

eip-agri
AGRICULTURE & INNOVATION



EIP-AGRI Focus Group

Optimising profitability of crop production through Ecological Focus Areas

DISCUSSION PAPER
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1 Scope of the focus group

In the 1960's, 1970's the dominant paradigm in crop science was that most of the factors of production could be controlled at field/ crop scale by using appropriate techniques (drainage, irrigation, fertilization, pesticides etc.). The negative side effects on the environment (water and soil pollution, loss of biodiversity...) and on human health, mostly due to pesticides are now widely acknowledged and alternative techniques based upon ecological principles are sought.

Among those techniques, the development of "ecological focus areas" (EFAs) is widely promoted. EFAs harbor a large variety of species (flora, fauna, microbial communities) which may provide a protection of crops against pest, enhance pollination, combat soil erosion, nutrient retention etc. The potential ecological benefits of the EFAs are now well demonstrated, though the assessment of their effect on cropping systems at field and farm scales deserves more work. Therefore, the focus group should work on: **How can EFAs, more specifically landscape features and buffer strips and their management, contribute to the profitability of crop production?**

The focus group is expected to carry out the following main tasks:

- Identify **types of management of EFAs** on arable land assessing the **costs and benefits** for the cropping system;
- Taking stock of **best practices and research** that result in EFAs management practices which enhance crop productivity and profitability through, for example, improved yields, pest and disease control, soil fertility, water retention, nutrients cycling, pollination...;
- Characterize the **success and fail factors** for the implementation of these identified practices/methods by farmers and land owners to enhance crop production profitability through EFAs management and summarise how to address these factors;
- Explore the role of **innovation and knowledge transfer** in supporting the enhancement of the productivity and profitability of the crop production through the establishment of EFAs;
- Propose directions for **future research and setting-up of Operational Groups**

The "Ecological Focus Areas" under consideration are landscape features and buffer strips, so mainly hedgerows, buffer strips and flower strips. The term "crop" refers to annual crops (wheat, maize, oil seed rape, sunflower etc...), excluding grassland, orchard, and vineyard. If vegetables are included in the crop rotation, they may be "crop".

The objective is to collect the elements that demonstrate the advantages of EFAs for primary production. Optimization must be considered at the cropping/ farming system level. The objective is to demonstrate to farmers when the implementation of these EFAs leads to a **win-win situation**: benefit for the environment and the society and benefit for primary production. Among the solutions, within this focus group, it is excluded to take into account EFAs that would provide some kind of income with little benefit for the environment, as short-term rotation willow.

The ecosystem services provided by EFAs to society as cleaning running water, increasing biodiversity, landscape amenities... and the higher prices some companies pay for crops grown in a field with flower strips are also out of the scope of this focus group. Figure 1 presents this scope schematically.

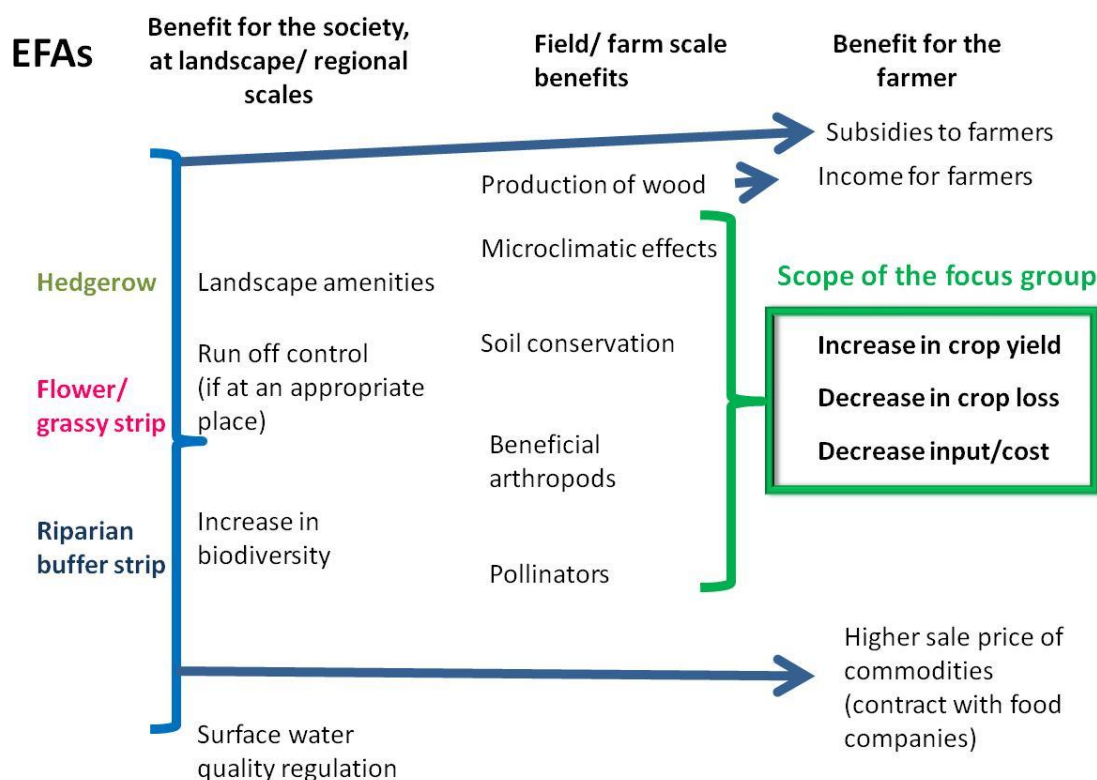


Figure 1: EFAs functions and scope of the focus group.

For the practices, we make a distinction between "design" and "management". Design referring to the implementation, localization, structure of EFAs and management to the early practices to maintain EFAs in good conditions. The focus group concentrates on crops and adjacent EFAs, managed by the same farmer or groups of farmers.

Challenges for the focus group will be how to assess individual EFAs when most studies have an approach at landscape level? And how to calculate the effects of EFAs vs. the effects of the global landscape and field scale farming practices?

The purpose of this document is to elaborate from the objectives of the focus group a general structure to collect information and to introduce some preliminary ideas to feed the discussion during the first focus group meeting in December 2014.

2 Evidences of the ecosystem functions of EFAs leading to enhanced crop production and profitability

The promotion of EFAs requires a synthesis of the different types of information available from different types of knowledge. Empirical evidences from experiences of farmers or groups of farmers are very valuable, but to be transferable to other situations, they must be evaluated in a broader scientific framework. This chapter explores how science provides evidence on the impact of EFAs on primary production.

Several functions and services are expected from EFAs, there may be synergies or antagonisms in the requirement of EFAs structure and management. For instance hedgerows and strips of vegetation with shrubs and/or trees harbor processes that may be different than those of strips made of herbaceous vegetation. Herbaceous strips may be flower strips, while the shade of hedgerows may impede the development of flowering plants.

Among the functions that will increase production or diminish the cost of production, the main ones are erosion and flood prevention, pest control, pollination, nutrient cycles and water retention and microclimatic regulation. For each of the functions we look at how EFA composition, structure and management influences the impact on crop production and profitability of cropping systems. When conserving / renovating an existing EFA or implementing a new one, we want to know how to proceed in the design (localization, species composition...) and how to develop a plan for future management (mowing...).

Agroecosystems are systems. EFAs are but one element in these systems. Their effects are in most publications demonstrated with a positive cumulative efficiency at the landscape scales and in combination with practices at field scale (minimum tillage, choice of varieties etc.). It is out of the scope of this paper to review these aspects, but one has to keep them in mind when designing the management of EFAs (see annex 1: the scale dependence of ecological processes).

2.1 Erosion and flood prevention

EFAs function is to control erosion and avoid the loss of top soil where organic matter and nutrients such as nitrogen, phosphorus are stored. Nutrient loss can be high. A ton of top soil contains 1 to 6 kg of nitrogen, 1 to 3 of phosphorus and up to 30 kg of potassium. Erosion may lead to the loss of several tons of top soil per ha. Organic matter is also lost, that is not only nutrients, but also an important factor of soil good physical conditions and a capacity to retain water. Topsoil erosion is an important cause of loss of nutrient, therefore a decline in production¹. Stallings found a negative linear relationship between topsoil loss and crop production.

Grassy strips to control erosion must be located on the slope. Its function is not only to stop soil particles, but also to decrease water runoff speed to limit the loss of soil particles. The best landscape feature for this objective is an earthen bank that stops eroded soil particles and water which can thus infiltrate into the ground. A layer of herbaceous plants helps to diminish erosion and to maintain the earthen bank. They should be combined with adapted tillage practices by the farmer.

This reduction of runoff also contributes to a reduction of flooding of downstream land², up to the point where the soil is saturated with water. Beyond this point no feature has any effect on flooding.

In annex 2 you can find the indications that Hackett and Lawrence³ give on the structure and management of strips to control runoff.

¹ Stallings, J. (1964). "Phosphorus and water pollution." *Journal of Soil and Water Conservation* 22: 228-231.

² MEROT, P. (1999). "The influence of hedgerow systems on the hydrology of agricultural catchments in a temperate climate." *Agronomie* 19(8): 655-669.

³ 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.

2.2 Pest control

Seeking means to decrease the use of pesticides is a major stake, and, nowadays, one of the first reasons to implement EFAs. The expected benefit for the farmer is a lower cost of inputs.

For pest control, the objective is to define a threshold of pest density above which there is an economic loss. Therefore, if EFAs permit to maintain pest population below the threshold it can be considered as efficient. A problem with this type of assessment is that pest populations usually fluctuate from year to year and it is possible that the populations stay below the threshold even in fields with no EFAs.

We also have to consider that beneficial arthropods are a "public good". As such, they may benefit to several farmers above a certain area of EFAs, the EFAs may be inefficient if isolated. Situations of large farms (several 100 ha) where a single farmer manages a landscape and situation of small farms where coordination among several farmers is required must be considered.

There is much evidence that EFAs are habitats for beneficial arthropods. Though in some cases, generalist predators as *Pterostichus melanarius* may be less abundant close to EFAs than in the center of fields. As many species reproduce in the fields and hibernate in field margins⁴, it is difficult to synthesize the role of the different elements. Certainly, species life cycles must be considered more closely to understand their use of EFAs. Furthermore, the fluctuations of populations from year to year receive little consideration; they may depend on the dynamics of the crop mosaic, on the climate. Not all the potential predators and parasitoids fluctuate at the same time. Therefore, the beneficial arthropods with the greatest impact are different from year to year. What do we know of the habitat requirement of the different groups? There is a controversy about the respective role of species richness in beneficials versus the abundance of targeted species. This question is related to intraguild predation, predators feeding on other predators, not on pests.

In 2002 Collins et al⁵ provided evidence that "beetle banks" are effective as a source of predators of aphids. They set up an experiment excluding ground moving predators from small areas. These areas had significantly less predators (between 25 and 60% depending on groups) and 34% more aphids at the peak period than non exclusion areas. Since, negative correlations between the abundances of predators and their preys have been found. The amount of grassy/ flower strips in the landscape within a few hundred meters enhance predators population. However, it is very difficult to go beyond these correlations as the number of predators decreases when preys diminish.

The relationships between pest threshold (beyond which pests become a problem) and predators or parasitoids populations are not clear. A recent evidence based review⁶ found that 65 individual studies reported the effects of flower strips on invertebrates. Of these, fifty reported positive effects.

HGCA (Home Grown Cereals Authority)⁷ made a guide to manage pests in cereals and oilseed rape.

The guide gives pros and cons about the different EFAs. For instance, field margins must not contain *umbelliferae* that attract carrot fly. For beetle banks, they warn about the risk of increase of cereal ground beetle⁸ populations.

⁴ MAREC, R., I. BADENHAUSSER, V. BRETAGNOLLE, L. BORGER, M. RONCORONI, N. GUILLON AND B. GAUFFRE (2014). "Crop succession and habitat preferences drive the distribution and abundance of carabid beetles in an agricultural landscape " *Agriculture, Ecosystems & Environment* 199: 282-289.

⁵ COLLINS, K., N. BOATMAN, A. WILCOX, J. HOLLAND AND K. CHANEY (2002). "Influence of beetle banks on cereal aphid predation in winter wheat." *Agriculture, Ecosystems & Environment* 93(1): 337-350.

⁶ DICKS, L. V., J. E. ASHPOLE, J. DANHARDT, K. JAMES, A. JÖNSSON, N. RANDALL, D. A. SHOWLER, R. K. SMITH, S. TURPIE, D. WILLIAMS AND W. J. SUTHERLAND (2014). "Plant nectar flower mixture/wildflower strips ". <http://www.conservationevidence.com/actions/442>

⁷ <http://www.hgca.com/media/335757/g14-pest-management-in-cereals-and-oilseed-rape.pdf>

⁸ *Zabrus tenebrioides* Goeze

2.3 Pollination

Few annual crops require pollination by insects, but those are cropped on large areas (oil seed rape, sunflower, etc.). The recognition of the role of wild bees is widespread. EFAs can complement and even enhance the activity of honey/ domestic bees.

The most important problem bee populations face is the temporal discontinuity in floral resources. Mass flowering crops require massive populations of pollinators, and a sufficient quantity of flowers, and reproduction sites. Investing in other landscape elements is the only way to maintain these populations in landscapes. This means that flower strips whose purpose is to provide pollinators resources should have a diversity of species to produce flowers over a long period. It is not clear if implementation of EFAs by individual farmers can achieve this goal or if they should be design at landscape scale.

2.4 Nutrient cycles and water retention

Except in the case of agroforestry where trees and crops are mixed, EFAs have little impact on the nutrient content of cultivated soils apart from their effects on erosion. EFAs perpendicular to the slope improve uptake and transformation of nutrients and pollutants like pesticides.

Parn et al⁹ made a review of the recent literature on nutrient transport in agricultural landscape, mostly focusing on riparian zones. The survey shows that " Riparian meadow grasses and herbs normally accumulate 20–70 kg N/ ha/year while riparian forests take up as much as 30–170 kg N/ ha/year". If this biomass is not harvested, most of the nutrients go to streams as leaves fall down. Nevertheless, this short-term retention is beneficial for streams. For Stutter et al¹⁰, EFAs retain nutrients, but leaching may also be more important than from fields because of microbial activities and more permeable soils.

When the nutrients are uptaken in EFAs within fields, fallen leaves enrich the soil. Another emerging technique is the ramial-chipped wood¹¹. Small branches (less than 7 cm in diameter) are chopped and incorporated into the soil, increasing the soil content in humus and nutrients. This could be a way to recycle the nutrients within fields.

Ryan et al¹² propose some principles to design agricultural landscape to store and recycle water, using windbreaks of native trees. These windbreaks store organic matter, hence humidity, also increase infiltration of water, and decrease evaporation. This results in a very positive water balance..

2.5 Microclimatic regulation

The windbreak function is one of the most analyzed of the functions of hedgerows with physical models based on a qualitative characterization. The windbreak effect is the most straightforward process to relate to hedgerow or shelterbelt structure. The positive effect of windbreaks against erosion has been recognized since the XIXth century. These observations fostered a public programs of hedgerow plantation as in Jutland, Denmark. Since the mid XXth century numerous studies assessed the effect of windbreak on yields. The effect of competition for water and nutrients with crops at the edge of fields is largely compensated by the increase further in the field. The results from different climatic zones are consistent. The relative responsiveness of various crops to shelter is shown in table 1.

⁹ PÄRN, J., G. PINAY AND Ü. MANDER (2012). "Indicators of nutrients transport from agricultural catchments under temperate climate: A review." *Ecological Indicators* 22: 4-15.

¹⁰ STUTTER, M. I. AND S. RICHARDS (2012). "Relationships between soil physicochemical, microbiological properties, and nutrient release in buffer soils compared to field soils." *Journal of environmental quality* 41(2): 400-409.

¹¹ CARON, C., G. LEMIEUX AND L. LACHANCE (1998). *Regeneration of soils with ramial chipped wood* Laval, Canada, Laval University, Faculty of Forestry and Geomatics: 9.

¹² RYAN, J. G., C. A. MCALPINE AND J. A. LUDWIG (2010). "Integrated vegetation designs for enhancing water retention and recycling in agroecosystems." *Landscape Ecology* 25(8): 1277-1288.

Table 1. Relative responsiveness of various crops to shelter. (Source: Kort¹³)

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

For Nuberg¹⁴ "The fact that windbreaks can have a significant, positive effect on crop production is supported by eight decades of research from many countries around the world". For him, the main mechanisms involved are "the protection of crops from physical damage; soil conservation; the direct augmentation of soil moisture; and the alteration of the crop energy balance and plant water relations".

Torita and Satou¹⁵ show that the product of the width and the total area density (the projected area of leaf, branch, and stem per unit ground area divided by the crown length) is a good predictor of the windbreak effect. Most of the time, hedgerow structure is not described from measurement because it is too time consuming; it is estimated in a semi-quantitative manner to map hedgerows over landscapes (e.g. DEFRA, 2007).

In regions where snow is a major source of water for crops, windbreaks are useful to prevent the snow from moving out of fields¹⁶, thence to increase soil moisture.

3 EFAs and crop production profitability

Many farmers have already put in place or made an explicit use of existing landscape elements as EFAs. To foster their adoption over Europe, it is necessary to consider the diversity of the geomorphology, climate, and farming systems. EFAs can be based upon general principles and tailored to specific conditions (environmental, social, technical). How important are the heterogeneities in terms of difficulty for farmers to adopt EFAs? How can we innovate in this aspect?

3.1 Examples of farmer's initiatives

Little technical advice can be found on the implementation or management of EFAs. The main information is on the improvement of habitats for beneficial arthropods, in which case a list of plants used by them is given. In 2009 DEFRA¹⁷ (UK) launched a program to increase the farming practices to improve the environment and monitor the progress¹⁸. Farmers adopted environmentally friendly practices, but decrease their area of cropped land and if progress is noted in their management, it is not always optimal. Counties were divided into two groups: target and non-target for the uptake of new practices. In the first group more farmers changed their practices, which demonstrates that the campaign has been fruitful.

¹³ KORT, J. (1988). Benefits of windbreaks to field and forage crops. *Agriculture, Ecosystems & Environment* 22: 165-190.

¹⁴ NUBERG, I. K. (1998). "Effect of shelter on temperate crops: a review to define research for Australian conditions." *Agroforestry Systems* 41(1): 3-34

¹⁵ TORITA, H. AND H. SATOU (2007). "Relationship between shelterbelt structure and mean wind reduction." *Agricultural and Forest Meteorology* 145(3): 186-194.

¹⁶ KORT, J., G. BANK, J. POMEROY AND X. FANG (2012). "Effects of shelterbelts on snow distribution and sublimation." *Agroforestry Systems* 86(3): 335-344.

¹⁷ DEFRA: Department for Environment Food & Rural Affairs (United Kingdom)

¹⁸ https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/183824/defra-stats-foodfarm-environ-obs-research-setaside-farmenviroment-cfevidencesummfeb2013-130214.pdf

- Erosion and flood prevention



Grassy strip against erosion & flooding (Pays de Caux, Normandy, France)

A short lasting EFA

in the Pays de Caux, in northern Normandy. Farmers received a large amount of money to implement grassy strips in the 1990 to prevent erosion. There had been two years of heavy rain and eroded soil went onto roads and in villages. Ever since, no big rain event happened and the price of wheat is decreasing, so, little by little, farmers plough the grassy strips, as they see no benefit in keeping them.

- Pest control

From 2011 to 2013, the research project AGRICOBIO was conducted. On a farm area of 50 ha of crops between two core natural areas: forest and marsh of Guines, Marc Lefebvre, a farmer, has planted 2 km of hedgerows and 2.5 ha of grassy strips over 4 km, to promote biodiversity and especially the beneficial arthropods. The three years of study have confirmed that these ecological focus areas are refuges in cultivated areas. The beneficials also move into cultivated plots.

- Microclimatic regulation



In Picardie, the most fertile area of France with the largest farms. A farmer planted hedgerows in the 1990 with subsidies (otherwise he would not have done it). Then he measured the yields and saw no clear effect. He has more beneficial insects. He says "at least we do not lose money". His main positive aspect was that this landscape design took him out of the production routine.

3.2 Geomorphologic and climatic contexts, landscape, and watershed

This diversity is important from a functional point of view. In some situations, EFAs may be totally nonfunctional, the focus group has to frame its advices with this diversity in mind.

Hydrology is a major factor for nutrients and pollutants fluxes in landscapes. These fluxes are controlled by the geomorphology: on ancient bedrock (granite, shale) the soils are shallow and subsurface water flow is frequent. By contrast, on sedimentary bedrock, water flows vertically to the water table. In the first case, EFAs may decrease the flow of pollutants with plants (trees) uptaking them, in the latter case, EFAs are of little use.

The functions may be different according to bioclimatic zones. Rainfall patterns over season vary; for the same total annual amount of rain, the impact on the soil is different if the rainfall is more or less equally distributed or concentrated over some short periods. In the latter case, EFAs, which can slow down water flow on the ground, at the beginning of the rain event, are rapidly saturated.

The landscape context (non-farmland etc.) also has an influence on EFA efficiency. Farmland occupies 50% of the land, so, other forms of land use interact with farming. It may be as a source of biodiversity (e.g. forest edges are a refuge for beneficial insects, forests are a source of wild animals damaging crops) or running water (e.g. built up areas). Farmers consider this environment in their farm design.

3.3 Farming systems

At farm scale, we must consider the type of crop, the field pattern, the crop management practices, ... The field pattern (fragmented or clustered fields) drives the distribution of crops over the landscape, thence the distribution of EFAs. At the scale of several nearby farms, a collective design of EFAs will be easier and more efficient to manage landscape scale processes (species dispersal, waterflows etc.).

It is possible to obtain the benefit EFAs provide (limiting erosion, enhancing beneficial arthropods, etc.) by selected crop management strategies (no tillage, keeping weeds etc.).

Swift et al¹⁹ state "The regulation of erosion and water flows operates at a higher level in the hierarchy of controls than do aspects of nutrient cycling, soil structure and gas emissions or pest controls. The next part of this volume takes up these higher-level aspects of landscape management under the title of 'watershed services'. The lower level services such as nutrient cycles and biological control activities may then be built in through focus on aspects such as the degree of connection between the patches and the location, direction and intensity of the flows between them. It may be useful to classify land-use types into 'functional groups' in a manner analogous with that for species in order to develop more meaningful relationships between diversity and function at the landscape scale."

3.4 Economic analysis of EFAs

This key point is barely studied, as most studies focus on the public benefit (monetary or environmental). It is assumed that the cost for farmers is compensated by subsidies. The modeling work of Schönhart²⁰ articulates cropping system functioning, environmental benefits and premium from Agri-Environmental programs. The level of premium has an effect on the adoption by farmers who participate more with higher premiums, but high premium do not provide more environmental benefits. The efficiency is computed as the environmental benefit per unit of premium paid.

¹⁹ SWIFT, M. J., A. M. N. IZAC AND M. VAN NOORDWIJK (2004). "Biodiversity and ecosystem services in agricultural landscapes--are we asking the right questions?" *Agriculture, Ecosystems & Environment* 104(1): 113-134.

²⁰ Schönhart, M., T. Schauppenlehner, E. Schmid & A. Muhar (2011). "Integration of bio-physical and economic models to analyze management intensity and landscape structure effects at farm and landscape level." *Agricultural Systems* 104(2): 122-134.

As a group, we need to look for case studies where farmers have assessed the cost and benefits, related to crop production (all other source of income are out of scope):

- The potential costs: land out of production, cost of implementation and management, increased risk of pest problems
- The potential benefits: a higher yield, a lower cost (less pesticide, fertilizer). But, reviews on the benefit of EFAs do not find published data on the effects of crop production at fields scale, though some increase at 10 to 30 m from the strip may be found.

Another aspect of cost is the assessment of the "best design" of EFAs. This requires external consulting for each farm, in principle. Therefore, the rule, in national policies is most often to promote a single type of buffer width, for instance.

Examples of direct monetary costs and benefits:

*Campi et al²¹ found, in a Mediterranean context that shelterbelts, that "*the maximum yield (0.40 kg/m²) was measured between 2.7H (windbreak height) and 4.7H. The area directly sheltered by the windbreak (<2.7H) was characterised by a production 12% lower than the maximum, while at distances greater than 18H, production was reduced by 25%.*" This is consistent with all the studies of this type done since 1950.

* Cordeau et al²² surveyed farmers in two French regions with large (160 ha) arable farms. A third of the farmers perceive no important loss of revenue associated with grassy strips. In fact, there is a cost in sowing, managing and decreasing the productive area. Their main finding is that 3% of sown grass strip in a farm decreases the income by 7%. The authors state that this loss is weak compared to losses due to insect attacks. However, there are other causes of loss as the increase risk of weed invasion.

* RSPB²³ evaluates the cost of implementing a flower strip (£76 per ha) and the loss of wheat production, when flower strip are subsidized (£ 400 per ha) and show a net benefit. In their calculation, they assume a lower level of production in field margins than in the center of fields. How much does that cost? The cost of seeds (data from a seed merchant²⁴) can be found in annex 3.

4 Management of EFAs: success and fail factors

A large part of EFAs are already existing (e.g. hedgerows, ditches, etc.) even if their functions are not yet fully incorporated in the cropping systems. Their conservation is at stake. Public policies generally provide tools to "protect" landscape elements for environmental or cultural reasons. Implementing new EFAs or conserving existing ones present legal, technical, economical, and social aspects.

4.1 Legal aspects

National regulations tend to make mandatory a single type of buffer strip, although variations are possible in some cases. This may impede the best adaptation to local conditions.

²¹ Campi, P., A. D. Palumbo & M. Mastroilli (2009). "Effects of tree windbreak on microclimate and wheat productivity in a Mediterranean environment." *European Journal of Agronomy* 30(3): 220-227.

²² Cordeau, S., X. Reboud & B. Chauvel (2011). "Farmers' fears and agro-economic evaluation of sown grass strips in France." *Agronomy for Sustainable Development* 31(3): 463-473

²³ <http://www.rspb.org.uk/forprofessionals/farming/advice/economics/margins.aspx>

²⁴ <http://www.bostonseeds.com/products/1/Grass-Seeds/8/Field-Margins/>

Property boundaries

Some legal aspects may be really a problem, 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 of the loss of arable land.

In the UK, hedges at the boundaries between properties are regulated by different rules²⁵. The Ordinance Survey is often a source of information on who is responsible for what.

Maintenance issues

Still in the UK, "*It is an offence under Section 1 of the Wildlife and Countryside Act of 1981 to intentionally take, damage or destroy the nest of any wild bird while it is in use or being built*", so the RSPB (Royal Society for the Protection of Birds) recommends not to trim hedges between march and august²⁶. In practice, this means no trimming after harvesting cereals, which may not fit in the farmer planning.

4.2 Technical aspects

These technical aspects are at the scale of the EFA and the scale of the farm.

At the EFA's scale, there is first a choice of type of structure, with shrubs, trees or only a herbaceous layer, then the choice of plant species, the methods of implementation (soil preparation, date of sowing...), and the management practices (mowing...).

Obviously, an EFA with trees is a requisite for microclimate regulation. The number of rows of trees, the density and the species must be adapted to the windbreak objective: reduction of wind speed and trapping of heat during spring and summer or snow management in winter.

For herbaceous strips, the choice of species must fit the requirements of the arthropods of interest. Having nectar and pollen resources during the growing season can be an objective. Some associations of insects with plants are highly specialized, while many concern generalist species. Root depth is also important; Deep-rooted grasses are the most effective buffer vegetation for minimizing the impacts of sheet flow runoff from surrounding agricultural fields. Marshall²⁷ provides a table of EFAs structure for different functions (annex 4).

Bentrup²⁸ provides guidelines to implement buffers and give some information on the economic benefits (marketable products, Reduce energy consumption, Increase property values, Provide alternative energy sources, Provide ecosystem services), but do not give any figure in terms of money.

At the farm scale, machines availability, for instance a mower to cut grassy strips, is a question. Not all farmers produce hay, so do not have the machinery. The width of the seeder constraints the strip width.

4.3 human/ social aspects

Labor issues

Labor is most often a limiting factor in farms. This will be a key point for EFAs management. The priority will be given to the management of crops.

Cultural acceptance

The base of the adoption of a new technology (EFA) is an innovation path that fits the existing system or that is part of a new design. The expectation of making profit may not last if the cultural acceptance is limited.

Increasing the willingness of farmers to implement EFAs is an important issue. A positive reaction from the public can be an incentive for the farmer.

²⁵ <http://www.boundary-problems.co.uk/boundary-problems/hedges.html>

²⁶ http://www.rspb.org.uk/makeahomeforwildlife/advice/gardening/planting/hedges/the_law.aspx

²⁷ *Marshall, E J P, /Guidelines for the siting, establishment and management of arable field margins, beetle banks, Cereal conservation headlands and wildlife seed mixtures, Defra UK Project BD0412*

²⁸ BENTRUP, G. (2008). *Conservation buffers: design guidelines for buffers, corridors, and greenways*. Gen. Tech. Rep.SRS-109. Asheville, NC: Department of Agriculture, Forest Service, Southern Research Station. 110 p, Gen. Tech. Rep.SRS-109. Asheville, NC: Department of Agriculture, Forest Service, Southern Research Station. 110 p (http://nac.unl.edu/buffers/docs/conservation_buffers.pdf)

5 Pathways to innovations

Innovation in farms is a process at the system scale, not a matter of changing one technique at any point in time. Innovation is taken up within trajectories, they differ from farmer to farmer²⁹.

The attitude of farmers regarding the environment and the adoption of agri-environment schemes (AES) is part of the trajectory of their farming activity. Ingram et al³⁰ attempt to position understanding of AES participation motivations in a dynamic context. They survey farmers in Wales and grouped them in three categories, similar to the categories of Greiner et al³¹ regarding the adoption of measures favorable to the environment by farmers are similar and noted in parentheses:

- **Low-intensity traditional pathways** (conservation and lifestyle motivation)

All farms in pathway A demonstrate a dynamic history of enterprise change, but an enduring pattern of low-intensity pathway development where traditional values, livelihood, lifestyle and attachment to, and protection of, the environment are particularly important.

- **Traditional but productive pathways** (social motivation)

A number of farmers (of pathway B) are prepared to revise their pathways to capture the opportunity agri-environment schemes offers,

- **Commercial agricultural pathways** (economic/financial motivation)

Farmers of pathway C are tied into intensive production systems to provide income and less likely to choose a trajectory that allows them to cut down on costs and labour inputs and compromise outputs.

Kelemen et al³² analyzed the perception of biodiversity by farmers' focus groups. They advocate a plural approach of biodiversity as farmers see both the positive and negative effects of conserving biodiversity (it has a cost). They find " *that scientific concepts become inherently context dependent and value-laden when they are introduced into public discourse*". They conclude " *Soft policy tools, as well as involving farmers in the design of pro-biodiversity agricultural policies may be important policy tools in addition to the monetary incentives that are widely applied nowadays*".

At the European level, organizations are set up to promote the understanding of the role of biodiversity. For instance, BiodiversityKnowledge³³ is an initiative by researchers and practitioners to help all societal actors in the field of biodiversity and ecosystem services to make better informed decisions. " *In this challenge, we invite you to develop with us an innovation called Network of Knowledge - an open networking approach to boost the knowledge flow between biodiversity knowledge holders and users in Europe*".

6 Directions for future research

A large body of evidences demonstrates that EFAS provide a large amount of environmental goods and services as the control of pest, microclimate, erosion, and nutrient loss. They provide habitat to numerous

²⁹ SUTHERLAND, L.-A., R. J. BURTON, J. INGRAM, K. BLACKSTOCK, B. SLEE AND N. GOTTS (2012). "Triggering change: Towards a conceptualisation of major change processes in farm decision-making." *Journal of Environmental Management* 104: 142-151.

CHANTRE, E. AND A. CARDONA (2014). "Trajectories of French Field Crop Farmers Moving Toward Sustainable Farming Practices: Change, Learning, and Links with the Advisory Services." *Agroecology and Sustainable Food Systems* 38(5): 573-602.

³⁰ INGRAM, J., P. GASKELL, J. MILLS AND C. SHORT (2013). "Incorporating agri-environment schemes into farm development pathways: A temporal analysis of farmer motivations." *Land Use Policy* 31: 267-279

³¹ GREINER, R., L. PATTERSON AND O. MILLER (2009). "Motivations, risk perceptions and adoption of conservation practices by farmers." *Agricultural Systems* 99(2-3): 86-104.

³² KELEMEN, E., G. NGUYEN, T. GOMIERO, E. KOVÁCS, J.-P. CHOISIS, N. CHOISIS, M. G. PAOLETTI, L. PODMANICZKY, J. RYSCHAWY AND J.-P. SARTHOU (2013). "Farmers' perceptions of biodiversity: lessons from a discourse-based deliberative valuation study." *Land Use Policy* 35: 318-328.

³³ <http://www.biodiversityknowledge.eu/>

beneficial arthropods. If the benefits of EFAs for the society are clear, the **effect on production have been poorly investigated**, except in the case of windbreaks. Probably because public money is used to develop them, the returns are investigated in terms of public goods. Biological processes are more complex than physical processes, so the impact of a flower strip on yield in the adjacent field is not straightforward to evaluate. **Landscape scale processes often dominate in biological processes** (dispersal, habitat supplementation and complementation) are important. Of course, the effects of *windbreaks* are also cumulative and build a boundary layer under which the wind speed is slowed. It is more efficient to set up of series of windbreak than to use a single windbreak.

It is **dubious that an experimental approach would suffice to evaluate the impact of EFAs on yields**. Not only because of the complexity of the processes, but also because EFA management is most of the time associated with other cropping practices (reduce tillage, winter cover, crop diversification etc.). Furthermore, **plot scales experiments cannot be easily extrapolate to field or landscape scale**. The spatial heterogeneity increases as the extent of the area under consideration increases and this heterogeneity introduces non-linear response to driving variable such as the presence of EFAs. For instance, White and Arnold³⁴ model an extrapolation of water flow entering vegetation filter strip from plot to field. At the plot scale, the flow is uniform, at field scale, the micro topography concentrates the flow in some parts, and thus 50% of the flow entering the strip occurs on a small portion of the boundary.

Participatory research involving farmers and farmers' advisors, as in the focus group, could develop protocols to assess the effects of EFAs. This will be a long-term (several years) study to incorporate the ecological and meteorological fluctuations that high input farming is meant to control. EFAs as a single, isolated factor of production are certainly not an epistemological option to study their roles in the production system.

An operational objective of the research is to set up principles that will help farmers and advisors to make decisions on the maintenance, implementation, design and management of EFAs. Annex 5 presents a first set of variables to consider .

Actually many farmers conserve, implement, and manage EFAs. If subsidies foster implementation, many EFAs are maintained with no monetary incentive. Many farmers is not "all farmers", they are different and these differences in economic or social objectives drive their decisions. Economics is not always the overriding factor . Even if the focus group is dedicated to production, we have to keep in mind that many factors are considered by farmers when they choose environmentally friendly techniques.

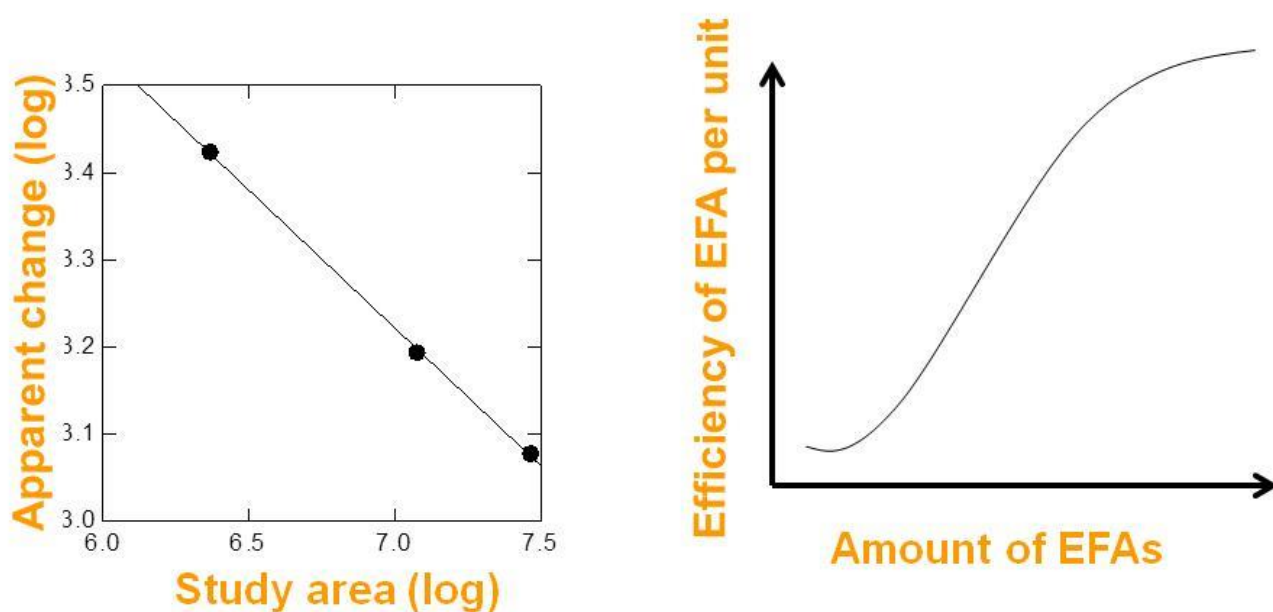
³⁴ WHITE, M. J. AND J. G. ARNOLD (2009). "Development of a simplistic vegetative filter strip model for sediment and nutrient retention at the field scale." *Hydrological processes* 23(11): 1602-1616.

Annex 1: Scale dependence in landscape ecological processes

Scale dependence is at the core of landscape ecology and landscape management. It means that responses to changes or the adding of EFAs will be non linear and may present threshold effects. Non linearities is what makes prediction of changes difficult.

Among the examples is the effect of successive windbreaks that produces a layer of calm air. For pest control, as none of the EFA can harbor all the beneficial species present in a landscape, redundancy of EFAs provide alternative habitats or alternative beneficial species.

Below, two examples of graphs that show scale dependence. The first is from an analysis of land use changes, the second a general patterns found in analysis.



Annex 2: Structure and management of strips

Hackett and Lawrence³⁵ give indications on the structure and management of strips to control runoff.

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 efficiency ⁹
Phosphorus	Width of 10 m (particulate phosphorus) to 15 m (dissolved) required for 70 to 80 % reduction efficiency ⁹
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 channelling of runoff and bypass of pollutants

³⁵ 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.

Annex 3: Cost of seeds

- **Buffer Strip & Beetle Bank**

Managed as low intensity grassland and can be used to create new habitats. Cocksfoot is included as a clump forming specie creating areas for birds and other mammals to nestle down for cover and nesting purposes

Pack size 20kg. Sow minimum 20kg per hectare

20% Timothy (*Phleum pratense*)

10% Hard fescue (*Festuca rubra ssp*)

10% Cocksfoot (*Dactylis glomerata*)

35% Creeping red fescue (*Festuca rubra*)

25% Tall fescue (*Festuca arundinacea*)

1 x 20kg - £70.00

- **Floristically Enhanced Buffer Strip**

Managed as low intensity grassland, similar to ELS2, but includes several wild flowers as advised by Natural England. Would be cut August/Sept to allow wild flowers to disperse seed back into the sward. May require cutting in March/April.

Pack size 20kg. Sow minimum 20kg per hectare

40% Strong creeping red fescue (*Festuca Rubra*)

20% Hard fescue

10% Smooth stalked meadow grass

25% Chewing's fescue

1% Birdsfoot trefoil

0.25% Selfheal

0.5% Ox-Eye daisy

2% Yarrow

0.5% Common knapweed

0.25% Wild carrot

0.5% Wild red clover

1 x 20kg - £134.00

Annex 4: EFAs structure in relation to different functions

Marshall³⁶ provides a table of EFAs structure for different functions:

Objective	Prescription	Comments
To conserve rare cornfield flowers	1. Conservation headlands, preferably without fertiliser. 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 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 2. Beetle banks	Tussocky grass is important
To provide pollen and nectar sources for hoverflies, butterflies and pollinators	1. Grass and wild flower margins 2. Conservation headlands, if suitable species are present 3. Sown wildlife mixtures (nectar sources)	
To provide seeds for birds	1. Grass and wild flower margins 2. Conservation headlands 3. Uncropped wildlife strips 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 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 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	

³⁶ *Marshall, E J P, / Guidelines for the siting, establishment and management of arable field margins, beetle banks, Cereal conservation headlands and wildlife seed mixtures, Defra UK Project BD0412*

Annex 5: Draft framework design EFAs

Draft of a framework for setting up guidelines to design EFAs taking into account farmer's objectives and the local context:

Diagram of EFA design analysis

