# EIP-AGRI Focus Group
# Benefits of landscape features for arable crop production

FINAL REPORT
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# 1. Summary


This report is the result of the work of the **EIP AGRI Focus Group (FG)** on Ecological Focus Areas (EFAs) and more specifically on how landscape features (LFs) contribute to the profitability of arable crop production.

The scientific literature shows that LFs provide habitats for beneficial insects and other arthropods, birds, plants etc. When appropriately designed and targeted, they also prove to be effective in controlling erosion, wind, and nutrient loss and providing landscape amenities.

In this report, we focus on:

i) **'field margins**', the spontaneously established strips of herbaceous plants at the edge of fields;

ii) **'hedgerows',** composed of one or two rows of planted or naturally established shrubs and/or trees, and;

iii) **'grassy or flower strips',** intentionally sown, the former mostly with grasses and the latter with flowering plants.

The central scope was to examine if and how landscape features could contribute to the profitability of arable crop production. Other direct economic effects for the farmers include the production of wood, fruits, grass for horses, etc. We also included the benefits of landscape features to the society (aesthetics, social value, ecosystem services towards society) that the markets mostly fail to provide. A farm and the embedding landscape are systems that should be approached in a holistic way.

The Focus Group ended with three main recommendations

First despite the large amount of research on the functions of LFs, several gaps and research needs from practice have been identified. Best practices of LF management for runoff control and biodiversity conservation have been developed and proven effective, but very few concrete measures have been developed that show benefits for specific ecosystem service providers such as pollinators and natural enemies of pests directly related to production. In the review of the different functions of LFs, the FG found limited research on their effects on production and on the economic benefits to farmers.

The second recommendation concerns training and educational programmes. The incorporation of ecological approaches in farm production requires a basic knowledge among farmers but also their advisers. The importance of training in interdisciplinary matters is highlighted. It supposes an understanding of 'diversity' i.e. that cropping techniques must be adapted to local conditions and that these local conditions may be changed by manipulating LFs. This implies changes in the curriculum of agricultural schools at all levels.

Finally the involvement of different expertise at different spatial scales – from landscape till farm and LFs – is highlighted. To foster the understanding of the role of LFs for crop production and the design and adoption by farmers of LFs at the landscape scale, the development of Operational Groups (OG) is well suited. They require collaboration between farmers, scientists, extension services, land users as well as agri-food firms, environmental NGOs and other stakeholders, including public bodies. In practice, the OG can start for example as a group of neighbouring farmers and motivated advisers to work with the landscape dimension. To develop win-win situations in which LFs support increased crop productivity as well as providing environmental benefits, it is important to define and prioritise the objectives. This will help to create an optimum design of the LFs which reduces any possible trade-offs. The best structure and management of LFs which maximise the effects are different for different functions. The aspect of time deserves a special attention. Fluctuations are a feature of ecological processes. Little is known about their amplitude and its impact on functions and services in the context of agroecological interactions. Ideally, landscape design should buffer fluctuations to deliver services when needed. Sufficient time should be given to the OGs to deliver.




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# 2. Introduction

## Context

Hedgerows, grassy and flower strips, field margins, herbaceous strips in modern agroforestry systems, these are examples of (mainly linear) semi-natural features found in agricultural landscapes. These features harbour a **high diversity of plant and animal species** which provide **ecosystem services** to society in general and/or to farmers in particular. "Ecosystem services" are the benefits to humans which come, directly or indirectly, from ecosystem functions (Costanza, 1997). An "ecosystem function" is a combination of structure and processes (Braat and de Groot, 2012), for example, the process of flowering helps maintain populations of pollinators thereby ensuring the pollination function. This function is essential for the service of the pollination of crops.

Many semi-natural features emerged with farming or have been maintained by farmers over centuries. However, nowadays semi-natural features are increasingly under pressure due to changes in farm structure, agricultural technologies and markets. Policies do still encourage farmers to maintain and manage these elements through the support of a variety of **subsidies**.

Within the **European Common Agricultural Policy (CAP)**, maintaining specific landscape features guided by the 'Good Agricultural and Environmental Conditions' defined in the Cross-Compliance[1] is mandatory in several EU countries. Following the 2013 reform, in order to receive their full entitlement of direct payments, farmers must adopt agricultural practices which are beneficial for the climate and the environment. One of the main practices within this 'greening' component of direct payments[2] is to establish and manage 5% of their arable area in a way that safeguards and promotes biodiversity. This **5% are considered as 'Ecological Focus Areas' (EFAs)** and in most of the Member States it includes landscape features (LFs) and buffer strips. Farmers may also receive additional support through the rural development programmes if they adopt more targeted agri-environmental farming practices.

**Market incentives can also support farmers to maintain semi-natural features.** An example is the French biscuit maker LU who has contracts with farmers providing the flour (LU'Harmony). The farmers agree to enhance biodiversity around their field and in return receive a higher price.

To date, these instruments have focused predominantly on preserving, restoring and implementing landscape features for environmental reasons, with little attention on their consequences for **on-farm production and productivity.**

[1] Regulation (EU) No 1306/2013 – art. 93 and annex II – GAEC 7
[2] Regulation (EU) No 1307/2013 – art. 46



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**Hedgerow**

**Field margin**

**Grassy strip**

**Flower strip**

**Figure 1: Types of landscape features discussed in this report (photos: J. Baudry & H. Elmquist)**



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This report focuses on four landscape features which are found at the edge of crop fields (see figure 1). In a sense, they are all field margins or boundaries, but they differ in structure and function. We consider **field margins** as a spontaneously established strip of herbaceous plants at the edge of fields (meaning the plants were not sown, they appeared naturally). **Hedgerows** are composed of one or two rows of planted or naturally established shrubs and/or trees above the herbaceous layer, this feature has been intensively studied for their functions (Baudry et al, 2000). **Grassy or flower strips** are intentionally sown, the former mostly with grasses and the latter with flowering plants, but a mix of both can be found. These strips are sown either because it is mandatory in the CAP or to provide food and shelter to beneficial arthropods. In **Annex 1** an overview can be found of the structure of landscape features in relation to their different functions.

Numerous studies have demonstrated the effectiveness of landscape features in terms of providing **habitats for beneficial insects and other arthropods, birds, plants, etc.** When appropriately designed and targeted, landscape features have also proven to be effective in **controlling erosion, wind, and nutrient loss**. Figure 2 gives the overview of the LF present in a heterogeneous landscape and their main functions.

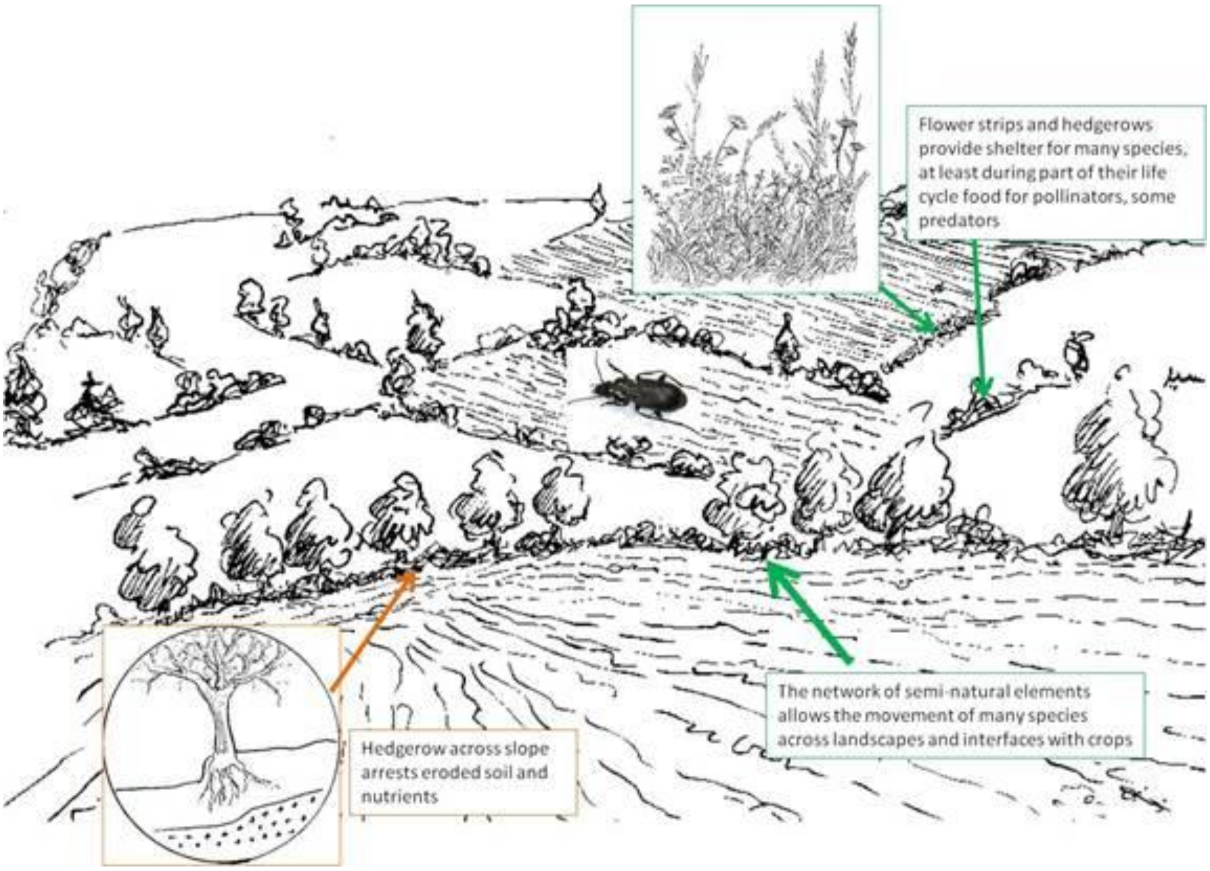


**Figure 2: Features in a heterogeneous landscape and their main functions (drawing Y. Le Flem, used by permission)**



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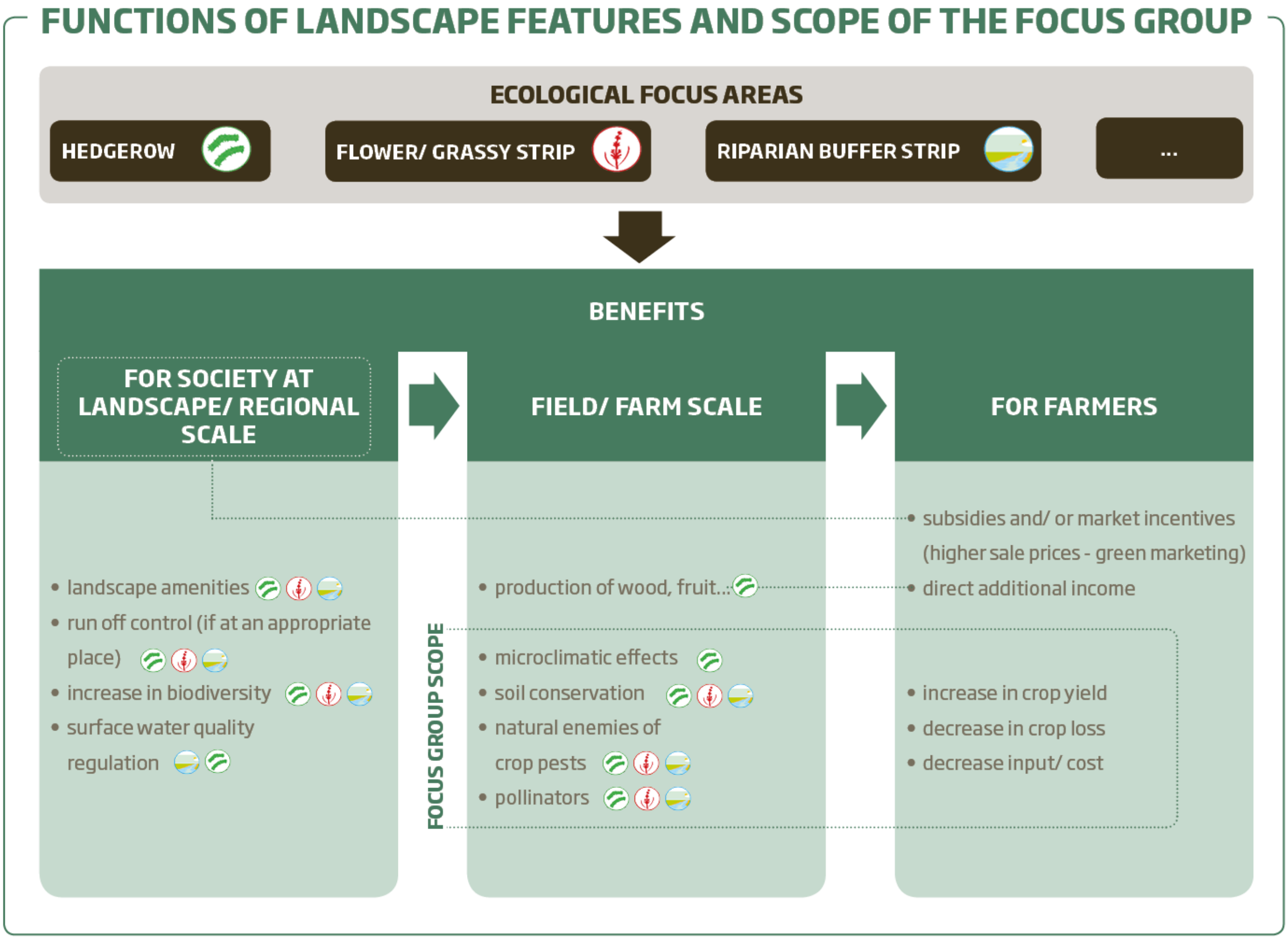
## Purpose and scope of the Focus Group

This FG looking into the benefits of landscape features for arable crop production was composed of 20 people, plus the coordinating team. The members represented a broad range of stakeholders involved in the study, implementation and promotion of agroecology, from farmers to agricultural advisers, conservationists, seed producers, and researchers (list in **Annex 2**). Starting documents from the coordinating team, two meetings and the writing of 'mini-papers' on specific issues helped build this final report. More information about the activities of the Focus Group and a link to the final version of the mini-papers can be found in **Annex 3**.

The **initial scope of the FG** was to examine if and how Ecological Focus Areas (EFAs), more specifically landscape features and buffer strips, and their management could contribute to the profitability of arable crop production (see figure 3). Potential direct economic effects for the farmers include: the production of wood, fruits, grass for horses, etc. In addition, the FG **broadened the scope** to include the non-monetary benefits of landscape features and buffer strips to the farmers and society such as aesthetics, social value, and ecosystem services towards society. A farm is a system and it should be approached in a holistic way.

The **purpose of this report** is to assess the current knowledge on the actual or potential benefits and constraints of LFs to farmers, such as enhancing crop yields or reducing costs of production. For example, biological pest control can reduce the need for pesticide spraying, with impacts on private production costs and likely benefits for biodiversity, the environment and human health. It also includes suggestions on successful ways to generate and disseminate this knowledge, as well as to foster the adoption of new practices by farmers.

Across Europe there are different climatic zones, geomorphological conditions, plant species, etc. so the FG worked primarily on the **common elements** that can be used by farmers **in different countries.**




In this report, we first present the expected benefits of landscape features in terms of managing natural resources, increasing production and decreasing production costs. Then, we address the question of the monetary benefits and the different ways that can encourage farmers to adopt LFs, ending with indications for future research.



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# 3. Ecosystem functions provided by landscape features

We distinguish between two broad categories of ecosystems functions:

1. those driven by **physical processes** (water and air movement) and associated elements, where the purposes of LF are to regulate abiotic fluxes of water, wind, nutrients and;
2. those driven by species' behaviour, i.e. the **biotic interactions,** where the purposes of LF are to enhance beneficial interactions.

## Control of water flows and wind

### Microclimate regulation and windbreak effect

The **use of hedgerows** to protect crops against wind and its effects (higher evapotranspiration, mechanical damage), and to mitigate excess heat is an ancient but still important practice. Even though the competition between the trees and shrubs in hedgerows and the crops in fields reduces crop production close to hedgerows, an overall gain in wind-prone areas is often likely. Table 1 gives the observed increase in yield when crops are protected by a windbreak. Compared to a similar field without a windbreak, the typical effect of a windbreak would be a decrease in yield close to the windbreak, followed by an increase in yield further away. The yield increase would be caused by a decrease in evapotranspiration and an increase in temperature. On the leeward side (the point towards which the wind blows), the windbreak effect persists for about 12 times the height of the hedgerow. Thus the effect is weak when the field width exceeds 200 metres, a common size in Western Europe. The effects also depend on the windbreak structure (see Cleugh, 1998 for technical details).
If you multiply the width of the hedgerow with the total area density (the projected area of leaf, branch, and stem per unit ground area divided by the crown length) you can predict the **windbreak effect** (Torita and Satou, 2007).

| **Crop** | **No. of field years** | **Mean yield increase %** |
|---|---|---|
| Spring wheat | 190 | 08 |
| Winter wheat | 131 | 23 |
| Barley | 30 | 23 |
| Oats | 48 | 6 |
| Rye | 39 | 19 |
| Millet | 18 | 44 |
| Corn (maize) | 209 | 12 |
| Alfalfa | 3 | 99 |
| Hay (mixed grasses and legumes) | 14 | 20 |

**Table 1. Relative responsiveness of various crops to shelter. (Source: Kort 1988)[1]**



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Usually, **hedgerow structure** is not described based on measurements because it is too time consuming; this is estimated in a semi-quantitative manner to map hedgerows over landscapes (e.g. DEFRA, 2007). The development of new remote sensing devices such as high resolution radars, or LiDAR allows a detailed quantitative analysis of the hedgerow structure and its consequences on the habitat it provides (Betbeder et al, 2014). More and more regional authorities want to assess the quality of their landscapes. Satellite images have a higher resolution and, in several cases, can be obtained for free, therefore these research results can be used relatively quickly.

## Erosion control and nutrient retention

### Erosion control

The **loss of soil** is a major threat for agriculture. Even on moderate slopes, erosion is a risk. Soil erosion depends very much on the soil surface determined by the crop rotation and tillage practices, the soil stability and on the landscape elements controlling water runoff or wind. Top soil is the **most fertile layer** where nutrients (phosphorus) and organic matter are abundant. Their loss is **not only costly for farmers,** it is **also costly for society** because as a result, surface water can be polluted, roads covered by mud and the storage capacity of water catchment areas is reduced when water storage basins are filled with sediments. Furthermore, erosion may also occur **during the growing season causing the loss of the crop itself** (see figure 4).

**Figure 4: Crops destroyed by erosion (photos: J. Baudry)**

Therefore three potential benefits of landscape features must be considered:

1. reduction of soil loss caused by erosion
2. increase in capacity to store nutrients or to decompose pollutants such as pesticides
3. reduction of runoff erosion also contributes to a reduction of flooding of downstream land (Mérot, 1999), up to the point where the soil is saturated with water. Beyond this point no feature has any effect on flooding.

Soil erosion leads to an irreversible deterioration of onsite soil quality. This results in the **reduction of the soil's production potential** and possibly even causing changes in the way the land can be used (Bakker et al., 2005). However, there is **little direct, clear-cut research on the association between erosion and productivity**. An accurate assessment of the impact of erosion on productivity is therefore difficult (den Biggelaar *et al.*, 2004). Furthermore, a decline in productivity may not relate directly to the amount of soil loss, but may be a result of **erosion-induced changes in the physical, chemical and biological qualities of soil** that influence production (Wang & Shao, 2013). Figure 5 shows a linear decrease in production as the top soil is lost by erosion.

From a farm management perspective, **soil erosion processes can be slow** and therefore they may not be noticed at all in the short term, this can lead to actions not being taken in time to avoid irreversible damage.

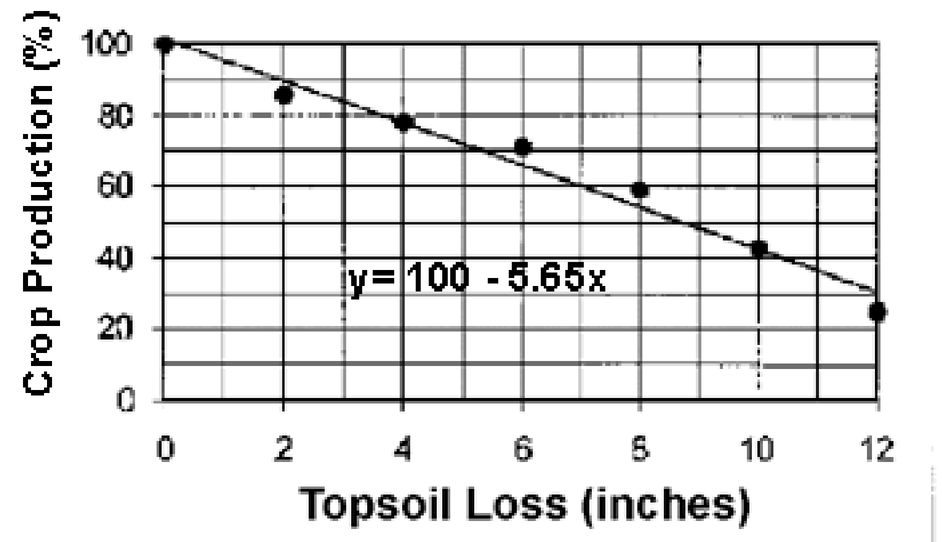


**Figure 5: Reduction in crop productivity from loss of topsoil. Data were primarily collected on soils without adequate fertiliser treatment. (from Stallings, 1964)**

Despite the potential harmful effects, very little data exists to directly assess the effects of erosion on yields.

More information about the structure and management of strips to control run-off can be found in **Annex 4.**

**Nutrient retention**

Sometimes the grassy strips become raised banks because they are not ploughed regularly, so the soil is not washed away. These banks can filter water, slow its movement and allow the reabsorption of some nutrients by the soil, especially **organic phosphorus**.

**Nitrogen** uptake by hedgerows, especially during the early spring (figure 6) encourages them to grow. The recycling of nitrogen when the leaves fall to the ground then keeps the resource within the system. Figure 6 shows the nitrate concentration along two soil profile transects from the same slope: one going across a hedgerow and the second with no hedgerow. In the first case, the concentration of nitrates in the soil is much lower, especially upslope of the hedgerow.



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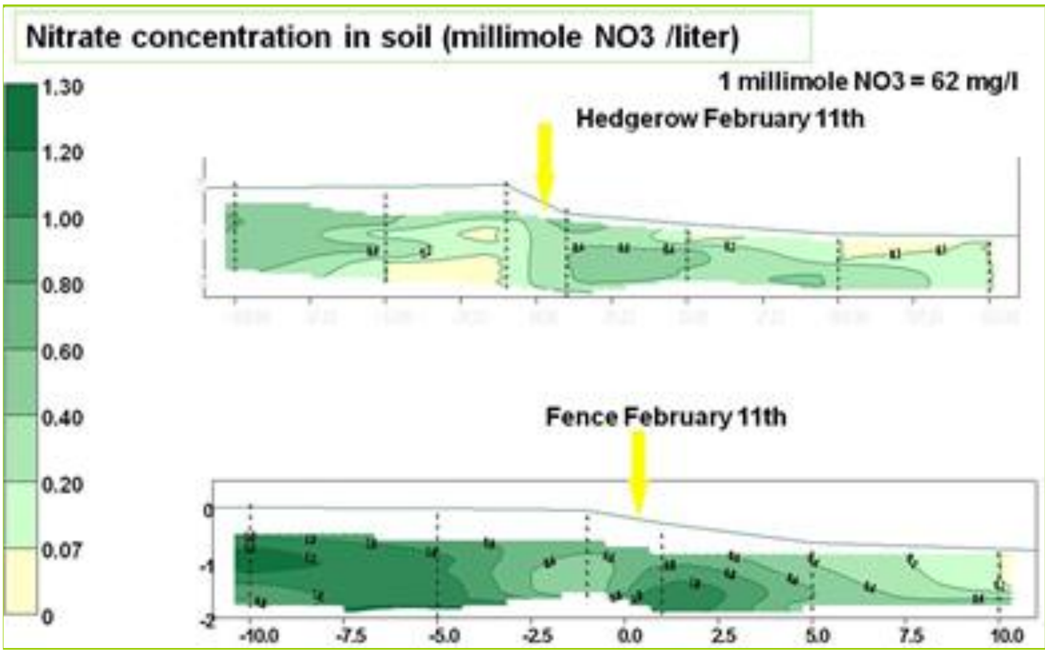


**Figure 6: Nitrogen uptake by hedgerows (Caubel-Forget et al, 2001)**

## Biotic interactions

Agricultural intensification over the last 60 years has resulted in a dramatic **decline in flower-rich habitats** such as extensively-managed grasslands, high diversity field margins and hedgerows. These semi-natural habitats provide a **range of vital resources for beneficial arthropods,** such as bees, spiders and predator insects which eat pest insects. They are a source of food, a nesting site and overwintering site (Biesmeijer et al., 2006; Ramsden et al., 2015). The loss of these semi-natural habitats has been strongly linked to the **decline of pollinators and pest predators**. It is dependent on agro-ecosystems (Biesmeijer et al. 2006, Winfree et al. 2009, Chaplin-Kramer et al. 2013).

To mitigate these declines, there is increasing interest in the **greening of productive agricultural landscapes.** The incorporation of semi-natural elements as key drivers can increase species richness. This increases **landscape heterogeneity** that is of utmost importance for providing habitats and resources to a wide range of organisms. This has the potential to create **a win-win situation**, as it generates benefits both for biodiversity conservation and for productive agriculture.

## Biological pest control

Among arthropod species living in hedgerows and strips, many are predators that can potentially play an important role in controlling pests which can be harmful to crops. Research indicates that these landscape features can increase the **diversity and abundance of beneficial arthropods (**e.g. Chaplin-Kramer et al. 2011, Holland et al. 2014).

Some recent data show an increase in yield when adequate flower strips are present. The choice of the species grown in the strips has an impact on how well the predator population is maintained (Wäckers & van Rijn 2012). An uninformed choice of species for semi-natural elements may even increase pests. Table 2 summarises the findings of predation experiments showing how the incorporation of different plant species in different landscape features had an impact on predator population. It shows the combinations that worked, if pest control was increased, for which pest and, in some cases, an estimation of yield increase.

| **(Arable) crop** | **Landscape management tool** | **Predator enhancement** | **Evidence for mechanism** | **Pest control delivery** | **Yield impact** |
|---|---|---|---|---|---|
| Wheat (ref 1) | Targeted annual flower margin | + (flower margin and field) | Floral resources | | |
| Wheat (ref 4) | Targeted annual flower margin | + (flower margin and field) | Floral resources | ++ (cereal leaf beetle | reduction below economic threshold |
| Wheat (ref 2) | Targeted perennial flower margin | + (flower margin and field) | Nectar (gut sugar analyses) | + (aphids) | +11% |
| Potatoes (ref 3) | Targeted annual flower margin | + (flower margin and field) | | | |
| Peas (ref 2) | Targeted perennial flower margin | + (flower margin and field) | Nectar (gut sugar analyses) | + (aphids) | +26% |
| Carrots (ref 2) | Targeted perennial flower margin | + (flower margin and field) | Nectar (gut sugar analyses) | + (aphids, carrot fly) | +32% |

**Table 2: Predation experiment in various landscape contexts: (1) Ramsden, et al (2014); 2) www.ecostac.co.uk; 3) Alebeek, et al. (2006); 4) Tschumi, et al. (2015)**

## Pollination

Insects are needed for the pollination of approximately 90% of plant species, including 75% of all crop species (Klein et al. 2007, Klatt et al. 2014). Benefits for crops include **increased yield and/or enhanced quality or shelf-life**. Globally, pollination services provided by insect pollinators has been estimated to account for 9.5% of the total value of food produced, equalling 215 billion US dollars worldwide (Gallai et al. 2009). There is growing evidence that the contribution of **wild bees (bumblebees, stingless bees, and solitary bees)** to crop production may be equal to, or even surpass, that of **honeybees** (Winfree et al. 2007, Garibaldi et al. 2013, Button and Elle 2014).

Table 3 presents the combined results of four studies on oilseed rape and beans, comparing the impact of pollinator access to the flowers on the production of fruits (pods), and on the weight of the fruits. In all cases studied, the weight of fruit and the number of flowers producing fruits when pollinators had access to the flowers was higher than when they had no access (for the experiment bags were put around the flowers to block pollinator access).



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| (Arable) crop | Important pollinators | Pollination impacts (Compared to when the pollinators had no access) | | | | |
|---|---|---|---|---|---|---|
| | | Pod set% | Pod weight | Market Value | | Ref* |
| Oilseed rape | Bumble bees | + 17% | +52% | | | 1 |
| | Honeybees | +16% | +51% | | | 1 |
| | Hover flies | + 17% | +45% | | | 1 |
| | Mason bees | + 17% | +70% | | | 1 |
| | Mixed | | +30% | | | 2 |
| | | | Seed weight | | | |
| | Mixed | | +18% | +20% | | 3 |
| | | | | | | |
| Field beans | Bumblebees | | +18% | +8% | | 1 |
| | Honeybees | | +12% | +6% | | 1 |
| | Bumblebees | +312% | +13% | | | 4 |
| | Honeybees | +292% | +11% | | | 4 |

**Table 3: Effects of pollinators on arable crop production**

*References : 1) Garratt et al (2014); 2) Stanley et al (2013); 3) Bommarco et al (2012); 4) Kendall & Smith (1975)

# 4. Win-win situations through design and management of landscape features

In the review of the different functions of LFs, we found limited research on their effects on production and on the economic benefits to farmers and the society. For farmers, using LFs as a tool for production requires information on how to manage LFs at field, farm and landscape levels. Success and fail factors arise at all of these levels and collaboration between the different stakeholders is essential. The following considerations should be taken into account **to set up Operational Groups related to LFs** but also to **develop research and innovative activities on the ground**.

## Defining the objective(s) of LFs – combining ecosystem functions and site specificities

Best practices of LF management for runoff control and biodiversity conservation have been developed and proven effective (see Annex 1 & Annex 4). However, very few concrete measures have been developed that show the benefits for specific ecosystem service providers such as pollinators and natural enemies of pests. The design of LFs for these environmental issues does not necessarily address crop production issues. It is important to **define and prioritise the objectives** that have to be tackled **in order to design the LF, reduce trade-offs and develop win-win situations where LFs support increased crop productivity as well as providing environmental benefits**. The impact of non-targeted LFs is variable. Using a meta-analysis of published studies on agroecosystem diversification, Andow (1991) found 52% showed reduced pest populations, 33% had no effect or variable effects, while 15% resulted in increased pest populations. Beneficial effects may be achieved with greater reliability by **using a more targeted approach**.

With regard to **the different functions** presented in section 2, the **structure and management of LFs** which maximise the effects **are different**. For instance, a good windbreak may need to have fewer flowers than a flower strip and it may also act as a barrier to the movement of insects. So, to mitigate these negative effects, it may be necessary to enlarge the windbreak with adjacent herb layers in order to support pollinators or natural enemies. The design of LFs must also take the **management of adjacent crops** into account to minimise the impacts on mechanisation costs from smaller field units and barriers within the field. **Cultural factors** associated with LF must also be accounted for. For example, the control of physical processes (wind, erosion, water runoff) by hedgerows and buffer strips is sometimes a traditional practice. This can be seen in Jutland, Denmark, where a state company has been planting windbreaks for over a century.

As it is not feasible to have all the functions in a single type of LF, it is important to **use their diversity and to combine their functions.** Their implementation must be planned to foster landscape scale functions (erosion control, species movement, beautification, etc.) and local functions (wood production, pollination, biological control etc.). Among the various ways to design LFs, the first distinction is between **wooded (hedgerows) or herbaceous structures**.

An important recommendation for the management of LFs is to control the plant composition and avoid dominance by a few, potentially ineffective, species which are incapable of promoting particular ecosystem services or that may even cause disservices (weeds). Partial mowing of grassy strips after flowering may be effective in achieving this. Given the differences in species composition in different biogeographic zones, it is often difficult to extrapolate results. One example when this can be done is with the results from northern EU to the south concerning flower morphology. Flower morphology and depth can determine the parasitoid's access to nectar whatever the plant species. For instance, for the common parasitoid *Episyrphus balteatus*, only flowers with nectar available at a depth of less than 2mm are suitable (Wäckers).

Pollinators also have specific requirements from LFs (Campbell et al., 2012) as various groups of insects have different resource needs and foraging ranges (Wäckers and van Rijn 2012, Garbuzov and Ratnieks 2014). A targeted, trait-based approach to landscape management has been developed for some key pollinator groups such as bumblebees or hover flies (van Rijn et al., 2015). However, this approach needs to be expanded to



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other pollinator groups if we want to develop landscape management strategies that are effective in supporting multiple pollinators.

## Spatial scale and time dimension of LF management

Scale is particularly relevant when managing LFs to **support effective pest control and pollination**. Potentially critical factors include the abundance of the different types of predators, parasitoids, and pollinators, and also the composition, extent and spatial configurations of LFs. All of these must be considered at **several scales**:

**At the field scale**, the success factors include involving farmers in a bottom-up approach to share evidence from the field of successful, tailor-made and farmer oriented measures. Sharing this evidence can be successful with high quality measures and a clear protocol for monitoring & evaluation. It is easier if the new landscape features can be implemented on the least productive land or on land which is difficult to access. Two additional factors play a positive role: usable products from the landscape features (e.g. wood, amenity for tourism, etc.) and a clear link to solutions to environmental challenges such as climate change, pollinator crisis, flooding, etc. Furthermore, when new LFs are designed, crop management on adjacent fields should be taken into account. The LFs should for instance be established in a way that will cause minimal additional labour and machinery demand for crop mechanisation.

At this scale the risks could be implementing easy and cheap measures that are inefficient or even increase the weed and pest pressure.

**At the landscape feature scale**, the search for innovative LF applications should focus on potential synergies and antagonisms. Which flowers favour both pollinators and arthropods to control pests? What are the advantages of a hedgerow vs. a flower strip? Could sown species provide better resources than semi-natural vegetation? How to design, target and manage them? What is a good combination of strip and crop?

**At the farm scale**, the question is how best to deploy LF in a way that accounts for the spatial distribution of cropping systems. Farms are often a set of fields scattered over an area and with various types of production system, distance to farmstead, soil quality, etc. They all play a role in farmers' decisions. The interactions between farming practices and LF functions need to be analysed. The main success factors are the availability of a decision support system (including cost-benefit analysis) with straightforward recommendations and a knowledge transfer mechanism (e.g. combination flower and grassy strips, population dynamics, etc.) to enable farmers to construct appropriate LF management plans based on available machinery and labour. The existence of demonstration farms nearby is also an important factor, providing positive feedback to peers and demonstrating locally successful strategies. In contrast, key fail factors to be taken into account at the farm scale are the lack of labour, time, knowledge, seeds, machinery as well as the financial risk, and insufficient communication. Their impact should be mitigated by an effective decision support process.

**The landscape scale** is frequently the most important scale for leading ecological processes relevant to farming (Tscharntke et al, 2005; Woltz et al, 2012). Therefore, the chances of success increase with collaboration and coordination between neighbouring farmers working towards a properly defined goal. In order to understand the operation of LF at the landscape scale, an interdisciplinary team from ecology, agronomy, sociology, geography etc. is necessary. The landscape is also the scale at which the farming community meets the local society. Success will be fostered if the LF plan creates public interest, confidence and recognition for the farmer. This is important because the pressure of the non-farming population on farmers is growing and many non-farmers are land owners and users whose practices have an impact on biodiversity, from road verge management to park and garden design. Upstream agribusinesses such as food processors and retailers can also have a positive role by paying farm producers a higher price if some LFs (flower strips) are sown around the fields. Farmers should be made aware of the possible benefits from LFs that can be used collectively such as fruit and timber production or landscape amenities for tourists. The landscape scale also coincides with the geo-social setting for coordinated action such as the sharing of machinery, exchange of ideas, experiments etc.


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Taking into account the history of the landscape and regional species will lead to the design of a coherent network of features within the landscape, while a poor design is likely to fail, either because it is ecologically inefficient or because it does not fit the farmers' organisation.

The landscape is also the scale to implement long-term, co-innovative research sites involving farmers for both observation and experiments. At the landscape scale, questions for this type of research would address the spatial distribution of the different types of LFs in accordance with the physical environment (soil, microclimate) and the distribution of crops.

The **time dimension** deserves a special attention. Pesticides and many intensive techniques are meant to maintain the cropping systems' production within narrow limits. **Fluctuations** are a feature of ecological processes. These fluctuations are driven by climate, land use and intrinsic population changes. Little is known about their amplitude and its impact on functions and services in the context of agroecological interactions. Ideally, landscape design should buffer fluctuations to deliver services when needed.
Furthermore, many conditions for agricultural production vary over time, such as markets for inputs and outputs or available technologies. Farmers anticipate such changes in their risk management and evaluate the option to reverse their management decisions in the future. These considerations likely govern farmers' long term decisions including those on developing LFs.

## Collaboration within groups of farmers and with other involved stakeholders

LFs are more effective when designed at the landscape scale which requires input from multiple actors and **dialogue among farmers, scientists, and other stakeholders including public bodies**. This can foster both the adoption by farmers of LFs due to increasing awareness of the private and public benefits that they provide. It may also stimulate the development of research which is better tailored to farmers' needs. Farmers may be more inclined to establish or maintain LFs when support schemes are flexible and involve secure property rights. Very often, farmers do not implement LFs because they fear that it will become illegal to remove them or even to place them elsewhere. In the UK the new schemes for flower margins are more flexible, there is a fixed minimum for some species but farmers can select other interesting species (with appropriate functions). It may also be important to farmers that there is some flexibility in the dates when the strips adjoining fields may be mown.

## The diversity of farmers regarding their attitude towards the environment

The fact that farmers, like any social group, are diverse has been investigated by several authors so as to understand their relationship with the environment and design appropriate schemes. Cultural and social factors are important in the adoption of technical systems. Monetary benefits may not be the main goal, as long as farmers can make their living.

According to a survey of French farmers, the factors enhancing the adoption of organic farming (OF) or integrated crop production (IP) are: "*(1) social concerns (e.g., showing to others one's environmental commitment) drive both IP and OF adoption; (2) moral concerns (e.g. do not feel guilty about one's choices) increase the probability of organic farming adoption only and; (3) farmers who give high importance to economic concerns (e.g., cutting production costs) are less likely to adopt OF* (Mzoughi, 2011)."

LFs often have a significant visual impact and are features of cultural value. LFs therefore show that farmers "care about the environment" and lead to a positive view of farming by others. It may also be an important factor to foster rural tourism, bringing income to holiday farms.

## Rules on property boundaries


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Some legal aspects may present substantial problems for the adoption of LFs, for instance, **in France** a hedgerow must be 2 meters away from the property boundary, unless there is an agreement between the two landowners to have it on the property line. This may be a constraint because it can mean a loss of arable land.

**In the UK**, hedges at the boundaries between properties are regulated by different rules. The Ordnance Survey, Britain's mapping agency, is often a source of information on who is responsible for particular boundaries.

**In the Netherlands,** if a farmer who rents land wants to plant a hedgerow, he/she has to ask permission from the land owner. This is also the case if they want to sign an agri-environmental agreement in pillar 2 of the CAP. The reason for this is that in agri-environmental schemes there are often restrictions in use of nutrients or pesticides, and this could be seen as a 'not good agricultural management' and reduce the quality and price of the land. Therefore the land owner has to agree with participation in these schemes. Voluntary buffer strips, sown field margins etc. and managed ecological focus areas in CAP pillar 1 (greening) can be ploughed up easily, therefore no permission from the land owner is needed in the Netherlands.

These examples illustrate the differences that exist in the legal context around the EU, they also make clear the need for agreement among various parties.

## The institutional level

**Education and information exchange** are key factors, first through the education of farmers and of their advisers, then through life-long learning and the formation of social groups where farmers can share knowledge and maintain the innovation process. The private and public costs and benefits of LF establishment and maintenance should be explored with farmers. Furthermore, building relationships between farmers and environmental organisations will lead to mutual trust and understanding.

From the policy side, farmers expect **clear, long-term, flexible and non-conflicting policy measures** (CAP, Natura 2000, national pollination strategy in the UK, erosion control ...). The lack of knowledge of farming activities or understanding of environmental policies by controllers is a factor that prevents farmers from engaging into LF implementation and management.

## Impact of LFs on crop production profitability

One key aspect of the innovation of a LF based approach is the **cost/benefit ratio and cost-effectiveness of LFs**. The decline of landscape elements in the past, for an example the extensive removal of hedgerows or orchard meadows in Europe (Herzog, 1998), suggests that their maintenance is costly. Farmers have an **economic incentive to establish and maintain LFs** only if one or more of the following arguments are satisfied:

- Private benefits to farmers exceed their private costs. For example, hedgerows may provide fuel wood or fruit of sufficient value to cover the profits from any alternative production of the land and the maintenance costs.
- They have a social benefit and public incentives are provided that exceed the private costs. One example is the greening measures required for the CAP single farm payment or agri-environmental payments.
- LFs do not create costs to the farmer at all. In some cases, costs of LFs may be low or negligible such as for landscape elements on marginal land.
- LFs are enforced by law. Nature protection policies typically enforce maintenance of valuable landscape elements.



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Major private costs and benefits of LFs are presented in Table 4. Table 5 gives more details of the costs of planting hedgerows

| ***Private costs*** | | ***Private benefits*** | |
|---|---|---|---|
| *Direct costs* | *Indirect costs* | *Market benefits* | *Non-market benefits*[3] |
| - Establishment (planting, seeding)<br>- Replanting<br>- Management measures for maintenance<br>- Harvest (e.g. fruits, fire wood) | - Alternative use of land with larger market benefits<br>- Reduced yields of adjacent crop<br>- Adverse mechanisation of adjacent field | - Fruit<br>- Firewood, fire-pellets<br>- Timber<br>- Forage, pasture | <u>Benefits mainly to the owner of LFs</u><br>- Soil fertility of adjacent fields (i.e. increased yields through decreased evapotranspiration and nutrient leakage as well as protection from wind and water erosion)<br>- Time saving through straightening of adjacent field borders<br>- Enhanced pollination<br>- Natural pest control<br>- Shelter for livestock<br>- Weed seed predation<br><u>Benefits to other farmers and the public</u><br>- Enhanced pollination<br>- Natural pest control<br>- Positive public perception and feedback for biodiversity and resource protection by farmers (e.g. by planting flowers on buffer strips or alongside landscape elements)<br>- increasing attractiveness of agricultural landscapes for rural development (e.g. tourism) |

**Table 4[4]: Potential private costs and benefits of ecological focus areas (LFs)[5]**

[3] excluding public payments; non-marketable benefits may increase marketable outputs such as yields from adjacent farm land or may reduce cost for market products such as pesticides and fertilizers
[4] From the mini-paper 'The farm economic dimensions of Landscape Features – costs, benefits, and risks of Landscape Feature establishment and maintenance', based on Schönhart et al. (2011)
[5] especially for landscape elements and buffer strips



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| Region | Arable crop | Gross margin of crop (€/ha) * | Loss of area for hedgerow (€/ha) | Mechanisation costs of hedgerow (€/ha) | Maintenance costs of hedgerow (€/ha) | Total costs excl. establishment (€) | Establishment costs of hedgerow (€/ha) |
|---|---|---|---|---|---|---|---|
| Baden-Württemberg, Germany[A] | - | 473-753 | 21-37 | 84-109 | 76-90 | 115-205 | - |
| Germany[B] | - | - | 28 | 49 | 31 | 118 | - |
| Lower Austria, Austria[C] | Winter wheat | 144-335 | 4-10 | 53-62 | - | 57-72 | 300-600 |
| Austria[D] | Crop mix | 460 | 40 | 29 | 102 | 171 | - |

**Table 5[6]: Examples of cost of hedgerow implementation [5]**

Based on a survey of farmers in two French regions with large (160 ha) arable farms (Cordeau et al, 2011), a third of farmers perceive no important **loss of revenue associated with grassy strips**. There is a cost in sowing, managing and decreasing the productive area, their main finding is that adding 3% of sown grass strip in a farm decreases the income by 7%. But the authors state that this loss is low compared to losses due to insect attacks. There are however other potential causes of loss attributed to the grass strip such as the risk of weed invasion.

Collaborations can have positive economic benefits with collective action leading to **reduced costs**. For example, there can be substantial reductions in implementation costs for the government if a group of farmers collectively designs a network of LFs with different functions. They could then set up an organisation acting as a final beneficiary from the Paying Agency, instead of individual farmers. In this way, the implementation of a public incentive LF scheme can be simplified (Terwan, 2014). The control should be at the level of the territory of the group of farmers.

Even from an economic point of view, increasing flexibility in the design and management of LFs decreases costs and increases private benefits. Environmental outcomes are likely to be site-specific as well. Consequently, spatially heterogeneous and scientifically sound rules on LFs need to be developed. The challenge is how to promote flexibility at the individual level while, at the same time, allowing for collective action.

**Fail factors in economy**

**Identifying and mitigating economic risk factors is an essential task.** Farmers face several risks related to the establishment and management of LFs. In the past, farmers removed landscape elements. First because they were a burden, they needed management, and made working with large machines difficult. Then, there were concerns that environmental regulations would decrease flexibility in future land management and increase

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[6] costs/area (€/ha) related to arable land including hedgerows; (-) no values published; values not inflation corrected; *gross margin of crop including hedges, e.g. for footnote 3 gross margin for 0.97ha wheat is estimated for a field of 1ha; gross margin of a field without hedgerow: gross margin of crop + loss of area for hedgerow

A Kapfer et al. (2003): Study analysed existing hedgerows in Baden-Württemberg; results from cropland dominated landscapes; (-) missing values; mechanization costs driven by the size of the crop plot; consideration of direct payments in gross margin/ha unclear

B Heißenhuber (1999): regional unspecified calculated data from 1992, proposed labor costs of 55€ are assigned to mechanization costs and maintenance costs with 50% each;

C based on Schönhart et al.(2011): wheat yield of 5-7t/ha, no direct payments included, data from BMLFUW (2008) for conventional production, hedge size of 0.03ha; mechanization costs calculated from the difference of 1ha and 3ha plot sizes; no annual maintenance costs assumed for a 30yrs period; establishment costs include maintenance for the first years.

D Steurer (2010): calculation for Austrian Program for Rural Development 2007-2014; average crop mix assumed, size of hedge 0.08ha cost burdens under a rapidly changing market, technological, and policy environments. The increasing size of farm machinery, climate change-related issues (e.g. the need to introduce irrigation systems) or changing prices of agricultural products impact the private costs and benefits of LFs and can increase the opportunity costs of future land use. (Heißenhuber, 1999). Mainly, institutional innovations would be necessary to manage this risk. For example, institutional level agreements may guarantee farmers sufficient flexibility in the future management of LFs or sufficient compensation for market losses.

The costs and benefits of LFs, and particularly opportunity costs of the land, depend on farm type. In New Zealand for example, Welsch et al. (2014) found that lifestyle properties (typically characterised by small pieces of farmland used for a variety of agricultural purposes, often serving as a second source of income for property owners) have a higher density of LFs compared to sheep and beef farms while dairy farms have the least (Welsch et al., 2014). Dairy farmers prioritise farmland productivity. Changing farm structure, increasing market orientation of farmers, and increasing economic pressures, such as observed in many parts of Europe, may be strong forces against LFs in the future.

Landscape effects of LFs on other farmers and the public can limit incentives to farmers maintaining LFs if they can benefit from the ones implemented by their neighbours, leading to undersupply of LFs in general. Typical policy choices are the internalisation of these benefits via agri-environmental programmes. Policy and institutional innovations, such as the replacement of public programmes by private regional programmes (e.g. tourism industry; for arguments on payments from the media industry - see Jepson et al, 2011) can alter market performance and incentives by increasing awareness and available budgets.

## Co-creation and exchange of knowledge and experience between farmers and other stakeholders

The sharing of knowledge and expertise is essential for the successful innovation of LF schemes and, in particular there are two main points that must be included:

1) to summarise and translate the scientific information and;
2) to have advisory techniques which take into account the tacit knowledge of farmers.

1) Research and development in agriculture have always been based on a large network of experimental and demonstration farms, including those in agricultural research and higher education institutes. Many of these farms run projects relevant to the functioning of LFs, e.g. biocontrol. Isolated collaborative initiatives in respect of LFs also exist (LEAF organisation in the UK, CIVAM network in France[7], CAP-pilot projects in The Netherlands) but most of the effects remain unknown because of the disconnection between science-based and farmer-based knowledge. More collaboration with an emphasis on a bottom-up approach between farmers and other actors is needed to provide a comprehensive understanding of LFs, their function and management.

   There are many benefits and potential benefits from cooperation on public goods. For example, better ecological results are achievable for habitats and species where these exceed the individual farm level (i.e. farmland birds and ecological corridors). Ecological benefits can also be produced from an increased participation by farmers. For example, in the Netherlands, over the last four years, pilot-projects were set up in four regions to build up experiences among farmers and their organisations on the value of local cooperation in providing ecosystem services.

   The networks of commercial farms developing innovation in this field is also growing. The flow of new information is enormous but the capacity to use this information may be growing at a slow pace due to lack

[7] CIVAM: Centres d'Initiatives pour Valoriser l'Agriculture et le Milieu rural (Centers of Initiatives to Develop Agriculture and the Rural Areas) (http://www.civam.org/)



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of synthesis. The development of 'resource centres' such as the one for biodiversity conservation, or, in France, for ecological networks[8] would allow the dissemination of scientific results to managers. Such centres must also provide protocols to improve the consistency of data collection, and also actually collect data themselves and provide tools to support meta-analysis across sites and groups.

Education at all levels, including life-long learning, is a key factor of success underpinning the co-innovation processes. This should include the education of farmers and advisers, but also of environmental NGOs to enable them to understand how a farm functions.

The resource centres should also ensure the promotion of novel technologies (DEMs, LIdar, radar etc.) as well as the development of tailored models that can help to simulate scenarios and design the implementation of LFs.

2) A shift of the advisory practices is needed. Most of the time, the adviser is an expert who operates the transfer of solutions in a linear way. Farmers' wishes, farmers' tacit knowledge are not highlighted and farmers' education is not favoured. In CIVAM networks, farmers are organised by a facilitator who interacts with farmers to help them to formalise their knowledge and to integrate new information.
New schemes, such as the new agri-environment scheme for 2016 in the Netherlands and the GIEE (Groupement d'intérêt Economique et Environmental = Group to foster the economy and the environment) in France, favour groups of farmers. These schemes can facilitate the emergence of demonstration farms and groups of farms.

Experiences with participatory or collaborative approaches show they give rise to tailor-made knowledge that is more appropriate for farmers working on the ground, being both validated and accepted by them. In effect, producing knowledge in a collaborative way promotes the sharing of knowledge between all actors and at each step of the project. The measures produced in this way are also more sustainable and more effective through the implementation of LFs in farms and changing practices based on shared wishes and interests. Collaboration among farmers on the implementation of LFs could result in better management responses, meaning less of a burden as they work with the same contractor and organise collective projects. It can also result in one of the farmers specialising in LFs management with specific investments. A key question remains on how to produce knowledge that is valid over a wide range of situations and knowledge relevant to a specific situation needs investigation.

[8] Examples are: http://www.conservationevidence.com/; Centre de ressources Trame verte et Bleue (http://www.trameverteetbleue.fr/)

# 5. Recommendations and conclusions

One aim of this final report of the Focus Group is to inspire the setting-up of innovative actions like Operational Groups (OGs) within the EIP-AGRI framework and to give direction to new research projects and educational programmes. Our review shows that more research focusing on the role of landscape features for crop production is needed.

Because of the multiple scales involved and the fluctuations of processes such as the dynamics of pests and natural enemies populations, understanding the system is complex. Research and demonstration and testing by Operational Groups requires several years of work at farm and landscape scales. Given the few results on the effects of LFs on production, Operational Groups will have to participate in the research effort.

The effects of LFs such as windbreaks, against erosion and as a source of amenities are well known and information can be used quite easily, so the focus of future research should mainly be on pest control and pollination.

## Recommendations for future research projects

Despite the large amount of research on the functions of LFs, several gaps and research needs from practice have been identified. The two major research needs are:
on the relationships between LF functions and improved crop production
on the profitability for farmers, including the costs and benefits of LFs.

In both areas, analytic and holistic approaches are needed. **Analytic questions are:**

- Which factors support **effective pest control and pollination?** This includes clarification of the role played by different types of predators and parasitoids, and pollinators, and the composition, amount and spatial configurations of LFs.
- Another aspect is to clarify the **roles, the synergies or antagonisms between landscape design with different LF and farming practices** at field scale, including within field non crop elements (weeds, strips of flowers etc.).
- The other key point is the **cost/benefit analysis of the effectiveness of LFs**.

**The holistic approaches** must be conducted at several scales (cf point 3.2). In a more integrated approach, the different types of benefits, **monetary** (lower cost of production, subsidies, better price for products etc..) and **non-monetary** (e.g. reduction of health problems linked to the use of pesticides, better acceptance of farming by the local society and the society at large) must be evaluated. Their potential synergies and antagonisms must also be assessed. The diversity of farmers' approaches towards LFs and their possible adoption must be explored to design a range of pathways of innovation.

It is also necessary to **translate scientific field evidence to farming practices**, taking, for example, the labour aspect into consideration. There is a need for a long-term monitoring and participatory research with the most innovative farmers. Afterwards, these experiences can be generalised to more farms.

Research should address the diversity of landscapes (physical conditions) and cropping systems (diversity of crops) regarding the need of specific LFs.


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When planning an experiment concerning pest control, either for research or demonstration, the two main questions are: how to attract natural enemies and how to make them efficient in terms of pest control?

Three aspects to be considered are:

- Look for adequate plant species: Particular plant species may be required for particular parasitoids that need nectar and pollen sources at a given time in the year, while others may be more effective in delivering habitats for generalist predators like spiders and carabid beetles.
- Consider patterns and processes at different scales, from field to landscape, interact. This includes understanding the influence of local and regional (landscape) population dynamics on the conservation of natural enemies (and pests) and the role of within-field elements and permanent habitats on these. The importance of within-field elements in modifying the behaviour of natural enemies should also be considered; can behavioural signals be used to 'capture' specific natural enemies from the regional species pool, redirecting them to deliver biocontrol within the crop?
- Have an integrative approach and consider simultaneously: (i) the production purpose (crop performance and quality of products), (ii) the socio-economic imperatives (farm organisation, farm income), and (iii) the environmental objectives (limitation of pesticide and nitrogen discharge into the environment, minimisation of water, and energy use).

Therefore, experiments consist in testing flower mixtures, assessing the efficiency of spontaneous vegetation while collecting natural enemies and pest in different fields of a landscape. The farms using these fields must be analysed in terms of cropping systems, crop management regime, labour organisation, farmers' objectives (production, environmental and way of living objectives).

Landscape features have, up to now, mostly been praised for their role in conserving biodiversity and other benefits for natural resources. Fostering their role as a crop production tool must not be antagonistic with these previous goals. Clearly, sowing flower strips may be at the expense of preserving wild flora. That is where a **landscape approach** permits to add or enhance novel services while conserving the broader environmental benefits. This requires **careful monitoring of biodiversity changes** associated with changes in LF design and management.

In all cases and for all variables, ecological or social **long term monitoring** is also required as farming/landscape systems are highly variable depending on weather and market conditions. These aspects challenge as much researchers, as advisers or farmers.



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## Recommendations for training and educational programmes

The incorporation of ecological approaches in farm production requires a basic knowledge among farmers and their advisers of ecology, agro-ecology and training in interdisciplinary matters. It presupposes an **understanding of 'diversity**' i.e. that cropping techniques must be adapted to local conditions and that these local conditions may be changed by manipulating LFs. This implies changes in the **curriculum of agricultural schools** at all levels.

It is crucial to make students aware of the fact that **crops are managed as part of a farming system and a landscape, not only as a cover of a field**. One may say that was the lessons of 'old' agronomy, but, the objective is to produce a hard scientific basis for novel practices. That also implies to have an important part of the curriculum on **collective organisation**. These organisations must be for farmers and advisers and other stakeholders to foster the overall land management and make farmers aware of how their practices affect different kind of biodiversity.

**Life-long learning** is an essential basis for the adoption of novel techniques. It must be based on the **analysis of case studies** of farmers having different experiences with LFs. **Field visits and demonstration projects** must be developed, and the use of the web will be increasingly important. A **MOOC (Massive Online Open Course)**, a course based on videos, forum etc. on the web on LFs could be a possibility, also **short videos** to promote LFs and to demonstrate management techniques and outcomes.

Education is based on a permanent renewal of knowledge, synthesis, dissemination, capability to acquire knowledge will be as much an asset as land.

## Recommendations for setting up Operational Groups

Operational groups are well suited to address the questions above as they require not only scientists, but also collaboration with farmers, advisers and other stakeholders, land users as well as agri-food firms. In practice, an OG working on Landscape features could for example consist of a **group of neighbouring farmers and advisers** who are **motivated** to work on issues beyond the farm level, including the landscape dimension.

For more information on Operational Groups, please see **the EIP-AGRI Brochure on Operational Groups** (available in English, Finnish, French, German, Greek, Hungarian and Italian)

It is important to **focus on a narrow question (type of flowers to seed or type of margin management)**. Otherwise, there will rapidly be too many variables to obtain interesting, practical results. Therefore, it is important to assess the characteristics of the landscape of interest to decide which would be the key points to change. The choice of the question may also depend of the group of scientists willing to join the OG in the long term. If a firm is interested in products with less pesticides, it will also be a key actor in the process of choosing the question.

A practical question for an Operational Group can be the monitoring of a specific pest and evaluate risk with scouting techniques. Farmers and advisers need methods to decide if the biological control will keep the pest below an economic threshold or if the use of pesticides is required.

An OG could also focus on the economic analysis of the implementation of specific LFs recommendations. This could include losses and savings evaluation but also labour constraints as well as the facilitation to sharing the machinery.

More broadly at the farming system, OGs could try to optimise the development of LFs by looking at the synergies and trade-offs between the different ecosystem functions for agronomic purposes.

Including other stakeholders at the landscape level, OGs could also define how to best design LFs to meet crop management and environmental needs (erosion, biodiversity, aesthetics, …).



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Actual or potential interactions among farmers for managing their fields and designing the landscape must be looked at. Farmers can make collective decisions regarding the allocation of crops to fields to design a mosaic and associated LFs that maximise biological control. Some economic benefits may also be dependent of collective actions like the branding of environmentally-friendly products. The sharing and collective production of information regarding the effects of LFs is of utmost importance.

So, Operational Groups can have different orientations and ways to tackle different topics. The work must be organised in networks to allow a rapid flow of information. There are also some very practical points to consider to make results comparable, as the size of traps for insects, their number per field, etc.. A short, common list of variables to characterise the farming system would also be useful.

## What is being done already?

To inspire you, we have listed 14 research projects and 11 best practices related to landscape features design, management and delivery of services across Europe in **Annex 5** and **Annex 6**.



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# 7. Annexes





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# Annex 1: LF structure in relation to different functions

(*Marshal, E J P,* Guidelines for the sitting, establishment and management of arable field margins, beetle banks, Cereal conservation headlands and wildlife seed mixtures, Defra UK Project BD0412)

| **Objective** | **Landscape Features** | **Comments** |
|---|---|---|
| To conserve rare cornfield flowers | 1. Conservation headlands, preferably without fertiliser.<br>2. Uncropped wildlife strips | Check that species are present. If so, grass and flower margins are not suitable |
| To enhance the plant species diversity of the hedge bottom or field margin | 1. Grass and wild flower margins<br>2. Grass margins; over time, species diversity of the hedge bottom may increase | Rates of species enhancement affected by fertility and opportunity for colonisation |
| To provide over-wintering habitat for predatory beetles and spiders | 1. Grass margins<br>2. Beetle banks | Tussocky grass is important |
| To provide pollen and nectar sources for hoverflies, butterflies and pollinators | 1. Grass and wild flower margins<br>2. Conservation headlands, if suitable species are present<br>3. Sown wildlife mixtures (nectar sources) | |
| To provide seeds for birds | 1. Grass and wild flower margins<br>2. Conservation headlands<br>3. Uncropped wildlife strips<br>4. Sown wildlife mixtures (seed sources) | |
| To provide insects as chick food for partridges | 1. Conservation headlands | Sawfly and other larvae associated with broad-leaved weeds are essential |
| To provide cover for groundnesting birds, including grey partridge | 1. Grass margins<br>2. Beetle banks | Tussocky grass is essential, providing cover and camouflage from predators. Skylark need short vegetation |
| To provide small mammal feeding habitat | 1. Grass and wild flower margins<br>2. Beetle banks | Encouraging small mammals can enhance predator populations, including owls |
| To buffer the movement of fertiliser, soil and pesticides to surface water | 1. Grass margins | |
| To reduce the ingress of hedgerow weeds, such as brome and cleavers | 1. Grass margins, with or without flowers | |



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# Annex 2: Members of the EIP AGRI Focus Group

| Name of expert | Country | Profession | Organisation |
|---|---|---|---|
| Alomar Oscar | Spain | Scientist | Institute of Agro-food Research and Technology (IRTA) |
| Begg Graham | UK | Scientist | The James Hutton Institute |
| Büren Christoph | Germany | Farmer | European Landowners Organization (ELO) |
| Chenaux Barthélémy | France | Farm adviser;Scientist;Other | CIVAM de l'OASIS |
| **Elmquist Helena** | Sweden | Farm adviser;Expert from agriculture organization, industry or manufacturing | Odling I Balans (Farming in Balance) |
| Flamm Clemens Walter | Austria | Expert from agriculture organization, industry or manufacturing | Austrian Agency for Health and Food Safety AGES |
| Gosme Marie | France | Scientist | INRA |
| Guerin Olivier | France | Expert from agriculture organization, industry or manufacturing | Chambre d'agriculture de Charente-Maritime |
| Jeanneret Philippe | Switzerland | Scientist | Agroscope Reckenholz - Tänikon |
| Keena Catherine | Ireland | Other type of adviser | Teagasc |
| **Korevaar Hein** | Netherlands | Scientist | Plant Research International, Wageningen UR |
| O hUallachain Daire | Ireland | Scientist | Teagasc |
| **Oppermann Rainer** | Germany | Scientist | Institute for Agroecology and Biodiversity (IFAB) |
| **Palma Francisco** | Portugal | Farmer | Associaciao de Agricultores do Baixo Alentejo |
| Reubens Bert | Belgium | Scientist | Institute for Agricultural and Fisheries Research (ILVO) |
| Robinson Claire | UK | Expert from agriculture organization, industry or manufacturing | National Farmers Union (& Copa-Cogeca) |
| Schönhart Martin | Austria | Farmer;Scientist | BOKU University of Natural Resources and Life Sciences, Vienna |


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| | | | |
|---|---|---|---|
| Theocharopoulos Sideris | Greece | Scientist | Helenic agricultural organization Demeter |
| Wackers Felix | Germany | Expert from agriculture organization, industry or manufacturing;Scientist | Biobest |
| Winspear Richard | UK | Expert from NGO | Royal Society for the Protection of Birds (RSPB) |

## EIP-AGRI Service Point team

**Jacques Baudry** – Coordinating Expert
**Gaëtan Dubois** – DG AGRI
**Ann-Sophie Debergh** – Task manager EIP-AGRI Service Point
**Frank Stubbe** – Back-up EIP-AGRI Service Point

**You can contact Focus Group members through the online EIP-AGRI Network.**
**Only registered users can access this area. If you already have an account, you can log in here**
**If you want to become part of the EIP-AGRI Network, please register to the website through this link**



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# Annex 3: Activities of the EIP AGRI Focus Group

## First meeting

The call for experts for the focus group was launched during the summer of 2014. The coordinating expert prepared a first discussion paper for the first meeting. This meeting was held in **Munich, Germany in December 2014**. In one day the discussion paper and the next steps of the focus group process, including the choice of topics for mini-papers and the responsible authors, were discussed. Two break-out sessions permitted more in depth discussions:

Break-out 1:

- How can farmers create a win-win situation through LFs and BSs?
- How to build field evidence of the effect of LFs and BSs?
- Which factors have to be taken into account in an economic analysis at farm level?

Break-out 2:

- What are the different success and fail factors at field level, farm level, landscape level and institutional level for the implementation (design and management) of LFs and BSs in arable farms?

Chosen topics for mini-papers:

- Capitalize existing knowledge into general guidelines / tailormade measures / decision tools :
  - Pollination
  - Pest Control
  - Erosion
- Exchange of knowledge and experiences between farmers and other involved actors (researchers, advisers, policy officers, …) (f.e. through trials / experiments)
- Economic analysis and management of risks and opportunities
- Collaboration and common targets between different actors in the field (farmer groups and other involved actors like industry, NGO's, general public, …)

During the following three months, the mini-papers were written and the coordinating expert wrote, with the EIP-AGRI service team, a draft for the final report based on the output of the first meeting.

## Second meeting

The second meeting was held **in Rennes, France in March 2015**. During the first morning, a break-out session dealt with two topics:

- Operational Groups oriented to specific agronomic issues & specific ecosystem functions (pest control, pollination and erosion & microclimatic regulation)
- Operational Groups oriented to integrated approaches at farm / group of farms level

In the afternoon a field visit was organized to the Long Term Ecological Research site "Zone Atelier Armorique". It is dedicated to research on land use/ landscape dynamics as related to changes in farming systems and their effects on ecological processes (species distribution, biocontrol, pollination, water quality etc.). This has been an opportunity for the members of the focus group to have informal discussions face to face with tangible landscape features as various PhD students, post-docs and researchers explained their projects. At the end of the afternoon, a meeting was held with the president of the local administration, a federation of municipalities in charge of environmental and tourism issues as hedgerow plantation, management of nature reserves. The group could discuss practical matters of helping farmers to manage their environment.


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The second day a break-out session was dedicated to the research needs that should be directly connected to needs from practice. Different points of view (farmer, adviser, agri-business, nature organization and local tourist) were taken into account. This was a moment to understand a diversity of points of views and research needs. The meeting ended at noon.

During the second half of 2015, the mini-papers and the final report circulated to enhance collaborative work.



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# Annex 4: Structure and management of strips to control run-off

HACKETT, M. AND A. LAWRENCE (2014). *Multifunctional Role of Field Margins in Arable Farming*, Report for European Crop Protection Association by Cambridge Environmental Assessments – ADAS UK Ltd.

| **Specific benefit** | **Details** |
|---|---|
| Pesticides | Width of 10 m to 20 m for 70 to 80 % reduction efficiency depending on pesticide properties (water soluble pesticides require greater widths |
| Sediment | Width of 5 m (coarse particles) or 10 - 20 m (fine particles) required for 70 to 80% reduction efficiency9 |
| Phosphorus | Width of 10 m (particulate phosphorus) to 15 m (dissolved) required for 70 to 80 % reduction efficiency9 |
| Nitrogen | Width of 10 m required for 70 to 80 % reduction efficiency. Waterlogged areas can improve nitrogen cycle functioning |

## Ideal management

| | |
|---|---|
| Location | Lower continuous width is required and improved performance is achieved if field margin buffers are located throughout the landscape to prevent concentration and channelling of runoff flows |
| Vegetation | Grass vegetation most favourable in majority of cases with dense compact growth and good root growth favoured (pesticides, sediment, and phosphorus |
| Maintenance | Frequent mowing is beneficial for buffering of pesticides, sediment, and phosphorus |
| Restrict vehicles | Restriction of vehicle traffic required in all cases to reduce channeling of runoff and bypass of pollutants |

**[1]** This gives averages and do not consider field size, neither overall landscape structure. Field year = combination of the number of fields and number of years for fields monitored over several years.
**[2]** CIVAM: Centres d'Initiatives pour Valoriser l'Agriculture et le Milieu rural (Centers of Initiatives to Develop Agriculture and the Rural Areas) (http://www.civam.org/)
**[3]** Examples are: http://www.conservationevidence.com/; Centre de ressources Trame verte et Bleue (http://www.trameverteetbleue.fr/)
**[4]** In France there is such a course on biodiversity, agroecology, (https://www.france-universite-numerique-mooc.fr/courses/).



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# Annex 5: Inspiring research projects

| Quantification of Ecological Services for Sustainable Agriculture (QuESSA) | |
|---|---|
| Topic | Measurement of ecosystem services delivered by landscape features and buffer strips |
| Region / Country | CH, UK, NL, IT, HU, FR, IT, EE, D |
| Start / end | 03.2013 - 02.2017 |
| Funding | EU FP7 |
| Webpage | www.quessa.eu |

| LInking farmland Biodiversity to Ecosystem seRvices for effective ecological intensification (LIBERATION) | |
|---|---|
| Topic | Link farmland biodiversity patterns to landscape context and farm management |
| Region / Country | NL, UK, SE, DE, HU, IT, PL |
| Start / end | 02.2013 - 01.2017 |
| Funding | EU FP7 |
| Webpage | www.fp7liberation.eu/ |

| Optimising ECOsystem Services in Terms of Agronomy and Conservation (ECOSTAC) | |
|---|---|
| Topic | Perennial field margins for arable and horticultural crops; targeted flower mixes designed to deliver combined biocontrol and pollination benefits with bird conservation |
| Region / Country | UK |
| Start / end | 2009 – 2014 |
| Funding | DEFRA HortLINK |
| Webpage | www.ecostac.co.uk |



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| ▶ Long-term monitoring of effects of conversion to organic farming (MUBIL IV) | |
|---|---|
| Topic | In the years 2003-2012 the development of the breeding bird community of an arable farm after conversion to organic farming (Biobetrieb Rutzendorf) and accompanying agro-ecological measures was documented in a multi-annual study using the mapping method. Since the start of the project in 2003 the number of species has increased. The abundance of breeding birds also increased until 2008 but declined afterwards. The significance of different crops and agro-ecologically important landscape elements is documented and discussed. |
| Region / Country | Lower Austria/Austria |
| Start / end | 2011 - 2014 |
| Funding | Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management (BMLFUW) |
| Webpage | mubil.boku.ac.at |

| ▶ Linking resource availability to pollinator diversity and pollination services in agricultural landscapes mutualism | |
|---|---|
| Topic | Pollination |
| Region / Country | Netherlands |
| Start / end | 2013 – ongoing |
| Funding | NWO-Biodiversity Works Program |
| Web-page | www.wageningenur.nl/en/project/The-relations-between-floral-resources-pollinators-and-pollination.htm |

| ▶ Improving pest control and pollination services in cider apple orchards by means of multi-functional flowering strips | |
|---|---|
| Topic | Targeted flower mixes for use within cider orchards to deliver combined biocontrol and pollination benefits |
| Region / Country | UK |
| Start / end | 2010 – 2015 |
| Funding | BBSRC CASE |
| Webpage | www.research.lancs.ac.uk |


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| ▶ Services provided by ecosystems (ECOSERV) | |
|---|---|
| Topic | ECOSERV researchers will establish a scientific basis for assessing the services provided by agroecosystems, optimise them through the regional distribution of activities and propose public policy instruments. Examining all of these services, as well as synergies and incongruities, represents a significant paradigm shift in the relationship between agriculture and the environment: now, in addition to minimising the effects of agriculture, the goal is to manage natural resources in an integrated way which includes all stakeholders. |
| Region / Country | France |
| Start / end | 2014 - ongoing |
| Funding | INRA |

| ▶ Zone atelier Armorique | |
|---|---|
| Topic | Interdisciplinary research (ecology, geography, law, hydrology, climatology, history, biogeochemistry etc.) on landscape patterns as drivers of ecological processes in an agricultural landscape characterized by hedgerow networks |
| Region / Country | France |
| Start / end | 2002 - ongoing |
| Funding | CNRS & INRA |
| Webpage | osur.univ-rennes1.fr/za-armorique/<br><br>website of the French network of "Zones Atelier" **www.za-inee.org** |

| ▶ FRB - ECOPHYTO | |
|---|---|
| Topic | Biodiversity as a mean to control and reduce pesticide use |
| Region / Country | France |
| Start / end | 2013 - 2016 |
| Funding | Ministry of Agriculture (France) |
| Webpage | **www.fondationbiodiversite.fr/fr/recherche/appels-a-projets/en-cours/appel-ecophyto-frb-2013-lancement-projets-laureats.html** |



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| ▶ RMT biodiversité | |
|---|---|
| Topic | Fostering agroecology and biodiversity for agricultural production |
| Region / Country | France |
| Start / end | 2014 - ongoing |
| Funding | Ministry of Agriculture (France) |
| Webpage | agriculture.gouv.fr/RMT-Biodiversite-et-Agriculture |

| ▶ Agroforestry in Flanders: an economically profitable answer to the demand for agro ecological production methods | |
|---|---|
| Topic | The overall project objective is to create a breakthrough in a relatively short time of feasible, profitable and effective agroforestry systems in Flanders. This will be realized by conducting a participatory process with relevant stakeholders, fueled both by in-depth research and effective dissemination of knowledge and experience. A substantial part of the research activities focuses on increasing knowledge of ecological interactions, ecosystem services, technical impact and economic opportunities for alley cropping systems in arable farming. |
| Region / Country | Flanders - Belgium |
| Start / end | September 2014 – August 2019 |
| Funding | Agency for Innovation by Science and Technology (IWT) |
| Webpage | www.agroforestryvlaanderen.be (ENG) |

| ▶ Flowering habitats to enhance biodiversity and ecosystem services in agricultural landscapes | |
|---|---|
| Topic | Investigating and promoting beneficials arthropods for pest control and pollination with wildflower strips in arable land |
| Region / Country | CH |
| Start / end | 2010 – ongoing |
| Funding | Agroscope, Hauser Foundation, Sur-La-Croix Foundation |
| Webpage | www.agroscope.ch/agrarlandschaft-biodiversitaet/03742/06745/ |



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| ▶ Evaluation of the Swiss agri-environment scheme | |
|---|---|
| Topic | The impact of the Swiss agri-environment scheme on biodiversity has been evaluated for the period 1996 - 2005. In particular, the role of landscape features and buffer strips had been investigated regarding the promotion of biodiversity on a set of selected indicators |
| Region / Country | Switzerland |
| Start / end | 1996 - 2007, and ongoing |
| Funding | Swiss Federal Office for Agriculture, Swiss Federal Office for the Environment |
| Webpage | www.agroscope.admin.ch |

| ▶ Pesticide Use-and-risk Reduction in European farming systems with Integrated Pest Management (PURE) | |
|---|---|
| Topic | Providing integrated pest management (IPM) solutions and a practical toolbox for their implementation in key European farming systems including strategies for ecological pest regulation. |
| Region / Country | France, UK, Denmark, Germany, Netherlands, Italy, Slovenia, Poland, Hungary, Belgium |
| Start / end | 2011-2015 |
| Funding | EU FP7 |
| Web-page | www.pure-ipm.eu/project |

| ▶ MUBIL III – Evaluation, Subproject: Influence of hedgerows on microclimate on field crops | |
|---|---|
| Topic | The optimisation of local-climatic and microclimatic relations by creation of landscape elements (e.g., windbreak arrangements, hedge structures) is an essential aspect in organic farming. Thus the changed microclimate in and near hedges has big effect on the attraction of the living space hedge and fulfils an important ecological niche function (e.g., for useful animals). Furthermore it has a positive effect on plant stocks and can change the local conditions (example the water balance due to changing rates of evapotranspiration, the wind field and dew, etc.) for crop production. |
| Region / Country | Lower Austria / Austria |
| Start / end | 2009 - 2011 |
| Funding | Federal Ministry of Agriculture, Forestry, Environment and Water Management , Stubenring 1, A-1012 Wien, Austria |
| Webpage | forschung.boku.ac.at |



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# Annex 6: Inspiring best practices

| ▶ "Mångfald på slätten" (Biodiversity in areas which are characterized by low biodiversity) | |
|---|---|
| Location | Sweden |
| Start – end | 2012 - 2014 |
| Objectives | Increase the biodiversity in areas with mostly grain production, using good examples on farms. |
| Participants | 8 demonstration farms<br>Jordbruksverket och Hushållningssällskapet (Department of Agriculture and a Swedish Advisory company) |
| Results | Several seminars and demonstrations on farms on how to increase the biodiversity using beetle banks, flowering areas etc..<br>Knowledge gathering, several information materials and movies on youtube showing the examples. |
| More info | **www.jordbruksverket.se/amnesomraden/miljoklimat/ettriktodlingslandskap/mangfaldpaslatten.4.e01569712f24e2ca09800012316.html** |

| ▶ Groupement d'Intérêt Economique et Environnemental (GIEE) "Field margins in my farm" | |
|---|---|
| Location | France, Brittany (Saint Aubin d 'Aubigné) |
| Start – end | 2015 - ongoing |
| Objectives | Collective experimentation on 1) field margin management, search for innovative techniques; 2) share ideas and practices in agroecology, develop expertise in field observation of biodiversity related to crop management, and 3) Improve the dialogue with administrations at local and regional scales |
| Participants | Farmers & Chamber of Agriculture |
| Results | ongoing |
| More info | Contact person: Isabelle Senegas at the chamber of Agriculture (isabelle.senegas@ille-et-vilaine.chambagri.fr) |


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| ▶ Association Vallée du Léguer | |
|---|---|
| Location | France, Brittany, Lannion a 50,000 ha watershed |
| Start – end | 1990 - ongoing |
| Objectives | First river restoration, "bocage" (hedgerow network) restoration and management for clean water and biodiversity provision |
| Participants | Municipalities, farmers, NGOs |
| Results | Hedgerow plantation and management, planning of firewood harvesting, management of road verges. Fact sheets, collective action |
| More info | www.riviere-du-leguer.com/leguer/qualite-eau.htm |

| ▶ An app for smartphones with pictures of insects eating aphids and other insect pests. | |
|---|---|
| Location | Sweden |
| Start – end | 2013 - ongoing |
| Objectives | Knowledge dissemination about "beneficial insects" |
| Participants | Department of Agriculture. |
| More info | www.jordbruksverket.se/5.2ae27f0513e7888ce2280001654.html |

| ▶ Trees on contour swales: an efficient and economically viable method to effectively combat erosion? | |
|---|---|
| Location | Heuvelland / Flanders - Belgium |
| Start – end | 2014 - ongoing |
| Objectives | Implementation of swales (ditch-berm structures) at landscape level to combat erosion and in the same time creating corridors, increasing biodiversity and realizing an agroforestry field site. |
| Participants | Initiative of an individual farmer together with the Agency for Nature and Forest (ANB) |
| More info | See EURAF newsletter and a few pictures |



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| ▶ **An evolving alley coppice/alley cropping system combined with grass buffer strips** | |
|---|---|
| Location | Vollezele / Flanders - Belgium |
| Start – end | 2011 - ongoing |
| Objectives | Implementation of hedgerows (mixture of tree and shrub species) on an arable crop field, over time evolving to a productive alley cropping system with walnut, cherry and lime trees. |
| Participants | Initiative of an individual farmer |
| Results | The farmer established a windbreak in an alley cropping system by combining a wide variety of densely planted tree & shrub species and tree species with the potential to produce valuable timber. The windbreak acts as a buffer against runoff and erosion and as a shelter for a varied fauna. In addition it creates an optimal situation where the targeted species for valuable timber production are stimulated to grow tall and straight. |
| More info | See **EURAF newsletter** and a **few pictures** here. |

| ▶ **Ecological compensation** | |
|---|---|
| Location | CH |
| Start – end | ongoing |
| Objectives | Protecting and promoting biodiversity in agriculture |
| Participants | Researchers, stakeholders including farmers |
| Results | Since 1993, the Swiss extension service (AGRIDEA) together with research institutes (e.g. Agroscope) and farmers has continuously been developing recommendations for managing landscape features and buffer strips (Ecological Compensation Areas, ECA) |
| More info | **www.agroscope.ch/oekologischer-ausgleich/**<br><br>**www.agridea.ch/fr/publications/publications/environnement-paysage/aspects-legaux-et-administratifs/surfaces-de-promotion-de-la-biodiversite-dans-lexploitation-agricole-annexe/** |

| ▶ **ÖPUL-Maßnahme Ökopunkte Niederösterreich (Austria's Agri-environmental Program 2007-2013: ecological scores in Lower Austria)** | |
|---|---|
| Location | Lower Austria - Austria |
| Start – end | 2007 - 2013 |
| Objectives | Farmers who farm environment-sparingly were supported in Lower Austria if they act sustainably, preserve and develope the cultural landscape (landscape features) |



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| | |
|---|---|
| Participants | Farmers in Lower Austria |
| Results | During this period the number of participating farmers increased significantly. Those farmers had a more positive attitude concerning landscape features compared with non-participating farmers. An evaluation of the program showed that the financial support was adequate to the cost of preserving the landscape features. |
| More info | **www.gruenerbericht.at/cm3/download/summary/128-studien/592-54-evaluierung-oekopunkte-niederoesterreich.html** |

### Distelverein

| | |
|---|---|
| Location | Lower Austria - Austria |
| Start – end | 1987 – on-going |
| Objectives | They started in 1987 to define ecological focus areas in Lower Austria but mainly in the "Marchfeld". |
| Participants | Farmers, hunters and environmentalists |
| Results | Flowering buffer stripes were installed between fields, forest and street boarders were structured as hideaway for animals and plants. |
| More info | No active website since 2007 |

### Hecken für Niedersachsen (Hedges for Lower Saxony)

| | |
|---|---|
| Location | Germany / Lower Saxony |
| Start – end | 2004 / other similar or related projects are ongoing |
| Objectives | Creating a network of hedges on farms in the whole country<br>Creating a positive image for hedge planting and doing PR work |
| Participants | Kompetenzzentrum Ökolandbau Visselhövede / many farmers |
| Results | Over 50 farms participated<br>Planting of 4,700 m hedges, 1,070 orchard trees, 12,000 hedge plants<br>18 school classes, 450 scholars and > 700 volunteers participated |
| More info | **www.oeko-komp.de/index.php?id=3926&languageid=1** |



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| ▶ The Campaign for the Farmed Environment | |
|---|---|
| Location | UK |
| Start – end | Ongoing |
| Objectives | Guide farmers on the voluntary sustainable management of LFs, e.g. by advising on pollinator support and hedge management. |
| Participants | It involves representatives from industry, environmental NGOs, farm advisers and the government. |
| Results | Guidance available on pollinators and recently produced guidance on good hedge management. It provides online training modules for farm advisers. These modules are linked to professional CPD. |
| More info | **www.cfeonline.org.uk/home/**<br>**www.cfeonline.org.uk/campaign-themes/pollinators/** |

**The European Innovation Partnership** 'Agricultural Productivity and Sustainability' (EIP-AGRI) is one of five EIPs launched by the European Commission in a bid to promote rapid modernisation by stepping up innovation efforts.

The **EIP-AGRI** aims to catalyse the innovation process in the **agricultural and forestry sectors** by bringing **research and practice closer together** – in research and innovation projects as well as *through* the EIP-AGRI network.

**EIPs aim** to streamline, simplify and better coordinate existing instruments and initiatives and complement them with actions where necessary. Two specific funding sources are particularly important for the EIP-AGRI:

- ✓ the EU Research and Innovation framework, Horizon 2020,
- ✓ the EU Rural Development Policy.

**An EIP AGRI Focus Group*** is one of several different building blocks of the EIP-AGRI network, which is funded under the EU Rural Development policy. Working on a narrowly defined issue, Focus Groups temporarily bring together around 20 experts (such as farmers, advisers, researchers, up- and downstream businesses and NGOs) to map and develop solutions within their field.

**The concrete objectives of a Focus Group** are:

- ✓ to take stock of the state of art of practice and research in its field, listing problems and opportunities;
- ✓ to identify needs from practice and propose directions for further research;
- ✓ to propose priorities for innovative actions by suggesting potential projects for Operational Groups working under Rural Development or other project formats to test solutions and opportunities, including ways to disseminate the practical knowledge gathered.

**Results** are normally published in a report within 12-18 months of the launch of a given Focus Group.

**Experts** are selected based on an open call for interest. Each expert is appointed based on his or her personal knowledge and experience in the particular field and therefore does not represent an organisation or a Member State.

More details on EIP-AGRI Focus Group aims and process are given in its charter on:
http://ec.europa.eu/agriculture/eip/focus-groups/charter_en.pdf
More information: EIP-AGRI brochure on Focus Groups

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www.eip-agri.eu | +32 2 543 73 48 | servicepoint@eip-agri.eu | Avenue de la Toison d'Or 72 | 1060 Brussels | Belgium