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Enhancing biodiversity in French crop production systems: Cost-benefits analysis on five measures from the Ecostack project

Alexandre Durand
International Double Degree Programme Msc Agroecology

Author: Alexandre Durand **Year: 2021**

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Résumé: Une diminution de la biodiversité dans les paysages agricoles a été observée au cours des dernières décennies. Renforcer la biodiversité autour et à l'intérieur des champs permettrait de contrer cet effet. Cette étude, menée dans le cadre du projet Ecostack, vise à déterminer les coûts et les bénéfices de plusieurs mesures améliorant la biodiversité. Parmi les cinq mesures étudiées on compte 3 mesures hors champ : haies, bandes fleuries, bandes enherbées, et 2 mesures concernant les cultures : le mélange de cultivars et le semis direct. Les données concernant les coûts et les bénéfices des mesures ont été recueillies lors d'entretiens avec des agriculteurs des départements du Rhône et de l'Isère. D'autres acteurs, tels que la Fédération de Chasse et la Chambre d'agriculture, qui aident les agriculteurs à mettre en place certaines de ces mesures, ont été interrogés afin de recueillir des données quantitatives. L'avis des agriculteurs pour la mise en œuvre ou non des mesures a été également recueilli. La viabilité des mesures est difficilement estimable. Les haies et les bandes enherbées sont largement implantées en raison de la législation actuelle. Les pratiques dans les champs sont réalisées par près de la moitié des agriculteurs mais les bandes fleuries sont mises de côté. Les agriculteurs ne sont pas vraiment intéressés pour adopter davantage ces mesures, principalement en raison de facteurs économiques. La présence importante des mesures hors culture est également un frein pour ces agriculteurs. Des recherches supplémentaires sur les bénéfices seraient nécessaires pour compléter l'analyse coûts-bénéfices.

Abstract: A decrease of biodiversity in agricultural landscapes has been observed in the last decades. Stacking biodiversity around and inside fields would provide a method to counterbalance this effect. This study, conducted within the Ecostack project, aims to determine the costs and benefits of several measures enhancing biodiversity. In the five main measures studied there are 3 off-crop measures: hedges, flowering strips, grassy margins; and 2 in-crop measures: cultivar mixture and direct sowing. Data concerning the

costs and benefits of the measures were gathered from interviews with farmers from the Rhone and Isère counties. Other stakeholders such as the Hunting Federation and the Chamber of Agriculture, which help farmers to implement some of these measures, were also interviewed to collect more quantitative data. The opinions of farmers for implementing or not the measures were also collected. Viability of measures is difficult to estimate. Hedges and grassy margins are frequently implemented due to the current legislation. In-crop practices are done by almost half of the farmers and flowering strips are set aside by the farmers. Farmers were not really interested in implementing more of these measures mostly because of economic factors. The important presence of off-crop practices is also a hindering force for farmers. Further research on benefits would be needed to complete the costs-benefits analysis.

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List of abbreviations

AECM: Agro-Environmental and Climatic Measures

CAP: Common Agricultural Policy

CBA: Costs-Benefits Analysis

EFA: Ecological Focus Area

lm: linear meter

PES: Payment for Ecosystem Services

PPP: Plant Protection Products

UAA: Utilized Agricultural Area

1 Introduction

The importance of biodiversity is increasingly recognized in Europe and worldwide. At the same time, human activities can be a threat to animal and plant biodiversity. Agriculture has an important role to play in the management of biodiversity and ecosystems. Indeed, during the past decades the intensification of agriculture and the homogenization of the landscape have been affecting negatively the populations of birds and insects (Moreau et al., 2018; Sánchez-Bayo and Wyckhuys, 2019).

To counterbalance the negative effects of agriculture the European Union provides subsidies for practices favouring biodiversity in agricultural areas; two main types of measures exist. The first ones are the Agro-Environmental and Climatic Measures (AECM) aiming to develop and maintain practices “protecting and improving the environment, the landscape and its features”. They were complemented in 2015 with an additional part in the Green Payments: the Ecological Focus Areas (EFA) which aim “to safeguard and improve biodiversity on farms” (European Council, 2013). To reach this goal the maintenance of landscape elements such as fallow land, hedgerows or green cover is promoted (European Commission et al., 2020). These semi-natural elements provide a wide range of food resources and habitats for numerous species (Wezel et al., 2014). However, the implementation of these landscape elements can lead to additional costs such as the purchase of specific machinery and increase farmers’ workload.

This study takes place in the EcoStack project. This project includes 22 partners all over Europe and started on September 2018. It aims to “develop ecologically, economically and socially sustainable crop production strategies via stacking of biodiversity service providers and bio-inspired tools for crop protection, within and around agricultural fields, in order to enhance sustainability of food production systems across Europe” (Ecostack, 2018). To improve and develop biodiversity in fields the project focus on several measures and researchers attempt to determine their importance in different European cropping systems through in-field experiments, modelling, and collection of farmers’ viewpoints.

The project is composed of 11 working packages studying different assets of biodiversity. The goal of this study, focusing on work package 9, is to calculate the costs and benefits, for farmers, of several practices aiming to enhance functional biodiversity in order to

determine whether or not they are viable for farmers. The farm sample is considered as representative of the region studied.

Five measures were chosen according to their importance determined by other members of the Ecostack project prior to this study. They are divided into off-crop practices which are hedgerows, grassy margins and flowering strips and in-crop practices which are cultivar mixture and direct seeding under cover crop. For such a prioritization, several traits of the measures that could be used were identified:

- Practicability and implementation
- Effectiveness concerning protection and support of biodiversity
- Insect pest control
- Pollination
- Costs of inputs and implementation
- If they are tested in diverse EcoStack regions and field crops
- If they can be modelled in ALMaSS[1] (Topping et al., 2019, 2003)

Hedgerows are “lines of different types of bushes and small trees planted or growing very close together, especially along the edge of a garden or field, between fields or along the sides of roads in the countryside” (Cambridge dictionnary, n.d.). Grassy margins are strips of mainly uncultivated vegetation dominated by grasses and herbs at the edge of fields or between cropped areas. Flowering strips are defined as agricultural areas on which seed mixtures of annual wild or cultivated plants have been sown (Dietzel, 2019). Flowering strips can be placed within the field or as field margins and are renewed yearly.

Cultivar mixture is the combination of different cultivars of one crop in the same field to increase the resistance against pests. Direct seeding under cover crop can be defined as “planting of crops directly (no tillage) in preceding cover crop (living or destroyed, i.e. mulched) or crop residues” (Wezel et al., 2014) to improve soil organic matter, soil biota activity, fertilization and weed suppression.

The off-crop practices contribute directly to the enhancement of biodiversity by providing overwintering habitats, breeding sites and alternative sources of food for beneficial

[1] ALMaSS (Animal, Landscape and Man Simulation System) is a predictive tool modelling the evolution of animal population according to the management of the landscape. Developed by the Aarhus university it was adapted by Ecostack team to other European landscapes (Topping et al., 2003).

arthropods such as carabids or spiders (Altieri and Nicholls, 2004). In-crop measures aim to reduce inputs and preserve soil biodiversity inside the fields (Wezel et al., 2014).

The other purpose of this study is to understand socio-economic factors and incentives affecting farmers' decision making. Indeed, their willingness to implement these measures can be numerous and are not always linked with economical gain or loss (Lastra-Bravo et al., 2015). As an example, farming landscapes embody "a highly valued form of cultural capital because these landscapes act as a display of the farmer's knowledge, values and work ethic"(de Krom, 2017) which means that peers' perception can be a factor influencing farmers' choices.

The overall research objective is to determine what are the individual costs and benefits associated to the farmers with the implementation of measures to enhance biodiversity for farmers in Rhone and Isère counties. The research will also determine what are the principal factors influencing farmers' willingness to adopt the selected measures.

2 Materials and Methods

This study took place in the Auvergne-Rhône-Alpes region in the southeast of Rhone County and the northern part of Isere County between February and July 2021. This area was chosen because of its proximity with the research centre based in Lyon and the high rate of crop production in the Utilized Agricultural Area (UAA), which is above 60% in the area (Meyronneinc et al., 2016).

To illustrate the advantages and drawbacks of these practices a costs-benefits analysis (CBA) has been done. This method has the advantage to identify the indicators that are easy to understand. The method of CBA linking environment and economy is mostly employed in ecology, territory development (Erdlenbruch et al., 2008), and forestry (Chevalier et al., 2009) to determine management strategies. Several studies performed CBA to demonstrate the advantages of practices stacking biodiversity, such as the association of service plants in cropping systems with winter wheat or rapeseeds(Valantin-Morison et al., 2019) or about the effect of hedges on pest control and pollination (Morandin et al., 2016).

In this case the analysis is conducted with farmers to bring out the individual costs and benefits. The final purpose is to determine if the practices are profitable for farmers and, in this case, identify the incentives that could encourage them to switch to new practices with individual benefits instead of collective ones.

Semi-directive interviews were conducted with 15 farmers to collect quantitative data on costs, cost components and benefits considering regional conditions. Interviews were done by phone between March and April 2021 and were around 35 minutes long. The farmers were chosen from a list provided by members of Ecostack. They were chosen depending on their location (Rhone and Isère counties), their type of farm (organic or conventional agriculture) and their availability and willingness to answer the questions.

Questions were split into 4 categories according to the questions defined in the introduction. 1) The presence of the measures on their farms and the reasons of this implementation. 2) Their estimations of the costs for machinery, implementation, workload compared to conventional practices. 3) Their estimations of yield gain or loss, evolution of the use of pesticides and fertilizers, the help they receive. 4) The way they find the information for these practices, effects of practices on farmers' image and product valuation. The questionnaire is presented in Appendix I.

A concise transcript of the interviews was done to highlight the main information and some verbatim records. The main causes of adoption or refusal of the measures were determined by comparing the different answers in an analysis grid.

After the farmers' interviews, several types of information were still missing especially about costs and benefits. Several interviews with other stakeholders were conducted. The organizations contacted to collect data were the Hunting Federation, which helps farmers with engineering and logistic to implement hedges, and a technician from the Chamber of Agriculture for the implementation and management of grassy and flowering strips and in-crop practices. The questionnaires of these stakeholders are presented in Appendix II and Appendix III. For hedges the management costs were found in the literature.

For each measure concise tables of cost components were filled with data gathered or calculated during interviews and bibliography research. To be able to compare measures each CBA was done on 100 linear meters (lm) for off-crop practices and on 1ha for in-crop practices. In case there is a variability in a component the best possibility, meaning the lower costs and the higher benefits, was chosen. Machinery costs include workload and fuel costs were calculated for a 150ha farm. Benefits available were presented separately (cf. section 3). Finally, the measures were ranked according to the result of the CBA (cf. section 3.7).

3 Results and Discussion

Agricultural land represents half of the area in this region, which is slightly lower than the national average. The main cereal crops are wheat and maize which represent respectively 36% and 26% of the areas under crop production; organic agriculture represents 4% of this surface (FranceAgriMer, 2016). The climate in the studied area is temperate. The average yearly rainfalls are around 1000mm and the average temperatures around 12°C (Auffray et al., 2010).

Table 1:Farmers' sampling, type of system and measures implemented

Farmer code	Utilized Agricultural Area (ha)	Farm type	Label	Hedges	Grassy margins	Flowering strips	Cultivar mixture	Direct seeding under cover crop
FR1	150	Specialist arable crop	Organic					X
FR2	120	Specialist arable crop		X	X	X		
FR3	220	Specialist arable crop		X	X			
FR4	110	Mixed crops livestock	Organic	X	X		X	X
FR5	150	Mixed crops livestock		X				X
FR6	220	Specialist arable crop		X	X		X	X
FR7	85	Mixed crops livestock		X	X		X	
FR8	150	Specialist arable crop		X	X			X
FR9	75	Specialist arable crop	Organic	X	X			
FR10	73	Specialist arable crop	Organic	X	X			
FR11	285	Specialist arable crop		X	X			
FR12	40	Mixed crops livestock		X	X		X	X
FR13	24	Mixed crops livestock	Organic	*X*	X		X	
FR14	130	Specialist arable crop	Organic	X	X		X	X
FR15	66	Specialist arable crop		*X*	X	X		

The sample is composed of 15 farmers, and the details from the farmers interviewed are presented in Table 1. In terms of production 10 farmers are specialized in crop systems, while the others have mixed crop-livestock systems. Among them, 6 farmers, including 4 in cereal production and 2 with crops-livestock system, are in certified organic agriculture. The average Utilized Agricultural Area is 127 ha/farm. The main crops grown are wheat,

maize, barley and rapeseed. In general, they had difficulties to give quantitative data and were unable to evaluate the effect of ecosystem services they receive from the measures.

For off-crop measures the main source of subsidies comes from the green payment from the CAP. The awarding of this payment is based on 3 criteria: the presence of 5% of EFA on the farm, the conservation of permanent grasslands and the crop diversity with at least 3 crops on the farm. Once the 3 criteria have been met, the green payment corresponds to a coefficient applied to the basic payment entitlements allowed for the farmer. In other words, it is proportional to the total area of the farm (Janin, 2021). The off-crop measures count for a surface area, as an example, 1 lm of hedges is equivalent to 10m² of EFA (Berruyer and Charmet, 2019). Due to this method of awarding it is impossible to calculate the subsidies for the EFA only.

3.1 Hedgerows

Almost all the farmers have hedges, 4 of them installed as part of the hedges linear on their farms the other inherited the already existing hedges on the farm "*historically they are here to mark out the plots and [to break] the slopes*" (FR15). As the farmers were unable to tell the total length of hedges they have, the costs calculation per linear meter is impossible from the results of farmers' interview. The main motivations at the farm level for setting up hedges are the windbreak effect, the creation of separation and biodiversity increase with the creation of attractive spaces for the auxiliaries. Indeed, studies showed that hedges have many benefits. With a good configuration windbreak hedges can reduce the costs of irrigation by reducing evapotranspiration without impacting yields (de Vries et al., 2010). Due to wind reduction yields are increased by 8%. Enhanced differences between protected and unprotected fields are observed in dry years (Frank and Willis, 1978). Windbreak effects avoid yield loss, especially in dry years.

The main obstacles to their implementation are the cost and the maintenance time deemed too high by the farmers and the fact that the region is already perceived as rich in semi-natural elements "*there are a lot of hedges and forest, we are not in the Beauce[2] region*" (FR8). Therefore, the farmers do not feel the need to install more hedges. Problems linked to the plots such as rural lease or plot fragmentation are also hindering forces. However, studies show that the areas with hedges and tree lines are decreasing in both counties and nationally between 2006 and 2014. There is a higher decrease in

[2] Beauce is an agricultural region south of Paris with intensive crop production

Isère, between 15 and 80%, than in Rhône, between 0 and 15% of decrease. The average decrease for France is 6% (Moreau et al., 2018). There may be a bias in farmer's perception as the surface of forest in Isère remains high, at 38% of forest cover, which is higher than the average in France which is around 30% (Meyronneinc et al., 2016).

Farmers observe that hedges influence crops yield. They said hedges have a protective effect in spring, but they will compete with the crop over a distance of 3 to 10m from the field edge in summer for the water resource. "*This is particularly observed for spring crops, not that much on winter crops*" (FR11). Only 2 farmers observe a negative effect on pests with an increase in the number of pigeons and crows nesting in the hedges. These birds affect only sunflower and corn leading to a change in the crops grown by these farmers.

The interview of people in the Hunting Federation, which helps farmers in logistic management of hedges, provided sufficient information to calculate the implementation costs for a 2-row hedge. The costs are presented in euros (without added-value tax) per 100 linear meters (lm) (Table 2).

Table 2: Costs for hedgerow plantation

Preparation before implementation	
Soil preparation	100 €
Planting	
Plants	130 €
Planting	400 € (planting, mulching and protecting)
Protection against wild animals	50 €
Mulch	150 €
Total	830 €

The available literature estimate planting costs between 535 and 710€ per 100 lm for a 1 row hedge in 2009 (Arnault et al., 2009). Due to the average inflation of 1% in the last 12 years (Insee, 2021) the current costs would be between 599 and 795 € per 100lm. The

cost calculated in this study, 830€ per 100 lm for a 2 rows hedge, is higher but remains coherent.

The Hunting Federation and the communes' communities finance the setting up of hedges and the purchase of plants, and sometimes the establishment. Most of the time, farmers have to pay for soil preparation and sometimes for mulch and protections depending on the municipality community partner of the project. At best the price paid by farmers would be 300€/100lm which represents less than half of the total expenses.

The other possibility to decrease the implementation costs is to use the funds from the "Plan de Relance" (Revival Plan). This plan was created to help the society to recover after the Covid-19 crisis. The expense item "Let's Plant Hedges" of this plan aims to subsidise hedges plantation to increase biodiversity in agricultural area (Ministère de l'Agriculture et de l'Alimentation, 2021a). This plan subsidises 100% for eligible expenses for project of 1000€ minimum and for non-productive investments. Hedges are eligible because they have these characteristics. Indeed, the value or the profitability of the farm is not increased by the creation of the hedgerow. The drawback of this plan is its duration as projects had to be proposed between September 2020 and June 2021 to be accepted (DRAAF, 2021).

Concerning the implementation duration, the Hunting Federation works in partnership with horticultural high schools. With 25 people 1000 trees can be planted daily in a single area or 600 in several areas (between 24 and 40 plants/day/person).

A document from the Revival Plan stated that a grassy strip should be implemented (DRAAF, 2021). The document does not provide detail on the reason to implement this strip but the interviews with farmers reveal that they use grassy strips to cover less productive area (cf. section 3.2).

The hedges are maintained with a flail mower or cutter bar. More than half of the farmers (53%) ask a company to maintain their hedge at a cost of between 60 and 70 €/h. Farmers who maintain their hedges themselves spend between 8 and 15 days per year. The huge variation could be explained by the difference of hedges length. Most of them use a flail mower; either they own it or share it in local agricultural equipment cooperatives[3] for 2 farmers. These local cooperatives help reduce the costs as the prices of the machines

[3] Local equipment cooperatives are cooperatives where farmers share part of their equipment. They allow small scale farmer to have access to costly equipment (FNCUMA, 2019).

are divided among farmers. Products from the hedge are used; 4 farmers use the wood from the hedge and the edges of forests for their personal heating or to compost (in the case of branches) to then spread it in the fields as a soil enricher to increase organic matter. However, the use of hedges' wood requires adapted material and time.

The management costs were gathered from literature. The costs are presented in euros (without added-value tax) per 100 linear meters (lm) (Table 3).

Table 3: Synthesis of costs for hedgerows management (Chambres d'agriculture de Normandie, 2021; DRAAF, 2021)

Management	
Maintenance – year N+1	83 €
Maintenance – year N+2	71 €
Maintenance – year N+3	60 €
Pruning – year N+3	144 €
Pruning – after year N+3	3.00€

After the 3rd year pruning is done with a flail mower set at 2m height and is done yearly. The cost would be 1.44€/100lm/year if the maintenance were done with a cutter bar every 3 years. Both techniques have advantages and drawbacks: the flail mower is appropriate for a yearly use for small branches (diameter <2cm), while the cutter bar is better for bigger branches. In the last case, branches can be collected (Prom'haies Poitou-Charentes, 2013).

The wood collected can be transformed into wood chips, and a hedge can produce yearly 1.5 m^3 of wood chips per 100 lm (Berruyer and Charmet, 2019) which represents a potential gain of 45€/100lm. Collecting and selling the wood is time demanding and require specific equipment. As most of the farmers ask a company to maintain their hedges it seems hardly probable that they will manage hedges' by-products themselves which reduce the potential gain.

Contrary to the implementation of the hedge, the Hunting Federation does not subsidise farmers for maintenance. The maintenance fees are covered by the revival plan until the 3rd year. Only 13% of the farmers received AECMs until 2020; the renewal of this subsidy is under discussion, and it does not represent a viable source of benefits as they are renegotiated every 5 years. Farmers also said that the subsidy was not significant without reporting the precise amount.

3.2 Grassy margins

Almost all the farmers (87%) have grass strips because they are mandatory at the edge of waterways according to the European directive concerning nitrate pollution (The Council of the European Communities, 1991). Since 2021, farmers have to keep a pesticide free zone around housing, schools and retirement homes. The minimum width of this buffer zone is 5m but is increased to 20m for dangerous plant protection products (PPP) (Ministère de l'Agriculture et de l'Alimentation, 2021b).

However, farmers have other reasons to implement grassy strips. The main motivation for their establishment is to cover a less productive area or passage for equipment or irrigation systems "*We have grassy strips near hedges, because in general [the crop] is not growing a lot*" (FR9); "*it is less expensive to maintain grass here [instead of growing crops]*" (FR13). Nonetheless, some farmers believe these strips represents a loss of productive surface as they would prefer to cultivate all the land they have.

According to the farmers, the total cost of establishment is around 350 €/ha or 17.5€/100lm. This price includes 100€ of seeds and the rest is the cost related to the preparation of the seedbed and diesel. Maintenance is carried out by grinding twice a year. The maintenance time varies between 4h and 2 days per year depending on the surface to mow and probably on the location of the strips on the farm if plots are far from one another. Advisers consider that it is better to mow than to crush to preserve biodiversity. The species recommended are ryegrass (*Lolium perenne L.*), fescue (*Festuca* sp.), orchard grass (*Dactylis* sp.) and potentially alsike clover (*Trifolium hybridum*). The use of late varieties to mow later is advised (Arvalis, 2014). The mower is also more interesting because it can be used for productive purpose with hay production from pastures.

The requirements in terms of equipment are low. For the maintenance 8 farmers have a crusher and 1 has a mower. For those using a crusher, 3 farmers share it with other farmers in a local agricultural equipment cooperative and 5 own it. The shredders are generally amortized over 10 years and cost between 2,500€ and 15,000€ without the cost of replacing the knives which is 1,500€ every 3 years. The gap in the purchase costs depends on the size of the shredder and the type (new or second-hand).

According to the farmers and the technician from the Chamber of Agriculture there are subsidies for improving agricultural equipment such as crushers. These subsidies come

from the “Plan de compétitivité et d’adaptation des exploitations agricoles” (Farms’ Competitiveness and Adaptation Plan). The goal of this plan is to modernize farmers’ equipment and to increase economic and environmental performances (Ministère de l’Agriculture et de l’Alimentation, 2021c). This plan can refund 40% of the equipment price.

Farmers do not observe effects of grass strips on yield, diseases nor pests. At the same time, they agree that the regular maintenance of the strips avoids spreading of weeds’ seeds in the field which has been confirmed by literature (Cordeau, 2010). The stability of the grass strips through years provides a refuge, and potentially alternative food resources, for insect species such as carabids and syrphids even if their abundance and diversity inside the strip is lower than in the fields or in hedges (Ernoult et al., 2013). Farmers do not receive direct support for establishing or maintaining these grass strips.

The interview with the technician from the Chamber of Agriculture highlighted the main costs for the implementation of a grassy margin of 5m wide and 100lm long (Table 4). The seed cost was calculated considering a mixture of ryegrass (12kg/ha), red fescue (12kg/ha) and alsike clover (2kg/ha) (Agriconomie, n.d.).

Table 4:Synthesis of costs for grassy margins including labor force

Seeds	4€
Ploughing	3€
Combined seeding machine	3€
Rolling	1€
Maintenance costs (crusher twice a year)	3€
Total (except maintenance)	11€

The implementation cost is low compared to the cost found in the report of Arnault et al. (2009) which were between 17 and 25€/100lm. Indeed, in this report one of the cost components is the loss of productive surface which was not taken into account here as the grassy strips are implement in low-productivity areas or are mandatory. The cost of 17.5€ given by farmers is higher to the cost calculated because of the difference in seed price and maybe because of an overestimation of mechanization costs.

To reduce the costs, it is possible to let the vegetation grow naturally. In this case the implementation costs decrease to 7€/100lm but there is a risk of development of weeds, such as ragweed (*Ambrosia artemisiifolia* L.).

3.3 Flowering strips

Two farmers set up flower strips. The motivation of the first one was that his municipality financed the flower strips to create user-friendly spaces. When the funding stopped, he stopped cultivating flower strips. The second farmer planted flower strips near his rapeseed to improve pollination but was not satisfied with their effect and will not repeat the experiment.

In general, farmers are not interested in flower strips. The main reasons are that the farm is already well supplied with grass strips and that flower strips are not "convenient " because they cannot be maintained as grass strips. The plants in the flower strips must bloom and therefore produce more biomass than in the grass strips, which limits passage with machinery. They also must be reseeded every year because of the development of weeds in the strip, unlike the grassy margins. People's opinions seemed to reflect both hindering and supporting forces: "*I was discussing about it with a friend who implemented flowering strips […] but people told him that on one hand you create flower strips for bees but on the other hand you treat [your crops] so you kill the bees so it's completely stupid*" (FR7). Indeed, farmers seem to be willing to implement flower strips to enhance their image which could be a key to promoting this practice.

Implementation costs are similar to those for grassy strips however the costs for seeds are higher because of the melliferous plants seeds which cost twice the price of grass seeds mixture (Lobbedz, 2021) leading to a cost of implementation of 16.3€/100lm. Moreover, the flower mixtures are not stable through years and must be reseeded regularly.

In terms of benefits, a study conducted by Albrecht et al. (2020) showed that there is an exponential increase of pest control and pollination service up to 20m from the strip but no significant effect on yields. Flowering strips also influence pest control by increasing the number of natural enemies. As an example, for cereal leaf beetle in winter wheat, flower strips lead to a reduction by 40% of this pest due to the increase of predators in the strips (Tschumi et al., 2015).

3.4 Cultivar mixture

Few farmers practice variety mixtures because this is not allowed under contracts with the cooperatives. Indeed, the cooperatives prefer pure varieties "*because of the protein rate, it is more homogeneous with pure varieties*" (FR5) and the cereal contracts made with the cooperatives concern a specific variety. The demand comes from the milling companies who need pure variety for their industrial process. They mix varieties themselves in order to have flour adapted for specific use with specific protein rates (Labarthe et al., 2018).

As a result, farmers who practice variety blending process the cereals themselves or use them for feeding their livestock. For those who absolutely want to sell their products the easier way to get around this issue is to export the cereals as logistic concerns force varieties to be mixed. The solution is debatable as it would impact food sovereignty if done at a large scale.

Cultivar mixture is done by 6 farmers who use this technique mainly for wheat, triticale and rapeseed. Half of these farmers are in organic farming. Their mixtures include between 2 and 4 varieties. Their interest in setting up a crop mix is to have stable yields and better resistance to diseases and predators. This resistance is possible due to the higher genetic diversity in the fields (Costanzo and Bàrberi, 2013). The main obstacle for using this technique is the need to mix each year to control the rate of each variety. If a variety is favoured one year, it will be found in a higher proportion in the mixture, which makes it difficult to reuse one's own seeds.

At the county scale, according to the technician from the Chamber of Agriculture, most of the time farmers grow different varieties on the farm but only a few of them practice cultivar mixture in the same field. In oilseed rape, more and more people are sowing a precocious variety that flowers earlier than the variety of interest to attract the meligethes (*Meligethes* sp.) which are spring pests attacking flower buds. Ready-to-use seed doses, already mixed, are beginning to be distributed commercially. Concerning the mixtures of species, the association of rapeseed's species represents almost 10 to 15% of the rapeseed cultivated in France.

There is no difference in the amount of labour required or the amount of fertilizer compared to a pure crop. As the cropping itinerary does not change compared to pure crop, it is not necessary to buy specific equipment. Two farmers note a decrease in the

quantity of pesticides they use, respectively from 20 to 30% for the first and 100% for the second. However, the choice of the second farmer to stop using pesticides is risky. He had a severe yield decrease (-86%) due to pest during a bad year. The other farmers do not perceive differences in terms of costs and benefits. The technician from the Chamber of Agriculture indicated that it is possible to reduce insecticides doses, but this reduction is difficult to evaluate. The effect of varieties in mixtures compared to pure varieties on yields depends on the crop type and the varieties in the mixture. This effect is significant in winter wheat and spring barley but not for winter barley and spring wheat (Kiær et al., 2009).

Farmers do not receive subsidies for this practice; the technician from the Chamber of Agriculture reported that this measure is a potential criterion considered for certain specifications but did not give details on the type of specification.

3.5 Direct seeding under cover crop

Direct seeding under cover crop is practiced by 7 farmers. Their yields were slightly lower at the beginning compared to a conventional cropping pattern. The main motivations for implementing this practice are to improve the quality of the soil by increasing the quantity of organic matter, to reduce the workload and to reduce the quantity of inputs "*the organic matter rate increased from 1.5% to 3% in the best plots*" (FR6). However, several obstacles are put forward by the farmers: the high need for chemical herbicides (such as glyphosate) and the lack of adapted equipment. Indeed, studies showed that 97% of French farmers in direct seeding use glyphosate, and direct seeding forces farmers to completely change their system (Derrouch et al., 2020).

Other problems such as the need to completely rethink one's cropping system, the development of certain pests (rodents, slugs) or the fact that the cooperative is not able to advise the farmers well were cited by the farmers "[the cooperatives' technicians] *are not prepared to the change of practices and are not able to advice farmers trying new things*" (FR5). As most of the farmers using direct seeding under cover crop are part of the same farmers' group there is a strong peer influence in their decision making.

The decrease in the amount of work for field's operations is estimated between 30 and 50%. Considering a workload of 6h/ha for cereal production (Heddadj, 2013) farmers can save between 2 and 3h/ha in a cropping season. In economic terms it represents a gain between 34 and 51€/ha. Farmers said they spend more time thinking and observing their

fields, but they assume it is mostly due to the recent change in their practices. The estimation of workload is difficult because it depends on each farmer's perception which is variable from farm to farm. No difference is made on the amount of fertilizer and only the farmer who had a slug problem increased his amount of PPP. At the same time, they observe an increase of organic matter in their soils. According to the Chamber of Agriculture less fuel is needed in direct sowing but there is as much equipment cost or sometimes even more because it is difficult to do 100% direct seeding on a farm so the farmers must keep the tillage equipment for the other crops. The seeding rates are also higher by 10 to 15% probably due to the lower germination rates. The workload can vary a lot depending on the number of field operations compared to a conventional cropping system using conventional equipment. As an example, the difference can be lower is the farmer were not ploughing.

In terms of equipment needs, the farmers are mainly equipped with no-till seeders with variable prices and service life duration, bought by local agricultural equipment cooperative for half of them. They do not receive subsidies for this practice. The technician from the Chamber of Agriculture told that direct seeding seeders are often very expensive and cost above 40000€ for seeders with discs and around 35000€ for seeders with teeth. Here again the farmer's competitiveness plan can refund 40% of the equipment price but it depends on the water agency financing. As an example, it does not concern the area of water collection.

The following table compares the costs between direct seeding and conventional cropping system for wheat production. The comparison was done on soil preparation and seeding, seeds and pesticide treatments. The other costs are considered as similar between both cropping systems. For the soil preparation the steps considered for the conventional cropping system are ploughing, passage with a vibro-cultivator and a roller and seeding. For the direct seeding the cover crop is destroyed with chemicals and seeding is done with a direct seeder. The costs are presented in euros per ha.

Table 5: Comparison of the costs between conventional and direct seeding, source: (Chambre d'agriculture de l'Isère, 2016; Walter and Heckenbenner, 2020)

	Direct seeding	Conventional	Difference
Soil preparation and seeding	45.1€	122€	-76.9€
Seeds	83.6€	76€	+7.6€
Pesticide treatment (product + machinery)	119.2€	99.2€	+20€
Total	247.9€	297.2€	-49.3€

The main decrease of the costs is due to the removal of tillage and especially ploughing, leading to a decrease of 63%, even if the use of a direct seeder is more expensive than a usual seeder. The costs for seeds and pesticide treatments are higher because of the higher seeding rate and the chemical destruction of the cover crop.

3.6 Technical information gathering and social values

The technical information comes mainly from the Chambers of Agriculture, from other farmers notably via farmers' groups and the internet (YouTube, social networks). Farmers then experiment with what they learned to adapt it to their system "*when it's working somewhere it does not mean it will work everywhere*" (FR1).

The measures do not lead to a higher value of the farmers' products, but they do allow better communication with the consumers for the farmers who make direct sales or use animations at points of sale. "*When people see a beautiful, flowered field it gives another image of the agriculture […] we will try to implement it in the plots near our shop […] it is a good beginning for people to ask questions and be interested in what we are doing*" (FR5).

About the effect on farmers' image, 9 farmers feel that their practices have a positive effect on the image they project, especially thanks to their contacts with consumers during visits on the farm or animations in sales outlets. In general, organic farmers feel less of an effect of these practices on the image they convey. An explanation could be that the organic label is well known and have a higher impact on people's opinion than the studied practices.

An additional source of benefits could be Payments for Environmental Services (PES). PES is a form of remuneration to farmers for their restoration and management of ecosystems providing services to society. Most of the financing organisms are private companies, but financers can be also local communities or the State (Duval et al., 2019). As an example, the Water Agency Rhone-Méditerranée-Corse[4] developed PSE with farmers to increase biodiversity and water quality in several waterways and water collection points (Agence de l'eau, 2020). PES are not yet developed in the studied area but could be an interesting to complement EFA.

3.7 Comparison of costs-benefits analysis

The following table ranks the measures according to the result of the costs-benefits analysis and the type of measure. For off-crop measures costs and benefits are presented for 10 years for 100lm length. For in-crop measures the result presented is the difference of costs with a conventional crop.

Table 6: Ranking of the measures according to the results of the costs benefits analysis

Off-crop measures	
Grassy margins	37€
Flowering strips	163€
Hedgerows	676€
In-crop measures	
Direct seeding under living mulch	-49.3€
Cultivar mixture	0€

For off-crop measures, costs increase when the diversity in terms of species and strata increase. As an example, hedgerow is the most expensive measure and have three strata which are trees, shrubs and grass. Grassy margin is the cheapest measure but also the one with the poorest diversity due to the number of species in the seeding mixture.

[4] In France, each Water Agency is in charge of a specific watershed. In the studied area the water agency oversees the watersheds of the Rhône River, the Mediterranean Sea and Corsica.

For in-crop practices, cultivars mixture does not bring any change in terms of costs nor benefits compared to conventional cropping system while direct seeding decreases the cost per hectare due to the removing of tillage.

4 Conclusions

This study allowed us to determine and calculate the main cost components for each measure. In some cases, benefits were also highlighted.

The willingness of the farmers to develop these practices is variable as they already have obligations for the preservation of semi-natural elements. Off-crop measures require systemic changes at the farm scale and in the food chain.

Hedges are expensive to implement despite important subsidies from different stakeholders and are present on most of the farms. Grassy strips are abundantly implemented due to the legislation on waterways protection. It is the cheapest measure but also the less interesting in terms of biodiversity. Flower strips are not interesting for farmers as they can replace grassy strips but are more expensive.

Cultivar mixture is difficult to implement due to current legislation on grain market. Direct seeding is interesting in terms of costs, but farmers need to rethink completely their cropping system and make huge investments.

It was not possible to calculate the entire cost-benefits analysis because of the lack of data on the economic gains especially from ecosystem services. Several studies are currently being conducted to determine the value of these services. Further studies will be needed to obtain more precise costs from field experiments.

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6 Appendices

Appendix I: Interview questions

Can you give a little presentation of your farm? (Surface, crops)

Do you have Ecological Focus Area? Which ones?

When were these areas created?

Do you have practices such as cultivar mixtures or undersowing?

What is the percentage of crops grown with these practices?

Part1: Farmers' motivation

Have you ever thought about implementing the measures we have talked about?

What are your motivations for implementing these measures?

What are the obstacles to the implementation of these measures?

Why aren't you interested in [measure name]?

If an important measure in terms of biodiversity but which is of little interest to farmers: under, what conditions would you put in place [name of the measure]?

If cultural practices change in the past: what motivated this change?

If setting up flowered or grassed strips / hedges in the past: what prompted, you to set up these flowered or grassed strips / hedges?

Where did you find the information, you need to change your practices? (advisers, other farmers, etc.)

What types of information have you received?

Did you learn certain things on your own or through experiences that you have carried out?

Do you know any Payments for Environmental Services (PES) initiatives in the department?

Part 2: costs and benefits

1) Hedges

How much hedges do you have?

Who are your plant suppliers? how much do plants and seeds cost?

Did you receive assistance in putting these measures in place? If so, by whom and in what way?

How do you maintain your hedges?

Did you have to buy specific equipment for setting up or maintaining these spaces?

When did you buy it? At what price? What is its remaining life for it to be fully amortized?

What is the annual maintenance period?

How much is it costing you?

Do you observe any differences between plots with and without hedges / flower strips / grass strips in terms of yield, diseases, pests? (information for each culture)

Do you have differentiated management according to the nearby EFA?

Do you notice a difference in terms of the amount of input needed (in quantity and price)?

Do you receive subsidies for these measures?

What is the amount of these subsidies?

Do you know of other subsidies that you could benefit from?

2) Grass / flower strips

What species do you use?

Who are your seed suppliers? how much do they cost?

Did you receive assistance in putting these measures in place? If so, by whom and in what way?

How do you maintain your flower strips / grass strips?

Did you have to buy specific equipment for setting up or maintaining these areas?

When did you buy it? How much did it cost? What is its remaining life for it to be fully amortized?

What is the annual maintenance period?

How much does it cost?

Do you observe any differences between plots with and without flower strips / grass strips in terms of yield, diseases, pests? (information for each culture)

Do you have differentiated management according to the nearby EFA?

Do you see a difference in terms of the amount of input needed (in quantity and in price)?

Do you receive subsidies for these measures?

What is the amount of these subsidies?

Do you know of other subsidies that you could benefit from?

3) Cultivar mixture

What is the amount of work required compared to conventional management?

Do you see a difference in terms of the amount of input needed (in quantity and in price)?

What are the yields for the two varieties?

Have you purchased specific equipment to implement these practices?

When did you buy it? How much did it cost? What is its remaining life for it to be fully amortized?

Do you observe any specific constraints linked to these practices?

Do you receive subsidies for these measures?

What is the amount of these subsidies?

Do you know of other subsidies that you could benefit from?

4) Direct seeding under living mulch

Practical in the fields what is the amount of work required compared to a conventional cultivation route?

Do you see a difference in terms of the amount of input needed (in quantity and in price)?

What are your returns?

Have you purchased specific equipment to implement these practices?

When did you buy it? At what price? What is its remaining life for it to be fully amortized?

Do you observe any specific constraints linked to these practices?

Do you receive subsidies for these measures?

What is the amount of these subsidies?

Do you know of other subsidies that you could benefit from?

5) General questions

Who buys your production?

Do the measures we have discussed allow you to better promote your products?

Do you feel an effect on the image you are reflecting? in what way?

Appendix II: Questions for Hunting Federation

I have read your Guide for Planting and Maintaining Field Hedges and I had a few more questions about hedges specific to field crops:

How much does it cost to set up a hedge (for 100 linear meters for example)?

How long does it take to plant it?

What is the average annual maintenance time?

Do you have figures on the effect of the hedge on the yield?

Concerning the assistance provided by the hunting federation to farmers, are there similar initiatives throughout France?

Appendix III: Questions for the Chamber of Agriculture

General questions

How to evaluate the costs of using agricultural equipment? Is it possible to estimate their work rate?

What is the maximum amount of subsidies for EFA? How to calculate them?

Grassed strips

What is the cost of setting up a grassed strip (seeds, equipment)? What is its maintenance cost?

What is the duration of work necessary for the installation and the maintenance of a grass strip?

Flower strips

What is the cost of setting up a flower strip (seeds, material)? What is the maintenance cost?

What is the duration of work necessary for the installation and the maintenance of a flowery strip?

Mixture of varieties

What is the percentage of farmers who practice variety mixing? What is their profile (mixed crop-livestock or field crop only; direct sales or to a cooperative)?

What is the amount of work required compared to a pure crop?

Is there a difference in terms of the amount of inputs needed (in quantity and price)?

Is there any support for this practice?

Seeding under cover

What percentage of farmers practice cover cropping? For which crops and with what cover?

What is the amount of work required compared to a "conventional" cultivation method?

Is there a difference in seeding density?

Is there a difference in terms of the quantity of inputs required (in quantity and price)?

What are the essential tools for sowing under cover? What is their price?

Is there any support for this practice?