establishment of the WFFs) severe drought affected the area, thus the studied organisms.

Fig. 24. The photo illustrate a WFF (HU-1 EBA), featuring Salvia species planted by us, on the left a cereal field after harvest

In **Portugal,** a mixture of eight plant species (Coriandrium sativum, Brassica napus, Orobrychus vicifolia, Trifolium suaveone, T. presupinatum, Vicia sativa, V. villosa, Lupinus luteus) were seeded to increase vegetation and floral resource abundance between olive tree lines (Fig. 25). It was sown at a density of approximately 15 kg of mixture per hectare. This plant mixture was though to increase the availability of food and shelter resources for target groups like bees and spiders but irrelevant for olive pests like the olive fruit fly a (Bactrocera oleae) and the olive fruit moth (Prays oleae).

Fig. 25. Pictures showing the impact of the intervention on the plant community between tree lines. Above, an intervention site sown with a mixture of native plants. Below, a control site within the same study olive orchard with no intervention.

In **Spain**, in 2022, a mixture of five species (*Trifolium pratense, Trifolium repens, Brassica juncea, Secale Cereale* and *Vicia villosa)* was seeded to improve floral resource abundance. It was sown at a density of approximately 10 kg of mixture per hectare, with an approximate price of 7 €/kg. After consultation of the first year results, in 2023, a new mix of grass and legume species at 98% and wildflowers including *Lolium rigidum, Festuca rubra, Poa pratensis, Bromus spp, Brachypodium distachyum, Festuca arundinacea, Medicago truncatula/M. polymorpha/M.scutellata, Trifolium repens/T. pratense/T.resupinatum. Centaurium erythraea, Anthemis arvensis, Anagallis spp., Anacyclus spp., Anthemis cotula, Papaver roheas, Bellis perennis, Taraxacum officinalis, Bartsia trixago, Glebionis segetum, Silene spp. Matricaria recutita, Calendula arvensis, Echium spp, Eruca sativa , Lupinus angustifolius, Salvia verbenaca , Coriandrum sativum* at 2% were seeded. The objective of this improved green cover was to favour the presence of a diversity of flowers on the farms, but selecting low-growing species that would not interfere with farmers' agricultural practices (Fig. 26).

Fig. 26. Pictures showing the differences between control and experimental plots in Spanish EBA.

In Sweden, the intervention consisted of intercropping of cereals and leguminous crops, in different combinations depending on farmer preferences (Fig. 27). Examples of combinations of crops were oats + peas or wheat + *Melilotus* sp. This was compared to monoculture fields with the corresponding cereal crop in a paired study design. The leguminous crops were typically harvested for livestock fodder after the harvest of the cereal crop.

Fig. 27. Newly sown intercropping field with Winter wheat and Melilotus in spring 2022. Photo by Anneli Adler. B: Intercropping with oats and lentils, summer 2022. Photo by Anneli Adler.

In **Estonia,** the intervention included grazing and mowing (Fig. 28). Most EBA were grazed (17 fields) coastal grasslands and only a few were mowed (2 fields). In most EBA, the restoration through grazing was going on for __ years before the experiment. The minimum years of grazing was 10. To determine the impact of the intervention on biodiversity and ecosystem services, surveys on the different macroarthropods and microarthropods enumerated above were carried out following the SHOWCASE modified protocol. Results were compared with the control fields, abandoned grasslands dominated by tall and fast growing plants (e.g. *Phragmites australis*). Grazing animals include cows, horses, or sheep at a density range from 0.4 to 1.3 LU per ha.

Fig. 28. Coastal grassland as experimental field in the Gulf of Riga Coastal Lowland in 2022. B: Abandoned coastal grassland as control field in the Gulf of Riga Coastal Lowland in 2022. C: Coastal grassland as experimental field in the Gulf of Riga Coastal Lowland in 2022. D: Abandoned coastal grassland as control field in the West-Estonian Lowland in 2022.

In the **Netherlands**, for the second study, we surveyed 26 fields in 2021 with 19 participating farmers, and 26 fields with 11 participating farmers in 2022. Most farmers were willing and cooperative, but three farmers were not willing to continue the second year. All control fields had adjacent road verges (2021=8 fields; 2022=7 fields), interventions included shaved hedges (8 and 7 respectively) and thicket hedges (10 and 7 respectively). See Fig. 29 for selection of photos.

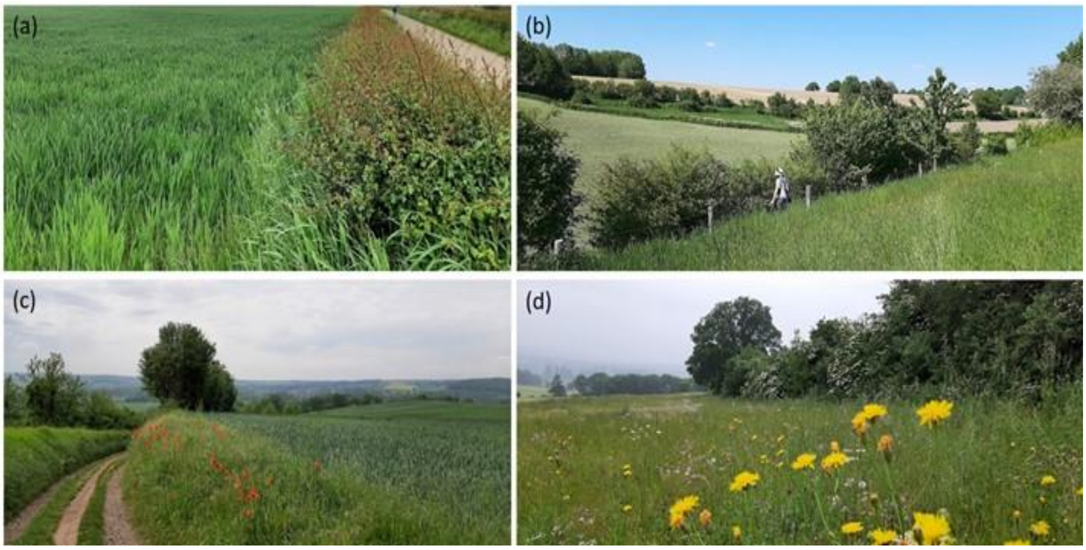

Fig. 29. Types of interventions studied. A) Hedgerow, B) Thicket hedge, C) Road verge, D) Grassland

Seven of the hedges interventions also included an adjacent herb-rich grassland which was analysed separately for the biodiversity indicators, however, we could not include the grassland effect on pest control and yield since they are never implemented solo (without a hedge).

In **France**, in 2022, the experiment (see Fig. 30 for an example) experienced an extreme drought during the summer which mainly affected spring-sowed crops, not wheat (which was crop selected for the intervention). No farmer nor field went out from the experiment, and almost all followed strictly the protocol that was agreed in previous autumn (some reduced less than expected, or only one pesticide category instead of two, or even all three).

Fig.30. A photo showing a two-factorial design within a wheat field. Left is nitrogen reduction, bottom is herbicide reduction. Photo taken in February 2023. Note that a plot was left unsown to estimate weed diversity and abundance from the seed bank.

In **Romania,** scrub removal has been done in 2022-2023, depending on fields (Fig. 31).

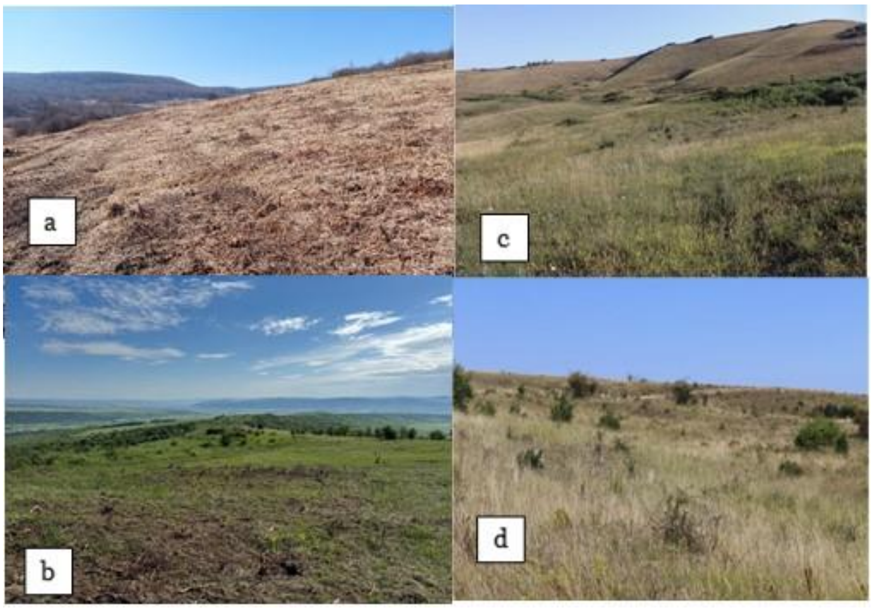

Fig. 31. Photos showing the sequence of a. Scrub just removed (Feb 2024); b. a freshly cut field. c. One year after removal. d. 3 years after.

4.2. Response of biodiversity to farm interventions

Biodiversity core indicators (plants, bees and spiders) were surveyed on all sites with very few exceptions, which thus provides very good tool for in depth comparative analyses. Analyses have been conducted on the impact of the intervention on biodiversity but not yet at the species levels because not all species identification is finished. These analyses revealed a common pattern: the farm interventions that were carried out in the EBA resulted in an increase of biodiversity, at least of one of the core groups. Below, we present the results per EBA.

In the **UK**, preliminary results indicate that biodiversity and biodiversity-mediated functions had benefited from the cover cropping (Fig. 32). Cover cropping (vs not planting cover crops) doubled plant ground cover and doubled or tripled plant biomass (cover crops and weed cover) during cover cropping, halved weed abundance during cover cropping, increased spider abundance by 40% and family richness by 25% during cover cropping, increased earthworm abundance by 40% and biomass by 50% during cover cropping as well as in the subsequent crop (Fig. 32), marginally improved soil structure and moisture retention during cover cropping as well as in the subsequent crop, and finally improved microbial decomposition rates during cover cropping. However, these results are preliminary since they need to be analysed statistically, and that spiders and earthworms have to be checked by experts. The differences between the cover crop treatments (winter sensitive vs tolerant) were however minimal, and unlikely to be significant. However, the experiment was carried out in a particularly extreme year in terms of weather conditions (record drought and then record frost), which likely impacted the outcome of the experiments. These figures show the mean and standard error of earthworm abundance and biomass. Note that these plots are not final, because the weight of some worms that are waiting to have their species IDs confirmed have not been included.

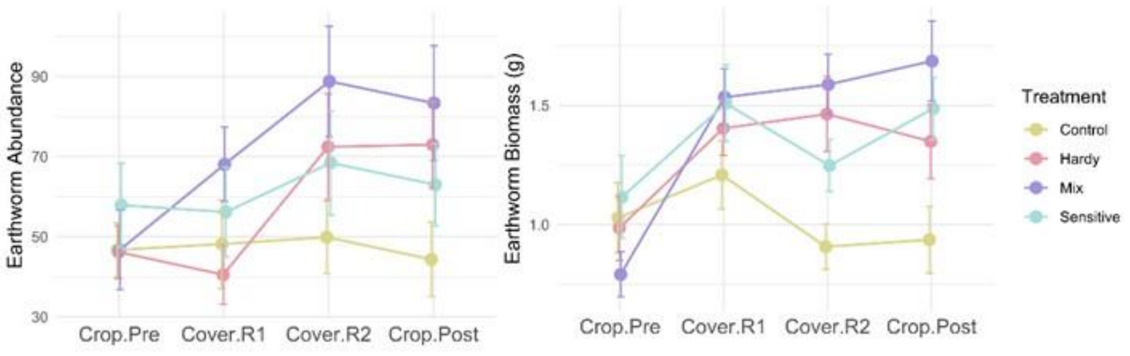

Fig. 32. Mean earthworm abundance in the UK EBA plots at four timepoints (crop pre-treatment, mid-point during the cover crop, pre-removal of the cover crop and in the following cereal crop).

In **Switzerland**, bees were dominated by the domestic bee (Fig. 33), *Apis melifera*. In contrast, some wild bees were found in the strips bordering the fields, both in those managed as WFS or unmanaged (innovative vs control): in barley a total of 2 wild bees were found in control strips, 29 in WFS, in wheat there were 13 wild bees in control strips, but only 6 wild bees in WFS bordering wheat fields. Interestingly, there were 20 wild bees counted in the core of 2 wheat fields in 2023 In OSR, there were 6, resp 7 wild bees in control, reps innovative field margins, and only 2 wild bees in the core of all OSR fields.

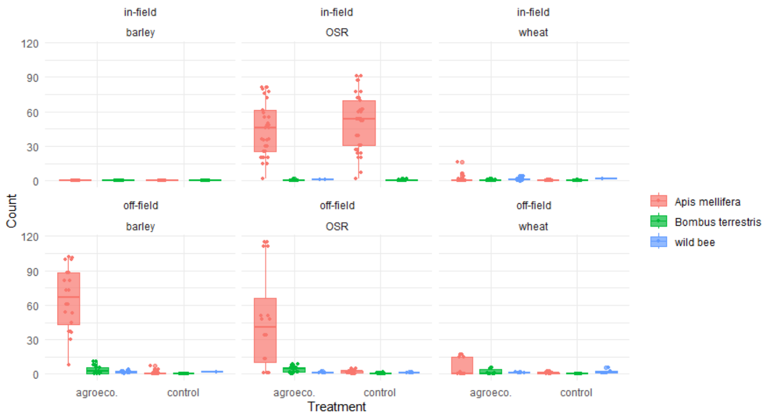

Fig. 33. Mean Bee abundance in the Swiss EBA according to taxon, crop type, and location within the field. Only Apis mellifera was abundant and showed a strong response to treatment.

The abundance of spiders both within fields (beta = 0.223, p = 0.23) and in field margins (beta = -0.012, p = 9.51e-01) were insignificantly higher in innovative fields (Fig. 34). Likewise, spider species richness was unaffected by the treatment, both within fields (beta = 0.775 p = 1.073e-01) and in field margins (beta = -0.454, p = 3.675e-01).

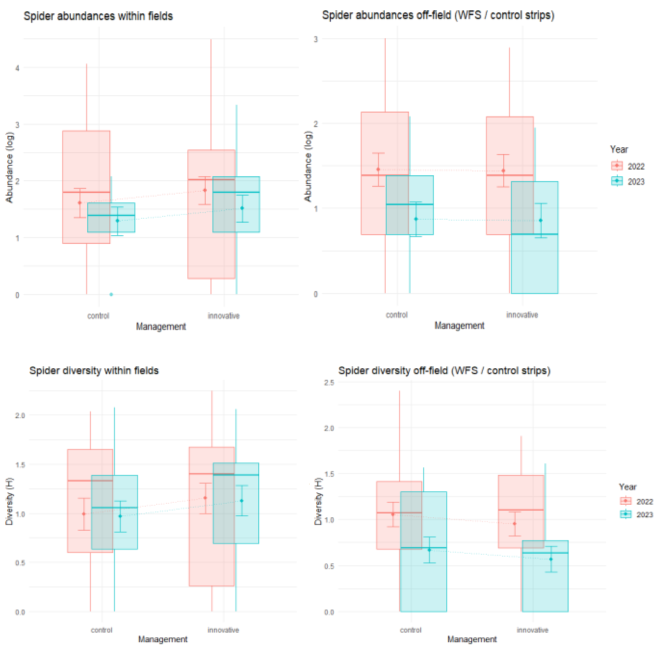

Fig. 34. Mean Spider abundance and diversity in the Swiss EBA according to location in field, between treatments.

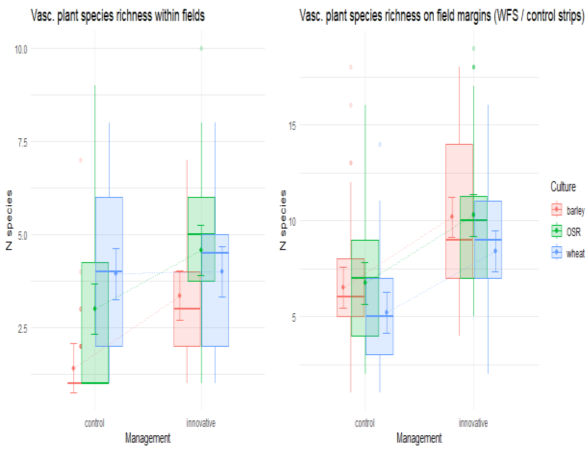

Fig. 35. Mean Weed abundance and diversity in the Swiss EBA according to location in field, between treatments.

Vascular plant species richness was significantly increased in innovative fields (beta = 1.953, p = 1.378e-11; Fig. 35)). There was a strong interactive effect of the management with culture; interestingly the effect of the treatment was much less pronounced in wheat (as compared to barley beta = -1.900, p = 7.074e-06). The wildflower strip harbored more plant species than the spontaneous vegetation of control fields (beta = 3.678, p = 2.292e-13).

In the **Netherlands**, **Study 1**, after lupin has bloomed, bumblebee densities of species that visit lupin (*Bombus terrestris/lucorum, B. lapidarius, B. pascuorum*) in landscapes with lupin are significantly higher than in control landscapes (Bishop et al. 2025), as shown in Fig. 36. Within the field, lupin did not perform much differently compared to a "standard" organic crop, with the exception of bees, which obviously were much greater in lupin fields because of the mass display of flowers. Solitary bees either rarely visited lupin, or when they visited lupin in large numbers (*M. willughbiella and M. ericetorum*), they were too rare in the landscape to analyze the effects. In the spring following lupin cultivation, there was no difference in landscape bumblebee densities, however (absence of year carry-over effect).

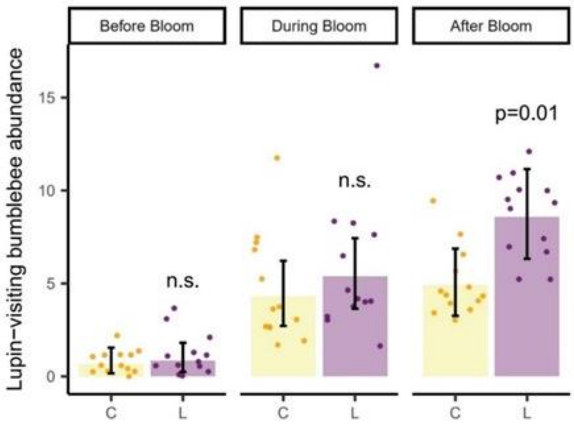

Fig. 36. Abundance of bumblebees that visit lupin in the landscapes surrounding crop fields before, during, and after lupin bloom. L = lupin landscapes, C = control landscapes.

Conversely, there was no significant difference in plant diversity between lupin and control fields, but lupin fields had higher wild plant cover due to issues with weed suppression (Fig. 37). There were no significant differences in spider diversity or abundance between lupin and control fields (Bishop et al. 2025).

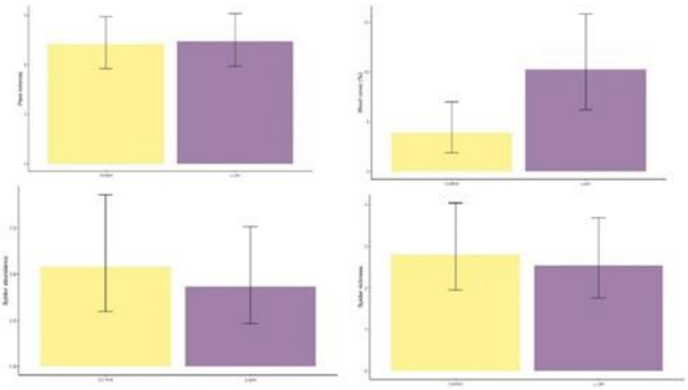

Fig. 37. A/ Plant richness (per 1 m²); B/ Weed cover (per 1m2); C/ Spider abundance (per 0.5 m²); D/ Spider richness (per 0.5 m²)

In the **Netherlands**, **Study 2**, hedgerows were more successful than grasslands in promoting biodiversity. The thicket hedges increased bees and hoverflies abundance and richness, whereas shaved hedges increased the spider abundance (Fig. 38. richness data not analyzed yet). There was no effect of the intervention inside the field, except for higher hoverfly abundance near interventions with more flowers (regardless of intervention type; Fig. 38). Therefore, for hedgerows but not necessarily for grasslands, biodiversity increased. It should be noted that for hedgerows, better planning is required since the payment for them is high but don't always provide a higher quality habitat.

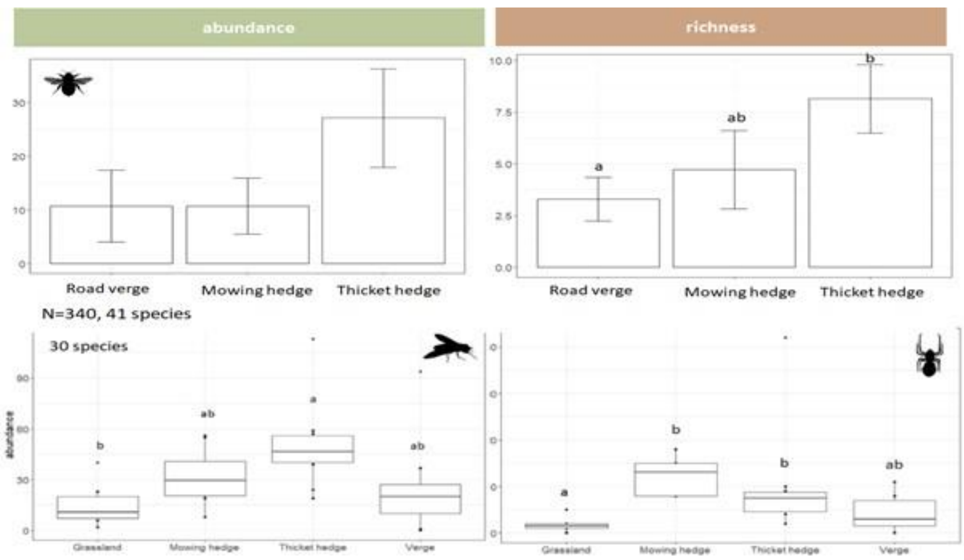

Fig. 38. Effect of intervention on bees (abundance and richness), hoverflies (richness) and spiders (richness) according to location and treatment.

Generally, hedgerows outperformed grasslands for hoverflies, bees and spiders (Fig. 38). Thicket hedges improved bees and hoverflies diversity, whereas shaved hedges improved spider diversity. Interventions with more floral resources boosted aphidophagous hoverfly activity in the adjacent fields (Fig. 39). In addition, flower availability in the intervention area had an effect on hoverfly richness (also inside the field). Therefore, in thicket hedge, natural enemy densities increased, which resulted in slightly lower leaf beetle damage, though this was not significant (Fig. 39).

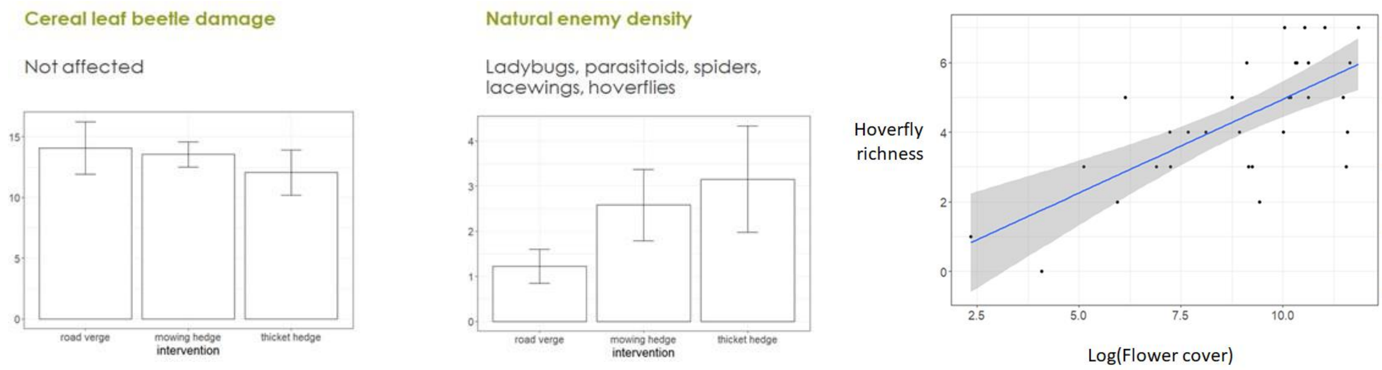

Fig. 39. Effect of intervention on pest control and pest damage in the field (the effect is not significant for the two left graphs).

In another study design, involving apple production, apple fields bordered with hedgerows predicted pollinator (negative relationship) and natural enemy communities with a positive relation (Bishop et al. 2023).

In **Hungary**, preliminary results of 2023 suggest that the diversity of plants and bees was the highest in the road verges and wildflower strips although spiders were also caught in large numbers in the fields (but with no clear pattern; Fig. 40). Bees preferred wildflower fields (WFFs) over crop fields and road verges (Fig. 40). However, pollination service was not measured, and we sampled cereal yield (i.e., wind-pollinated); thus, we cannot prove the effect of WFFs on farming. The number and cover of non-cultivated herbs species were also high(er) in the WFFs. Therefore, the farm intervention increased biodiversity.

In the overseeded fallow lands experiment, floral availability and wild bees, hoverflies, and butterflies along transects were surveyed for four years (2020-2023). The species richness of hoverflies and bees was positively correlated with floral abundance. In the last two years, the number of hoverfly and bee species significantly increased. Additionally, more bee species were detected in late summer than in early summer. In the first year after overseeding, pollinator abundance did not increase, but in the final two years, the abundance of butterflies, wild bees, and hoverflies significantly grew in the overseeded areas, while no such increase was observed in the control plots. A one-time overseeding of fallow lands with wildflower seeds significantly enhanced pollinator community richness, suggesting that this method could be applied to additional areas.

In **France**, no statistical significant differences in weeds (richness, abundance, % of cover) were found between experimental and control plots or fields in 2022/2023 (Fig.41). Experimental areas (either plots or entire field) had on average a higher richness or abundance compared to the control plots and fields. On the opposite, spider richness and abundance increased in experimental plots and fields, both in organic and conventional fields (Fig. 41). Bees were in the middle, showing an increase in particular in organic fields (fig. 41). Previous experiments on wheat (with similar levels of pesticide/nitrogen reduction) found similar results on weed, both in terms of diversity and abundance (Berquer et al. 2023).

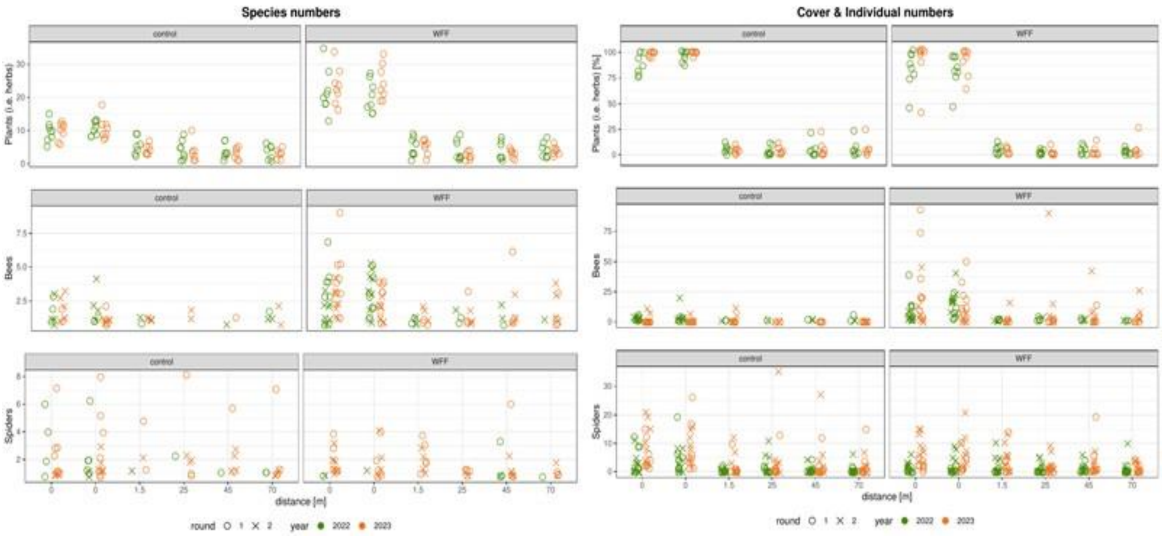

Fig. 40. Left. Species number of non-cultivated herbs, bees and spiders during the two sampling years. Symbols indicate sampling rounds (o - first, × - second), and colours refer to the sampling year (green – 2022, orange – 2023). Data points are jittered for better visibility. Separated panels show the control (i.e. road verges and the neighbouring crop fields) and wildflower field (WFF) areas (including the neighbouring crop fields). Right. Cover of of non-cultivated herbs, and individual numbers of bees and spiders during the two sampling years. Symbols indicate sampling rounds (o - first, × - second), and colours refer to the sampling year (green – 2022, orange – 2023). Data points are jittered for better visibility. Separated panels show the control (i.e. road verges and the neighbouring crop fields) and WFF areas (including the neighbouring crop fields).

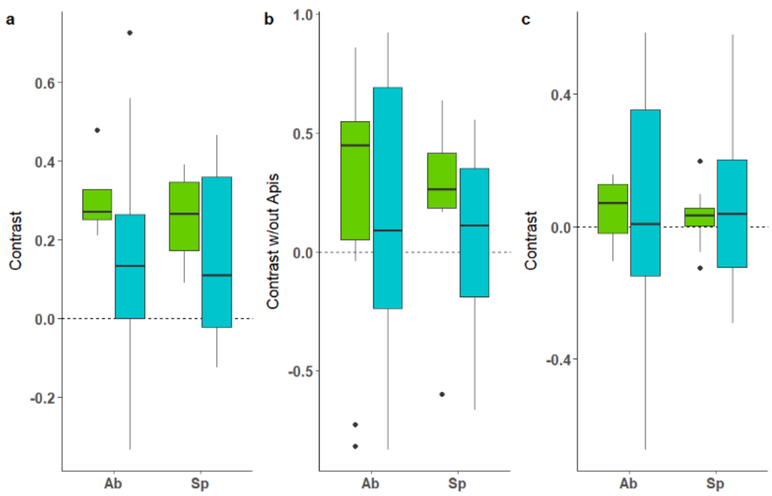

Fig. 41. Boxplots showing the difference in overall spide (left panel), bees (central panel) and weeds (right panel) abundance (Ab) and species richness (Sp) between control and intervention sites, in organic fields (in green) and conventional fields (in blue).

In **Portugal**, results demonstrate that the herbaceous vegetation occurring between the line of trees significantly increased the overall abundance of bees and spiders (Fig. 42). It should be noted that the intervention did not suggest any effects (neither positive nor negative) on pest infestation level. Plant monitoring revealed the occurrence of other wild species within the intervention sites than those sown. The occurrence of these plants could be favored by the intervention itself, which consisted in plowing the soil superficially. Because most of these plants were flowering species (e.g. *Daucus carota*), plowing the soil superficially might be sufficient to favor the emergence of spontaneous vegetation and provide suitable resources for bees and spiders, and in turn, increase their diversity and abundance.

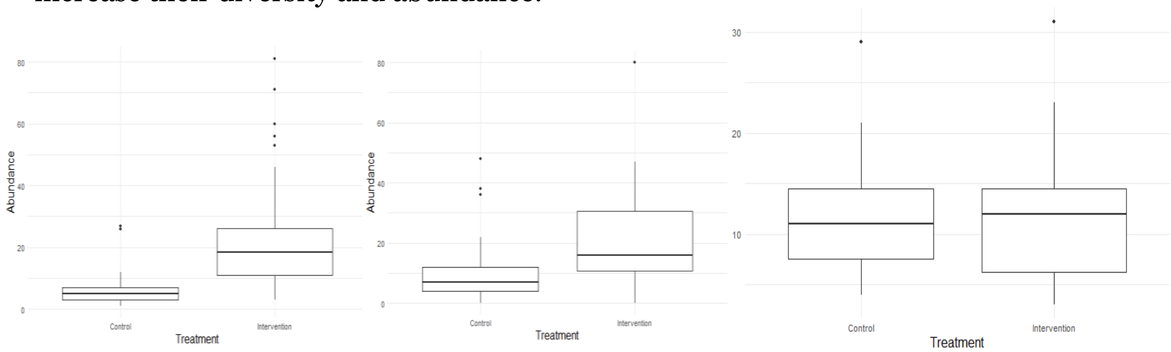

Fig. 42. Boxplots showing the difference in pest infestation levels between control and intervention sites.

In **Sweden,** preliminary analyses showed that there were on average a higher number of carabid beetles species (in 2022) in fields with intercropping than in monoculture fields (Fig. 43a). However, the number of species varied more among intercropping fields than among monoculture fields. The data on spiders in 2023 showed a similar pattern: a slightly higher number of species (but not statistically significant), but also a higher variability between fields, in intercropping compared to monoculture fields (Fig. 43b). These patterns suggest that intercropping can sometimes, but perhaps not always, increases biodiversity. Further analyses will be conducted to understand if this variation is related to the specific combinations of crops in intercropping.

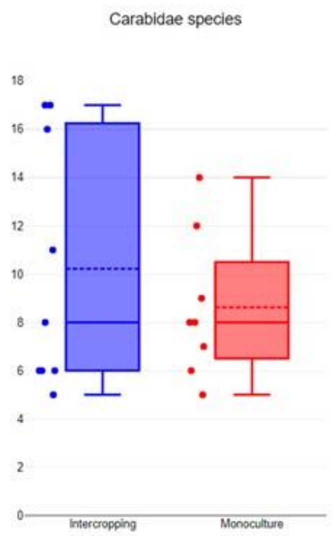

Fig. 43a. Average number of Carabidae species in intercropping and monoculture fields in 2022.

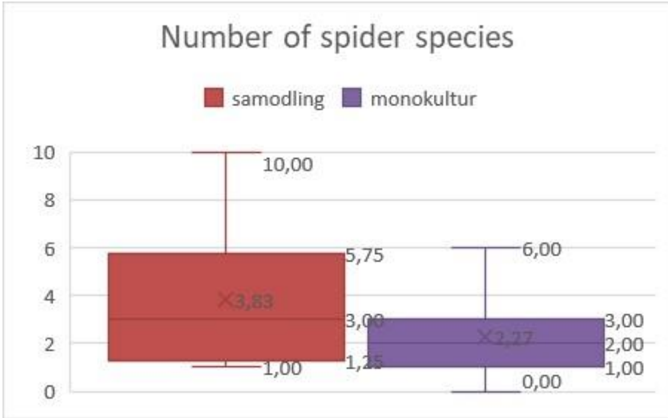

Fig. 43b. Average number of spider species in intercropping and monoculture fields in 2023.

In addition, the abundance of arable weeds was higher in fields with intercropping than in fields with monoculture. Similarly, bee abundance was higher in intercropping fields than in monoculture fields. This seems to be related to weed abundance rather than to the type of farming *per se*, since many of these bees were observed visiting weeds (e.g., thistles, etc.) rather than the sown leguminous crops.

In **Estonia**, studies in coastal meadows led to the discovery of new species of ground beetle and spiders, as reported in Sammet et al. (2023). Systematic sampling resulted in seven new spider species from pitfall traps in 2021 and four additional spider species from suction samples in 2022. Some of these species are consistent with neighboring countries, while others mark their first occurrence in the Baltic States. The presence of some species in Estonia may indicate a northward shift in range, possibly due to the effects of climate change. Based on the data collected in 2021, we found that assemblages of ground beetle depended on landscape topography, land use, ecotopes and their interactions, as described in Fig 44. The Gulf of Riga Coastal Lowland showed a higher species richness and diversity of ground beetle assemblages compared to the West-Estonian Lowland. And in general, intervention and open coastal grasslands contributed to increased activity density, species richness and diversity of ground beetles. The effects of intervention, grazing in Estonian coastal grasslands were also positive for spider assemblages. We observed a positive effect of interventions on the species richness and diversity of spiders collected by pitfall traps during the 2021 field season. It may

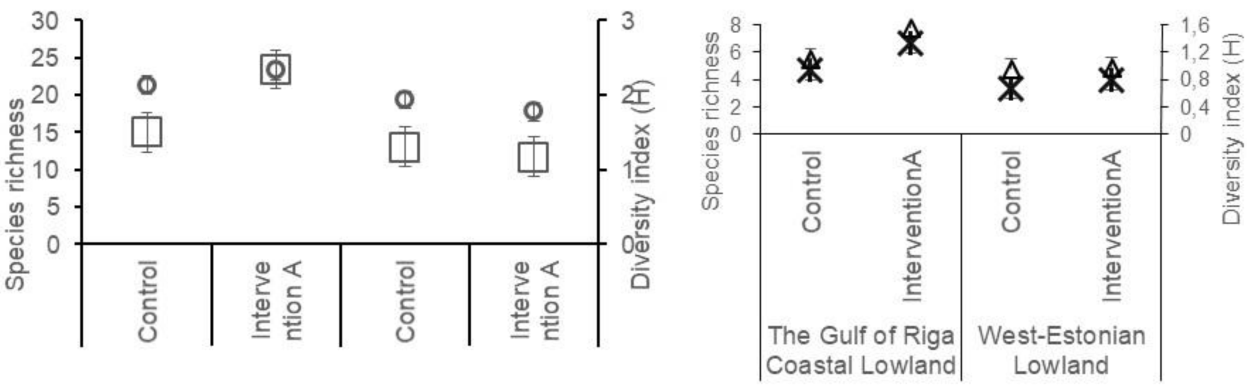

Fig. 44. Average species richness (quadrat) and diversity (circle) of ground beetles in Estonian coastal grasslands in 2021 (Left). Figure. Average species richness (cross) and diversity (triangle) of spiders in Estonian coastal grasslands in 2021 (Right).

imply that animal grazing provides more suitable microhabitats for macroarthropods. In addition, vascular plant species richness and diversity were higher in grazed grasslands (with intervention) than in abandoned grasslands implying that grazing improved and supported plant diversity in the Estonian coastal grassland.

In **Spain**, 3860 pollinators representing 61 species were found in all farms. From those, 1814 were honey bees. The wild pollinators included a 57% of bees, a 36% of hoverflies, and 7% of butterflies. Only 3 species were only found in control plots whereas 35 species were only found in the green cover treatment (Fig. 45).

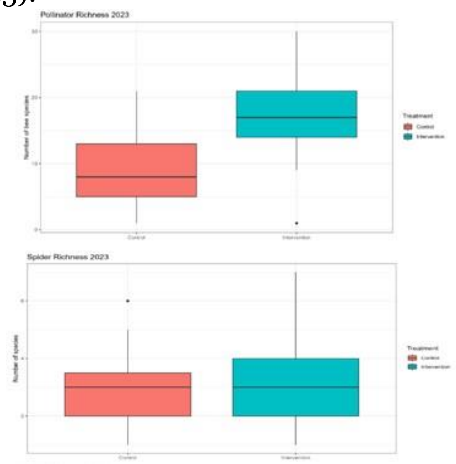

Fig. 45. Pollinator and spider diversity between control (red) and treatment plots (blue) showing an increase in bees.

A total of 506 spiders from 64 species were collected in year 2022. Sixteen species were found only in control intervention, compared to 23 species only occurring in green cover plots. For the vegetation survey, 98 different species were found among all farms, with 22 species found only in control transects, and 24 only in treatment transects (see Fig. 46).

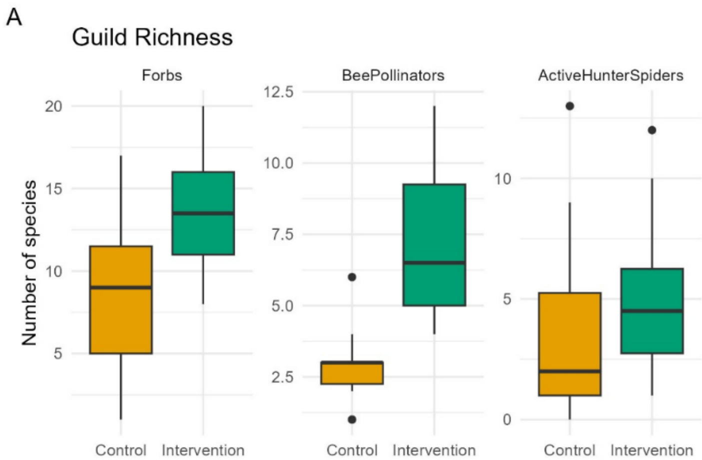

Fig. 46. Plants, bee and spider diversity between control (orange) and treatment plots (green) showing an increase in plants and bees. No difference was found in fruit production.

Of the four sown flower species in green cover alleys, only *Brassica juncea* flowered during pollinator monitoring. In addition, a total of 123771 arthropods, distributed over

74 identified taxonomic groups were caught in the sticky traps. Of these, 12 taxonomic groups representing 10611 individuals could be classified as predators and 12 taxonomic groups representing 10212 individuals could be classified as parasitoids, with very few pest taxa identified. Pollinator abundance and richness were significantly higher in green covers, with a positive interaction effect with management intensity. Compared to the control scenario, green covers almost doubled pollinator abundance in fields where management intensity was low, but increased up to a 40-fold in fields that were intensively management.

In fields with low management intensity, pollinator diversity in green covers was 2.4 times greater than in the control scenario, and increased up to 6.2 times in fields with the highest management intensity(Fig. 46). On average, the number of spiders in alleys with green cover was 1.5 times greater than in control alleys (Fig. 46). Additionally, the diversity of spider species in green cover alleys was 1.3 times greater compared to alleys without green cover. In addition, predator and parasitoid abundances in green cover alleys were 1.9 and 1.4 times higher, respectively, compared to control alleys. In general terms, there was different mechanisms by which the green cover can increase the abundance of different groups. Green covers with high flower cover enhanced pollinators, parasitoids and predators, while forbs with high vegetation height improved the abundance of active hunter spiders. Green covers dominated by graminoids were less efficient in increasing biodiversity abundance. In 2023 we expect similar results, but final taxonomic resolution is only available for pollinators. In total: 2851 observations for pollinators, including 77 different species. From which only 122 individuals were honey bees. 2219 individuals where found in intervention treatment whereas 632 where found in controls.

In **Romania**, in the fields that were cut, the diversity of butterflies increased year after year after the cut. The shrubs in our fields were cut in 2021, and we visited the monitored fields in 2022 and 2023. The control fields where fields where there has been no cutting done for many years and those fields where not used. In the surveyed fields the diversity of the butterflies increased from 2022 to 2023 (Fig. 47), the difference between the years the difference was statistically significant. The diversity in the control fields remained the same. But the diversity in the control fields is overall higher than in the fields that where cut. If the fields were not cleaned of shrubs then shrubs would overgrow the remaining open patches and corridors and the diversity of butterflies will decrease to lower levels than in the surveyed fields which were cut.

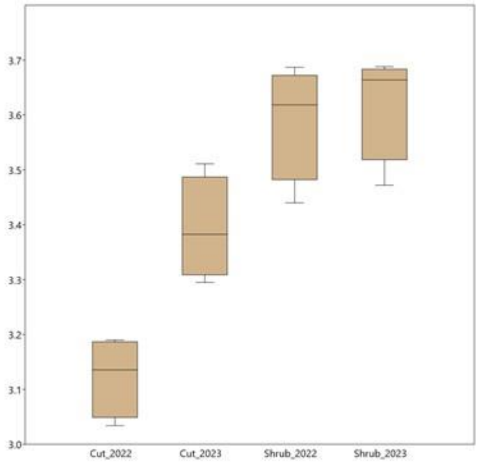

Fig. 47. Butterfly diversity according to year after treatment.

4.3. Preliminary results on yields

For various technical and logistical reasons, yield and/or margin data were not collected systematically, and for those which were collected, analyses are still in progress. Despite this, the preliminary analysis of the effect of the interventions on yields and margins are of great interest.

In the **UK**, the experimental treatments did not impact yield (Fig. 48). The final measurements for thousand seed weight are on-going and the statistical analysis is pending, but preliminary plots indicate that there is unlikely to be a difference.

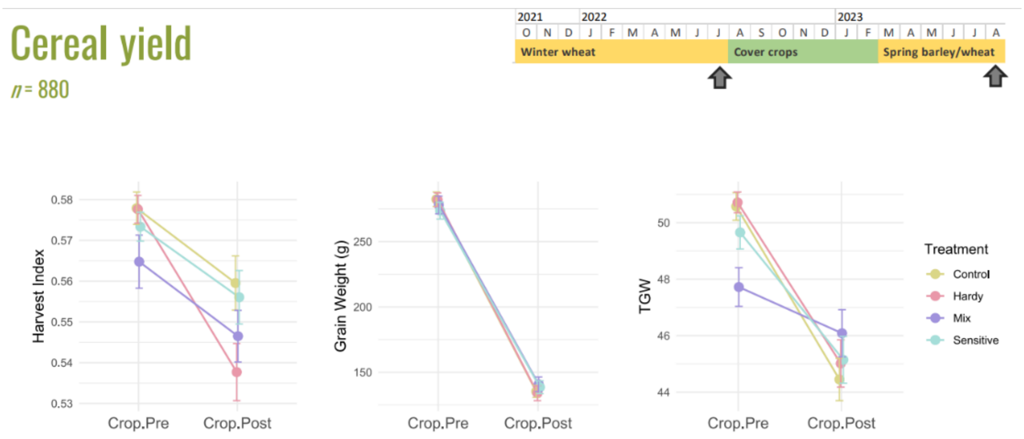

Fig. 48. Mean thousand grain weight (TGW) for the UK EBA plots at harvest pre-treatment and at the subsequent harvest in the plots post-treatment.

In **Switzerland**, the yield was significantly lower in agroecological fields (β = -0.18, p = 2.70-02) as shown in fig yield. All the differences between agroecological vs control in percent of all the yield variables assessed are given in the table below.

Culture	Delta Yield (%)	Delta TSW (%)	Delta Protein Content (%)	Delta Plant Density (%)	Delta Fruiting Rate (%)
barley	10.58907	-2.71392	8.754209	NA	NA
OSR	17.96969	2.477674	NA	18.91304	-11.7246
wheat	8.103264	-3.32873	11.4891	NA	NA

The yield was 10.6% higher in barley, 8.1% higher in wheat, and 18.0% higher in OSR control fields compared to agroecological fields (Fig. 49). Protein content was 8.8 % higher in control cereal fields (8.75 % in barley, 11.5 % in wheat, β = -0.27, p = 3.55-22). Interestingly, however, the weight of 1000 seeds (g, TSW) was not affected-agroecological management (β = 0.04, p = 1.75e-01). The fruiting rate in OSR was 11.7% higher in agroecological fields (β = 0.04, p = 4.13e-02), while plant density was 18.9 % lower (β = -0.08, p = 1.27e-02).

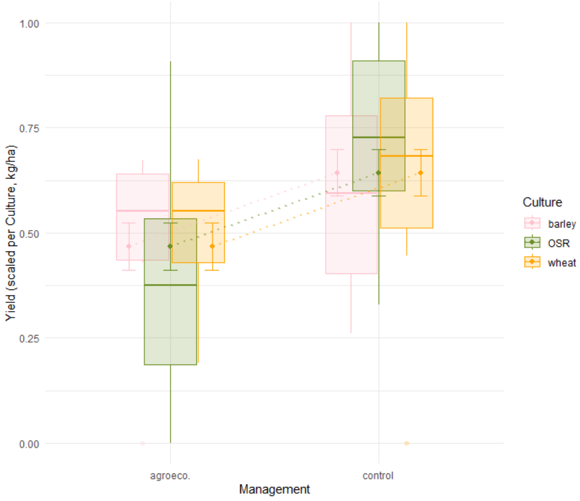

Fig. 49. Histograms showing yield according to 3 crop types between treatmlent (agroecological practices) and control showing a yield gap of about 12-15% (see table above).

In the **Netherlands**, **Study 2**, there was no effect on yield (Fig. 50), at least in regard to grain weight, whatever the field border.

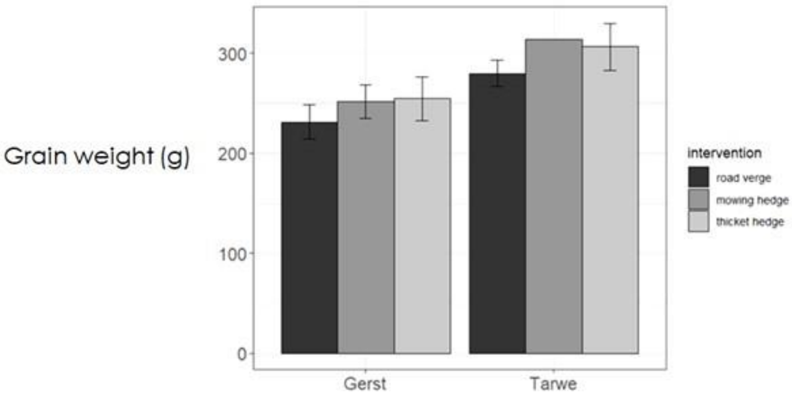

Fig. 50. The effect of intervention type on grain weight for barley (gerst) and wheat (tarwe)

In **Hungary**, in the first EBA, cereal yield was monitored in the same eight landscape plots during the two years: among the 16 cases, 6 were cereal crops (wheat or barley). Several parameters related to yield were measured: the sample's mass, dry mass, moisture-, protein-, and wheat gluten- and starch content. In general, no significant differences were found among years (Fig. 51). Cereal yield quantity and quality were lower near the wildflower fields (WFF) than the road verge, but at 90 m, the difference was not significant. Samples from 10 and 90 m away for the edges of the WFFs or road verges were also not significantly different in quantity or quality. Thus, the WFFs did not seem to affect the cereal yield negatively, probably due to the absence of spillover of pests. Preliminary results of wheat suggest that yield varied significantly between years, with variable patterns of yield at different distances from the field edge.

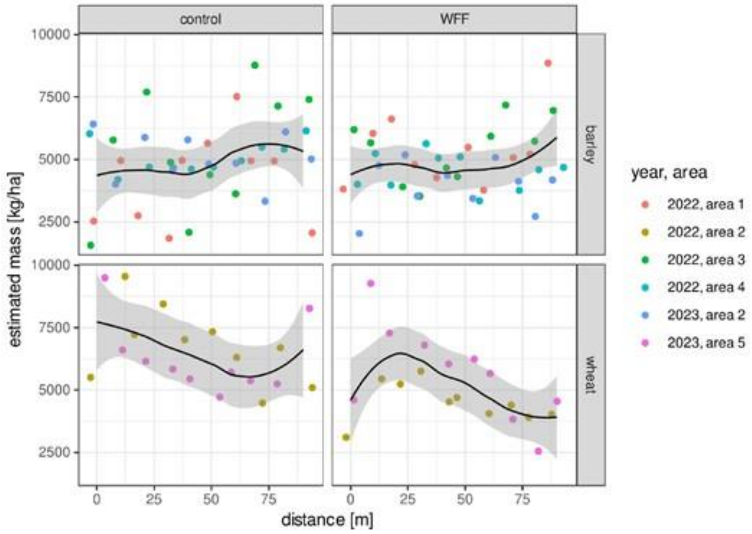

Fig. 51. Estimated cereal yield mass [kg/ha] in relation to the sampling distance [m]. Panels show data separated for crop species (barley and wheat) and area (control [i.e. sampled from the edge of road verges] and WFF [i.e. sampled from the edge of WFF]). Colours refer to sampling areas in different years.

In **Sweden**, in 2022, there was no consistent difference in crop yield between intercropping and monoculture fields. Yield data from 2023 remains to be analysed.

In **France**, we detected no significant (i.e. statistically supported) differences in wheat yield between experimental and control plots in either the conventional farms (first experiment, average decrease of yield 4%) or organic farms (second experiment, average decrease of yield 8%), as shown by Fig. 52. Reducing pesticides (experiment 1) had no effect on yield, while nitrogen reduction had a marginal effect of 5.8% decrease (Figure 3). Overall, the reduced costs of using less pesticide and nitrogen in conventional farms, more than offset any minimal reduction in yield, resulting in conventional farmers improving their gross margins by an average of €95/ha (Fig. 52). In Organic farms, there was no effect on the gross margin. Considering both years and both conventional and organic farming systems together, we found a moderate positive effect on arable weed diversity and abundance, a positive effect on bee diversity (more pronounced in organic fields), and a very strong positive effect on both spider abundance and diversity in experimental versus control plots.

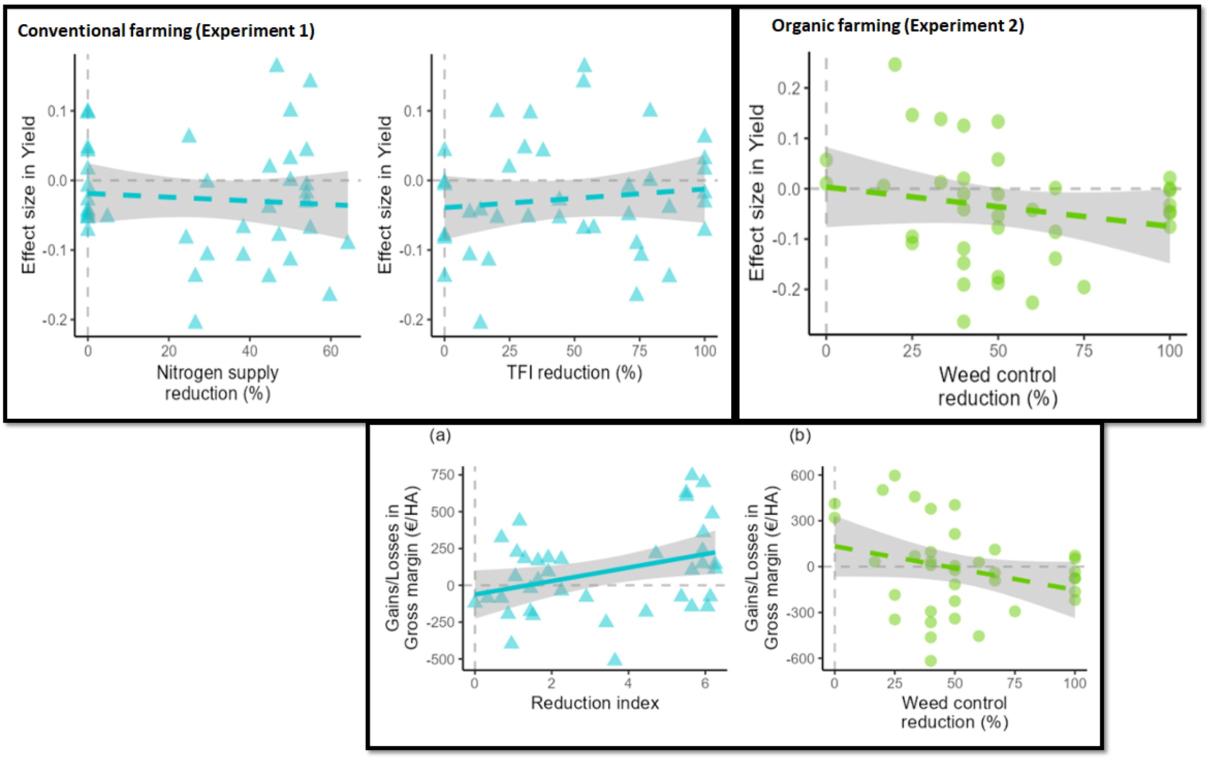

Fig. 52. The upper panel of the figure shows average cereal yields (2022 and 2023 combined) in conventional (left, in blue) or organic farming (right, in green) across all fields, according to type of reduction (left panel = Nitrogen reduction; middle panel = Pesticide reduction, measured here as Treatment Frequency Index (TFI); right panel = mechanical weeding). The lower part of the figure shows the effects of experimental reduction on farmer's gross margins (a) left for conventional, in blue; (b) right for organic, in green). Significant trends are shown with continuous line, non-significant effects are in dashed line.

In **Spain**, fruit production was not affected by the intervention and many farmers realized that implementing green covers was an easy measure that improves the farm agroecological status without interfering with the highly intensive production system. The intervention did not affect fruit development. No significant effect of the green covers was found in the fruit caliber, thus we do not expect any effect on the final yield (Fig. 53). Interestingly, the only two plum farms showed an increase in yield

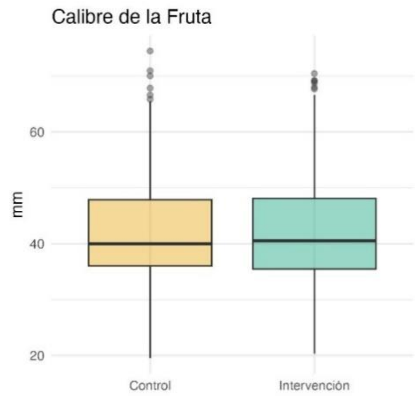

Fig. 53. Boxplots showing the fruit caliper in mm as a function of treatment, where no differences are detected.

In **Estonia**, herbaceous biomass yields were quite severely depressed in intervention fields (Fig. 54). Studied fields situated on coastal grasslands: control fields were abandoned, undisturbed coastal grasslands and fields with intervention were coastal grasslands managed by traditional way, grazing. Grazing is the main activity to maintain coastal grasslands and this activity is supported within the CAP. Legally the grazing in the subsidized Estonian coastal grasslands have to start before the end of May, 31^{st}. Grazing as intervention is the main reason of lower herbaceous biomass yield in the coastal grasslands than that in the control coastal grasslands. This herbaceous biomass was converted to the meat by livestock in June and August 2023. Control fields were abandoned, undisturbed and return of tall-fast-growth vegetation (e.g. encroachment of *Phragmites australis*) or biomass accumulation is natural process, ecological succession if management intensity declines in the coastal grasslands. This is expected that abandoned or unmanaged or natural coastal grasslands dominated by reed store more atmospheric carbon dioxide into above- and belowground biomass.

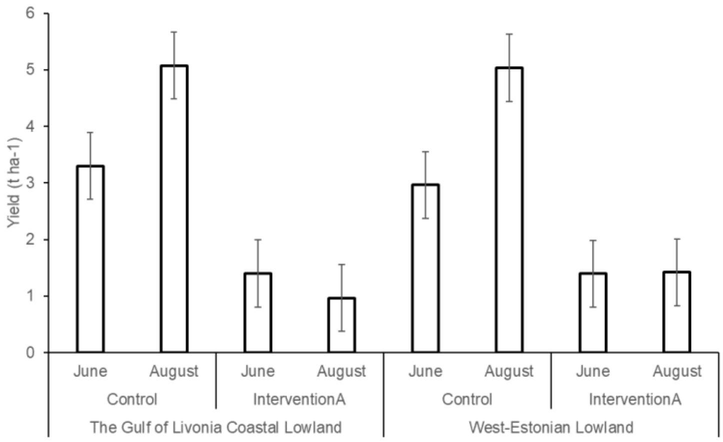

Fig. 54. Average yield of herbaceous biomass in Estonian coastal grasslands in 2023.

In **Romania**, we could not record data about the exact amount of hay that was produced by the farmers. Exchanging with some farmers, they mentioned that no hay was produced in the first year, because or vegetation recovering. Later years however (2–4 years after the cut) they found that fields were producing 60 to 80 % more hay than the first year after the cut. New species of plants appeared in fields.

5 A retrospective analysis

5.1. Co-design and co-production

Co-production projects have reported participant involvement ranging from minimal (e.g. providing feedback via a survey) to full integration (e.g. fully defining project aims through to implementing solutions). Co-producing experiments with stakeholders is a powerful tool for sustainability. Benefits include increased acceptance by stakeholders (farmers in our case), local or indigenous expertise, knowledge exchange, behaviour change, access to rare data, and policy impact. However, poorly executed co-production can waste resources and may reinforce inequalities via tokenistic involvement. Drawing on more than 200 years of collective experience across 23 countries, including four SHOWCASE sites, a team of 28 researchers and practitioners developed ten steps to maximise benefits and reduce risks in social-ecological co-production. This practical guidance includes advice on facilitator selection, participant engagement, objective setting, conflict resolution, and project legacy. These steps can improve co-production outcomes, thereby fostering research opportunities, impact, inclusivity, and sustainability. Based on the experience gained in SHOWCASE, a paper has been submitted on guidance of co-production knowledge, which drew upon data and knowledge from SHOWCASE sites ("Ten steps to maximise benefits and reduce risks when co-producing social-ecological experiments", by Hood et al. currently in review).

In addition, an exit strategy is being developed for each EBA. Research teams of the 10 European countries as well as the farmers who conducted the experiments have completed detailed questionnaires. The survey aims to collect information about researcher experiences as well as the farmers perception of the experimental work and relationships with scientists during the project. The findings will be used to evaluate the effect of research management (e.g. frequency of contact) on researcher and farmer perceptions of the project and outcomes (e.g. satisfaction with the intervention chosen). It will also identify the potential resources (e.g. funding, joint research project, availability of a facilitator) and partnership organisations (e.g. extension services, NGOs, farmer cooperatives) which could help sustain, and even possibly grow the current EBAs. Full findings from the exit strategy development will be reported in the Deliverable 1.6

5.2. Difficulties encountered

Working with farmers, and especially starting from scratch, in uneasy task. Several EBAs encountered troubles and issues in regard to communication and work with farmers. In several cases, experimental farms could not be included in the final analysis of the EBA because they did not follow, or could not follow the protocol. In the **UK**, 15 farmers were involved originally and collected baseline data across all of these farms. However, one farmer dropped out after this and before the cover crops were planted for personal reasons. In the **Netherlands** (study 2), the research team worked with interventions implemented by the farmers themselves; thus few farmers did not want to continue the cooperation, although, some interventions were not successful in biodiversity conservation due to poor management by the farmers. In **Hungary**, it turned out that the people doing agricultural activities in the croplands neighbouring the wildflower fields (WFFs) did not like its design and would prefer the WFFs to be in the corner, where it is easy to bypass the WFFs with the big machinery. In **Estonia**, the fieldwork revealed that one of the control fields was flooded, too wet. It was more like a coastal marshland, even though historically it was marked as coastal grassland on the vegetation map. Another problem encountered was on of the selected control fields, which was in the selection in 2022 and 2023, had been converted to pasture in 2023. The farmer, who also managed an experimental area, had an agreement with the local landowner and extended his pasture area to the control site as well. In **Romania**, Some of the encountered difficulties included herds of sheep passing through and staying on the intervention parcel, as well as electric fences that hindered access to and passage through the study plots. Additionally, it was challenging to maintain communication with the involved farmers because they lacked time, being busy with farm tasks. Out of the 7-8 farmers contacted, 4 agreed to participate. We did not lose any field.

More broadly, co designing interventions that fit both farmers' and researchers' aims is a complicated process. In **Sweden**, the research team feel that they could have taken an easier path with respect to setting up the EBA and selecting intervention, if it would have used a more "prescriptive" approach (i.e. researchers telling the farmers what we wanted them to do), rather than trying a bottom-up approach. On the other hand, the research team acknowledges that they learnt much more about the attitudes and motivations of the farmers by doing it the way they did. It is also believed that it was an advantage that the farmers felt that researchers were interested in farmers' experiences and opinions. In hindsight, the researchers could probably have used a slightly more structured procedure from an early point, for example asking farmers about a number of different options, rather than starting by asking with an open question about what would be interesting from their point of view. This would have been more efficient, but at the same time having the advantage of the farmers feeling that they were listened to.

The three years of SHOWCASE also showed very peculiar meteorological conditions. In **UK**, there was a severe drought in the year the cover crop was planted (end 2022), which meant that three farmers were unable to plant the cover crop due to lack of rain. They were still included in the project and invited to meetings and will receive the results. In the **Netherlands**, lupin suffered greatly due to weather (flood in 2021) and weeds (all years). Only two farmers harvested their lupin (2 fields 2021, 2 fields 2022, 1 field in 2023). One farmer did not continue in 2023 because he did not want to continue growing lupin. One nature management organization did not continue in 2023 because they did not have any other available land. Another nature organization tried to participate in 2022, but the field failed (not included in this study). One farmer who participated in 2022 tried again in 2023, but the field failed (not included in this study). Some fields in the hedgerow study suffered severe damages during the 2021 summer floods in south Limburg. We tried to account for that when we collected yield samples from these fields (e.g. by avoiding damaged parts or removing specific fields from the yield analysis). In **Spain**, some difficulties were encountered when setting up the intervention. For instance, in the first year to guarantee that the green covers were seeded following a common protocol, the research team was responsible of this task. However, farmers were willing to do this task in the following year after promising results. In autumn 2021, there was an extreme drought situation in the region which affected the development of green covers. This was even worst in the year 2023. Even on this conditions, green covers developed well enough. In the social aspect, farmers were willing to participate in the experiment, but not always to devote the required amount of time for a participatory approach and it was especially difficult to access to management information. During the period of the experiment farmers have faced several challenges as for example, the energy crisis and economy inflation, but the most important problem happened in year 2023 when many farms lost around 75% of yield because of drought.

Finally, in a few cases, workload for both the research team and the farmers had been underestimated. In **Portugal**, many difficulties were encountered. Above all, the intervention was really difficult to perform because heavy machinery was unexpectedly needed. Fortunately, all associated farmers selflessly provided such resources even knowing the high economic costs associated. In **Sweden**, another difficulty was that the research team could not offer the farmers any financial compensation for participating in the project. This limited the types of interventions that they could propose.

5.3. What else could have been tested

During the course of the experiments, or even before but because of lack of resources, several additional possibilities or parameters to be monitored or even experiments to be carried out appeared. As this document aims at providing a portfolio of potential solutions, it appeared useful to list such additional items here.

In the **UK**, soil mesofauna (e.g. collembola) during the pre-treatment sampling using soil cores and Tullgren funnels were surveyed, but their abundances were too low to merit repeating it. Our hypothesis was that the frost sensitive mixes would promote belowground decomposers due to the gradual release of organic matter. In the **Swiss EBA**, a possible option that would consider both biodiversity and agriculture aims was the implementation of pure legumes such as lentils. This option has been discussed during initial PestiRed workshops. Only legume-cereal mixtures have been finally chosen for legumes because lentils had not sufficient market opportunities. In **the Netherlands**, other mass-flowering crops could have been considered for the crop-type intervention, but the study focused on lupin due to the connections with previous research and with an organization promoting lupin cultivation in the Netherlands. Also, in the second site, all potential interventions in the area suitable for arable fields which are promoted by the local subsidies plans were explored. The research team chose interventions that could ensure for a good sample size, and also for a higher uptake. In **Hungary**, it would have been useful to measure ecosystem services (e.g. plant bagging for pollination, predation cards for pest control) to get direct measures of changes of some ecosystem services as a result of the interventions. In **Portugal,** biodiversity monitoring should have included vertebrates like birds and bats which exhibit higher foraging ranges than invertebrates, thereby responding to environmental variables at larger spatial scales. Moreover, vertebrate species are much more easily monitored than invertebrates. In addition, monitoring crop-specific insect pests could have been integrated, particularly because many farmers did not want to participate to the EBAlentejo because they were afraid of pest outbreaks in experimental sites. In **Romania** as well, other bio-indicators could have been explored, such as orthopterans and coleopterans, as they are very good and easily observable indicators. In **Sweden**, there were several options for other biodiversity-based option that could have been explored in the project, such as cover crops (which is conceptually related to intercropping). However, that did not really make sense for the farmers, partly due to climatic reasons, i.e. a short season for the cover crops to grow. In addition, some farmers were more interested in intercropping annual crops with perennial woody plants (i.e. “agroforestry” in a very wide sense). Finally, integration of grazing livestock in the arable system (i.e. a sort of transformation from purely arable to mixed farming) was also discussed with farmers. The idea was to let livestock graze on under-sown vegetation (grasses, clover etc.) after harvest of the cereal crops, and contribute organic manure to the fields. Here, a major challenge was the cost of fencing the fields. In **Estonia**, the investigation of microbial communities (especially abundance and distribution of zoonotic pathogens by birds and domestic animals) along the gradients of moisture, salinity and vegetation etc. in coastal grassland-forest ecosystems during global changes would be scientifically attractive. There is scanty literature about this topic in Estonia and understanding the ecology of microbial communities in Estonian coastal grasslands would shed light on how pathogenic microorganisms can inflict mortality on the livestock grazing in coastal grasslands affecting farmer's income. The deepened study of microbial communities and zoonotic pathogens in Estonian coastal habitats interconnected with migrative birds (e.g. several Estonian breeding birds are connected with habitats in Africa) and livestock offers insights into coastal ecosystem health, the impact of global changes, and public health implications. In **Spain**, many farmers and agricultural technicians were interested in the potential benefits of hedges for enhancing pest control fauna. However, the implementation of hedges requires a larger time to implement and fully develop that exceeded the project interval, and special water care is needed in the first stages. However, in 2023 and in funded by the NGO Abejas Silvestres, we gave for free more than 1000 shrub plantings to local farmers so they can initiate their own hedges. Besides some farmers mentioned the possibility of a secondary crop in the alleys, but this was difficult to integrate with the required management of stone fruit orchards, and many farmers were against. Finally, one company was interested in assessing the potential quality improvement in fruits thanks to wild pollinators, but early varieties mostly bloomed before the wild bees peak of activity and building up pollinator populations early in the season requires multiple years. In **France**, the interventions mainly responded to farmers' interest. However, it appears that for the interventions to be adopted the scale of the experiments (i.e. part of a field or the field) was may be not the most relevant as the farmers' decision and profitability are at the farm scale. However experimenting at the farm scale is pretty challenging and would need redefining the way to monitor biodiversity and agricultural indicators.

In addition, some interventions could not be tested because time scale was not relevant: for instance, growing hedges, or agroforestery, both of which are known to improve biodiversity while ensuring income to farmers, were not tested here.

6 Next steps

6.1. Is there a win-win situation?

Although analyses are ongoing, several findings are worth highlighting here. In most EBAs, biodiversity was improved by the intervention, which is not surprising because they were mainly aimed at this goal. In the meantime, in regard to yield, a decrease in yield was only found in a few cases, sometimes rather strong (Estonia, NL1, Romania in first year), in other cases moderate (Switzerland, France). Overall in many EBAs, the effect on yield was neutral (UK, Switzerland, Sweden, France though in the latter there was a non-significant decrease by a bout 2-5%). Interestingly, these are all arable systems. In orchards, yield was not modified in one of the two experiments, in Spain, while in Portugal the outcome is unknown. If, overall, there is not much difference in yield, SHOWCASE therefore found win/win situation, not between biodiversity and yield, but between biodiversity and income. This was the case in France and Switzerland, and possibly in Sweden. Indeed, one can expect an increase of income when no yield effect was found and when the intervention was at no or reduced costs (e.g. pesticide/nitrogen reduction). In the Netherland, the UK, Hungary and Spain, the outcome depends on the actual cost of implementing the intervention. These results obtained with a range of interventions are very encouraging. The next step will be to evaluate the true quantitative effect on farmers' income; which could not be established yet. The Table below provides a qualitative analysis of the potential trade-offs and win/win situation between biodiversity and either yield or margin. Margins have not yet been calculated, so it is inferred.

In addition, it would be of great interest to evaluate the outcome of the intervention on the mid-term because the effect of biodiversity increase on the agroecosystem functioning could be time lagged or because it could buffer the negative effects of disturbances and extreme events (e.g. climate change). In some cases (NL-2), control fields also suffered more from climatic events than experimental fields, possibly indicating a better resilience of biodiversity intervention against climate negative effects.

EBA	Farming system	Benefit for Biodiversity?			Benefit for yield?			Benefit for income?			**Win/Win outcome?**
		Negative	Neutral	Positive	Negative	Neutral	Positive	Negative	Neutral	Positive	
UK	Arable		+	++		+++		++	+		Depends on costs of undersowing
SW	Arable		++	+		++			++	+	YES depending on cost of 2^{nd} crop
HU1	Arable		+	++	+	++					Depends on costs of flower strips
FR	Mixed		+	++		+++			+	++	YES
CH	Mixed		++	+		++	+		+	++	YES
NL1	Mixed			+++	++	+					Depends on external funding
NL2	Mixed		+	++		+++					Depends on costs of Hedges
RO	Grassland			+++	++	+					Depends on cost of scrub removal
EE	Grassland		++	+	+++						Possibly, if meat production taken into account
ES	Orchard			+++		+++					Possibly depending on cost of flower strip
PO	Orchard		++	+		+++					Unknown

+: slight effect
++: moderate effect
+++: strong effect (+++ if "neutral" indicates no effect at all)
When spread over two levels (e.g. Neutral/positive), +/++ means that the effect is overall positive, but not in all cases (it can be neutral), ++/+ would mean that it is overall neutral, sometimes positive

Green highlights interesting and potential win-win outcomes.

6.2. Acceptability and farmer's response

Overall, we found that farmer's acceptability of the intervention was very dependent on EBA. In some, acceptability was very high. However, in many countries, farmers were skeptical or even negative toward the interventions in the initial stages, and the general idea of the SHOWCASE project as a whole. Since this is a very important aspect of SHOWCASE EBA interventions, we detail below, per EBA, farmers' impressions.

In the **UK**, farmers responded very positively to the experiment and the project as a whole. Several of them have invited the SHOWCASE scientists to speak to their farmer clusters. The farmers indicated that they wish to continue as a research group, and the research team will support them to find a facilitator for this (e.g. farmer-led research organizations). The farmers were really impressed with the ecological results given the short timeframe and difficult year for establishing the cover crops. In the **Swiss EBA**, farmers were also very positive. The SHOWCASE interventions in the Swiss EBA have been part of the PestiRed running project (2019-2025). Consequently, they had been discussed with farmers and the extension services, adopted and implemented in fields before the start of SHOWCASE. This has for sure simplified the process. There are still many issues that require improvement (e.g. selection and timing of flowerstrip sowing, machine use, input optimization), the PestiRed setup provides an accompanied, secured framework that allow farmers to explore without the fear of income loss (note that farmers were freely participating to the PestiRed project). Farmers were divided in those considering such interventions as a mean to get direct payment only, and those seeing a meaning for nature in addition. Undersowing is a marginally biodiversity-oriented intervention (at least above ground) but the few benefits can be considered a success, and farmers are easier convinced of the benefit. The implementation of flower strips as a margin can contribute to natural pest control in crops but the effect is usually concentrated in the first 10 meters of the field. Few examples proved an economic benefit (full cost analysis), given the cheap cost of pesticides. Undersowing has been shown acting positively on weed suppression, nitrogen supply for the current and next crop of the rotation. Concrete results of the full cost analysis including yield and the cost of intervention implementation has not yet been discussed with farmers having SHOWCASE fields. They were skeptical with regard to the flower strips partly because of the difficulty to implement such a strip successfully. During the experiment, several flower strip implementations failed because of inappropriate soil, non-adapted sowing date, or bad weather conditions. With more experience from farmers for undersowing, this measure has been easier to be implemented. Direct payment and additional contributions for participating have played a central role in the acceptability by a majority of the farmers. In **Sweden**, the farmers have been very interested, and some have asked questions about the results. They have also been committed to the project, probably due to our bottom-up approach which means that only quite interested farmers were included from the beginning. In **France**, farmers were very positive but faced huge increase in the cost of inputs due to the war between Ukraine and Russia in 2022. They were therefore looking for solutions to reduce the input costs while maintaining yield and without a significant increase in work load. They had some ideas of the interventions they wanted to explore and see the SHOWCASE project as an opportunity for biodiversity and yield monitoring as well as scientific inputs on the results interpretations. In 2024, some farmers set up experiments on their own based on SHOWCASE protocols but experimenting other factors (i.e. crop mixture). Others are willing to modify their practices to be more robust to climate and geopolitical crisis. In the **Netherlands for Study 1**, the farmers were curious about the intervention because for most farmers it was completely new. During the experiment they expressed many difficulties due to the weather and difficulties with cultivation, including weeds and harvesting issues. After the experiment, even though two farmers had acceptable yields in the second year, all farmers expressed that the crop was too difficult to manage to continue farming it without subsidy. In the second study, the farmers preferred the simple hedges, regardless of biodiversity (easier management). Most of them showed little interest, some of them are interested and a few were negative. In **Hungary (in the first EBA)**, the company, which manages thousands of hectares, was not concerned on pulling out 4 hectares of croplands from production, and turn into wild flower fields, and the company's agronomists had a positive attitude towards the wildflower fields; they value WFFs aesthetics and the fact that they can provide habitat for game species. But the people doing agricultural activities in the croplands neighbouring the wildflower fields did not like its design and would prefer the WFFs to be in the corner, where it is easy to bypass the WFFs with the big machinery. In **Portugal**, all farmers who participated in the project see this increase in biodiversity as an incentive to conserve and promote vegetation cover within their farms. In **Estonia**, farmers were quite passive participants, but of course accepted the experiment. They liked the news about Estonian new records of ground beetles and spiders. Some of them expect more information, final report about biodiversity values and socio-economic issues related to their coastal grasslands. In general, they are fine if biodiversity management is beneficial for their farms. During some meetings and discussions, for some farmers this is like a lifestyle and economic output is not primary, but for some farmers, they wanted some changes e.g. improve, meliorate coastal wetland because of the expansion of the area of coastal grasslands. In **Spain**, many farmers maintain bare soil or pruning leftovers in the tree alleys. Hence, before the experiment, some farmers were interested in trying new soil management measures, but many were skeptical, since they considered green covers as a pest refugee and weed bank. Interestingly, during the experiment, many of the farmers have realized the importance of having soil covers that include flowers and have learned how to manage them in order to facilitate the tree management and fruit collection, after the experiment, and most farmers will continue to implement green covers in all the orchard in the next season. In **Romania**, farmers responded positively to the intervention, as they were already implementing it on their owned lands. The acceptability has been consistent. They desire to protect biodiversity as long as they receive compensatory payments for their work.

7 To conclude

SHOWCASE was qualified as a huge success by most, whatever the EBA, and whether farmers or scientists were asked. SHOWCASE was qualified as a great example of combining biodiversity conservation, farming practices and farmers' interest. The point was made that during SHOWCASE external conditions changed drastically (drought, Covid, Ukrainian war) and prices for both external inputs and crop prices changed drastically as well. This was particularly pronounced in arable farming systems. New questions become relevant: How should we interpret the results of our experiments in the face of such variability? Are there new drivers? What arguments should be made to convince farmers?

Despite most had a particularly difficult year in 2022 to establish the cover crops, and the treatments were only in for a short period of time. These are very promising results given these limitations, particularly the benefits that we see spilling over into the subsequent crop. The success of the implementation in one EBA (Swiss EBA) is also due to the financial remuneration farmers got for participating such as in Swiss EBA, a limitation that was considered important however in the Swedish EBA. Greater benefits will likely accrue over longer timescales. The farmers also view this as a massive success, and this response was captured during exit interviews during final AGMs in May 2024. The challenge still remains to show the benefits of such interventions and make farmers aware of the contribution, and of the necessity to preserve biodiversity, its functions, and to foster biodiversity-friendly practices all along the food production chain. Already now, thanks to farm interventions experienced during the two years, some farmers have decided to continue in the same direction. For instance, in Hungary, the director promised to continue our cooperation that is the EBA wild flower fields won't be destroyed with the end of the contract. In Spain, the intervention was not too risky from an academic point of view, but still very new for the region. A great success is that most farmers are willing to use green covers in all the orchard, as they see this as cost effective. In France, a living-lab with SHOWCASE farmers and new farmers is underconstruction.

Farm Biodiversity Interventions have achieved knowledge exchange in many directions, meaningful and lasting relationships with farmers and partners. The project also had significant research opportunities: one farmer funded 2 ha Agroforestry trial; two PhDs and one fellowship co-designed with SHOWCASE farmers on agroforestry; one additional SHOWCASE trial citizen science; two proposals in development of forest understory and in-field flower strips.

Data analyses at the level of individual EBAs and results will be discussed with each multi-actor community and serve as a basis for further improvement of the biodiversity innovations. Indeed, there are many data still to be analysed, in particular in the win-win possible outcomes. SHOWCASE will quantify the multiple relationships between biodiversity enhancing management, and biodiversity, ecosystem functioning, crop yield, revenue and marginal costs in a representative set of European landscapes with contrasting farming systems and land use along the entire intensification-abandonment gradient.

8 References cited

Albrecht, M., D. Kleijn, N. M. Williams, M. Tschumi, B. R. Blaauw, R. Bommarco, A. J. Campbell, M. Dainese, F. A. Drummond, and M. H. Entling. 2020. The effectiveness of flower strips and hedgerows on pest control, pollination services and crop yield: a quantitative synthesis. Ecology Letters **23**:1488-1498.

Ali, A., N. Desneux, Y. Lu, and K. Wu. 2018. Key aphid natural enemies showing positive effects on wheat yield through biocontrol services in northern China. Agriculture, Ecosystems & Environment **266**:1-9.

Alignier, A., L. Raymond, M. Deconchat, P. Menozzi, C. Monteil, J.-P. Sarthou, A. Vialatte, and A. Ouin. 2014. The effect of semi-natural habitats on aphids and their natural enemies across spatial and temporal scales. Biological Control **77**:76-82.

Batáry, P., A. Báldi, D. Kleijn, and T. Tscharntke. 2011. Landscape-moderated biodiversity effects of agri-environmental management: a meta-analysis. Proceedings of the Royal Society B: Biological Sciences **278**:1894-1902.

Bengtsson, J. 2015. Biological control as an ecosystem service: partitioning contributions of nature and human inputs to yield. Ecological Entomology **40**:45-55.

Benton, T. G., J. A. Vickery, and J. D. Wilson. 2003. Farmland biodiversity: is habitat heterogeneity the key? Trends in Ecology & Evolution **18**:182-188.

Berquer, A., V. Bretagnolle, O. Martin, and S. Gaba. 2023. Disentangling the effect of nitrogen input and weed control on crop–weed competition suggests a potential agronomic trap in conventional farming. Agriculture, Ecosystems & Environment **345**:108232.

Berthet, E. T., V. Bretagnolle, S. Lavorel, R. Sabatier, M. Tichit, and B. Segrestin. 2019. Applying ecological knowledge to the innovative design of sustainable agroecosystems. Journal of Applied Ecology **56**:44-51.

Bianchi, F. J., C. J. Booij, and T. Tscharntke. 2006. Sustainable pest regulation in agricultural landscapes: a review on landscape composition, biodiversity and natural pest control. Proc Biol Sci **273**:1715-1727.

Bishop, G. A., T. P. Fijen, B. N. Desposato, J. Scheper, and D. Kleijn. 2023. Hedgerows have contrasting effects on pollinators and natural enemies and limited spillover effects on apple production. Agriculture, Ecosystems & Environment **346**:108364.

Bishop, G. A., D. Kleijn, I. I. Vicente, and T. P. Fijen. 2025. Mass-flowering lupin has positive, but limited, effect on wild bee conservation in agricultural landscapes. Journal of Applied Ecology.

Bretagnolle, V., E. Berthet, N. Gross, B. Gauffre, C. Plumejeaud, S. Houte, I. Badenhausser, K. Monceau, F. Allier, P. Monestiez, and S. Gaba. 2018a. Description of long-term monitoring of farmland biodiversity in a LTSER. Data Brief **19**:1310-1313.

Bretagnolle, V., E. Berthet, N. Gross, B. Gauffre, C. Plumejeaud, S. Houte, I. Badenhausser, K. Monceau, F. Allier, P. Monestiez, and S. Gaba. 2018b. Towards sustainable and multifunctional agriculture in farmland landscapes: Lessons from the integrative approach of a French LTSER platform. Sci Total Environ **627**:822-834.

Bretagnolle, V., S. Gaba, A. Hood, and S. Potts. 2022. Deliverable D1. 1 Network of EBAs established across Europe. ARPHA Preprints **3**:e93505.

Bretagnolle, V., F. Herzog, M. Albrecht, P. Jeanneret, K. Haefner, A. Piorr, S. Potts, S. Gaba, J. Herrera, and E. Ockinger. 2021. Experimental framework and standardised protocols for EBAs described in first version of a living document. Deliverable D1 **2**.

Brown, C., E. Kovacs, Y. Zinngrebe, A. Albizua, A. Galanaki, I. Grammatikopoulou, I. Herzon, D. Marquardt, D. McCracken, and J. Olsson. 2019. Understanding Farmer Uptake: What measures are most promising to deliver on supporting biodiversity and ecosystem services in the next round of the Common Agricultural Policy (CAP)?

Catarino, R., V. Bretagnolle, T. Perrot, F. Vialloux, and S. Gaba. 2019a. Bee pollination outperforms pesticides for oilseed crop production and profitability. Proceedings of the Royal Society B **286**:20191550.

Catarino, R., S. Gaba, and V. Bretagnolle. 2019b. Experimental and empirical evidence shows that reducing weed control in winter cereal fields is a viable strategy for farmers. Sci Rep **9**:9004.

Chateil, C., I. Goldringer, L. Tarallo, C. Kerbiriou, I. Le Viol, J.-F. Ponge, S. Salmon, S. Gachet, and E. Porcher. 2013. Crop genetic diversity benefits farmland biodiversity in cultivated fields. Agriculture, Ecosystems & Environment **171**:25-32.

Costa, A., B. Silva, G. Jiménez-Navarro, S. Barreiro, N. Melguizo-Ruiz, J. Rodríguez-Pérez, S. Vasconcelos, P. Beja, F. Moreira, and J. M. Herrera. 2020. Structural simplification compromises the potential of common insectivorous bats to provide biocontrol services against the major olive pest Prays oleae. Agriculture, Ecosystems & Environment **287**:106708.

Dainese, M., E. A. Martin, M. A. Aizen, M. Albrecht, I. Bartomeus, R. Bommarco, L. G. Carvalheiro, R. Chaplin-Kramer, V. Gagic, and L. A. Garibaldi. 2019. A global synthesis reveals biodiversity-

mediated benefits for crop production. Science advances **5**:eaax0121.
Duru, M., O. Therond, G. Martin, R. Martin-Clouaire, M.-A. Magne, E. Justes, E.-P. Journet, J.-N. Aubertot, S. Savary, and J.-E. Bergez. 2015. How to implement biodiversity-based agriculture to enhance ecosystem services: a review. Agronomy for Sustainable Development **35**:1259-1281.
Herrera, J., B. Silva, G. Jiménez-Navarro, S. Barreiro, N. Melguizo-Ruiz, F. Moreira, S. Vasconcelos, R. Morgado, and J. Rodriguez-Pérez. 2021. A food web approach reveals the vulnerability of biocontrol services by birds and bats to landscape modification at regional scale. Sci Rep 11: 23662.
Herrera, J. M., A. Carvalho, S. Barreiro, G. Jiménez-Navarro, N. Melguizo-Ruiz, P. Beja, F. Moreira, S. Vasconcelos, R. Morgado, and B. Silva. 2024. Temporal mismatches in flight activity patterns between Pipistrellus kuhlii and Prays oleae in olive farms: Implications for biocontrol services potential. Journal of Applied Ecology **61**:526-537.
Isbell, F., D. Craven, J. Connolly, M. Loreau, B. Schmid, C. Beierkuhnlein, T. M. Bezemer, C. Bonin, H. Bruelheide, and E. De Luca. 2015. Biodiversity increases the resistance of ecosystem productivity to climate extremes. Nature **526**:574-577.
Jeanneret, P., G. Lüscher, M. K. Schneider, P. Pointereau, M. Arndorfer, D. Bailey, K. Balázs, A. Báldi, J.-P. Choisis, and P. Dennis. 2021. An increase in food production in Europe could dramatically affect farmland biodiversity. Communications earth & environment **2**:183.
Karp, D. S., R. Chaplin-Kramer, T. D. Meehan, E. A. Martin, F. DeClerck, H. Grab, C. Gratton, L. Hunt, A. E. Larsen, and A. Martínez-Salinas. 2018. Crop pests and predators exhibit inconsistent responses to surrounding landscape composition. Proceedings of the National Academy of Sciences **115**:E7863-E7870.
Klebl, F., P. H. Feindt, and A. Piorr. 2024. Farmers' behavioural determinants of on-farm biodiversity management in Europe: a systematic review. Agriculture and Human Values **41**:831-861.
Kleijn, D., R. Bommarco, T. P. Fijen, L. A. Garibaldi, S. G. Potts, and W. H. Van Der Putten. 2019. Ecological intensification: bridging the gap between science and practice. Trends in Ecology & Evolution **34**:154-166.
Lang, D. J., A. Wiek, M. Bergmann, M. Stauffacher, P. Martens, P. Moll, M. Swilling, and C. J. Thomas. 2012. Transdisciplinary research in sustainability science: practice, principles, and challenges. Sustainability Science **7**:25-43.
Lechenet, M., V. Bretagnolle, C. Bockstaller, F. Boissinot, M. S. Petit, S. Petit, and N. M. Munier-Jolain. 2014. Reconciling pesticide reduction with economic and environmental sustainability in arable farming. PLoS One **9**:e97922.
Losey, J. E., and M. Vaughan. 2006. The Economic Value of Ecological Services Provided by Insects. Bioscience **56**:311-323.
Maas, B., Y. Clough, and T. Tscharntke. 2013. Bats and birds increase crop yield in tropical agroforestry landscapes. Ecology Letters **16**:1480-1487.
Marja, R., M. Albrecht, F. Herzog, E. Öckinger, H. Segre, D. Kleijn, and P. Batáry. 2024. Quantifying potential trade-offs and win-wins between arthropod diversity and yield on cropland under agri-environment schemes–A meta-analysis. Journal of Environmental Management **353**:120277.
Möhring, N., K. Ingold, P. Kudsk, F. Martin-Laurent, U. Niggli, M. Siegrist, B. Studer, A. Walter, and R. Finger. 2020. Pathways for advancing pesticide policies. Nature food **1**:535-540.
Morales, M. B., M. Díaz, D. Giralt, F. Sardà-Palomera, J. Traba, F. Mougeot, D. Serrano, S. Mañosa, S. Gaba, and F. Moreira. 2022. Protect European green agricultural policies for future food security. Communications earth & environment **3**:217.
Pe'er, G., L. V. Dicks, P. Visconti, R. Arlettaz, A. Baldi, T. G. Benton, S. Collins, M. Dieterich, R. D. Gregory, F. Hartig, K. Henle, P. R. Hobson, D. Kleijn, R. K. Neumann, T. Robijns, J. Schmidt, A. Shwartz, W. J. Sutherland, A. Turbe, F. Wulf, and A. V. Scott. 2014. Agriculture policy. EU agricultural reform fails on biodiversity. Science **344**:1090-1092.
Perrot, T., A. Rusch, C. Coux, S. Gaba, and V. Bretagnolle. 2021. Proportion of grassland at landscape scale drives natural pest control services in agricultural landscapes. Frontiers in Ecology and Evolution **9**:607023.
Perrot, T., A. Rusch, S. Gaba, and V. Bretagnolle. 2023. Both long-term grasslands and crop diversity are needed to limit pest and weed infestations in agricultural landscapes. Proceedings of the National Academy of Sciences **120**:e2300861120.
Pywell, R. F., M. S. Heard, B. A. Woodcock, S. Hinsley, L. Ridding, M. Nowakowski, and J. M. Bullock. 2015. Wildlife-friendly farming increases crop yield: evidence for ecological intensification. Proceedings of the Royal Society B: Biological Sciences **282**:20151740.
Ratto, F., T. Bruce, G. Chipabika, S. Mwamakamba, R. Mkandawire, Z. Khan, A. Mkindi, J. Pittchar, S. M. Sallu, and S. Whitfield. 2022. Biological control interventions reduce pest abundance and crop damage while maintaining natural enemies in sub-Saharan Africa: a meta-analysis. Proceedings of the Royal Society B **289**:20221695.
Rusch, A., R. Chaplin-Kramer, M. M. Gardiner, V. Hawro, J. Holland, D. Landis, C. Thies, T. Tscharntke, W. W. Weisser, and C. Winqvist. 2016. Agricultural landscape simplification reduces natural pest control: A quantitative synthesis. Agriculture, Ecosystems & Environment **221**:198-204.

Sacchi, G., L. Cei, G. Stefani, G. V. Lombardi, B. Rocchi, G. Belletti, S. Padel, A. Sellars, E. Gagliardi, and G. Nocella. 2018. A multi-actor literature review on alternative and sustainable food systems for the promotion of cereal biodiversity. Agriculture **8**:173.

Schneider, G., J. Krauss, V. Riedinger, A. Holzschuh, and I. Steffan-Dewenter. 2015. Biological pest control and yields depend on spatial and temporal crop cover dynamics. Journal of Applied Ecology **52**:1283-1292.

Séchaud, R., F. Herzog, M. Albrecht, P. Jeanneret, V. Bretagnolle, K. H. A. Piorr, S. G. Potts, J. Kantelhardt, L. Schaller, and D. Kleijn. 2021. Overview of selected SHOWCASE biodiversity indicators. Deliverable D1.3 EU Horizon 2020 SHOWCASE Project, Grant agreement No 862480.

Senapathi, D., J. Fründ, M. Albrecht, M. P. Garratt, D. Kleijn, B. J. Pickles, S. G. Potts, J. An, G. K. Andersson, and S. Bänsch. 2021. Wild insect diversity increases inter-annual stability in global crop pollinator communities. Proceedings of the Royal Society B **288**:20210212.

Sirami, C., N. Gross, A. B. Baillod, C. Bertrand, R. Carrié, A. Hass, L. Henckel, P. Miguet, C. Vuillot, and A. Alignier. 2019. Increasing crop heterogeneity enhances multitrophic diversity across agricultural regions. Proceedings of the National Academy of Sciences **116**:16442-16447.

Tschumi, M., M. Albrecht, M. H. Entling, and K. Jacot. 2015. High effectiveness of tailored flower strips in reducing pests and crop plant damage. Proceedings of the Royal Society B: Biological Sciences **282**:20151369.