CONSOLE

CONtract Solutions for Effective and lasting delivery of agri-environmental-climate public goods by EU agriculture and forestry

Research and Innovation action: H2020 - GA 817949

Modelling land tenure and land dynamics in AECPGs provision

Reports on the role of land tenure and land dynamics in AECPGs provision (T4.2)

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Contributors	

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QUALITY ASSURANCE PROCEDURES

An internal review and validation process were applied to ensure the quality and correctness of the current deliverable. Draft version was developed by Alice Issanchou.

TABLE REVISION HISTORY DELIVERABLE

Row	Version	Date	Reviewers	Description
1	V1.0			Sending the first draft to UNIBO be reviewed
2	V1.0			Review with few changes and recommendations

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Project Consortium

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3	CONSORZIO DELLA BONIFICA DELLA ROMAGNA OCCIDENTALE	IT
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1 Introduction

1.1 Scope of Task 4.2

In this task, we focus on one of the contract solutions envisaged in WP1: land tenure contractual solutions. Land tenure-based contracts are contracts including land tenure arrangements with environmental clauses.

The objective of Task 4.2 "**Modelling land tenure and land dynamics in AECPGs provision** " is to evaluate how the success of contract solutions is affected by different land tenure systems and how different contract solutions can affect land tenure and land markets.

In particular, this task focuses on:

a) How specific environmental lease contracts can be designed to promote environmental-friendly land use.

b) How the success of contract solutions is affected by different land tenure systems.

c) How different contract solutions can affect land tenure and land markets.

In accordance to the objectives of WP4 (simulations and performance of new contract solutions), modelling exercises are built upon the work carried out in WP1, WP2 and WP3 – respectively addressing the development of end-users-led contractual framework ; diagnostics of existing experiences on agri-environmental and climatic public goods (AECPG) and feasibility of new contract solutions for farmers and other stakeholders. In particular, WP1 and WP2 contributed to propose a theoretical set up of the models developed, while WP3 provided data. The models aim at understanding how contract solutions work and interact with the context and their anticipated results, with a focus on land tenure systems and land markets. When possible, models were complemented with sustainability indicators assessing performance and/or environmental impacts of the contractual solutions.

1.2 Deliverable outline

In this deliverable, we propose to report results of simulations and performance evaluations related to land tenure and land dynamics that have been conducted by the project partners involved in Task 4.2.

In the first part, we propose an agent-based model to investigate the design of environmental lease contracts that promote environmental-friendly land use. The effect of different contract types on a specific AECPG provision is tested, here an increase in biodiversity through the implementation of extensive grassland.

In the second part, we investigate whether land tenure status may have a differentiated impact on the adoption of an innovative result-based AECM compared to conventional action-based AECMs. We consider in particular the

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level of the land rent, assuming it reflects the agricultural productivity of the land enrolled, and the land tenure status (proportion of land rented). To do that, we identify a panel of observations from the Farm Accountancy Data Network (FADN) of farms (potentially) eligible to RB AECM during the last CAP programming period. We apply two Probit models to estimate on the one hand the probability to participate in a RB AECM, and on the other hand the probability to participate exclusively in action-based AECM.

In the third part, the impact of contract solution on land abandonment and land demand is addressed through the analysis of the effects of entire common agricultural policy (CAP) payments to prevent soil erosion due to climate change in hilly and mountainous areas. We consider explicitly the effects of an instrumental mix of policy on marginal land abandonment, in particular in Ligurian territories. The different policy mix impacts on land demand are simulated, using a mathematical programming model. The farmers' behaviour is simulated considering different combinations of environmental demand implementation, such as enhanced conditionality, eco-schemes or agri-environmental schemes.

2 How specific environmental lease contracts can be designed to promote environmental-friendly land use: simulation of land tenure contracts (VU)

2.1 Introduction

2.1.1 Context

The expansion of intensive agriculture in Europe has resulted in a decline in biodiversity (Benton, Vickery, and Wilson 2003). Specifically, farmland bird populations and insects have seen rapid losses (Donald, Green, and Heath 2001; Benton et al. 2002). A major influence on this decline has been the implementation of large monocultures of intensively managed grassland, which replaced their habitat consisting of herb-rich meadows (Kentie et al. 2015).

Dairy farmers who manage grasslands are inclined to strive for the highest possible production level in order to cover their costs, which decreases incentives to make adjustments in regard to the quality of biodiversity, as implementing measurements such as extensive grassland can decrease the production capacity of the land (Westerink et al. 2018). As financing costs are increasing for farmers, specifically for dairy farmers who make up around 60% of the agricultural land in the Netherlands, (Jukema, Ramaekers, and Berkhout 2020; Vink and Boezeman 2018), Agri-Environment Schemes (AES) are implemented to support farmers to adopt a more extensive farming style to combat biodiversity decline.

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Within an AES a farmer receives compensation to increase incentives to take measurements on their land in regard to the quality of environmental public goods. In 2016, 5.267 of the 55.681 Agricultural companies in the Netherlands had contracts for agricultural nature conservation with (semi-)governmental parties such as the Ministry of LNV, Staatsbosbeheer or Natuurmonumenten (CBS Statline in Handboek melkveehouderij). Currently in the Netherlands farmers can participate in collective AES. This means that instead of the farmers entering into a contract directly with the government, the agricultural collective is the beneficiary of the subsidy and is responsible for realizing the AES together with the farmers (Barghusen et al. 2021).

Next to contracts with governmental organizations, there are possibilities for tenure contracts with other land owners. For investors, increasing land prices means buying agricultural areas has become an appealing investment. For these investors, the long-term return of the investment is the prime motivation. As a result, they are more likely to be satisfied with a lower short-term return and often tenure the land under a long-term tenure contract (Silvis and Voskuilen 2018). This is believed to be attractive to farmers as longer contracts provide more security. Additionally, more security in continuing the use of the land increases incentives for investing in sustainable land (Silvis and Voskuilen 2018). Within these contracts, there are also monetary benefits that can incentivize farmers to participate. Some institutional investors of agricultural land for instance starting to implement environmental land tenure contracts that focus on sustainable farming in which, next to longer contracts, in return for certain measurements, the farmers receives a 5 to 10 percent discount on the tenure (Dedeurwaerdere et al. 2016; Runhaar et al. 2017) (NOS, 2020).

These tenure contracts interact in a complex way with other initiatives to increases AES delivery. Since 2016, AES implementation is more and more coordinated through big collectives of farmers, who, based on province-level (NUTS2 region) planning, jointly specify and implement measures.

2.1.2 Aim of the research

Environmental tenure contracts could potentially be promising for more sustainable farming. However, little research has yet been conducted to analyze the potential impact on land use change. The interaction among farmers and the interaction between individual contracts and collective contracts is even less clear. This research aims to design an agent-based model (ABM) of environmental land tenure contracts (TLC) in Agri-Environmental Climate Public Goods (AECPG) provision to test the effect of different contract types on the implementation of extensive grassland in relation to the quality of biodiversity. This is further elaborated with a model-based evaluation of TLC and collective contracts (D4.3).

2.2 Modelled area

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The area modelled for the study is situated in the north west of Friesland, a province in the northern part of the Netherlands (see Figure 1). It is used as an example to provide insights into potential land use changes as a result of varying design of land tenure contract characteristics. The area is regarded as suitable for the purpose of the study as it contains a mixture of grassland and cropland, a large part of the open grassland is labelled as suitable for meadow birds and there is already some nature conservation occurring.

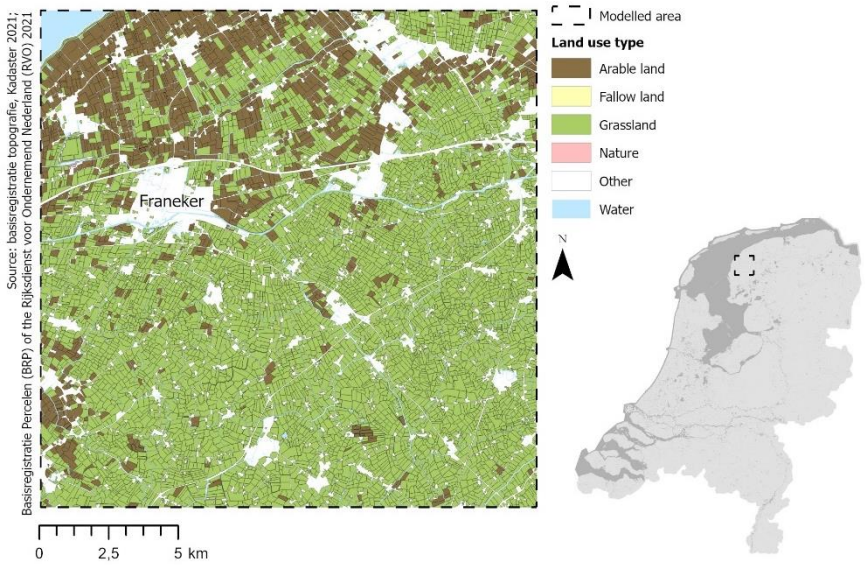

Figure 1: Modelled area

The study focuses on tenured land. As can be observed in **Errore. L'origine riferimento non è stata trovata.** , 25.8% of the agricultural land in the province of Friesland is tenured under tenure contracts shorted than 26 years. Most of these contracts are regular tenure, followed by liberalized tenure contracts (shorted than 6 years) and one-off tenure contracts. This is relatively similar to the total tenured land in the Netherlands, however the land tenured under long-term contracts is slightly higher compared to the country's average.

	The Netherlands		*Friesland*	
	Absolute	*%*	*Absolute*	*%*
Ownership	1036395	57,4	136450	60,8
Long term tenure (> 26 years)	47170	2,6	13223	5,9
Tenure (< 26 years).	480170	26,6	57967	25,8
Regular tenure	*223656*	*12,4*	*30292*	*13,5*
Liberalized tenure (< 6 years)	*13774*	*7,3*	*12114*	*5,4*
one off tenure	*91087*	*5,0*	*11480*	*5,1*
other	*34093*	*1,9*	*4081*	*1,8*
Other	240636	13,3	16669	7,4
Total agricultural land	1804374	100	224310	100,0

Table 1: Distribution of agricultural land usage type in the Netherlands and Friesland

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2.3 Conceptual framework

2.3.1 Farmer decision making

Various studies have analysed the factors of influence in farmer's decision on becoming more nature inclusive. Their decision-making is based on various factors which can be divided into different parts. We here make a distinction based on economic needs, personal needs, habitual learning and social interaction. Also discussed is the difference between behavioural intention and behavioural achievements.

With regards to economic needs, the costs for implementing measures play a role. Farmers might be motivated to participate in collective AES due to governmental *compensation payments*, which are the most important economic benefit (Dedeurwaerdere et al. 2016; Runhaar et al. 2017). These should be large enough to cover income decreases, including hidden costs (Westerink et al. 2018) and transaction costs (Sutherland et al. 2012; Tacconi, Mahanty, and Suich 2013; Prager 2015b).

However, (Kolinjivadi et al. 2019) highlighted the fact that financial rewards alone do not explain motivation. In a study of Dutch farmers, (W. F. A. van Dijk et al. 2015) found that perceived profitability had no significant influence on their intention to participate. Conditionality is also discussed in the context of payments (Lokhorst et al. 2011). (Groeneveld et al. 2019) stated that, in a system with a participation threshold but no additional incentive, there is a risk that if participation levels fail to reach the threshold, initially motivated participants may drop out. We expect that various motivations are interrelated, following (Siebert, Toogood, and Knierim 2006), who published a review of studies dealing with different aspects of farmers' motivation for individual AES to argue that there was often an interaction of agronomic, cultural, social, and psychological factors, all of which were affected by location and specific context. For the Netherlands, farmers' motivation to participate in the former individual AES was found to be not only influenced by monetary rewards, but also by attitude towards conservation (Lokhorst et al. 2011).

Farmers might be motivated due to problem awareness, which subsequently contributes to a personal norm that promotes participation in collective AES. Problem awareness is less of a driver as such, but instead a base to understand the need for behavioral change. It comprises *problem knowledge* and *action knowledge* (see (Hamann, Baumann, and Löschinger 2016). This ideally integrates knowledge about the relationship of agricultural management with biodiversity and ecosystems at a landscape scale. (Riley et al. 2018) observed that, although farmers were parties to the contract, they didn't know about the impact of their management on the wider landscape (see also Emery and Franks, 2012).

According to Stobbelaar et al. (2009), intrinsically motivated farmers who value nature highly are more likely to internalize policies. Increasing the environmental

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values of farmers can be triggered through communication among farmers as well as between farmers and other stakeholders, and feedback loops that could spark enthusiasm for conservation (Prager 2015a; 2015b).

Farmers' perception of responsibility further depends on their *self-identity* (see (Hamann, Baumann, and Löschinger 2016). They are experts on the specific needs of management for their lands and thus value their autonomy (Wynne-Jones 2017; Riley et al. 2018). Collective AES might be associated with increased control by public agencies or other farmers, which could result in reluctance (Villanueva et al. 2015; Nilsson et al. 2019). AES, several authors have highlighted the involvement of farmers in the program's design and the chance to implement the regulations flexibly (Emery and Franks 2012; Prager 2015a). Advisors should facilitate knowledge exchange rather than top-down knowledge transmission (Blackstock et al. 2010; Mills et al. 2011). Other authors have highlighted the importance of identification with the landscape (Westerink et al. 2018) or the region (Prager 2015a), and a sense of responsibility and service to the community to maintain the landscape (Wynne-Jones 2017) as additional facets of farmers' self-identity. Supporting an identity as landscape managers by means of framing and labeling was observed to increase the participation of Dutch farmers in measures that required more effort, such as bird protection (W. F. A. van Dijk et al. 2015; W. F. van Dijk et al. 2016).

Related to the knowledge of the farmers is the reinforcement learning effect. The CONSOLE survey demonstrates that farmers who previously participated in an AES are more positive towards participating again or expanding.

According to the theory of planned behavior by (Ajzen 1991), behavioral intention and perceived behavioral options can together predict behavioral achievement. Farmers who state they want to be a part of a contract are likely to put in more effort to be in a contract, compared to farmers who state they do not want to be a part of it, but this does not mean they will actually participate. (Ajzen 1991) collected 17 studies for which the average correlation between the intention of the behavior and actual behavior was 0.51.

Apart from existing or evolving group norms of duty to engage in collective AES, farmers might also be motivated through others' actual engagement, e.g. neighboring farmers acting as social role models (see (Hamann, Baumann, and Löschinger 2016). The *peer pressure* a farmer perceives can, however, encourage or hinder participation, depending on the local context (Blackstock et al. 2010; Emery and Franks 2012; Taylor and Van Grieken 2015; Josefsson et al. 2017). The desire for social approval, respect, and a good reputation can motivate individual farmers to behave like the peers they perceive as 'good' farmers (Sutherland et al. 2012; Kolinjivadi et al. 2019). Maintaining their own reputation is another attribute referring to the concept of social capital and related to trust and reciprocity (Ahn and Ostrom 2002). Communication of detailed monitoring data that relays others' contributions (Yoder and Chowdhury 2018), peer monitoring, and events of peer-to-peer learning (Taylor

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and Van Grieken 2015; Dedeurwaerdere et al. 2016) can also maintain a positive peer pressure.

2.4 Methods

To develop the ABM the CONSOLE survey is used, satellite imagery of the area to determine which plots contain extensive grassland and information on the location and size of farms. Farmer behaviour theory is combined with an analysis of the survey data to group farmers and determine contract characteristics. Consequently, the ABM model is designed, parameterized with the survey data and developed in NetLogo 6.2.2. What follows is an analysis of the scenarios and sensitivity analysis.

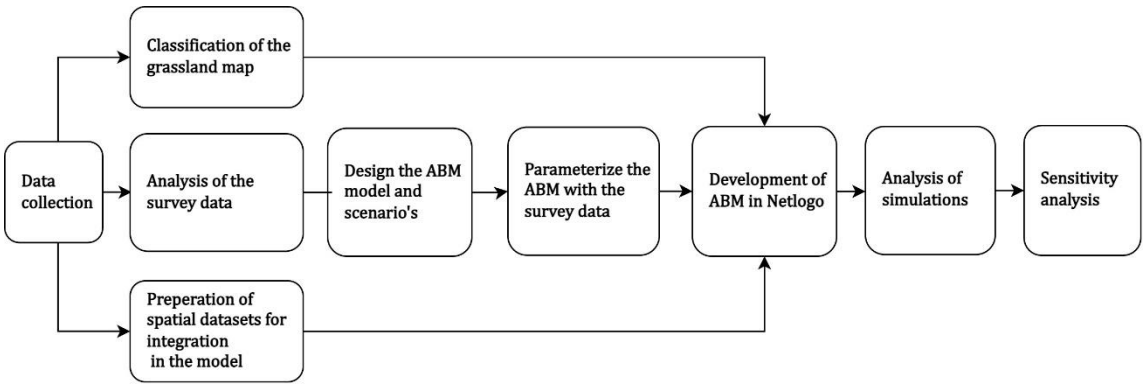

Figure 2: Research steps

2.5 Data collection

2.5.1 Spatial data

Table 2 contains an overview of the spatial data used in the ABM. Public spatial data of areas with suitable conditions for meadow birds is integrated, areas labelled as nature conservation, and a crop plot dataset containing the location of the plots and crop type. Access to data on the type of usage of the land (e.g. ownership of tenure) and location of farms is provided by RVO. This data has a disclaimer as it is directly based on the reporting of farmers themselves and not verified by a second party.

To determine the location of species-rich grassland Sentinel imagery is collected and classified. According to Bekkema and Eleveld (2018) imagery in spring, before the first mowing date provides the most accurate result. In this study, an image of the 31 of March is used as it is cloud-free.

Dataset	*Source*	*Access*
Meadow bird opportunities	Friesland (province)	Public
Nature conservation plans (natuurbeheerplannen 2021)	Friesland (province)	Public

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Basic registration of crop parcels (Basisregistratie gewaspercelen BRP 2021)	Ministry of Economics (State)	Public
Basic registration of businesses (Basis bedrijvenregister, BBR 2021)	Rijksdienst voor Ondernemend Nederland, RVO - Minstry of Economics (state)	Restricted
Sentinel imagery 2021-03-31		Public

Table 2: Spatial input data

2.5.1.1. Preparation of the species-rich grassland map

To determine which plots contain species-rich grassland a classification with S2REP is produced. S2REP uses RED (Band 4), VNIR (band 5), VNIR2 (band 6) and VNIR3 (band 7) and is both sensitive to the growth status and the chlorophyll content of the crop (Guyot and Baret 1988). For vegetated areas, the range of S2REP lies between 690 and 740 nm (ESA Step Forum, in Bekkema and Eleveld 2018). The higher the S2REP value, the higher the chlorophyll content (Guyot and Baret 1988).

In **Errore. L'origine riferimento non è stata trovata.**, on the left the results of the S2REP classification are demonstrated. Areas labelled as nature conservation in general have lower S2REP values compared to other areas which is the result of more extensive grassland management practices. The average S2REP value of the plots within nature conservation areas is 724 while the average 2REP value of non-nature conservation areas is 719. Consequently, grassland plots are classified as either extensive grassland or monoculture by determining the frequency of the average S2REP values of plots within nature conservation areas and non-nature conservation areas. The overlap between the frequency graphs happens at 721. Consequently, plots with a value lower than 721 are regarded as monoculture, and higher than 721 as extensive. This results in the classification demonstrated on the left in **Errore. L'origine riferimento non è stata trovata.**.

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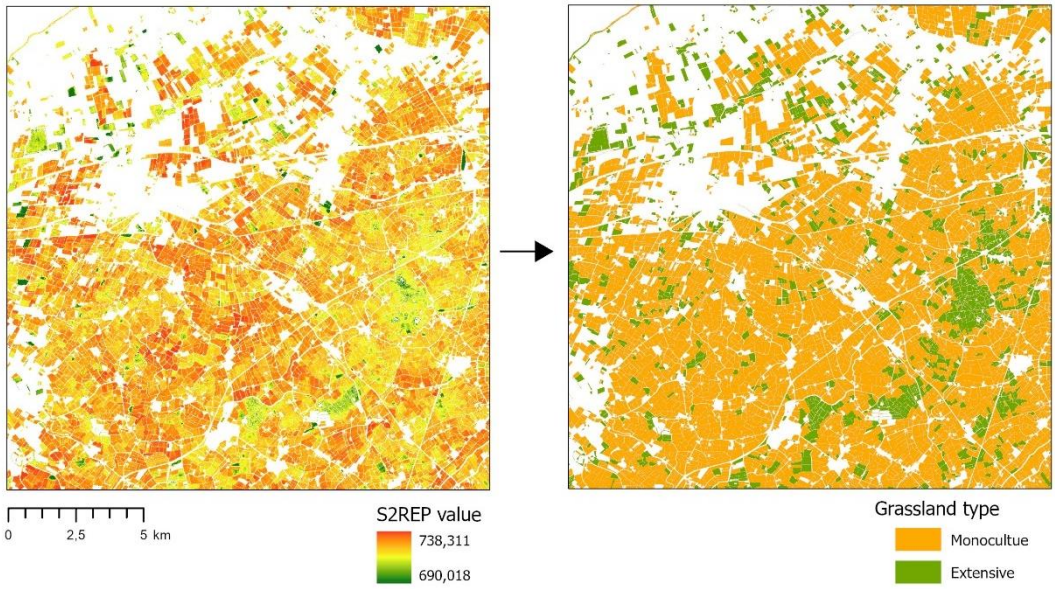

Figure 3: Classification SREP and grassland type of the modelled area

To validate the map a site-specific accuracy assessment is applied with the use of high spatial resolution imagery (0.08 m), collected the 20th of February 2021. A random selection of 10% of all the plots classified as extensive and 10% of the plots classified as monoculture is acquired and based on the interpretation of the high-resolution imagery classified as extensive or monoculture. With the reference data, an error matrix can be produced which demonstrates how effectively plots are put in the correct grassland class (Congalton 2001). The resulting overall accuracy of the grassland map is 0.826.

2.5.2 Survey data

The CONSOLE survey used is conducted in 2021 with 264 farmers throughout the Netherlands. In the parameterization of the ABM only the answers of 71 dairy farmers who tenure land are included, as these would be the farmers to potentially implement extensive grassland on tenured land.

Included in the survey are questions on the likelihood of participation, how much certain contract elements increase or decrease participation, and open questions in which farmers can describe why they would or wouldn't participate in the contract, The open answers are coded and quantified in order to determine which elements are mentioned most often.

2.6 Model description

In Figure 4 an overview of the model is shown. In the following parts the different decisions in the model are explained in more detail.

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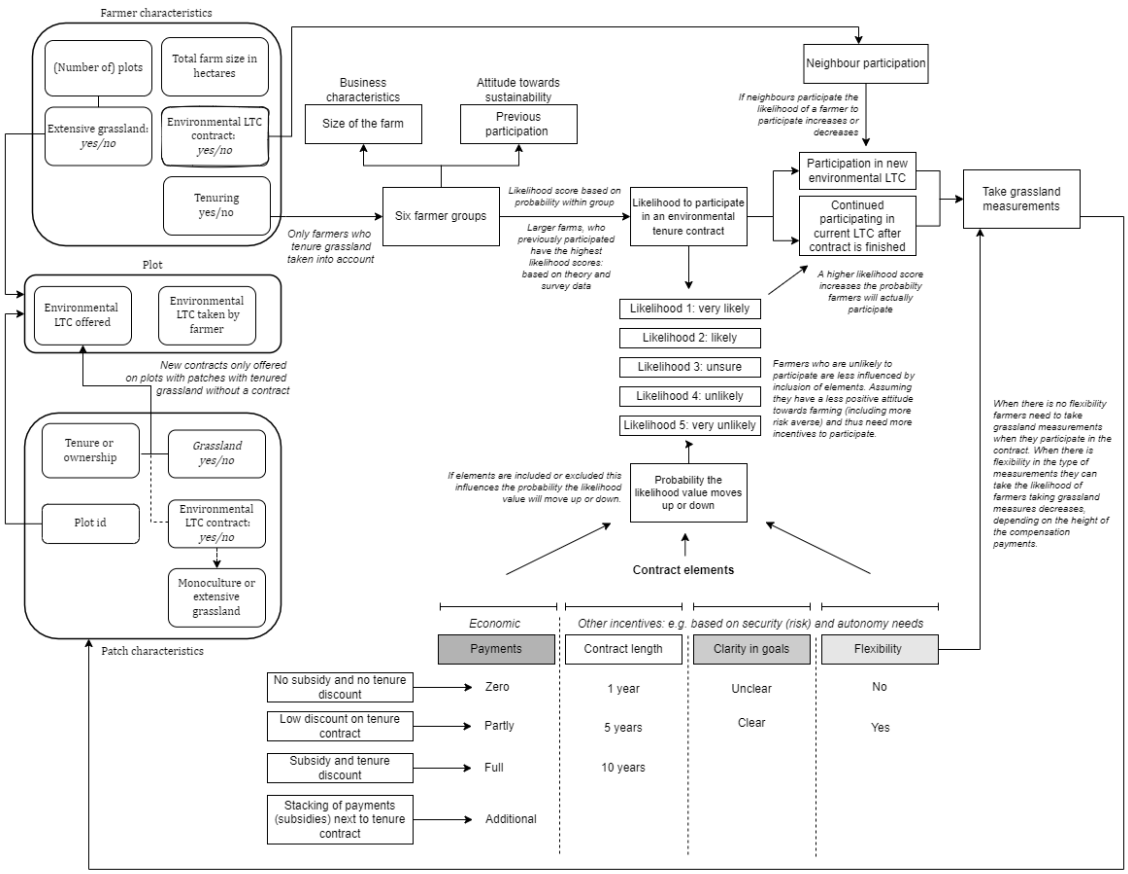

Figure 4: Overview of the model design

2.6.1 Farmer groups within the model

What is known of the farmers in the research area is their size and implementation of extensive grassland. In the model it is assumed that each farmer who implemented extensive grassland is participating in some kind of AES. From the survey, it becomes clear that farmers who previously participated are likely to be interested in environmental tenure contracts. This corresponds to the literature on the influence of habitual behavior or reinforcement learning (Schlüter et al. 2017). Furthermore what becomes clear from the survey is that larger farmer are more likely to have previously participated in AES. This also corresponds to the literature in which it is states it is easier for larger farmers to implement more extensive measurements and participate in AES (Lastra-Bravo et al. 2015). Consequently, six farmer six groups are formed based on the size of the farm and previous implementation of extensive grassland.

In the survey, each farmer had to assign a number on a Likert scale from 1 to 5 which represents how likely they would be to participate in an environmental Land Tenure Contract (LTC). 1 indicates very likely and 5 very unlikely. Consequently, in the model, each farmer in the study area will be assigned a number from 1 to 5, based on the distribution within their group.

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2.6.2 Likelihood versus actual participation

In the survey, only the intention of performing the action of being in a contract is collected and not the actual behavior of signing a contract and taking grassland measurements. As described earlier, according to the theory of planned behavior by (Ajzen 1991), behavioral intention and perceived behavioral options can together predict behavioral achievement. Farmers who state they want to be a part of a contract are likely to put in more effort to be in a contract, compared to farmers who state they do not want to be a part of it, but this does not mean they will actually participate.

In Table 3 the probability of farmers actually participating when they state they have a likelihood value of 1 to 3 to participate in an environmental LTC is demonstrated.

Likelihood value	Continue current contract	Participation in new contract
1 (very likely)	100%	80%
2 (likely)	80%	50%
3 (unsure)	65%	35%

Table 3: Probability of farmers actually participating in a contract

The probability of continuing to participate within a current environmental contract when a farmer indicates to be likely to participate is believed to be relatively high as changing behavior results in more constraints compared to continuing current behavior. This is based on theories about the influence of habitual behavior (Schlüter et al. 2017). When they expand this means they participate in a contract on a grassland tenure plot where a contract is offered, but had not been taken yet. The probability of making this decision is lower as it requires more effort. In the model, farmers can only expand if they have also decided they want to continue participation in the contracts they already have.

Neighbor impact on participation

According to theory, neighborhood effects among farmers can have a significant influence on farmers' intensity strategy (Spoerri et al. 2021), which is why a neighbor impact is added to the participation probabilities. This is measured by calculating the mean of how many farmers have a contract in a radius of 35 hectares, which results in an average of 5 neighbors. The weight assigned to the mean of the participation of neighboring farmers is set at 0.1. If the mean of neighbor participation is more than 50% there is a positive influence and with a mean of less than 50% there is a negative influence.

2.6.3 Contract elements

Four elements of importance in an environmental tenure contract are most often mentioned by farmers in the open answers of the survey, based on the inclusion

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or exclusion of these elements the model is used to determine the influence on farmer contract participation and resulting land-use changes.

Similar to the literature, the most important element influencing the likeliness to participate seems to be made based on financial incentives. 15% of the farmers explicitly mentioned this in the open answers. Farmers want the reduction in the price of the land to accurately reflect the efforts and decrease in yield. Some farmers also mention the need for additional compensation. Furthermore, 10% of the farmers mention the need for longer contracts. When they take measurements to increase the quality of their environment farmers also want the efforts to pay off and make actual changes, which from their viewpoint is more difficult with shorter contracts. 8% of the farmers explicitly mentioned the need for flexibility in the contract. They want freedom in their (local) management practices and not top-down conditions. Lastly, 8% of the farmers also mention a need for clarity in the contract, long-term goals and the steps to achieve these goals.

For the first two components, flexibility in management practice and timeframe of the contract survey data is available on how much these elements would increase the participation of farmers. 83% of the farmers argue more freedom in their management practice increases the likelihood to want to participate in a contract. Additionally, it can be concluded that 13% would be interested in a contract of 1 year, 56% of the farmers in a contract of 5 years, and 30% in 10 years. This demonstrates 5-year contracts would actually be the most popular length. For the other elements, clarity in long-term goals and monetary incentives literature is used to determine the impact of the contract elements.

Currently, mainly farmers with a likelihood of 2, 3 and 4 are influenced as it is expected farmers who have a likelihood of 1 are in general more positive towards more sustainable farming and thus less influenced by how a contract is constructed and farmers with a likelihood of 5 are in general less positive towards sustainable farming and thus also less influenceable by certain elements in a contract. This corresponds to McGurk, Hynes, and Thorne (2020) who state some farmers are resistant to ever participating and thus also less likely to be influenced by incentives and Bouma, Koetse, and Brandsma (2020) who argue mainstream farmers need more incentives to increase their participation. There is no difference made between the six groups in the impact of the inclusion of contract elements as all farmer groups mention similar components of a contract would increase or decrease their participation. In Table 4 and Table 5 the values used in the model are shown. The parameters representing clarity in goals and flexibility are set at 25, compensation payments is set at 50 (with full compensation at 25) and contract length is also set at 25. These values are added to the parameter indicating the probability the likelihood of a farmer moves up or down.

Compensation payments parameter: +50 to -50

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		Likelihood				
		1	*2*	*3*	*4*	*5*
	none	-25	-50	-50	-50	-25
	party	-12,5	-25	-25	-25	-12,5
	full	+12,5	+25	+25	+25	+12,5
	additional	+25	+50	+50	+50	+25
Clarity in goals parameter: +25 to -25						
		Likelihood				
		1	*2*	*3*	*4*	*5*
	Inclusion	+12.5	+25	+25	+25	+12.5
	Exclusion	-12.5	-25	-25	-25	-12.5

Flexibility parameter: +25 to -25

		Likelihood and probability per likelihood to receive the value									
		1	prob	*2*	prob	*3*	prob	*4*	prob	*5*	prob
Inclusion	*Strong increase*	+12.5	0.59	+25	0.52	+25	0.53	+25	0.54	+12.5	0.1
	increase	+6.25	0.23	+12.5	0.32	+12.5	0.29	+12.5	0.29	+6.25	0
	unsure	0	0.18	0	0.03	0	0.17	0	0.18	0	0
	Decrease	-6.25	0	-12.5	0.06	-12.5	0	-12.5	0	-6.25	0
	Strong decrease	-12.5	0	-25	0.06	-25	0	-25	0	-12.5	0
Exclusnion	*Strong increase*	+12.5	0	+25	0.06	+25	0	+25	0	+12.5	0
	increase	+6.25	0	+12.5	0.06	+12.5	0	+12.5	0	+6.25	0
	unsure	0	0.18	0	0.03	0	0.17	0	0.18	0	0
	Decrease	-6.25	0.23	-12.5	0.32	-12.5	0.29	-12.5	0.29	-6.25	0
	Strong decrease	-12.5	0.59	-25	0.52	-25	0.53	-25	0.54	-12.5	0.1

Table 4: Impact of contract elements (compensation, clarity and flexibility parameters)

Contract length parameter: - 25 to 25

length = 1 year

Farmer with likelihood = 1			Farmer with likelihood = 2			Farmer with likelihood = 3		
5%	increase	12.5	26%	increase	25	6%	increase	25
68%	decrease	-6.25	39%	decrease	-12.5	65%	decrease	-12.5
27%	decrease	-12.5	35%	decrease	-25	29%	decrease	-25

Farmer with likelihood = 4			Farmer with likelihood = 5		
8%	increase	25	33%	increase	12.5
62%	decrease	-12.5	67%	decrease	-6.25
31%	decrease	-25	0%	decrease	-12.5

length = 5 years

Farmer with likelihood = 1			Farmer with likelihood = 2			Farmer with likelihood = 3		
5%	decrease	-6.25	26%	decrease	-12.5	6%	decrease	-12.5

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68%	increase	12.5	39%	increase	25	65%	increase	25
27%	decrease	-6.25	35%	decrease	-12.5	29%	decrease	-12.5
Farmer with likelihood = 4			Farmer with likelihood = 5					
8%	decrease	-12.5	33%	decrease	-12.5			
62%	increase	25	67%	increase	25			
31%	decrease	-12.5	0%	decrease	-12.5			

length = 10 years

Farmer with likelihood = 1			Farmer with likelihood = 2			Farmer with likelihood = 3		
5%	decrease	-12.5	26%	decrease	-25	6%	decrease	-25
68%	decrease	-6.25	39%	decrease	-12.5	65%	decrease	-12.5
27%	increase	12.5	35%	increase	25	29%	increase	25
Farmer with likelihood = 4			Farmer with likelihood = 5					
8%	decrease	-25	33%	decrease	-12.5			
62%	decrease	-12.5	67%	decrease	-6.25			
31%	increase	25	0%	increase	12.5			

Table 5: Impact of length of the contract

Influence freedom measurements on implementation of extensive grassland

	If freedom of measurements is:	
Compensation	included	excluded
None	10%	99%
Party	50%	99%
full	80%	99%
extra	99%	99%

Table 6: Percentage farmers taking measurements for extensive grassland if freedom in measurements is included

If freedom of measurements is included it is assumed less farmers are likely to implement extensive grassland. However, it is also assumed more compensation results in an increase in likelihood to participate. With no compensation it is assumed 10% takes extensive grassland measurements, partly compensation

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50%, full compensation 80% and with extra compensation 99%. If there is no freedom in if farmers take grassland measurements also 99% takes measurements (see Table 6).

2.7 Sensitivity analysis

An overall sensitivity analysis of the model is performed on the most positive and negative scenario. Four parameters are included in this sensitivity analysis: the impact of contract elements on the change in likelihood, the impact of neighboring farmers, actual participation (versus likelihood of participation) and probability of taking grassland measurements when flexibility is included in a contract. The parameters are increased and decreased with 20% and the impact on the results is measured by determining the averages of 10 runs per scenario (60 runs in total).

In Figure 5, the resulting overall sensitivity of the model is demonstrated. This sensitivity analysis reveals for the positive scenario there is a much smaller range compared to the low scenario. Under more negative scenario's the parameters thus have a larger influence on behavioral outcomes. The parameters representing the value of the impact of contract elements seems to have to biggest influence on the sensitivity of the model but additional independent exploration of the parameters in necessary to determine specific effects.

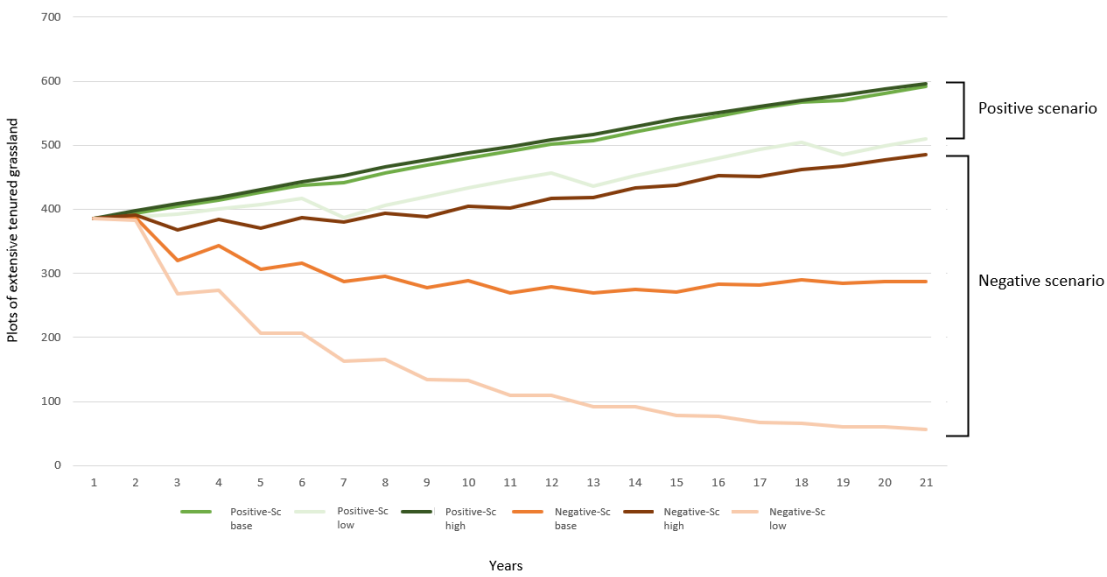

Figure 5: General sensitivity of the model

2.8 Results

The results in Table 7 are preliminary and only of a subset of the modelled area. For each of the scenarios shown in the Table 5, runs are performed and the average percentage increase in extensive grassland is compared to the current situation (18% of grassland tenure hectares and 23% of plots).

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Contract increase each year	1%	1%	1%	1%	1%	1%	1%
Flexibility (freedom in measurements taken)	No	Yes	Yes	Yes	No	No	Yes
Clarity in the long-term goals	No	Yes	yes	Yes	Yes	yes	Yes
Contract length	1	10	5	10	5	5	5
Compensation	None	None	Partly	Partly	Partly	Full	Additional
% change in hectares of tenure extensive grassland	-9,3	-1,5	-0,2	4,4	6,7	10,3	12,2

Table 7: Model results of multiple scenarios (Shaded cells indicate contract conditions currently used in commercial tenure contracts).

This study demonstrates that mainstream farmers are more difficult to persuade to participate by increased incentives and usually take fewer complex measurements (such as the implementation of extensive grassland). Farmers who are already participating have a more positive attitude towards sustainable farming and incentives are more likely to push them towards more complex measurements. Without increased incentives, mainstream farmers would not be persuaded to increase their participation, and farmers who are already participating might decrease participation. As previous experience has a positive influence on farmer participation, increasing mainstream farmer participation is needed in order for these farmers to shift from a mainstream position to a farmer who is already participating in AES on parts of their land (and is thus more likely to increase participation). This is primarily achieved by a combination of multiple incentives.

With the use of multiple incentives, under a standard contract availability increase of 1% per year, the contract specifications of Environmental Land Tenure contracts can induce a change in extensive grassland from a decrease by more than 9% to an increase of over 12%. The shaded cells in Table 7 indicate contract specifications that are currently used in commercial tenure contracts, showing that also within such contracts the exact specification matters. Flexibility and contract length interact here, when compensation payments are on the lower end increased flexibility can trigger farmers to adopt less far-fetching, but also less effective measures, resulting in a lower increase of extensive grasslands.

Figure 6 suggests that extra extensive grasslands is often added to the existing cores of extensive grasslands. The scenario with a 9.3% decrease in area clearly reduces connectivity, the most favorable scenario obviously adds more extensive grasslands and patch distance seems to be considerably decreased. However, the maps demonstrate no obvious connectivity increases in the

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location of extensive grassland plots. Nevertheless, as farmers can engage in Environmental Land Tenure Contracts simultaneously with other AES, a combination of tenure contracts with a collective approach could potentially stimulate more connectivity, while also catering to farmers needs of increased compensation payments, in combination with other incentives.

These results suggest that contract specification should be done in the light of the desired changes in the region and the regional context. A region where biodiversity might benefit from widespread uptake of simple measures might benefit from contracts with flexible measures, a region that aims for ambitious biodiversity increase might benefit from more strict specification of measures. In all cases but particularly for contracts towards more ambitious biodiversity goals, medium- to long-term contract have more effects.

Finally, the additional compensation model (i.e., more than actual costs and revenue loss) only provides a relatively small increase in total extensive grassland area. Although increases in payments reflect farmer's comments in the survey that additional compensation might increase uptake, care should be taken that extra costs are in balance with gains of extensive grassland.

Figure 6: Visualization of the impact of the least and most favorable scenario

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3 How the success of contract solutions is affected by different land tenure systems: Investigating the impact of land tenure systems on the enrollment of farmers in agri-environmental and climatic measures (INRAE)

In this section, we present a study conducted by INRAE, exploring how the success of contract solutions is affected by land renting. In particular, we focus on result-based (RB) agri-environment-climate measures (AECM), and we look at success in terms of farmers' participation.

3.1 Introduction

The success of contract solutions can be affected by different land tenure systems and various factors can lead to an unsecured provision of AECPGs: land tenure changes, that jeopardize the provision of AECPGs over time; opportunity costs changes (for instance, an increase in commodity prices); or uncertain payments in the future.

Here, we propose to focus on the impact of different land tenure systems on the provision of AECPGs and in particular on which extent owning the land or renting it can impact farmers' adoption of agri-environmental and climatic measures (AECM) where the payments are based on the environmental results.

Several studies have shown a significant impact of land tenure on farmers willingness to adopt AECM (see Lastra-Bravo et al. 2015): farmers are less likely to adopt long-term contract when they rent a high proportion of land on their farms (Defrancesco et al. 2008; Ruto and Garrod 2009) especially when it implies long-term changes in land use (Defrancesco et al. 2008). These results have been pondered by an Austrian survey relative to the adoption of conservation practices where the participation in an AES is not impacted by tenure status in a context where renting is secure and long-term (Leonhardt, Braito, and Penker 2021).

Here we investigate whether land tenure status may have a differentiated impact on the adoption of an innovative AECM with result-based payments compared to conventional AECM, where the payments are based on practices or actions.

Compared to action-based AECM, result-based AEMC are considered as more efficient and effective since farmers are paid based on the actual environmental results while considering the value of the benefices obtained (Matteo Olivieri et al. 2021). Indeed, in result-based schemes, farmers are more likely to enroll the more suitable lands to provide the environmental results targeted (Matzdorf, Kaiser, and Rohner 2008). Nonetheless, they are still sensitive to other external

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factors such as market prices so that risk adverse farmers would have a low participation in such schemes (Matteo Olivieri et al. 2021).

The objective here is to compare the land related drivers of the enrollment of farmers in action-based and result-based AECM, in order to better design result-based AECM so that when suitable, these can be successfully implemented. Farmers whom have low agricultural productive lands with high environmental productivity should be more willing to enroll result-based AECM than their counterparts. Indeed, although agricultural land price is positively impacted by governmental support schemes (Latruffe and Le Mouël 2009a), this may not be the case when farmers implement AECM, especially if there are no or negative effect on the agricultural productivity (Baldoni and Ciaian 2021). Compared to action-based AECMs, in result-based schemes farmers can implement whichever practices as long as the environmental results are achieved, thus may be able to better conciliate agricultural and environmental productivity on their farm, thus being more attractive for farmers to enroll.

Here, we test in particular which land related factors impact the adoption of result-based schemes compared to action-based schemes. We consider in particular the level of the land rent, assuming it reflects the agricultural productivity of the land enrolled, and the land tenure status (proportion of land rented).

To do that, we identify a panel of observations from the Farm Accountancy Data Network (FADN) of farms (potentially) eligible to RB AECM during the last CAP programming period. We apply two Probit models to estimate on the one hand the probability to participate in a RB AECM, and on the other hand the probability to participate exclusively in action-based AECM. We include the share of rented land in the utilised agricultural area (UAA) in the explanatory variables to estimate the effect of the land tenure status, and the land rent as a proxy of the agricultural land productivity of the farm. We use instrumental variables to control for endogeneity bias of the share of rented land (potentially decided simultaneously to the AECM adoption decision).

3.2 Model description

3.2.1 Data

The modelling approach was developed using French data from the Farm Accountancy Data Network (FADN), providing farm-level information on land tenure systems, such as the amount of land rented and renting costs, and on participation in AECM. The second dataset used was on the beneficiaries of the second pillar of the Common Agricultural Policy (CAP), collected by the French services and payment agency (ASP), providing additional information on the specific AECM contracted from 2015 to 2019. Both dataset were remotely accessed from the Secure Data Access Centre (CASD).

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Collectively implemented and/or RB AECM available during the 2014-2020 CAP programming period were identified by screening the website of the Rural Development Observatory (ODR) https://odr.inra.fr. We identified four of them: HERBE_07 (Maintain the floristic richness of a permanent grassland - RB), SHP_01 (Individual operation grassland and pastoral systems - RB), SHP_02 (Collective operation grassland and pastoral systems - RB and COL) and HAMSTER_01 (Collective management of crop rotations for the protection of the European Hamster - COL).

After merging the FADN and AECM beneficiaries' datasets over the years 2015 to 2019, we identified FADN farms involved in HERBE_07 and SHP_01. The characteristics of the RB contracts are presented in Table 8. A balanced panel of 1,613 FADN farms eligible to those two RB AECM was defined. Farms were considered eligible or not based on necessary herbivorous livestock units, pasture areas and region. Among them, 5.15%[1] are RB participants (102 farms). 49.55% of those RB participants were also participants of an action-based AECM targeting the same type of environmental objective (biodiversity maintenance in extensive grasslands[2], hereafter mentioned as AB). 6.72% of our sample are action-based (AB) participants exclusively.

	HERBE_07	SHP_01
Objective	Maintain the floristic richness of a permanent grassland	Individual operation grassland and pastoral systems
Payment conditionality Yearly monitoring in parentheses: • In bold : administrative, all participants • In italic: on-farm, 5% of AECM beneficiaries	Plot level: • 4 species indicating good agro-ecological balance on each third of the plots (*on-site*) • Recording of interventions (*records*) • No ploughing (**CAP statement**, *visual*) • No pesticides (visual, records)	Farm level: • >70% grasslands (**CAP statement**, *visual*) • >50%, >30% or >20% of target surfaces (**cap statement**, *visual*) • Maximum 1.4 LU/ha (**CAP statement**, *records*) « Target » plot level: • Permanent grasslands with floristic diversity: 4 species indicating good agro-ecological balance on each third of the plots *(on-site)* • Pastoral areas : no indicators of undergrazing, soil or

[1] The participation rate is weighted by the extrapolation coefficient.

[2] HERBE_03 (no mineral and organic nitrogen fertilisation on grassland, 131€/ha), HERBE_04 (adjustment of grazing pressure in certain periods, 75.44€/ha), HERBE_06 (delayed mowing on grasslands and remarkable habitats, 223€/ha), HERBE_09 (improvement of pastoral management, 75.44€/ha).

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		grass cover degradation *(on-site)* • Recording of interventions (*records*) • No ploughing (**CAP statement**, *visual*) • No pesticides (visual, records)
Beneficiary	Individual farms	Individual farms
Eligibile plots	Permanent grasslands	All farmland
Yearly payment (€/ha)	66.01	From 58 to 147, proportional to the share of target surfaces
Participation sample[1] (%)	2.37	2.82

Table 8: Description of result-based AECM contracts of the sample.

Descriptive statistics of the sample, and in particular the land tenure systems, are presented in Table 9. The sample analyzed considers the observations of the 1065 FADN farms eligible to the two RB AECMs HERBE_07 and SHP_01 over five years (2015-2019).

	All	Result-Based participants	Action-Based participants
Observations	8,065	510	610
Utilised agricultural area (UAA) (ha)	117.0 (529.5)	125.9 (441.1)	160.1 (591.9)
Rangelands (ha)	5.1 (174.6)	17.3 (296.1)	9.2 (223.3)
Permanent grasslands (ha)	48.1 (309.1)	79.2 (287.9)	72.9 (383.0)
Herbivorous load (LSU/ha)	1.6 (7.9)	1.0 (3.5)	1.4 (3.7)
Renting land (%)	93.9	97.9	96.1
Rented area (ha)	94.6 (540.7)	96.3 (424.2)	143.3 (621.2)
Land rent (€/ha)	123.4 (618.9)	87.8 (330.2)	106.0 (374.6)
Standard gross production (1,000€)	143.2 (842.7)	108.5 (473.0)	168.2 (859.9)
Permanent non salary labour (AWU/ha)	0.02 (0.1)	0.01 (0.04)	0.01 (0.05)
Organic (%)	8.7	13.0	4.3
Less Favoured Area (%)	66.3	90.7	66.6
More than half of the UAA in Natura2000 (%)	7.1	20.9	15.1
Depreciation (1,000€)	34.4 (183.6)	30.9 (118.7)	40.2 (174.6)

Table 9: Descriptive statistics of the sample (1/2). Weighted mean (standard deviation in parentheses).

It can be noticed that RB AECM participants have in average lower land rent and lower standard gross production than AB AECM participants and the overall sample. In addition, 90.7% of the RB AECM participants lands are categorized has a less favoured area. This is consistent with our hypothesis that farmers are more willing to enroll in RB AECMs when having low agricultural productive lands.

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	All	Result Based participants	Action-Based participants
Observations	8,065	510	610
Otexe: 15-Cereal, oleaginous and protein crops (%)	6.9	0.0	7.8
Otexe: 16-Other field crops (%)	0.4	0.0	0.5
Otexe: 28-Market gardening (%)	0.1	0.0	0.0
Otexe: 29-Flowers and diverse horticulture (%)	0.1	0.0	0.0
Otexe: 37-Quality wine (%)	0.6	0.0	0.0
Otexe: 39-Fruits and other permanent crops (%)	0.9	0.8	0.0
Otexe: 45-Dairy (%)	27.6	35.8	20.6
Otexe: 46-Cattle meat (%)	21.4	31.95	24.7
Otexe: 47-Cattle dairy and meat (%)	7.05	7.6	10.05
Otexe: 48-Sheep, goats and other grazing livestock (%)	10.8	14.0	8.5
Otexe: 50-Granivores (%)	2.4	1.1	2.9
Otexe: 61-Mixed crops (%)	1.0	0.3	0.0
Otexe: 73-Mixed livestock, mainly grazing livestock (%)	2.3	1.05	0.0
Otexe: 74-Mixed livestock, mainly granivores (%)	2.8	2.4	1.2
Otexe: 83-Field crops and grazing livestock (%)	13.7	3.2	22.8
Otexe: 84-Mixed crop-livestock farming (%)	1.9	1.8	1.0
Region : Champagne-Ardenne (%)	4.1	6.2	17.1
Region : Centre (%)	5.0	5.3	2.7
Region : Bourgogne (%)	7.6	9.15	6.6
Region : Lorraine (%)	6.1	12.5	6.95
Region : Alsace (%)	1.9	8.6	0.9
Region : Franche-Comté (%)	5.1	2.9	7.3
Region : Pays de la Loire (%)	16.9	1.5	20.3
Region : Aquitaine (%)	9.2	2.1	4.7
Region : Midi-Pyrénées (%)	15.4	1.8	10.25
Region : Rhône-Alpes (%)	11.35	24.7	12.7
Region : Auvergne (%)	13.25	13.7	7.7
Region : Languedoc-Roussillon (%)	2.5	6.4	1.4
Region : Provence-Alpes-Côte d'Azur (%)	1.6	5.2	1.6
HERBE_03 (%)	6.1	31.2	67.4
HERBE_04 (%)	1.5	5.6	18.1
HERBE_06 (%)	1.5	6.6	17.4
HERBE_07 (%)	2.0	39.1	0.0
HERBE_09 (%)	1.8	21.4	9.9
SHP_01 (%)	2.4	46.3	0.0

Table 10: Descriptive statistics of the sample (2/2). Weighted mean (standard deviation in parentheses).

3.2.2 Empirical model

We are interested in modelling participation in RB (AB) contracts and estimate the effect of the proportion of land rented and the land rent on this decision. We apply a Probit model to estimate the probability $D_{it}{}^{*}$ of individual i to participate in a RB (AB) contract in year t. The dependent variable of the model is the

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observed binary variable D_{it} equals to 1 if the farm participates in a RB (AB) contract, 0 otherwise (1). The explanatory variables of interest are the share of rented land X_{1it} and the land rent X_{2it}, as well as farm and farmer characteristics $X_{j\geq 3it}$. To control for simultaneity bias, we instrumented the endogenous share of rented land, such that the system of equations estimated is (2). The land rent was calculated from the observed renting expenditures over the rented area. For farms which were not renting any land, the land rent was estimated using the parameters of equation (2) estimated with the sub-sample of renting farms only.

$$D_{it} = \begin{cases} 1\,, D_{it}{}^{*} \geq 0 \\ 0\,, D_{it}{}^{*} < 0 \end{cases} \qquad (1)$$

$$\begin{cases} D_{it}{}^{*} = \beta_0 + \beta_1 X_{1it} + \beta_2 X_{2it} + \sum_{j\geq 3} \beta_j X_{jit} + \varepsilon_{it}\,, \varepsilon_{it} \sim N(0, \sigma_1{}^2) \\ X_{1it} = \alpha_0 + \sum_{j\geq 2} \alpha_j X_{jit} + \sum_{j\geq 1} \gamma_j Z_{jit} + u_{it}\,, u_{it} \sim N(0, \sigma_2{}^2) \end{cases} \qquad (2)$$

Z_{jit}: Instrumental variables explaining the decision of renting more or less land: non-salary permanent labour (AWU/ha), standard gross production (€), year (binary for 2015, 2016, 2017, 2018).

3.3 Main results: Effect of land tenure systems on participation in result-based or action-based AECM

The results of the statistical model are presented in Table 11.

	Participation in Result Based contracts		Participation in Action Based contracts only	
	Probability	S. d.	Probability	S. d.
Share of rented land (%)	0,003	0,031	0,092*	0,472
Land rent (100€/ha)	-0,025***	0,231	-0,017**	0,085
UAA (ha)	0,008*	0,075	0,024***	0,125
Share of permanent grasslands (%)	0,048***	0,440	0,021*	0,108
Herbivorous load (LSU/ha)	-0,040***	0,362	-0,015***	0,075
More than half of the UAA in Natura2000 area (binary)	0,038***	0,352	0,059***	0,299
Less Favoured Area (binary)	0,044***	0,401	0,005	0,024
Level of agricultural education (ordinal)	-0,007**	0,065	0,009**	0,048
Level of general education (ordinal)	0,016***	0,151	-0,005	0,026
Organic certification (binary)	0,001	0,007	-0,04***	0,206
Depreciation (100,000€)	-0,014	0,124	-0,031*	0,157
Otexe : 45-Dairy	0,047***	0,430	-0,01	0,051
Otexe : 46-Cattle meat	0,060***	0,551	0,015+	0,077
Otexe : 47-Cattle dairy and meat	0,045***	0,414	0,019+	0,097
Otexe: 48-Sheep, goats and other herbivorous	0,066***	0,601	0,003	0,016
Otexe: 84-Mixed crop-livestock farming	0,048**	0,438	-0,043	0,218
Otexe: others	-	-	-	-
Region : Champagne-Ardenne	0,077***	0,710	0,087***	0,446
Region : Centre	0,016	0,150	-0,047***	0,242
Region : Lorraine	0,083***	0,760	-0,01	0,053

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Region : Alsace	0,185***	1,696	0,011	0,055
Region : Midi-Pyrénées	-0,074***	0,682	0,002	0,010
Region : Rhône-Alpes	0,033***	0,299	0,008	0,040
Region : Auvergne	-0,017**	0,158	-0,04***	0,204
Region : others	-	-	-	-
Rho	-0,043	0,126	-0,086	0,092
Log Likelihood	-1313		-1919	
AIC	2745		3959	
BIC	3165		4379	
McFadden 's pseudo-R^2	0.66		0.56	
N	8065		8065	
Number of participation observations (dependent variable =1)	429		541	

Table 11: Results of the estimation (weighted average of the individual marginal effects).

Weighted mean (standard deviation in parentheses).
******p<0.001, **p<0.01, *p<0.05, +p<0.1.***

First, the land rent is significantly reducing the probability to participate in both RB and AB (Ceteris paribus, +100€/ha decreases the probability to participate in RB by 2.5%, and AB by 1.7%). However, the proportion of rented land is not significantly affecting the probability to participate in RB, but is significantly increasing the probability to participate in AB only.

The non significant effect of the correlation between the share of rented land and the RB (AB) adoption decision (Rho) suggests the land tenure status is not endogenous. The share of rented land is also significantly and negatively affected by the land rent.

As expected, the higher the share of permanent grasslands, the higher the probability to enroll in the RB or AB schemes and the higher the herbivorous load, the lower the probability to enroll in these AECMs, which are both related to extensive grasslands. Consistently, the Otexes related to herbivorous production (meat or dairy) impact positively the probability to enroll in RB AECMs

We observe contrasted impacts of the level of agricultural education: a higher level of education significantly decrease (RB) or increase (AB) the probability of participating in these schemes, by less than 1%. In addition, the regional location of farms impacts significantly the probability of enrolling in RB or AB only schemes : being located in Champagne Ardennes increases positively the probability to enroll in both schemes, while being located in Auvergne decreases both these probabilities. The regional impacts can partially be explained by the descriptive data, where for instance in Champagne Ardennes, compared to the proportion of farmers eligible to these measures located there (4,1%), there is a higher proportion of farmers that have enroll in RB AECMs (6.2%) and AB-only AECMS (17.1%).

3.4 Conclusions

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There is a limit to the generalization of our results, as we only focused on AECM designed to favor biodiversity maintenance in grassland, for they are the only ones that exist in France that can be observed within the data available in the FADN. Furthermore, although some of the monitoring criteria are result-based, the payment is not yet proportional to the results obtained. It would be interesting to strengthen our analysis with schemes that include such proportionality, although to our knowledge such innovative AECMs are not yet implemented in France.

Our empirical analysis shows that the land tenure system affects the decision to participate in both RB or only AB AECMs. The higher the land rent, the less likely the farmer will adopt an AECM. This suggests that having access to more productive agricultural land (with higher rent) makes it less economically profitable to dedicate it to extensive environment-friendly grassland production. The effect of land rent is stronger for RB, suggesting it is even more true when the AECM conditionality rules requires the provision of environmental (biodiversity) outputs. It suggests also that in these areas, a decrease in land rent as a counterpart for enrolling lands in these programs could increase the probability of farmers to adopt these AECMs.

The land tenure status (whether the farm rents more or less of its UAA) only significantly affects the decision to adopt AB (positively), and not RB. The literature shows that the effect of the share of rented land on AECM adoption depends on the area and the type of land use targeted by the scheme. Defrancesco et al. (2008) found a differentiated effect on the adoption of grassland conservation schemes in Italy: a negative one in the aquifer recharge belt where adoption means having to convince the landlord to convert arable land into grassland, and a positive one in the Alps where grassland is often the only possible land use in marginal areas. In Germany, Pufahl and Weiss (2009) found a positive effect of the share of rented land on the probability to participate in agri-environmental schemes in general, while Massfeller et al. (2022) also found a none significant effect on the adoption of a result-based scheme (but they found a significantly negative effect on the amount of land to be enrolled in the contract).

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4 Modelling the effect of contract solutions on land dynamics: Modelling impact of different policy mix on the land market in Liguria Region (UNIFE-UNIPI)

4.1 Introduction

While much is known about the role of direct payments on land markets, considerably less is known about how AES affects land demand. (Latruffe and Le Mouël 2009b) pinpoint that direct payments can explain the evolution of land prices between 15-30% (up to 70%). (Ciaian, Kancs, and Swinnen 2013) argue that a combination of several factors can explain how payments affects the land market. These factors are a) the implementation model (historical vs regional); b) tradable or non-tradable entitlements; c) the cross-compliance requirements; d) the land market regulations; e) the capital market imperfections; and f) the length of rental contracts. Other studies (Graubner 2018; O'Neill and Hanrahan 2012) find a more significant impact of cross-compliance and greening commitments on land demand than of payment level.

Only a few studies describe the impact of AESs (or payments for ecosystem services) on land demand and/or farmland prices. For example, (Takayama et al. 2021) indicate that less-favoured areas and AES payments positively affect farmland size and slow down farmland abandonment. This result is in line with (Raggi, Sardonini, and Viaggi 2013) and (Bartolini and Viaggi 2013), showing that a) receiving the organic payment reduces farm exits and b) the AESs payment increases the land operated, especially in less-favoured areas. These Authors also show that the abolishment of CAP favours the farm exit and the reduction in the operated land for those that remains. Thus, land abandonment has a detrimental effect on environmental quality. (Quintas-Soriano, Buerkert, and Plieninger 2022) highlight from a review that the land abandonment in Mediterranean Areas can determine the reduction of landscape heterogeneity, soil erosion and desertification, reduction of water stocks, local biodiversity decrease and loss of cultural and aesthetic values. Therefore the design of an effective policy mix or instrumental mix (i.e. first, pillar payment and second pillar payments) is crucial to understanding the provision of public goods.

This study aims to analyse the effects of EU payments within the CAP framework to prevent soil erosion due to climate change in hilly and mountainous areas, explicitly considering the effects of policy on marginal land abandonment. Policy programs can have indirect effects (preventing hydrological instabilities) and direct effects (reducing land abandonment). In Ligurian territories, small and hobbyist farmers produce a large percentage of environmental goods. Although actions implemented by single farmers seem insignificant because of the small farm dimension, collective actions from small farmers can improve land

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protection. However, the EU measures often exclude them because of their failure to reach the minimum acreage or economic dimension requested.

In Ligurian territories, small and hobbyist farmers produce a large percentage of environmental goods. Although actions implemented by single farmers seem insignificant because of the small farm dimension, collective actions from small farmers can improve land protection. However, the EU measures often exclude them because of their failure to reach the minimum acreage or economic dimension requested. We analysed several agri-environmental commitments and how they affect the final quantity of soil erosion. We tested the introduction of different policy mixes considering a combination of the first and second pillar measures, including different contract types for Agri-Environmental Scheme (AES) payments (i.e. payments based on simulated results). This could be a relevant innovation in AESs that also require low public transaction costs in designing and monitoring the results.

4.2 Model description

We simulated different policy mix impacts on land demand using a mathematical programming model. The model enables the simulation of farmers' behaviour in front of a different combination of an environmental prescription under enhanced conditionality, eco-schemes, and agri-environmental schemes. We applied a dynamic mathematical programming model that optimises the Net Present Value of cash flow between the years 2022 and 2040. Formally,

$$\max NPV = \sum_t^T cf_t * (1-k)^{-t} \quad (1)$$

$$cf_t = \sum_i^I \sum_j^J \pi_{t,i,j} * x_{t,i,j} + SFP_t + ECO * x_{t,i,j\in eco} + AES_t * x_{t,i\in aes,j} - tc_{eco} - tc_{aes} - cc - l_{in} * rent - tc_{in} + l_{out} * rent - tc_{out} \quad (2)$$

$$s.t. \quad \sum_i^I \sum_j^J a_{t,i,j,h} * x_{t,i,j} \leq b_h \quad (3)$$

$$x_{t,i,j} \geq 0 \quad (4)$$

$$\sum_i^I \sum_j^J x_{t,i,j} = l_o + l_{in} - l_{out} \quad (5)$$

where

NPV = net present value between years 2022–2040

cf_t = annual cash flow for generic t year

k = discounted rate,

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$\pi_{t,i,j}$ = profit of *ith* crop with *jth* farm practice

$x_{t,i,j}$ = area of *ith* crop with *jth* farm practice

SFP_t = decoupled payments received during generic year *t*

AES_t = agri-environmental-climate payments received during generic year *t*

tc_{aes} = transaction cost of participating in agri-environmental climate schemes

tc_{eco} = transaction cost of participating in eco-schemes

cc = cost of the enhanced compliance

$rent$ = land rental price

$a_{t,i,j,h}$ = scalar element of a generic *h-th* technical coefficient used by *i-th* crop with *j-th* farm practice during generic year *t*

b_h = vector of available resource quantities

l_o = land owned

l_{out} = land rented-out

Equation 5 indicates the land-use constraint. The equation constrains the land use (sum of all activities including land abandoned) to be equal to the sum of land owned plus the land rented in minus the land rented out. Due to low land market activities, we assumed that farmers could also decide not to cultivate some land, based on the current crop specialisation. For example, if the farmers could grow olive trees in a plot but left the parcel uncultivated, the model simulated the environmental performance of an abandoned olive farm.

In the absence of monitoring data that directly measure soil types in the regional agricultural systems, the potential impact of measures was estimated using the difference in the contribution to erosion reduction between holdings under commitment and holdings not participating in measures. Using the general formula, we have :

$$\delta_{aes} = S_{p1} - S_{p0}$$

S_{p1} = annual potential erosion per farm under commitment to a generic action aimed at reducing soil erosion

S_{p0} = annual potential erosion per farm without environmental commitment

The calculation of potential erosion was conducted by applying RUSLE, developed by Wischmeier and Smith (1978):

The RUSLE equation allows the estimation of the annual tons of soil loss by erosion of a generic farm *p* by considering five factors:

$S_p = R * K * LS * C \quad * P$

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The R-factor is the aggressiveness and leaching of rain, and measures the kinetic energy and intensity of rain in the area associated with the run-off. It is worth noting that the parameter was the value of R, which is uniformly distributed between the current value of approximately 900 to 1500 (MJ mm/ha h year). The variability was simulated considering the projection from (Panagos et al. 2021).

The K-factor expresses the susceptibility of a soil to erode and is computed by considering soil properties such as texture, organic matter, structure, and permeability of the topsoil.

The LS-factor represents the topographic parameters of soil erosion, and integrates the effects of slope steepness (S-factor) and slope angle (L-factor) on soil loss.

The C-factor describes the land cover and management factor, measuring the combined effect of land use and management.

The P-factor describes the corrective factor in the case of an existing installation of erosion containment and control measures such as terraces, countering farms, stone walls, strip cropping, terracing, and grass margins.

The C and P factors are endogenous to the model simulation, whereas R, K, and LS are exogenous.

4.3 Empirical implementation

4.3.1 Selection of representative farms

We assessed the model over representative farms in the Italian province of La Spezia and Genova, an administrative subregion of Liguria. We chose this area for the following reasons: a) its exposure to hydrogeological instability and the peculiarity of agriculture, which make the issue of soil erosion relevant; b) the area is an inner area; and c) the area shows very low activities in the land market. We selected the representative farms based on a list of 'professional', part-time, and hobbyist farmers. We conducted a non-hierarchical cluster analysis with a k-means algorithm, and used the highest Calinski/Harabasz pseudo-F value as the 'best clustering' criteria. Two surveys were used to gather the data for the model. Farm total agricultural area, Farm usable agricultural area (UAA), and the number of direct payments were the three clustering variables. We ran the clustering procedure over three different areas of the region, given the importance of farm location, land slope, and farm specialisation for farming profitability and land-use-diversification potential. The 302 farms in the area fitted 12 representative clusters with well-defined features in terms of size, labour, and payment level (Table 12).

Farm	System	Weight (%)	Plots (#)	UAA (ha)	Arable crops (ha)	Permanent crops (ha)	Forest area (ha)	BPS* (€ per farm)

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1	olives	0.07	3	1.65	1.32	0.33	-	243.71
2	olives	0.07	4	2.49	1.76	0.73	-	433.00
3	olives	0.01	3	1.91	1.60	0.31	-	346.00
4	forest	0.30	3	4.66	0.52	-	4.13	196.23
5	forest	0.06	4	13.69	1.03	-	12.67	285.50
6	forest	0.01	7	551.00	0.05	-	550.95	-
7	forest	0.01	4	6.05	1.76	-	4.29	300.00
8	arable	0.26	5	14.27	14.27	-	-	713.04
9	arable	0.11	4	24.49	24.49	-	-	1,086.09
10	arable	0.04	4	69.20	69.20	-	-	3,221.00
11	arable	0.01	7	114.95	114.95	-	-	22,580.00
12	grapewine	0.06	4	5.72	3.84	1.89	-	348.50

*Table 12: Characteristics of representative farms; *Basic payment scheme*

4.3.2 Policy scenario

To the best of our knowledge, the economic literature has not yet investigated the policy impact on soil erosion under different climate change scenarios. The reasons could be principally related to the difficult linkage between the types of policies and the final environmental effects. Certainly, payments strictly related to farm actions do not encourage the positive policy effects (M Olivieri et al. 2021). In the last decade, the interest in instruments that are capable of paying farmers for their environmental results has been increasing. There is much literature on results-based contracts (Herzon et al. 2018). The results can be counted with real-level indicators; but, this can be difficult for certain measures. However, these promising instruments can significantly improve the practical actions of EU funding in terms of both effectiveness and efficiency (Wuepper and Huber 2021).

We believe it is important to have a model capable of linking the first part of policy implementation to the practical results. This can help better tailor the entire policy process based on payments with simulated results.

Referring to the case study of the Liguria area, the following policy instruments were intended to reduce soil erosion: conditionality, eco-schemes, and agri-environmental schemes (for further details, see below).

These policy instruments are coherently designed to promote a gradient of commitments in accordance with the application of either charges or payments. Therefore, the regulation of measures to reduce soil erosion represents a real combination of policy mix, as it employs several principles (the polluters pay principle and providers get principle) and different measures (cross-compliance, eco-schemes, and agri-environmental climatic schemes).

We simulated the impact of CAP on land demand considering a policy mix. Environmental regulation in agriculture integrates measures based on the polluters pay principle (i.e. enhanced conditionality) with measures based on the providers get principle (i.e. eco-schemes and agri-environmental schemes).

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Based on the focus on reducing soil erosion by water, we kept the policy scenario limited to the following measures in the first and second pillars.

4.3.3 Basic Payment Scheme (BPS)

As mentioned above, land demand is very sensitive to the level of decoupled payments (i.e. the basic payment scheme). We assumed two BPS: the first is based on the Irish model, considering internal and external convergence; and the second is based on uniform area payment. The last column of **Errore. L'origine riferimento non è stata trovata.** shows the payments received per farm. These payments are based on partial convergence (situation a). The uniform area payment was assumed to be equal to 178 € per hectare for UAA. It is worth noting that after receiving their first payment, farmers are obliged to respect the Good Agricultural and Environmental Condition (GAEC). See next paragraph for more details. In the other case (when they do not receive payments), the farm could rent out the land or abandon the land, with different impacts on soil erosion (i.e. abandoned land has performed the worst in reducing soil erosion).

4.3.4 Enhanced conditionality

GAEC measures include compulsory land management, such as cover crops in the spring and summer periods for areas with erosion problems (BCAA 4), or water management required for vulnerable areas (BCAA 5). Cross-compliance also requires the maintenance of permanent grasslands and existing terraces. This measure was simulated as the change in production costs (labour allocated and variable costs) with respect to a situation without GAEC commitments.

4.3.5 Eco schemes

We simulated the introduction of two sets of eco-schemes above the conditionality:

a) Winter soil cover and catch crops above conditionality

b) Agroforestry

The payments of eco-schemes were simulated using 30% of the direct payment (See (Runge et al. 2022) for a detailed presentation of the current implementation of the schemes)

4.3.6 Second pillar measures

Following the ongoing debate on environmental regulation within the CAP post 2020 regulation, we limit our analysis to two AESs, which will go beyond the baseline set out by GAEC (total permanent *grassing* of the vineyards and olive oil crops) and the eco-schemes (winter soil cover and catch crops above conditionality, and agroforestry).

The two AES measures are as follows:

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AES1: Grassland conservation measure that provides a payment to avoid conversion or abandonment of permanent and semipermanent grasslands. This measure is currently included in the list of measure 10 of the Ligurian RDP.

AES2: Renaturalisation measure. This is a new measure that the regional administration would like to introduce during the new programming period. This measure integrates and promotes the combination of arable crops with significant areas of natural vegetation to increase biodiversity and introduce elements that can avoid soil erosion, such as wood, permanent crops, or other natural landscape elements.

Option A payments based on compensation costs

The first option is the current payment calculation which is based on the compensation of participation cost, income foregone, and private transaction costs with the following:

Option B results-based payment on (simulated) results

We also simulated the introduction of results-based payments on (simulated) results to assess the change in soil erosion due to the introduction of different levels of payments. Formally, the parameter of AES payments ($AESpay$) is calculated as:

$$AES_t = \left(x_{t,j,i}K_1(1-r)\right) + (rV * \delta_{aes})$$

where

$x_{aes} =$ area under AESs

K_1 = compensative payment

r = share of payment based on the simulated results

V = economic value of reduced soil erosion (€ /t/ha year)

δ_{aes} = reduced soil erosion due to AESs

The results are presented considering different levels of r and V.

4.3.6.1.1 Exclusion criteria

Small and hobbyist farms characterise the Liguria region's agriculture situation. However, the current AES includes a threshold that makes the AES farmers below a threshold of three hundred euros and with an annual standard output below five thousand euros ineligible. This has the practical consequences of excluding hobby and part-time farmers by payments, although they are relevant in reducing soil erosion.

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2.5.1.2. Resultant policy mix

The baseline included only the current cross-compliance measures (CC) that link the EU agriculture funding to positive environmental effects. The simulated scenario included reductions of different percentages in the CC and their substitution with voluntary measures (AESs and eco-schemes). This created a new hybrid scenario with a different combination of mandatory and voluntary measures that we wanted to assess. The second scenario followed the first one, but all the companies were allowed to participate. This was an innovative scenario because the Liguria program does not include the small and non-professional hobbyist farmers. The sum of all the activities of small farms has a strong positive effect on these areas.

Therefore, we simulated the following policy mix:

NO CAP: abolishment of all payments (both first and second pillar)

Baseline (CC_AES1): conditionality + AES1

Policy mix 1 (CC_ECO_AES1): baseline + introduction of eco-schemes

Policy mix 2 (CC_ECO_AES1+2): baseline + introduction of eco-schemes + AES2

Policy mix 3 (CC_ECO_AES1+2 hobby): baseline + introduction of eco-schemes + AES2 + AES per hobby farmer

Policy mix 4 (CC_ECO_AES1+2_hobby_rb1): baseline + introduction of eco-schemes + AES2 + AES per hobby farmer (payment based on simulated results with r=1)

4.4 Results

According to the methodology, we present the results by comparing four different policy mixes plus the baseline with respect to a situation without CAP payments. We created two different tables to present the results assuming changes in BPS: Table 13 presents the results of the current BPS based on the partial convergence model, and Table 14 presents the results of fully uniform area payments. We compared the amount of operated area (UAA plus area allocated to forestry), change in land abandonment, and environmental performance (i.e. amount of soil erosion) with respect to the current policy regime for each simulated policy mix.

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Farm	Baseline			NoCAP			Policy mix 1			Policy mix 2			Policy mix 3			Policy mix 4		
	UAA (ha)	Abd* (ha)	Erosion (t /year)	Δ1	Δ2	Δ3	Δ1	Δ2	Δ3	Δ1	Δ2	Δ3	Δ1	Δ2	Δ3	Δ1	Δ2	Δ3
1	1.65	-	0.70	-	-	1.44	-	-	-	-	-	-	-	-	-0.04	-	-	1.44
2	2.30	-	1.21	-	-	1.71	-	-	-	-	-	-	-	-	-0.05	-	-	1.71
3	1.91	-	3.87	-	-	0.06	-	-	-	-	-	-	-	-	-1.06	-	-	-
4	4.13	-	0.03	-	0.79	0.50	-	-	-	0.53	-	0.08	0.53	-	0.08	-	-	-
5	12.67	-	0.09	-	2.41	1.53	0.92	-	0.22	1.02	-	0.20	1.02	-	0.20	-	-	-
6	550.95	2.43	4.25	-	-	-	-	-	-	-	-0.61	-0.59	-	-2.34	-0.62	-	-2.43	-2.22
7	6.05	-	3.91	-	-	-	-	-	-3.46	-	-	-3.59	-	-	-3.59	-	-	-
8	14.27	-	31.45	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9	15.59	-	4.00	-	-	2.70	-	-	-0.30	8.05	-	1.12	8.05	-	1.12	-	-	8.24
10	69.20	-	152.55	-	-	25.2	-	-	-	-	-	-	-	-	-	-	-	-
11	114.95	-	27.31	-	53.24	186.73	-	-	-	-	-	-2.47	-	-	-2.47	-	-	6.91
12	5.36	-	10.03	-3.47	-	-7.73	0.18	-	-6.86	0.36	-	-6.94	0.36	-	-6.16	-3.47	-	-7.73

Table 13: Land demand and environmental performance (basic income payment based on partial convergence)

Δ1 = change in land operated in hectares (owened land + rented in – rented-out); Δ2 = change in land abandoned in ha; Δ3 = change in soil erosion (tons per farm)

Farm	Baseline	Baseline_regionalised	Policy mix 1	Policy mix 2	Policy mix 3	Policy mix 4

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	UAA (ha)	Abd* (ha)	Erosion (t /year)	Δ1	Δ2	Δ3	Δ1	Δ2	Δ3	Δ1	Δ2	Δ3	Δ1	Δ2	Δ3	Δ1	Δ2	Δ3
1	1.65	-	0.70	-	-	-	-	-	-0.02	-	-	-0.06	-	-	-0.04	-	-	1.44
2	2.30	-	1.21	-	-	-	-	-	-0.04	-	-	-0.09	-	-	-0.05	-	-	1.71
3	1.91	-	3.87	-	-	-	-	-	-	-	-	-1.17	-	-	-1.06	-	-	-
4	4.13	-	0.03	-	0.79	0.50	-	0.79	0.50	0.53	2.16	1.43	0.53	2.16	1.43	-	-	-
5	12.67	-	0.09	-	2.41	1.53	-	2.41	1.53	1.02	6.63	4.32	1.02	6.63	4.32	-	-	-
6	550.95	2.43	4.25	-	-	0.84	-	-	0.84	-	-	0.84	-	-	0.84	-	-	0.84
7	6.05	-	3.91	-	-	-0.46	-	-	-3.46	-	0.41	-3.34	-	-	-3.59	-	-	-
8	14.27	-	31.45	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9	15.59	-	4.00	-	-	-0.30	-	-	-0.30	-	-	-0.63	-	-	-0.63	-	-	17.01
10	69.20	-	152.55	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	114.95	-	27.31	-	-	-	-	-	-186.7	-	-	-189.2	-	-	-189.2	-	-	11.38
12	5.36	-	10.03	-3.47	-	-7.73	-3.47	-	-7.73	0.36	-	-6.94	0.36	-	-6.05	-3.47	-	-7.73

Table 14: Land demand and environmental performance (basic income payment based on uniform area payments)

Δ1 = change in land operated in hectares (owned land + rented in – rented-out); Δ2 = change in land abandoned in ha; Δ3 = change in soil erosion (tons per farm)

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The model could reproduce the current operated area under the baseline, except for farm 6. The farm finds it unprofitable to operate on all available land, which could be a consequence of the decision to avoid, in the simulation, the forestry measures and focus only on the agricultural areas. It is worth noting that the forestry areas are not eligible for BPS.

Both basic payment schemes scenarios indicate that without CAP, the farms reduce operated land and increase the amount of abandoned land. Increasing land abandonment worsens the environmental performance of the farms. In these marginal areas, the most relevant changes are in the forestry farming and arable sectors. The results indicate an abandonment of area of approximately 40% in farm 11, as farmers find it non-profitable to maintain permanent grassland. As a result of the abandonment, soil erosion is increasing; an abolishment of BPS implies that farmers are not keeping their farms under GAEC commitments, which can further worsen the hydrogeological situation.

Although land demand seems static for other farms, the abolishment of BPS and lack of conditionality measures in place make it non-profitable to adopt practices that reduce soil erosion. Consequently, the amount of soil erosion increases. This result is consistent with previous literature findings which indicate that the first pillar payment has reduced soil erosion by water by 20% in the last year (Panagos, Borrelli, and Robinson 2015).

Our model indicates the overall benefit of the introduction of eco-schemes (policy mix 1) along with a reduction in soil erosion for almost all farming sectors. It is worth noting that the possibility of getting access to these voluntary payments would increase the demand for land for grapewine farm type (farm 12), mainly through the introduction of winter soil cover (beyond conditionality) for arable areas.

The introduction of the new AES (policy mix 2) has positively affected the demand for land, as four farms found it profitable to increase their operated land with the new measure. Increases in operated land were pursued by either increasing the land rented in or reducing the abandonment of land. These farms belonged to forest and arable farms; while this is quite intuitive for arable farms (i.e. the level of payment was quite high compared to the rental value of land plus the additional costs), the same can be applied to the forestry areas, where these farms can enlarge their size by renting-in permanent grasslands in mountainous areas, which are abundant in the local land market. The increase in land operated under AES2 made a positive contribution to the reduction of soil erosion (unitary contribution per area is lower than the baseline).

The abolishment of the threshold of AES payments below three hundred euros and the minimum requirement of standard output (policy mix 3) determined an increase in participation in both AESs by hobby farmers. This did not provide any change in land demand compared to the previous policy mix, but rather an

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improvement in the environmental performance of small olive oil and arable farms.

The introduction of payments based on simulated results (policy mix 4) showed a generally low environmental performance with respect to the baseline, as the simulated value of environmental goods was lower than the participation costs (see report D4.2 for discussion of the results-based measures).

The introduction of uniform payments had a similar effect to that of its abolishment in farm specialisations other than arable farms. This can be a consequence of the threshold used by the regional administration that avoided distributing direct payments below a threshold of three hundred euros. Only the grapewine farms showed an increase in land demand. The uniform payment for policy mixes 1, 2, 3, and 4 did not make relevant changes with respect to the convergence model of BPS.

The next section presents the aggregated results for each farm type (Figure 7 and Figure 8). Figure 7 and Figure 8 present the results under the current BPS (i.e. partially decoupled) and the regionalised payments, respectively.

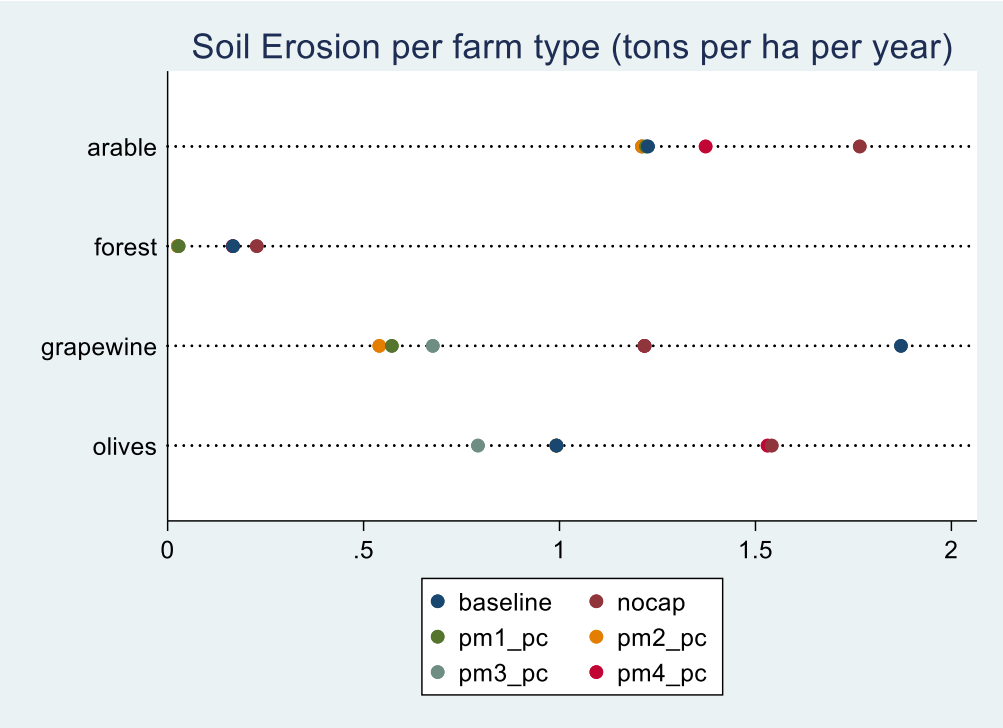

Figure 7: Dot chart presenting the impact of different policy mixes (assuming partial convergence)

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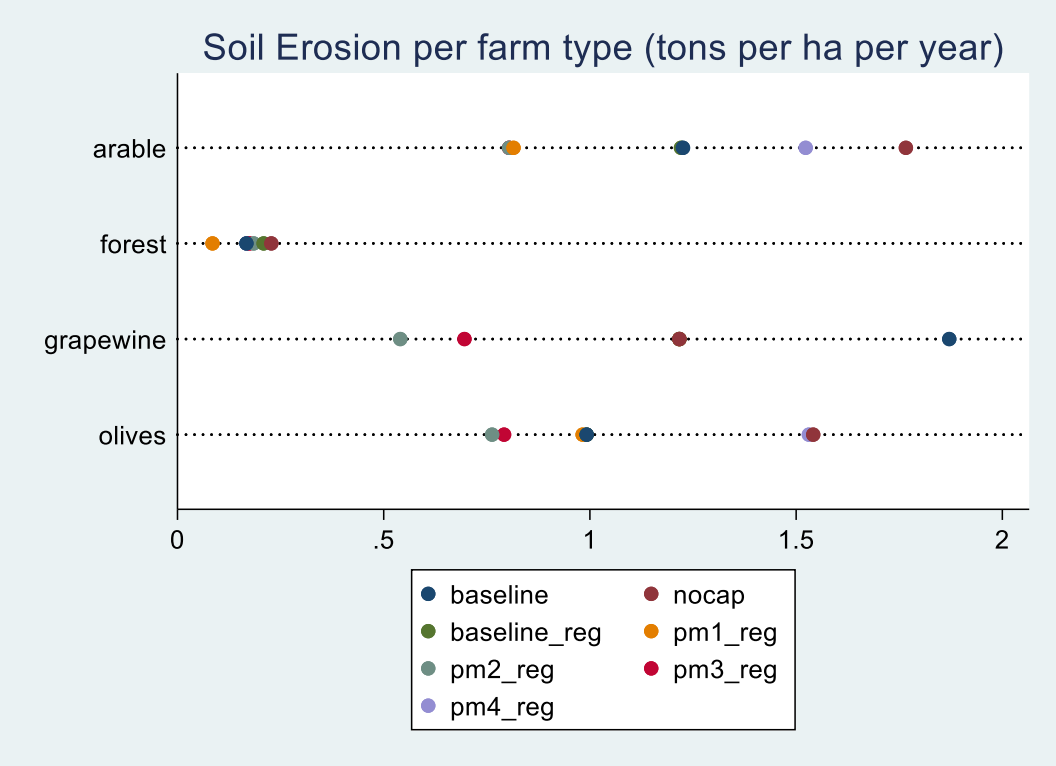

Figure 8: Dot chart presenting the impact of different policy mixes (assuming regionalised payments)

Figure 7 and Figure 8 show the amount of erosion per farm type under the different policy mix compositions. The erosion scenario is the worst on the right side of the lines. Going from right to left, the situation improves and shows the best policy mix to limit soil erosion and protect the environment. The baseline and no-CAP scenarios represent the worst protection scenarios. In this mix, farmers were not remunerated for their protection activities. They could not have positive economic effects with their landscape custodian activities. The figure shows that arable crops can enhance erosion activity. Wine and olive production in the area influenced the erosion scenario in similar ways. Forest crops without payment could limit erosion more than other crops under the best scenario. The high land cover and action of the roots guarantee superficial soil horizon stability. We can say that the natural forest can limit soil erosion without payments but can almost avoid soil erosion with the right remuneration scheme, guaranteeing a good rational administration of the forest. However, the reforestation of abandoned land can have strong negative effects. The coloniser species are not able to physically protect the soil. Landslide and erosion phenomena are common in abandoned land in the case of colonial vegetal cover. Hobbyist farmers play a vital role in preserving the landscapes, mostly in a region characterised by small farms and a low level of professional agriculture. Figure 1 shows that a more complicated but coherent set of measures can reduce erosion. There are three different patterns. The worst scenario is characterised by the no cap and baseline payments. The best scenario includes all the instruments

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that can be exploited (policy mix 2 and policy mix 3). The inclusion of hobby farmers can slightly improve the best situation. In arable and olive crops, the difference between the inclusion of hobbyists and professionals was larger with respect to other types of crops. This difference can be attributed to the high presence of small landowners who care for small arable and olive lands in Liguria. The situation was not as easy for the hobbyists regarding forest land administration and wine production.

4.5 Conclusions

We simulated the combination of different policy mixes and action-based/results-based payments on land demand. Although the literature has pinpointed an extremely high dependence between the land market and payments, scant literature has investigated the role of AESs.

Our results suggest that there is no conflict or distortion between the first and second pillar payments and that first-pillar payments are relevant for maintaining a minimum level of public goods provision by farmers.

Although land demand does not change, hobby farmers are relevant actors to be included in future policy as they play a crucial role in protecting the landscape from hydrogeological instabilities.

Our analysis shows that the combination of the first and second pillar payments has a strong implication on the change in land demand. Therefore, by ensuring the provision of public goods, the policy mix is particularly relevant in the inner and marginal areas where even low amounts of direct payments can ensure the continuation of farming activities.

The results show countervailing effects among the different policy instruments when not designed properly. This implies that the policy mix requires high public transaction costs to provide public goods effectively.

The design of different policy instruments and evolution of the baseline between the polluters pay principle and providers get principle are crucial to ensure an efficient AES measure followed by acceptable and justified first-pillar payments.

5 General conclusion

Through these three models, we proposed here to investigate the following questions regarding the role of land tenure and land dynamics in AECPG provision:

a) How specific environmental lease contracts can be designed to promote environmental-friendly land use?

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b) How the success of contract solutions is affected by different land tenure systems?

c) How different contract solutions can affect land tenure and land markets?

The different models presented give some insights to these questions, which are summarized in the section below.

Summary Model 1

The results from the agent-based model indicate that contracts should be specified in the light of local targets for AECPG delivery. For example, if the local aim is to increase the base level for biodiversity, flexibility in contract setup can trigger a wide adoption of measures, but might result in less effective measures prevailing. If on the other hand the target is a more ambitious biodiversity benchmark, a stricter specification of the measures to be implemented can help reaching the target. In the case of the delivery of other public goods or in the case of a societal demand for high levels of biodiversity that require widespread implementation of ambitious measures, commercial tenure contracts should probably be aligned, or complemented with, collective implementation and planning of measures.

Summary Model 2

The impact of land tenure systems on the success of contract solutions has been investigating using a Tobit model to estimate the impacts of land renting and land rents on the probability to participate in a result-based AECM or to participate only in an action-based AECM. To conduct this analysis, we used a panel of observations from the Farm Accountancy Data Network (FADN) of farms eligible to RB AECM during the 2015-2019 CAP programming period.

Through our statistical analysis, we found a significant impact of the level of land rent on the participation in both RB and AB only AECM with the stronger effect of RB AECMs, for schemes that focus on grasslands: the higher the value of the land, the less likely the farmer will adopt an AECM. In addition, renting farmers are more likely to only adopt action-based AECM (positively) while a decrease in land rent could increase the probability of farmers to adopt these AECM.

Summary Model 3

A mathematical programming model is used to analyse of the effects of a policy payments to prevent soil erosion due to climate change in hilly and mountainous areas, explicitly considering the effects of policy on marginal land abandonment. Different combination of policy-mix are simulated including conditionality, eco-schemes, and agri-environmental schemes, in the particular setting of the Liguria area.

From these simulations, it appears that the policy mix is particularly relevant in the inner and marginal areas where even low amounts of direct payments can ensure the continuation of farming activities, ensuring also the higher environmental benefit. When AECPG are not coherently designed with

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Conditionality and Ecoschemes, the provision of public good (i.e. reduction of soil erosion) may hampered by land abandonment.

There are some limitations to these models: the contractual solutions can take various forms, and some choice have been made, especially for the application of these models. They take into account specific AECPG provision, on specific areas and specific contract types. Indeed empirical modelling requires information and data that are often not available. Some interesting initiatives are emerging that are promising for better measurement through time of the environmental impacts of agriculture: for instance the FLINT project (see the project website), which outcomes would be to include sustainable development data within the FADN, for instance with data relative to inputs and livestock both in monetary value and quantity to better grasp the environmental pressure of agriculture. Another promising lead to increase data collection is the use of remote sensing or satellite data.

Nonetheless, these models demonstrate that modelling is possible and useful to anticipate and compare the consequences both economic and environmental of different contractual solutions, here related to land tenure and land dynamics. Through these models, it appears that land tenure contracts can foster AECPG delivery, and allows to secure the provision of AECPG over time. Such contracts can complement other schemes as there are numerous interactions between land tenure contracts features specification and other measures, depending on the local objectives and in accordance with the local spatial variation of AECPG-supporting landscape elements.

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