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# Designing carbon markets connecting farmers and companies: stakeholders claiming territorial-based devices to promote synergies between diverse environmental challenges

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## Abstract

Because of its capacity to provide numerous ecosystem services, agriculture is an essential lever in the fight against climate change and the preservation of biodiversity. However, trade-offs between economic strategies and environmental outputs, as well as between environmental challenges themselves, remain an important issue. In this paper, we seek to better understand how the different stakeholders manage these contradictions, based on a specific case study exploring the potential of setting up a local and voluntary carbon market in Western France involving farmers, companies, and local authorities. Applying a survey approach, we identify and discuss the preferences and trade-offs made by the potential stakeholders of this scheme. Our results show a strong preference for solutions that emphasize the provision of environmental co-benefits (biodiversity and landscapes) rather than strict carbon storage. We also show that criteria such as the duration of commitment or the scope given to the length of committed hedges are important components of stakeholders' preferences. Our results allow us to discuss the potential of different types of market systems, depending on traceability, governance, control method, and technical support, in relation to the respondents' heterogeneous preferences.

**Keywords** Carbon market · Agroecological scheme · Hedgerows · Ecosystem services · Governance

## Introduction

Developing an approach to managing the variety of environmental challenges is not an easy objective to achieve. In agriculture, production and land management practices are not always synergetic with climate change mitigation, biodiversity

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preservation, and water quality objectives. Furthermore, environmental performance does not always go hand in hand with better economic or work efficiency (Guyomard et al., 2013). The difficulty encountered whilst trying to achieve climate change goals, in addition to a diversity of other challenges, can sometimes lead to denial or avoidance attitudes (Norgaard, 2006; Thureau et al., 2014). How can the protagonists engage in ecological transition projects and manage these dilemmas? This research explores this question, relying on a combined sociological and economical approach to understanding perceptions related to market-based economic incentive schemes.

Our findings are based on a partnership research project aimed at designing a voluntary carbon market as a direct result of the carbon storage capacity of hedgerows. This research has been conducted in partnership with the *Chambre of Agriculture*, the main regional farming organization. In support of their own agenda to deploy innovative policy devices, our research team has focused on the issue of stakeholders' perceptions. Indeed, in the West of France, one of the important levers of carbon storage is the maintenance of hedgerows. The French Environmental Public Agency (ADEME) has identified hedgerows as one of the various ways to mitigate greenhouse gas emissions, particularly through carbon sequestration, in addition to other ecosystem services, including preventing erosion, regulating water flows, and improving biodiversity and landscape quality. This importance is endorsed in the greater western region of France, particularly in the Loire region and Brittany areas where hedgerow conservation is paramount (ADEME, 2015). In regard to the importance of hedgerows for carbon sequestration, these claims are also supported by research conducted on hedgerows, which has shown that the carbon stocks in soils observed in the vicinity of a hedgerow are higher than those observed in cultivated plots (Follain et al., 2007; Lacoste et al., 2015). Three reasons were given: (1) carbon inputs from the hedgerow's perennial vegetation are greater than those for annual crops, whose biomass is often partly exported; (2) deep mineral soil horizons below the hedgerow have a significant organic matter content relating to significant biological activity in the entire root depth of trees; (3) in situations subject to erosion, hedgerows can limit soil and carbon loss associated with eroded particles. Recent research measured the storage potential of hedgerows in the west of France (the Loire region and Brittany). The research confirmed the estimations previously proposed by Pellerin et al. (2013) of approximately 0.5  $\text{TeqCO}_2/100 \text{ m/year}$  for mixed hedgerows (in above-ground, root, and soil components). But not all hedgerows are equivalent. This level of storage greatly varies in relation to the plant species composition of hedgerows, the age of hedgerows, and the level of initial carbon stock in the soil (Viaud & Künnemann, 2021). In this research, we begin with the hypothesis of two types of hedgerows with divergent ecosystemic characteristics: mixed hedgerows (three strata hedges with tall trees, coppice, and shrubs), known for their high biodiversity benefit but with low efficiency for carbon storage, and, on the contrary, coppice hedgerows (hedges without high throws with tree crowns on more than 50% of the linear) considered to be very efficient in relation to carbon sequestration but with less biodiversity benefits.

Hence, designing a voluntary carbon market from hedgerows as a carbon sink creates an interesting opportunity to discuss the nature of the goods to be exchanged

(what kind of hedgerow should be promoted? For what environmental benefit? How should the transaction be evaluated? As a carbon unit or as an agronomic unit?). It also presents the opportunity to discuss ways to combine climate and biodiversity efficiencies. With this objective, we conducted a survey with farmers, companies, and local authorities in which they faced a dilemma. Should carbon sequestration be maximized or should trade-offs between diverse environmental issues be established? Nevertheless, it has to be highlighted that agronomic research conducted at the same time demonstrated that our starting hypothesis needs to be defined: if we exclude the above-ground components of hedgerows that are exploited (often burned) from the capacity to store additional carbon, then mixed hedgerows prove to be both the most efficient for carbon storage and for biodiversity preservation (Colombie et al., 2020). Although this simplifies stakeholder choice, the results of the research are nonetheless useful in clarifying their preferences and the conditions for creating climate schemes.

The paper is organized into four sections. The “[Carbon markets: specific agri-environmental schemes](#)” section describes the singularity of voluntary carbon markets with respect to existing policies that support hedgerow preservation in our regions. It allows us to highlight several issues inherent in the design of these markets: reaching an agreement in relation to the nature of goods to be exchanged, but also on the coordination strategies between stakeholders, particularly linking territorial practices to global climatic issues. The “[Method](#)” section describes our methodology in detail. The “[Results](#)” section presents our results and describes the preferences of the respondents in two main dimensions: the nature of the contract between farmers as sellers of carbon storage and companies as buyers; the organization structure (scale, intermediation). Finally, we discuss these results in the last section of the paper.

## Carbon markets: specific agri-environmental schemes

Various environmental policies promote the implementation and maintenance of hedgerows, such as those within the framework of the agri-environmental contractualization of the common agricultural policy (CAP) or planting support programs run by local authorities. In context of the rise of “market-based policies,” voluntary carbon markets appear as a possible way of valuing environmental carbon storage services. However, agriculture makes a modest contribution to compensation projects: 22% of the companies surveyed by Tronquet et al. (2017) say they compensate through agricultural projects, while 38% of the respondents would like to do so. At the beginning of this research, to our knowledge, there was no method to estimate carbon storage by hedgerows. As a result, individuals have been unable to access this “market.”

Designing such a scheme is not self-evident given the singularities of voluntary carbon markets. In the following, we discuss three key points raised in the literature on hedgerows maintenance schemes: (i) the multifunctional aspect of the object of the transaction; (ii) the articulation between the localized issue of agricultural practices and the more global issue of climate change and their different temporalities;

(iii) the limited role of public institutions. On this basis, we propose a framework for analyzing the mobilization of parties in voluntary carbon market schemes.

### **Consideration of a hedgerow from its carbon storage potential**

The ambition to enhance hedgerow management in rural territories is far from new. As McCollin, (2000) states, concern regarding hedgerow maintenance arose in the early part of the twentieth century. Following the American dustbowl episode, the focus of early conservation measures was often on the soil and the microclimate effect of hedgerows as shelterbelts. Biodiversity started to become a key issue supported by conservationists in the 1970s. Meanwhile, a variety of arguments were discussed, such as the visual benefits of hedgerows—for instance, using a case study from Brittany, Burel et al. (1995), show how hedgerows networks can be perceived as emblematic elements of the local cultural landscape and appreciated for their natural aspect—and more recently the agronomic, zootechnic, and economic benefits regarding grass and crop production or animal welfare. Using data from 60 studies, Bert et al. (2017) evaluate the simultaneous impact of hedgerows on different ecosystem services such as phosphorus and soil sediment interception or pest regulation. They highlight the ways in which diversified ecosystem services are delivered according to the characteristics of the hedgerows.

The role of hedgerows in carbon sequestration is of recent interest. If the concern for climate change mitigation emerged at the end of the last century, the identification of the maintenance of hedgerows as a key landscape component in climate change mitigation only emerged recently: in France, the publication of an INRAE study in 2013 on the effect of agricultural practices on climate change mitigation has been a starting point. The authors estimate that the development of hedgerows on agricultural land could allow for 1.2 MTeqCO<sub>2</sub> to be stored by 2030 in France, placing this measure at the 10th rank of the 26 measures studied (Pellerin et al., 2013). These results were later clarified by INRAE, highlighting that the maintenance or development of hedgerows does not appear to be the most effective measure for sequestering carbon (Pellerin et al., 2019). This finding leads us to believe that the functioning of a voluntary carbon market scheme depends on the perception of other co-benefits associated with hedgerow maintenance.

Thus, the first issue emerges in the design of market-based hedgerows maintenance schemes: the object of transaction appears to be specific and multifunctional. Indeed, far from constituting one single environmental service of carbon storage, hedgerows are characterized in a more complex way by a set of socio-environmental attributes that have been progressively recognized since the 1970s.

### **Spatial and temporal mismatches**

The second issue highlighted by the literature relates to the articulation of different spatial and temporal scales. Assessing the carbon storage of local practices is neither easy nor immediate. Hedgerows are the subject of several measurements. Bocage diagnoses or regional ecological plans propose measurements of hedgerow linear,

connectivity, and general state. These metrics are spatialized and adopted by local institutions (mainly at the intermunicipal and regional levels). The environmental impact of hedgerow presence is also the topic of studies relating to, for example, biodiversity (Pithon et al., 2018). These metrics are in this case again linked to spatialized, observable, and sensitive indicators such as the presence and diversity of birds. If biodiversity values associated with hedgerows are recognized on a global scale (Millennium Ecosystem Assessment), then there is the possibility that this environmental benefit can also be reflected on a local scale. The climate issue on this point is quite different. Observing carbon storage is difficult and involves the destruction of hedgerows and soil sampling. The effects of this storage contribute to a global climate process; link between local mitigation measures and evolution of climate is indirect.

In addition, knowledge related to ecosystem services is intermediated by assessment systems that were still to be constructed at the time of the survey. Several biodiversity promotion schemes have involved local stakeholders. One of the aims of these schemes was to produce knowledge for action. These schemes facilitate the link between expertise and practical knowledge and connect farmers and naturalists alike. They stage knowledge and stakeholders anchored in their territories. These social scenes also provide a place for strategic discussions that participate in building reasons to act in society for the preservation of a common good (Candau & Ruault, 2002; Pinton et al., 2007). What distinguishes climate schemes is the lack of local social scenes as centers for learning and dissemination of knowledge (Billaud, 2022; Thareau et al., 2015). Linking action at local scale with global climate issues is not self-evident. For Jean-Paul Billaud (2022), the ability of climate schemes to mobilize farmers depends on the resolution of two challenges: helping stakeholders to better understand the benefits to global climate and giving it a political meaning through its discussion at a local scale involving climate change specialists.

Moreover, the temporality of the change in hedgerow practices is another point of specification of our object. The already-existing hedgerows and the practical knowledge relative to their maintenance may create a path dependency likely to influence farmers' tradeoffs. Hanger-Kopp et al. (2022) define path dependency as "a process that has the property of staying on a particular path so that past decisions and contingent events predetermine what further steps may be taken." Self-reinforcing mechanisms, and among them learning processes, contribute to the reproduction of practices and diminish the range of likely alternatives. Rivaud & Mathé (2011) show that farmers are confronted with "limitations in terms of skills for implementing environmental standards in productive systems." The routines adopted by farmers have deprived them of certain tacit skills that are now necessary to implement practices promoted for their environmental virtues. The founding work of Henri Mendras and Forsé (1983) does not pose anything else: the implementation of new practices by farmers is linked to their compatibility with their values and skills or implies a long-term learning process (Darré, 1992; Turnheim et al., 2015). Here, the importance of mixed hedges both in local professional culture and in local policies promoting the hedgerows constitutes a cultural and political context likely to limit the adoption of new hedge management practices (coppice hedges). Furthermore, the provision of carbon storage through hedgerows design and maintenance implies

a long-term investment on the part of farmers, which may lead to unanticipated costs and raises the question of trust between the stakeholders. These considerations of temporality constitute a new specific singularity for this economic market.

### **Markets that operate without the intermediation of public institutions?**

Public schemes concerning hedgerow management issues have evolved. Until the 1990s, in France as in other European countries, the state assigned rural management strategies to landowners and farmers (McCollin, 2000). In the 1990s, European legislation invested environmental issues, demonstrated by the establishment of the first agri-environmental measures. Concerning hedges, it was reinforced in 2015 with the measure of “good agri-environmental condition” 7 (GAEC7): any beneficiary of aid from the Common Agricultural Policy has since then the obligation to maintain the hedges that are present on his farm (Magnin, 2019). In France, the 2000s were a period of reinforcement of the role played by local communities in the animation of territorialized environmental projects (Thareau & Fabry, 2013). It was at this time that the first territorial climate projects emerged (2004). In 2009, the French State created a pivotal role for large local authorities with regard to local environmental policies: it extended their area of competency into the field of climate and biodiversity (Bertrand, 2013). However, local authorities have not yet integrated carbon offsetting into their policies to fight climate change (ADEME, 2016).

In this context, carbon markets may be a unique mechanism for agriculture, particularly because they are a market-based instrument that could instigate private corporate investment in a political landscape dominated by a contractual logic between the French State or Europe and farmers (for example, AEMC for maintaining the hedgerows), public investment (such as planting subsidies from local communities), or coercive policies to protect hedgerows (for example, urban planning).

Therefore, access to this market, that is to say, the connection between sellers (farmers) and buyers (firms), is not self-evident. Alice Valiergue (2021) describes precisely what this work entails in the case of international voluntary carbon markets: it is a matter of establishing the legitimacy of the offer (carbon storage) and of the seller (the carbon credit producer or broker), of enhancing the quality of the product, and also of building a relationship between suppliers and buyers. These different tasks in the making of the market are largely the responsibility of the service providers. It can also embed the state in proposing frameworks for organizing markets (developing demand for compensation, standardizing metrics, and certifications) (Barral, 2022). In our case, this means establishing market links between farmers and third parties, sometimes outside the agricultural sector. A process of de-sectorization of agriculture is at work. It is characterized by the diversification of the forms of cooperation between farmers and other actors in the territories, in particular NGOs and local institutions (Anzalone & Mazaud, 2021; Thareau et al., 2020). However, few mechanisms bring together French farmers and businesses outside the agricultural sector. Making these carbon markets exist presupposes new forms of intermediation.



## **A framework for analyzing the mobilization of parties in voluntary carbon “market”**

Because of the specificities stated above, namely (i) the multifunctional aspect of the object of transaction, (ii) the complex spatial and temporal articulation of the targeted agricultural practices and the climatic stakes, and (iii) the need for intermediation, the notion of economic market itself may seem inappropriate to address the issue of carbon trading. Understanding the commitment of the parties in the trade thus implies paying attention to three dimensions: the values and judgments related to the offer; the transaction costs associated with the market; and finally, the forms of institutional arrangements.

Although agri-environmental schemes can interfere with cognitive and cultural processes and thus contribute to modifying the parties' judgments, this process is long and complex. The commitment of stakeholders to the system is therefore also linked to their initial representations of the usefulness of hedges and/or carbon markets. As far as farmers are concerned, various studies have pointed out the variety of perceived utilities of hedgerows (Alavoine-Mornas & Girard, 2017; Fleming et al., 2019), beyond the various ecosystem services previously stated: animal comfort, natural boundaries, forestalling land erosion, harboring beneficial organisms, wood production, etc. These perceptions are linked to the characteristics of the farms (hedgerow density and production systems) and to the local context (environmental schemes). Analyzing different low-carbon farming programs in Australia, Fleming et al. (2019) also point out that farmers view carbon programs as useful devices to market their products or provide a source of public recognition or accreditation. As far as companies are concerned, their involvement in environmental schemes has been studied in relation to corporate social responsibility (CSR) measures. Some authors interpret a company's commitment to sustainable development or CSR schemes as an attempt to enhance their image and gain a more competitive advantage (Cabagnols & Le Bas, 2008). Others seem to act for ethical reasons or to anticipate future regulations (Chenost et al., 2010). Moreover, depending on the size of the company, carbon offsetting takes on different meanings. For small companies, it is most often a matter of singling out an activist offer or of enhancing the value of their offer via carbon labels. Within large companies, it is often linked to intern challenges of promoting sustainable development strategies among salaries (Valiergue, 2021).

In line with Williamson's work on transaction costs economics, several authors have shown how the lack of consideration of transaction costs by policymakers can constitute a barrier to the involvement of farmers (Ducos et al., 2009; Espinosa-Goded et al., 2013; Falconer, 2000; Fleming et al., 2019). Indeed, the decision of farmers to engage in an environmental scheme generally depends on the associated compliance costs, including operational costs (technology and practices adaptation), level of income loss (which, in the case of carbon markets, could be offset by additional income resulting from the profit generated on the sale of carbon credits), and transaction costs that may themselves evolve over time (McCann et al., 2005). In the case of hedgerows maintenance schemes, planting costs and contractual commitment over time lead to the emergence of sunk costs that need to be taken into account by institutions. Studying the drivers of agro-environmental contract



adoption among 328 French farmers, Ducos and Dupraz (2007) show that a high level of asset specificities can be an obstacle to farmers' commitment as it leads to higher transaction costs. Farmers' sensitivity to transaction costs is accentuated by a potential distrust in the government or uncertainty regarding public decision process. Long-term institutional arrangements must then be designed for the transaction to occur. Research suggests that engagement of farmers within these arrangements is linked to contractual considerations such as the duration of the contract, time spent on non-operational aspects, level of payment, technical assistance, flexibility in relation to the requirements of the scheme, and flexibility with regard to the area included in the contract (Ruto & Garrod, 2009; Espinosa-Goded et al., 2010; Christensen et al., 2011; Siebert et al., 2006).

Some research explores more innovative schemes and questions the effects of forms of intermediation on stakeholder involvement. They demonstrate that the conditions of some schemes do influence stakeholder involvement: the strong involvement of an intermediary and trusting relations within the farming community (Magnin, 2020; Mariola, 2012). Schirpke et al. (2017) show that to succeed, these schemes should benefit from public support and involve human resources to conduct a participatory process. This process should be inclusive for all types of stakeholders, to understand and consider stakeholders' values and objectives, to identify local dynamics, and eventually produce trust. Lockie (2013) underlines that the success of schemes such as cap and trade regimes in GHG emissions depends on the legitimacy of the scheme: the success relies on a clear understanding of the ecosystem services in question as well as a transparent, robust and broadly accepted institutional and regulatory framework for monitoring and trading (see also Valiergue, 2021).

In conclusion, our literature review points out three dimensions that interfere with the implementation of market-based climate schemes dedicated to hedgerows preservation: (i) the parties, their practices, and their representations of the good and of the arrangement; (ii) the multifunctional nature of the exchanged good; and finally, (iii) the components of the intermediation arrangement (credibility assessment, management of spatial and temporal mismatches, linkage between parties). In line with these considerations, our research aims to clarify the conditions for creating market-based climate schemes dedicated to hedgerows preservation.

## Method

We have developed a prospective approach to innovative systems since these systems do not exist at the beginning of this research. We therefore chose to collect stakeholders' perceptions, relate them to their situations, and report on their stated preferences as developed in the literature on the use of stated preference methods to evaluate innovative systems (Powe, 2007; Birol & Koundouri, 2008; Bostan et al., 2020). Our research focused on three categories of stakeholders—farmers, companies, and local authorities—regarding the objective and conditions of participation in a carbon market. To do so, we conducted in 2018 and 2019 a survey of 88 respondents in 3 territories of Western France (22 companies, 45 farmers, and 21 local authorities) to

measure and explain their stated preferences. The results of this survey were consolidated into 3 focus groups, including firms, local representatives, and farmers.

### **Measuring relative preferences for an innovative scheme**

To enable respondents whose understanding of the carbon sequestration potential of hedgerows is minimal to invest in little-known carbon market schemes, we chose (i) to provide information on the carbon sequestration potential of hedgerows and carbon market schemes before and during the interview and (ii) to propose scheme scenarios and to test respondents' preferences for possible alternatives.

We presented the voluntary carbon market to the respondents as a device allowing companies, local authorities, and farmers to voluntarily exchange carbon credits resulting from the carbon stored by the hedgerows managed by farmers. This system brings together, through a contract, the buyers, i.e., companies and/or local authorities wishing to voluntarily offset their greenhouse gas emissions by purchasing carbon, and the sellers, i.e., farmers or local authorities managing hedgerows in their area. A third actor serving as an intermediary intervenes to support the actors, gather supply and demand, and to control the respect of the contracts.

The object of the contract, i.e., the carbon potential stored by a hedgerow, is described as coming from its root biomass as well as from the organic matter of the soil (excluding the aerial biomass used for energy or timber). This storage potential varies according to the type of hedge (with different environmental interests), its age, and the maintenance method.

Respondents' preferences regarding the objective of the contract, and thus in particular how carbon credits were associated or not with environmental co-benefits, were central to our research. It was measured by assessing the preferences of respondents between two types of hedgerows: mixed hedgerows are presented as hedgerows that moderately store carbon but generate multiple environmental co-benefits (biodiversity, landscape, water purification, and erosion control), and coppice hedgerows, which store more carbon but generate fewer environmental co-benefits. The estimated carbon storage was based on the knowledge available at the time of the survey. For both hedgerow maintenance and hedgerow planting, we reported to respondents a 15% higher storage capacity for coppiced hedgerows compared to mixed hedgerows (7.6  $\text{teqCO}_2/\text{km}/\text{year}$  for coppiced hedgerow maintenance and 6.6  $\text{teqCO}_2/\text{km}/\text{year}$  for mixed hedgerow maintenance; 11.4  $\text{teqCO}_2/\text{km}/\text{year}$  for coppice hedgerows planting and 9.9  $\text{teqCO}_2/\text{km}/\text{year}$  for mixed hedgerows planting). This additional carbon storage resulted in an increased remuneration for the farmer and an increased purchase price for the company or the local authority.

Three different questionnaires were designed and submitted to the three categories of respondents. Each questionnaire was structured into four sections: (1) the characteristics of the respondent and the entity (farm, company, and community), their relationship to the environment and climate mitigation strategies, (2) their knowledge of hedgerows and the carbon market, (3) their preferences toward different possible systems, evaluated on the basis of a set of cards based on the

**Table 1** Distribution of the sample by study area

Territories	Farmers	Companies	Local authorities
Pays des Mauges	18	9	4
Pays du Roi Morvan	16	2	5
Pays de la Vallée de la Sarthe	10	1	3
Outside territories	1	10	9
Total	<b>45</b>	<b>22</b>	<b>21</b>

discrete choice experiment (DCE)<sup>1</sup> method, and finally (4) the reasons for their preferences according to the different attributes of the system. The first three themes were mainly addressed through closed questions; the fourth was mainly addressed through open questions. The questionnaires were administered face to face. Answers were recorded and partially transcribed.

Several analytical methods were used to process the data collected. They consisted of statistical analyses of quantitative and qualitative data (AFCM, discrete choice methods) and qualitative analyses of responses to open-ended questions.

### A sampling of respondents affected by hedgerows or the climate

The aim of the sampling method was to test the possibility of creating a carbon market and its potential characteristics, even though the respondents were more inclined to engage in the scheme. We, therefore, constructed reasoned sampling based on two criteria for farmers (belonging to the study areas and prior participation in bocage or agri-environmental projects), two criteria for companies (link to the target territories and commitment to a diagnosis or carbon offset approach), and two criteria for local authorities (link to the target territories and field of activity: agriculture, climate energy, or environment). We sought to favor respondents who had initiated climate or agro-environmental initiatives in these three categories of respondents (Table 1).

The farmers surveyed are mainly male (35/45) aged around 50 years old, with education levels varying between secondary school and higher education. Farms have an average agricultural area (UAA) of 107 ha. A third of the respondents have obtained organic certification, and more than 41 of the 45 farms have already participated in other environmental schemes (AEM, tree planting program, etc.). This sample therefore corresponds to farms larger than the average in Western France (about 65 ha in Brittany and Pays de la Loire in 2017) and farmers more involved in environmental schemes (about 8% of farms are organic certified in these same regions in 2017).

The sample of companies is dominated by males (15 of 22) relatively young (9/22 are under 40 years of age) with high levels of education (master's degree level represents 68% of the respondents). The companies surveyed are divided between SMEs (nearly 9/22), FTEs (8/22), and large companies (5/22). There are no

<sup>1</sup> A method introduced by Louviere and Woodworth (1983) in environmental economics to assess the value of a property via its attributes or characteristics.

microenterprises with less than 10 employees. This sample therefore over-represents medium to large companies at the expense of companies with less than 10 employees. Indeed, at the national level, 96% of companies, excluding financial activities and insurance, are microenterprises, while large companies represent less than 1% of them (Insee, 2017). More than 18 of the 22 companies surveyed say they have carried out a diagnosis of their greenhouse gas emissions and undertaken actions to reduce their carbon footprint.

The sample of local authorities is composed of 10 elected officials and 11 agents. They are in charge of energy, sustainable development, or climate issues (7 of them) or involved in agricultural and agri-food issues (7 of them). They are elected or agents of the intermunicipalities of the survey areas, of the municipalities, or for a third of them, of other communities (nearby agglomerations, departmental councils). They are mainly male (15/22). The levels of education are generally high since a Master's degree represents more than half of the sample. More than 13 of the 21 local authorities surveyed did not carry out a greenhouse gas (GHG) emissions diagnosis, but 13 of them carried out a bocage diagnosis, which illustrates the interest shown in hedgerows.

### **Survey areas characterized by the density of hedgerows, the preexistence of hedgerow projects and the importance of livestock farming**

The three territories surveyed are included in the two regions of Brittany and Pays de Loire. These territories were chosen for their determination on energy and climate transition issues, which is reflected in the fact that these three have set up a climate local policy, but also for their longstanding work on bocage and carbon storage. In the three territories, the hedges traditionally present are mixed-hedges; these are the hedges promoted by the professional and local projects. Agriculture is very important in these three rural territories, with important production capacities. Production is generally oriented toward livestock (mainly dairy farming), poultry, and pig farming (Table 2).

## **Results**

### **High commitment linked with different views of local carbon markets**

We had chosen respondents a priori concerned with maintaining hedgerows or with climate change issues (which would tend to increase interest in our proposal); many of these respondents had already invested in hedgerow plantations or climate change systems (more than three-quarters of them). It was therefore far from certain that they would be interested in testing a new type of mechanism.

After describing the characteristics and main features of a local carbon market for hedgerows, we asked them, “*Would you be willing to engage in this type of scheme?*” Nearly 80% of respondents want to get involved, regardless of the type of individuals involved. This result is consistent with our sampling strategy and

**Table 2** Territory characteristics

Territories	Pays des Manges	Pays du Roi Morvan	Pays de la Vallée de la Sarthe
Number of residents	121,000	26,500	78,000
Surface area (km <sup>2</sup> )	1315	763	1104
UAA (utilized agricultural area) in ha and % of surface	103,663 79%	43,801 57%	70,773 64%
Hedgerow length (km) (in 2011)	10,343	4314	5098
Main production orientation	Livestock farming	Livestock farming	Livestock farming
Policies in place	<ul style="list-style-type: none"> <li>• Circular economy</li> <li>• Territorial Climate-Air-Energy Plan, initiated in 2003</li> <li>• PAT (territorial food program)</li> </ul>	<ul style="list-style-type: none"> <li>• Territorial Climate-Air-Energy Plan initiated in 2010</li> <li>• Hedgerow plantation programs (2003–2006 and 2011–2013)</li> </ul>	<ul style="list-style-type: none"> <li>• Territorial Climate-Air-Energy Plan initiated in 2009</li> <li>• CEP (Shared Energy Advisor)</li> </ul>

allowed us to question respondents about their preferences regarding the carbon market.

The reasons behind the respondents' commitment illuminates the significance of such a scheme. Local authorities see this scheme as a way to increase support for hedgerows preservation. The multiple advantages of the scheme, particularly in terms of ecosystem services (preservation of biodiversity and landscape quality, and therefore quality of life), appear to influence their commitment. Local authorities also underline the importance of these schemes in relation to stakeholders, who are encouraged to engage in climate and environmental issues, and in order to generate added value for the territory itself. These respondents more often project themselves as intermediaries in the market; only a third imagine themselves as intermediaries and buyers of carbon credits. For companies, engaging in a carbon offset market allows them to be part of a virtuous environmental approach and to establish their territorial anchorage, in addition to economic interests and positive spinoffs in terms of the company's image. Farmers mainly see it as an opportunity to better remunerate hedgerow maintenance, which many already do. Some are also motivated by environmental and climate ambition, by the possibility of increasing their social recognition, and by improving their hedgerow management. Respondents who are hesitant to engage in this scheme mainly say they lack information on the scheme (cost, relevance, interests, and actors involved) in order to be able to give their opinion.

### **A shared ambition to combine different environmental benefits: carbon storage, biodiversity, water quality, and landscapes**

The objective in these voluntary markets would be carbon sequestration. However, the definition of this objective can be clarified according to different dimensions, including the consideration of environmental co-benefits and the inclusion in the contract of requirements concerning the practical modalities of carbon sequestration.

We have chosen to measure respondents' preferences for different qualities of carbon credits through three indicators:

- Affiliation to environmental co-benefits was measured by assessing the preferences of respondents between two types of hedgerows: mixed hedgerows are presented as hedgerows that moderately store carbon but generate multiple environmental co-benefits (biodiversity, landscape, water purification, erosion control), and coppice hedgerows are presented as those that store more carbon but generate fewer environmental co-benefits.
- The duration of farmers' commitment (5, 15, or 30 years). A 5-year contract corresponds to the duration of the MAEC; 15 years is the time frame of the sustainable hedgerow management plan proposed by the professional organizations; finally, the 30-year duration seems coherent with the objective of long-term carbon storage and can be considered on the scale of a farmer's career.

- The proportion of hedgerow length is managed by the farmer. Either all the hedgerows present on the farm or part of his hedgerow length with the possibility of changing them (moving, grubbing up, and replanting).

Our survey shows a strong preference, from all types of respondents, for hedgerows with environmental co-benefits. Sixty-one of 86 respondents say they prefer this modality, while only 9 of them say they prefer coppice hedgerows. This preference is supported by the statistical analysis of the DCE (discrete choice experiment) (Coisson et al., 2019). For all types of respondents, this preference is explained by the perceived importance of other environmental issues: biodiversity in particular for companies, water in particular for local authorities, aesthetics, and biodiversity for farmers. Preference for mixed hedgerows is also linked to the desire to maintain existing types of hedgerows on farms or in the area and to implement previous hedgerow projects or policies (communities and farmers). Finally, farmers are interested in the economic co-benefits associated with mixed hedgerows: wood production and valorization.

Preferences are more heterogeneous with regard to the duration of the engagement and hedgerow length to be managed. A small majority of respondents prefer a 15-year commitment period, with very mixed responses for hedgerow length. We can thus distinguish four types of preferences concerning the contract objective.

- The whole length of a mixed hedgerow. The aim here is to support the creation or improvement of mixed hedgerows during a 15-year contract that covers the entire length of a farmer's hedgerow. For these respondents, it is a question of proposing a contract that is consistent with the ambition of storage in the medium or long term, with hedgerow maintenance cycles. The commitment of the entire length is a guarantee of maintaining hedgerows (for local authorities) and securing the scheme (for companies), whose main fear is that farmers will continue to pull up trees. Farmers consider that it is coherent and interesting to think globally about the management of hedgerows on their farm and that the commitment of the entire length is a guarantee of administrative simplicity.
- Latitude concerning mixed hedgerows. Here, too, it is a question of giving priority to the creation or improvement of mixed hedgerows, but this time the respondents prefer 5- or 15-year contracts and give priority to the possibility for farmers to lease only part of their hedgerow length or to be able to move the committed hedgerows. The aim is to enable farmers to commit themselves in stages, to test the scheme, but also to adapt it to changes on their farm, by allowing adjustments to the contractualized hedgerow length and by maintaining a certain freedom to manage their entire hedgerow length. This is the preferred contract for all categories of respondents. However, companies highlight the importance of implementing precise control over hedgerow length developments.
- Strong commitment regardless of the type of hedgerow. Respondents who prefer a long contract tend to also prefer a total commitment of the hedgerow's length. Farmers who prefer these contracts also want to create new hedgerows and not just improve on or manage existing ones. Respondents think it would



**Table 3** Preferences for contract types according to the respondents surveyed

Obs	Farmers	Local authorities	Companies	Total
The whole length of a mixed hedgerow	16	2	3	21
Latitude concerning mixed hedgerows	15	10	8	33
Strong commitment regardless of the type of hedgerow	6	1	4	11
Partial coppicing	2	2	4	8
Undecided	5	5	3	13
Total	44	20	22	86

be desirable to propose a highly engaging scheme to strengthen its credibility (companies, local authorities) and its impact in the fight against climate change. Farmers also underline that they do not plan to remove hedgerows, with or without contractualization. Finally, some mentioned the environmental challenge of maintaining ecological continuity, which justifies the use of the whole hedgerow length.

- **Partial coppicing.** This fourth type of contract is the only one that favors coppice hedgerows over commitment periods of 5 or 15 years and management of only part of the hedgerow's length. For these respondents, the challenge of rapidly storing carbon is a priority, and in this respect, justification lies in supporting the most efficient hedgerows only. For farmers, it is also the contract that appears to be the most profitable. In any case, the flexibility of the length of the hedgerow system used makes it possible to adapt to the challenges facing farms but also to other measures to fight climate change that could be developed, such as land exchange.

For the three variables tested, the level of indecision (cumulative nonresponse and “don't know” responses) is high, particularly for the sub-population of local authorities. Respondents explain that they do not feel competent to arbitrate or that they consider that farmers should be given the choice to adapt as best they can to their situations. It also concerns respondents who are not interested in the scheme (farmers and local authorities).

These preferences are different according to respondent type (Table 3). In particular, it should be noted that company preferences are more dispersed than for the other categories and that more community respondents are willing to give farmers some latitude. When analyzing farmers' perceptions, it appears that their experience with agri-environmental schemes and their perception of hedgerows explain their preferences. Organic farmers tend to prefer a strong commitment (whole length of a mixed hedgerow for long duration). Those who are undecided about the type of contract are often the same having an agronomic and zootechnical approach to hedgerows, both in terms of their perception of constraints and their usefulness, and also those not being very involved in agri-environmental schemes already.

#### **Four preference categories relating to the socio-economic attributes of the scheme**

We hypothesized that the conditions under which the voluntary carbon market mechanism was organized influenced the respondents' desire to engage in it and their willingness to pay or receive. We therefore asked the various respondents to give us their opinions on a set of possible scheme characteristics: the nature of the intermediate actor within the market and the methods of control, but also traceability (in a "traced" market, buyers identify carbon as coming from a group of farmers in a given area, and in return, these farmers know their buyers and each of the stakeholders), the possibility of benefiting from technical support, the nature of carbon credit certification, and finally, the way the price is constructed (indexed to another carbon market, at hedgerow maintenance cost or not indexed).

Respondents generally agree on the interest in implementing a traced market. A total of 61 respondents (over 86) prefer this modality compared to only 7 who prefer an untraced market. Local authorities and companies underline the importance of traceability in creating links between buyers and sellers, facilitating the monitoring and control of the action, and making it possible to communicate with employees or customers of companies by directly involving farmers. For farmers, this facilitates local recognition of their commitment to climate change issues. Some farmers prefer an untracked market. In this case, they consider that traceability is unnecessary since, on the contrary, the aggregation of carbon credits at a regional or national level makes it possible to simplify the scheme, reduce transaction costs, or facilitate access to the market.

For the other characteristics, the preferences appear more contrasted, and we distinguish four desirable profiles:

- **Local development system.** The voluntary market would strongly involve a local organization as a central actor in its governance. Control could mobilize buyers and sellers through a participatory guaranteed system. As the aim of the scheme is to support better management of hedgerows, it seems important here that there be technical support and that the price paid to farmers be indexed to the costs of maintaining the hedgerow.
- **Over-the-counter (OTC) contracts between companies and farmers in a simple and inexpensive system.** To implement a local carbon market, it must be simplified. Systematically, these respondents prefer uncomplicated forms of governance (no certification, no technical support); the preference is oriented toward a direct contractualization between companies and farmers, and for this, a link to a private intermediary is appropriate.
- **National aggregated environmental public policy scheme.** The local roots of the market and its traceability are of little importance to these respondents. The focus is on ensuring the implementation of reliable and credible storage practices, including certification and technical control. The state appears to be the right intermediary for this mechanism.
- **A local supply traced within the international carbon market.** For these respondents, the voluntary carbon markets resulting from hedgerows must be able to

**Table 4** Preferences of the different categories of respondents according to scheme type

Obs	Farmers	Local authorities	Companies	Total
Local development system	15	16	8	39
OTC contracts	8	4	8	20
National aggregated public scheme	11	0	1	12
Local supply within the international carbon market	10	0	5	15
Total	44	20	22	86

integrate into international markets. To do this, the price must be indexed to international prices. Nevertheless, companies want to be able to buy locally, and farmers want to rely on a local collective and make their area and region benefit from the scheme. Finally, these respondents are concerned about the credibility of the system; for this, they prefer a control that doubles the photo-interpretation of a technician's visit, and they are committed to setting up a reliable and serious certification system (international or national).

The stakeholders' preferences for these different types of schemes are very much shared, particularly for companies and farmers (Table 4). As far as farmers are concerned, this diversity of preferences partly reflects the diversity of farmers and their farms. Those who prefer a local development system type of scheme are mostly farmers who were established in the 1980s and 1990s, who run large farms (in terms of both utilized agricultural area and labor force), and who are involved in a replanting project, often supported by local authorities. Those who are more inclined to engage in OTC contracts are often farmers who have settled more recently (2000s) on smaller farms and are also the most skeptical respondents with regard to climate change. Those who prefer international schemes are often older farmers with large farms; they know the carbon markets and are convinced of the importance of farmers' mobilization to fight against climate change.

## Discussion—conclusion

Our research aimed to test the opportunity to implement voluntary carbon markets to support the maintenance of hedgerows in a context where a diversity of bocage support systems already exist (at national and local scales). Thus, aimed to clarify the form that this market could take.

### A market involving a bundle of environmental services

Most of the respondents surveyed are interested in this type of scheme. They prefer to enter a market that values mixed hedgerows. This result should be considered with caution as it concerns a statement of prospective intent and is based on a

selected sample of respondents interested in our objective. Nevertheless, this result is confirmed by the analysis of the Choice experiment associated with this survey, which succeeds in identifying a potential price range for trading carbon credits from hedgerows (Coisson et al., 2019). It is also confirmed by the results of the three focus groups within each territory, in which the respondents have highlighted that they are ready to commit to the establishment of local carbon markets.

Overcoming preference for a type of hedgerow, some contract attributes are designed in relation to the intended service. In particular, some farmers prefer to manage the entire length of their hedgerows in order to increase the ecosystemic service through better connectivity of hedgerows; some stakeholders prefer 15-year contracts in order to guarantee medium-term storage, which is consistent with the climate objective of the scheme. However, it should be emphasized that in most cases, these contract characteristics (linear and duration) are primarily designed to engage farmers, ensure scheme credibility, and minimize administrative complexity (Ruto & Garrod, 2009; Espinosa-Goded et al., 2010; Christensen et al., 2011; Siebert et al., 2006). This result illustrates the strong interplay between socio-economic factors and the enhancement of a bundle of ecosystem services (Raudsepp-Hearnea et al., 2010).

For the majority of stakeholders interviewed, the scheme should promote hedgerows, which produce a diversity of ecosystem services (ecological, landscape, and water-related). Moreover, for each type of respondent, the device is associated with a diversity of cobenefits: environmental, but also social, and economic. These results are consistent with the literature (Tronquet et al., 2017; Alavoine-Mornas & Girard, 2017; Cabagnols & Le Bas, 2008; Chenost et al., 2010; Fleming et al., 2019; Valiergue, 2021). Moreover, our results underline the strong preference for a market involving a bundle of environmental services, even if this means limiting the efficiency of the service in terms of carbon storage. This reflects a desire to integrate this scheme into the continuity of prior commitments (local authority policies, agricultural practices). Stakeholders thus participate in a form of erasure of the climate objective in the face of the ambition of environmental coherence, which constitutes a way of managing environmental injunctions that is often seen as contradictory by the respondents (Fleming et al., 2019; Thareau et al., 2014). It should be noted that it is within companies that we encounter the highest number of respondents concerned about the climate efficiency of the scheme, even if it means transforming local landscapes and practices. Less rooted in agri-environmental schemes, companies can be drivers of transformation in local practices.

### **Social links to ensure scheme credibility**

Our research identifies four forms of schemes which are desirable from the respondents' perspective: "local development system," "OTC contracts between companies and farmers in a simple and inexpensive system," "National aggregated environmental public policy scheme," and "Local supply traced within the international carbon market." What is at stake in respondents' preferences is the way in which trust between the parties and the credibility of the scheme are

organized: via a direct and local link in “local” and “over-the-counter” development schemes, or via national or international institutions in the “international” and “national market” schemes. Our results show a strong preference for the first option to ensure credibility of the scheme. Respondents prefer a scheme in which parties are involved via a contractual relationship to enable the evaluation of practices thus resulting in credibility. The implementation of this social link requires a connection from an intermediary (a local authority or a company) and for some, the coordination of a participative guaranteed system. In addition, the development of these links between buyers and sellers leads to other benefits, especially from the companies’ point of view: it makes it possible to communicate with employees or customers by directly involving farmers. In this way, the intermediation of public institutions (national or international) is relegated to the background. Respondents’ preferences for types of schemes are also explained by the anticipated transaction costs. Some respondents thus systematically prefer simplified intermediation arrangements in order to facilitate the commitment of the parties and maximize payment to the farmers providing the service.

The trade-offs of the different types of stakeholders are differentiated in this respect. Local authorities systematically prefer a scheme in which credibility relies on a social local link, and in most cases, a scheme in which they would play a decisive role in terms of governance. Companies also tend to prefer this type of intermediation, and more precisely an OTC contractual mechanism which is easily integrated into their business practices. On the contrary, farmers are more interested than others in schemes characterized by high intermediation that provides technical support and robust public certification of the effectiveness of the environmental service. These scheme attributes resemble the AEMs largely mobilized by these farmers. For all types of respondents, the compatibility of the scheme with their own experience helps to explain their preferences (Gherib & Berger-Douce, 2012; Spence et al., 2007).

Two other hypotheses can be suggested to understand the preference of farmers for systems based on strong public intermediation. Like Ducos and Dupraz (2007) before us, we observe that farmers’ sensibility to transaction costs is accentuated by distrust, in our case, distrust in the role of the farming sector in the climate change process... and thus conversely, their preference for schemes driven by national or international institutions seems to be linked to a strong belief in the responsibility of farmers to mitigate global warming. Moreover, the investments made by actors in credibility mechanisms (labels, certifications) are linked to the risk they perceive of engaging in a “contested” market (Valiergue, 2021). Here, this sensitivity to the risk of contestation is expressed more by farmers. Beyond the carbon markets, it is their own activity that they consider to be contested (Delanoue, 2018) and they express preferences marked by a greater demand for credibility. Finally, the preference for a system based on a metric certified by the State is sometimes associated with an ambition for up-scaling. In this respect, the farmers’ option should be nuanced: based on the analysis of ecological compensation markets in the USA, Stéphanie Barral shows that up-scaling requires a balance between precise metrics of environmental efficiency and transaction efficiency requirements (simplification) of the economic actors involved (Barral, 2022).

This research has been conducted in partnership with the *Chambre de Agriculture*, the main regional farming organization. At the end of the research, this organization proposed and obtained an official carbon storage estimation methodology for hedgerows (low carbon label). As a result, this farmers organization developed a tool for the credibility and legitimation of future carbon markets. Meanwhile, it allows stakeholders to use this label in different types of schemes, based or not on local social links as support to ensure other components of contract (control, implementation).

### **Anchoring the climate schemes in local territories**

The survey highlights a strong preference for a scheme anchored in local territories, via identification of storage origin (traced contracts) and/or via the linking of stakeholders (local governance of contracts between farmers and companies). This willingness for anchoring is partly due to the ecological co-benefits of hedgerows: local authorities in particular emphasize the promotion of ecological services in their area, which contribute to the enhancement of biodiversity, landscapes, and living conditions. Nevertheless, the articulation of biodiversity and climate services does not alone explain this ambition of territorialization of markets. Other local benefits are expected: economic (territorial added value; reinforcement of links with suppliers of agri-food companies) (Tronquet et al., 2017), social (improvement of company image with their consumers and employees, local social recognition of the climatic commitment of farmers) (Fleming et al., 2019), and politics (convergence with local environmental or food policies). However, our survey did not allow us to identify territorial specifications relating either to the object of the contract or to the conditions of intermediation between parties.

Two prominent characteristics of the preferred schemes should be highlighted: the involvement of an on-site specialist and the facilitation of local dialogue between stakeholders. In most of the envisaged schemes, specialists appear as necessary figures to support farmers in hedgerow maintenance in order to guarantee the effectiveness of carbon storage services. Therefore, they seem to us to be an essential component of the schemes in order to create an intelligible relationship between hedgerow maintenance practices and climate change issues. They would promote local learning and an enlightened commitment to climate change (Billaud, 2022; Thareau et al., 2015). In most of the envisaged schemes, means to connect stakeholders are expected at local scale. Here again, these social interactions seem to us to be an important component of the schemes to provide political meaning to stakeholder involvement (Billaud, 2022).

Surprisingly, the objective to find new connections between farmers and enterprises in a local and communitarianism scheme seems less affirmed by farmers than by companies. Farmers concerned with reducing the transaction costs of the schemes and achieving a minimum supply on the carbon markets tended to prefer regional scales of market organization. After this research, several professional agricultural organizations are implementing schemes to promote payments for ecosystem services between farmers and companies, among which carbon storage is one.

Some are initiating schemes on a small scale (inter-municipalities); the partners in the research project presented here have focused on setting up a regional scheme. Thus, dealing with farmers' preferences and the anchoring issues highlighted by the research, they execute a regional association. Within this association, and thus at the regional level, representatives of companies, farmers, climate, and environmental causes (NGOs) are invited to debate, at a strategic level, about the contribution of agriculture to ecological services. At the same time, the association offers technical support for writing contracts and connects farmers and companies in the implementation of localized service contracts.

### **Inertia and renewal of transitional measures toward agro-ecology**

Our research aims to shed light on the development of an innovative scheme for the valorization of ecosystem services. However, it also highlights a certain inertia or path dependency in the preferences of farmers and local authorities (with regard to both the objectives and mechanisms of the scheme). The respondents' preferences reflect visions of the system's anchoring in political existing strategies at different scales: in the context of territorial projects (local development) or in relation to national policies, created or not created in the context of the COP (national mechanism and international market). This inertia raises questions about the way in which the parties can use this device: will these carbon markets only be an opportunity to support projects or practices that are already underway? To finance the European obligation to maintain hedgerows? In the proposed scheme, companies are new players. Like Tronquet et al. (2017), our results indicate that agri-food companies are not more inclined to engage in these markets than companies in other sectors. If the effects of these new market relations have yet to be examined from the point of view of the new forms of dependence that they imply (Debril et al., 2016), the commitment of companies appears to us as factors for renewal and social innovation in a context of a profusion of agri-environmental measures to maintain hedgerows. With firms' commitment, two major challenges are affirmed: the desire to anchor the system in the territories via direct links between buyers and sellers and the ambition of measurable climate efficiency. These local carbon markets could contribute to reorient carbon investments, historically more forest-oriented, to the agricultural sector which faces budgetary and social difficulties. They could also make it possible to create mixed workspaces in the evolution of agricultural models and practices, which mobilize new stakeholders (companies) and seem to be able to contribute to improving knowledge and recognition of the role of farmers in their territories.

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**Data availability** The datasets generated during and/or analyzed during the current study are not publicly available due to the difficulty of efficient anonymization, but are available from the corresponding author on reasonable request.

**Code availability** Not applicable.

## Declarations

**Ethics approval** The research meets ethical requirements and protects the welfare of study participants.

**Consent to participate** Respondents were informed of the purpose of the research and how the data collected would be processed. No sensitive data was collected. However, as the data collection began before the implementation of the RGPD, the authors did not collect and retain the explicit consent of the respondents.

**Consent for publication** The authors have permission to publish research findings.

**Competing interests** The authors declare no competing interests.

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