

> C-DIVERS

Métaprogramme BIOSEFAIR

Project report: 2024 - 2026

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A transition toward sustainable and resilient agricultural systems, which combine biodiversity conservation with enhanced ecosystem services, is necessary. Diversified, low-input cropping systems (i.e., systems designed with a high level of crop diversity in rotation and reduced use of pesticides and nitrogen fertilizers) and hedgerows are identified as potential means of making this transition. However, significant knowledge gaps persist regarding their respective contributions to promoting agroecosystem multifunctionality. The spatial scales—field or landscape—at which the effects of diversified, low-input cropping systems and hedgerows operate, as well as the factors that hinder or facilitate their adoption by farmers, are also insufficiently understood to date. In the context of mixed farming systems in Brittany, the objective of the C-DIVERS project was twofold: first, to explore the effects of crop diversity, the use of inputs (pesticides and nitrogen fertilizers) and hedgerows at the field and landscape scales on the agroecosystem multifunctionality; and second, to explore the barriers and drivers to the implementation of diversified, low-input cropping systems and hedgerows within farms.

The initial hypotheses of the C-DIVERS project were as follows: (i) Cropping systems with high level of crop diversity in rotation and low levels of chemical inputs, with hedgerows bordering fields, as well as a heterogeneous landscape context (high crop diversity and hedgerow density) combined with low pesticide use (large areas of organic farming) promote high agroecosystem multifunctionality; (ii) The barriers and drivers of plant diversification (i.e., the

implementation of diversified rotations, the establishment or maintenance of hedgerows) differ depending on the time scale considered and on the socioeconomic and technical determinants behind these barriers and drivers; and (iii) The opportunity cost (i.e., a way of assessing the economic barriers and drivers of plant diversification) is, in the long term, unfavorable to hedgerows due to their high maintenance costs.

In order to test these three hypotheses, the following approaches were used: (i) An assessment was conducted of the environmental (seven functions), agronomic (one function), and socioeconomic (two functions) performances underlying the agroecosystem multifunctionality of winter cereal fields with varying levels of crop diversity in rotation and contrasting landscape contexts; (ii) A comprehensive survey was carried out based on the results of a prospective external study prior to the C-DIVERS project; the aim of the survey was to identify the socioeconomic and technical determinants acting as barriers and drivers for the adoption of diversified cropping systems and the establishment or maintenance of hedgerows in the short and long term; (iii) An economic assessment was made of the long-term opportunity costs of establishing or maintaining hedgerows on a farm, according to different valorisation scenarios (it was not possible to make this assessment for the implementation of diversified cropping systems).

The results showed that the levels of crop diversity and the presence of hedgerows, whether at the local or landscape scale, do not promote all the performances expected for the development of multifunctional agroecosystems. However, they highlight that the presence of a hedgerow at the field border promotes specific ecological (pollination) and agronomic (agricultural production) outcomes. Furthermore, the reduction of pesticide use at the local scale could be beneficial for biodiversity conservation. However, the spatial diversity of crops within landscape mosaics appeared to reduce the regulation of crop pests in crops, possibly due to dilution effects.

With regard to socioeconomic and technical determinants, the results of this project showed that, in the short term, farm characteristics (e.g., perceived risks and personal norms expressed by farmers) are decisive for plant diversification, along with market-related costs and benefits and agronomic management considerations. Factors external to the farm, including public policies and the configuration of supply chains, have been demonstrated to exert influence. Conversely, access to technologies and consumer behaviour, often mentioned in the literature, have not been pointed as significant determinants during our survey. Over the long term (15 years), the results showed that factors related to agronomic management outweigh perceived risks and market-related considerations: plant diversification emerges as a strategy that facilitates pest management, reduced dependency on chemical inputs, and enhances livestock feed autonomy. However, the calculation of opportunity costs over a 25-year period for hedgerows showed that no valorisation scenario can fully offset the loss of productive area converted into hedgerows compared to specialized dairy farming. Among the options considered, enrolment in the CAP second pillar agri-environmental scheme (MAEC "Biodiversity") appeared to be the most profitable in terms of return on investment and opportunity cost.

Detailed results

Objective #1: Assessment of the effects of diversified low-input cropping systems and hedgerows, at different scales, on agroecosystem multifunctionality

To meet this objective, an assessment was conducted in 2024 of the multifunctionality of 24 winter cereal fields in the Zone Atelier Armorique. These fields varied in terms of crop diversity in rotation and landscape context, which included variations in hedgerow quantity. Field surveys and interviews with the farmers managing these fields enabled the production of a database comprising 23 indices used to generate indicators for ten functions (seven environmental functions, one agronomic function, and two socio-economic functions) and an average multifunctionality index (Table 1). We had the opportunity to collaborate with C. Mony,

an ecologist at UMR ECOBIO, which enabled us to include indices related to microbial diversity in our study, in addition to what was initially planned.

Table 1: List of indices and indicators used to characterise the environmental, agronomic and socio-economic performances of cropping systems.

Performances	Potential function	Proxies of function
Environmental	Nutrient cycling	pH
		Ratio carbon /nitrogen (C/N)
		Microbial biomass (mg/kg)
		Mineralization of carbone (mg/kg) and nitrogen (mg/kg)
	Carbon storage	Soil carbon content (%)
	Erosion control	Water-stable aggregate content (%)
	Regulation of crop pests	Carabid, spider and staphylinid activity density
		Aphidophagous hoverfly abundance
	Pest infestation	Weed cover (%)
	Pollination	Pollinating-insect abundance
Biodiversity conservation	Weed, carabid and spider species richness	
	Richness of bacteria and fungi taxonomic units	
	Richness of pollinating-insect morphogroups	
Agronomic	Agricultural production	Grain yield (t/ha)
		Grain protein content (%)
Socio-economic	Farmers' income	Semi-net margin (€)
	Farmers' labor	Cumulative number of working hours(h/ha)

In parallel with the production of this database, we documented the cereal crop management systems carried out by the farmers in the studied fields and characterized the landscape context of the fields within a radius of 1,000 m.

Effects of crop diversity in rotations and input levels used

The results showed that the agroecosystem multifunctionality index, as well as the single function values, do not vary according to the level of crop diversity in rotation. A tendency towards higher levels of agroecosystem multifunctionality was observed in systems characterized by highly diversified rotations. The levels of chemical input use had no effect on the agroecosystem multifunctionality index; however, they did impact the pollination function (higher in the case of high mineral and organic nitrogen inputs) and biodiversity conservation (lower in the case of high amounts of herbicides and fungicides used). The limited effects of the types of crop rotations and of the amount of inputs could be linked to insufficient variability in these practices within the sample of fields considered in the present study.

Effects of hedgerows at field borders

The results showed that the presence of a hedgerow at the field border had no effect on the agroecosystem multifunctionality index and had little overall influence on single functions. However, it resulted in higher levels of pollination, particularly in the immediate vicinity of the hedgerow (+23%), possibly due to the floral resources provided by the hedgerow to pollinating insects. The agricultural production function was also higher (+10%) in the presence of a hedgerow, suggesting a windbreak effect. With regard to the other functions studied, the absence of an effect could be linked to the variability in the plant composition and structure of the hedgerows studied, characteristics that could not be controlled when constructing the sample.

Effects of landscape heterogeneity

None of the landscape metrics tested had a significant effect on the agroecosystem multifunctionality index. However, the effects of landscape composition were observed for certain functions. Surprisingly, the nutrient cycling function was higher in landscapes with large amounts of semi-natural habitats. Crop diversity in the landscape had negative effects on crop pest control. Further analysis, testing the landscape effects on the indices comprising each

function, is needed to understand these effects. Finally, we did not observe any effect of the quantity of hedgerows and the percent cover of organic farming on the functions studied.

Objective #2: Barriers and drivers of plant diversification in the short and long term

In order to explore the barriers and drivers of plant diversification, semi-structured interviews were conducted with 11 farmers whose main production is distributed as follows: two dairy cattle and arable crops, one beef cattle, three mixed cattle and arable crops, one pig and arable crops, and four arable crops. The objective of the interviews was to identify the short- and long-term socio-economic and technical determinants, both internal and external to the farm, that act as barriers and drivers to plant diversification.

In addition to the usual questions posed in such interviews, respondents were presented with three hypothetical scenarios, derived from the study ‘Agricultures bretonnes en 2040’ (Chambres d’agriculture de Bretagne 2020), with the objective of focusing specifically on long-term prospects. These scenarios, designated as Trend, Low Carbon, and Territorialization, were developed to elicit projections regarding the future of plant diversification. A series of profitability indicators were computed over a 25-year period based on the compilation of positive and negative cashflows incurred by a farm in a specialized dairy system when planting and valuing hedgerows on 6% of its area. Thus, the farm benefited from the hedge-bonus of the CAP eco schemes. These calculations were based on a range of hypotheses concerning the planting, maintenance, and use of hedgerows. The objective of this analysis was to assess the long-term opportunity cost of hedgerows (Figure 1).

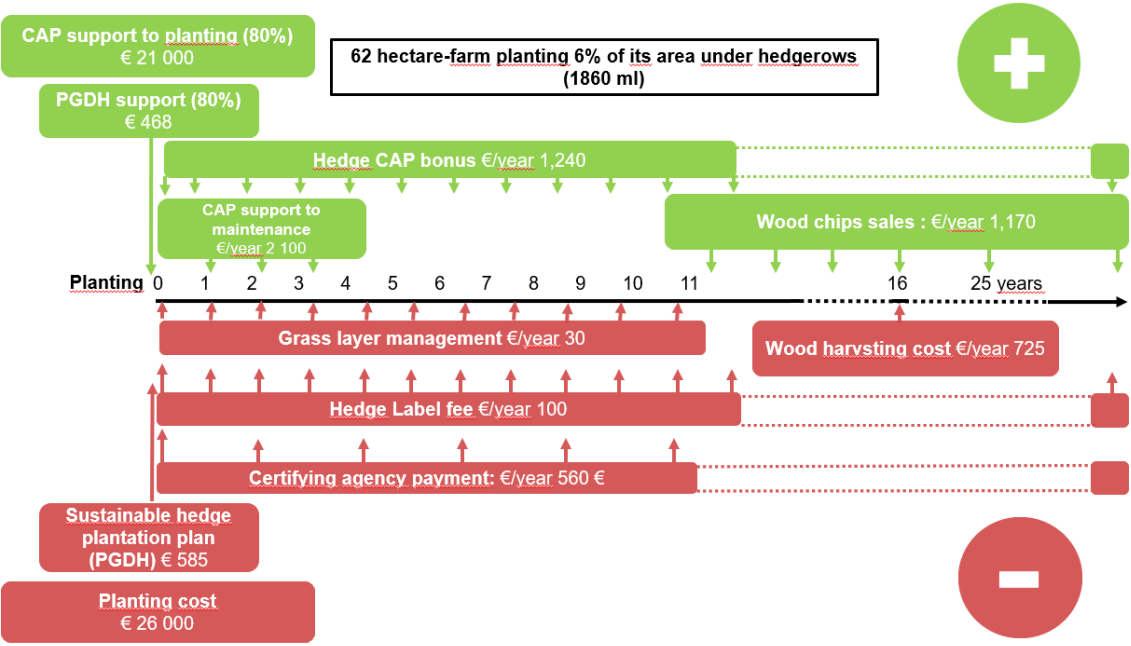


Figure 1. Cashflows over 25 years, for a 62 hectare-farm planting 6% of its area with hedgerows and valuing it in the form of wood chips.

The interviews showed that most of the perceived short-term barriers and drivers to plant diversification were internal to the farm, particularly in relation to standards and perceived risks, as well as market costs and benefits and agronomic management. None of the scenarios under consideration emerged as particularly favourable to plant diversification. The Low Carbon scenario was cited on 4 occasions out of 11, while the other two scenarios each received 3 citations. Projections made for the year 2040 indicated that agronomic management was the most frequently cited factor favouring plant diversification (crop protection, nutrient supply, reduced use of chemical inputs). Ecosystem services were consistently seen as long-term levers (i.e., carbon storage, water filtration and storage, protection of animals and crops,

erosion control, and biodiversity preservation). Constraints related to the maintenance and use of wood, as well as reluctance to include hedgerows in a regional initiative rather as opposed to a private endeavour, can also be obstacles.

The opportunity cost calculations showed that, under current investment subsidies, planting projects yielded higher profitability than projects aimed at maintaining existing hedgerows, except in cases where wood (chips) was harvested and sold. Furthermore, the opportunity cost of hedgerows compared to the status quo over a 25-year period was favourable: more than €1,200 per hectare and per year for an area corresponding to 6% of the Used Agricultural Area of 62 ha in a specialized dairy farming system. Maintenance costs remained very high. Finally, it appeared that the MAEC Biodiversity scheme was more attractive than the hedgerow bonus alone, if it was maintained over a 25-year period.

Conclusion

The results of the C-DIVERS project suggest that cropping systems characterized by diversified crop rotations and low levels of chemical inputs do not promote all of the expected performances for the development of multifunctional agroecosystems. However, they highlight that reducing the number of treatments locally, maintaining hedgerows around fields, and diversifying crops in the landscape mosaic remain levers for promoting certain ecological or agronomic performances of agroecosystems. With regard to socioeconomic and technical determinants, factors internal to the farm (i.e., farmer characteristics, costs and benefits, agronomic management) and external factors (i.e., public policies and sector structuring) are decisive in the adoption of plant diversification practices. In the long term, factors related to agronomic management outweigh perceived risks and market costs and benefits. However, the loss of productive land associated with the planting of hedgerows will be difficult to compensate for economically.

Scientific perspectives

Several research perspectives emerged at the end of the project:

Agroecosystem multifunctionality was assessed by calculating an average index for the levels of function indicators. However, this approach does not take into account farmers' potential expectations in terms of thresholds for certain functions (e.g., thresholds for crop pest infestation below which treatment is not necessary). We would like to explore this point further by considering decision trees based on expert opinion, scientific literature, and farmer expectations.

With regard to the factors impacting agroecosystem multifunctionality and functions, further analysis is needed to explore the local effects of hedgerows, taking into account the variability linked to their plant composition and structure (which is strongly linked to farmers' management practices). This issue will be addressed in 2026 by using existing data on the characteristics of hedgerows and associated biodiversity, collected in particular during the 2024 sampling campaign.

In addition, we would like to conduct a more in-depth analysis of the effects of crop diversity, input use levels, and hedgerows at different scales, not only on the indicators of functions, but also on the detailed proxies used to calculate these indicators. Indeed, aggregating proxy indices (by average or sum) to calculate indicators of functions could mask responses that are more meaningful from an ecological perspective. For example, certain functions, such as biodiversity conservation, pollination, or crop pest control, are based on biodiversity data that aggregates groups of species with contrasting life traits (e.g., predatory arthropods, soil microorganisms, vascular plants) and potentially contrasting responses to agricultural practices and landscape structures.

Furthermore, the limited effects of crop diversity and hedgerows observed in our study raise questions about the inherent limitations of assessing agroecosystem multifunctionality on the basis of a single year of observation. Indeed, these levers are likely to operate over longer periods and to impact the stability and resilience of agroecosystem functions rather than their

state at a given moment in time. Our study should therefore be replicated in the medium and long term.

We also identify research opportunities concerning the issue of work organization and risk management, which emerge as key factors in farmers' decisions, particularly with regard to hedgerows. On the one hand, socio-psychological factors (personal and social norms and attitudes toward risk) were recurring determinants in the interviews of farmers. On the other hand, diversification was cited more often as a factor that increases rather than reduces risk. Similarly, aspects related to work, managing peak periods, prioritizing work with animals, and human risks are recurring obstacles to plant diversification. Finally, the opportunity cost of hedgerows, calculated over a 25-year period, is positive and high in all scenarios, reminding us that the remuneration for the work involved in planting them would be negative. It therefore seems to us that all these aspects of plant diversification constitute a topic for future research. Furthermore, in terms of risks, our exploratory approaches do not take into account the long-term effects of climate change, which could shift the balance back in favor of hedgerows and overall plant diversification.