Identifying drivers of land use change (D3.1)

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Abbreviations

AES	Agri-Environmental Schemes
BE	Belgium
CH	Switzerland
COM-B	Capability, Opportunity, Motivation - Behaviour
D	Deliverable
DK	Denmark
ELO	European Landowners' Organization
EU	European Union
HU	Hungary
M	Milestone
PL	Policy Lab
PLC	Private Land Conservation
PT	Portugal
RQ	Research Question
WP	Working Package

About MOSAIC

For many decades already, the scientific community warns about the detrimental impact of current **land use practices** on biodiversity, soil fertility, water reserves, climate change, to name a few, eroding the safe operating space for humanity on Earth (Rockström, 2009; Richardson, 2023). Yet, despite the piles of reports with irrefutable evidence, not much change can be seen on the ground. Facts, figures and scenarios of the future we are heading for appear not to be enough to convince land use decision makers to make more sustainable choices.

MOSAIC therefore wants to contribute to a better understanding of why this is the case, and, more importantly, contribute to the solutions. To that effect MOSAIC investigates the **drivers behind land use choices**. Are farmers, business managers, nature conservationists, policy makers and other land use decision makers **aware** of what is at stake? And what role can they play in finding a solution? What kind of land use do they favour and why? What motivates them to go for their choice? How can their decisions be aligned or reconciled with policy targets in the fields of climate change mitigation and adaptation, biodiversity and renewable energy? What **tools and incentives** can help to align these individual land use decisions on the ground with high-level policy targets and international agreements aimed at the conservation of our common home?

To investigate these questions, six **Policy Labs**, comprising a diverse array of policy makers in Belgium, Denmark, Hungary, Portugal, Switzerland, and a European Lab, are set up as pivotal platforms for MOSAIC's transdisciplinary research. Each one is linked to a specific case of land use decision making. These Policy Labs help the researchers investigate these questions and allow practitioners to co-create relevant knowledge, so the gained knowledge becomes truly actionable for them.

MOSAIC's modelers will build upon this knowledge about drivers and motivations to characterize expected future land use patterns – an indispensable tool in land use policy processes. Based on spatial, social and economic insights, potential displacement effects can be made visible, as well as evolutions jeopardizing European biodiversity, climate and renewable energy goals.

To enable this, the Policy Labs receive support from a **digital learning environment** in which MOSAIC bridges the siloes of researchers' and practitioners' worlds. During the project, this environment allows for knowledge transfer, learning, evaluation and collaboration between researchers and practitioners, both within the cases and in cross-case settings. After the project, this learning environment will live on to give answers to the research questions outlined above, questions about the practical implementation of these learnings; and will it function as a source of inspiration for those wanting to render land use more sustainable in other places as well.

This way, MOSAIC will showcase in six cases how policy, science and society can work hand-in-hand on concrete solutions to accelerate the transition towards more sustainable land use.

Abstract

This report presents some of the findings of the MOSAIC project's Work Package 3 (WP 3), aimed at identifying the perceived drivers, land-use optimization considerations and values behind land use decision-making across Europe. Utilizing a transdisciplinary approach through six 'Policy Labs', the research employs mixed methods - including interviews, photovoice and surveys to analyse the gap between high-level sustainability targets and local implementation.

The study highlights a significant diversity of land use challenges across six distinct European contexts. In the Vlaamse Ardennen (Belgium), the analysis focuses on peri-urban pressures where traditional livestock farming struggles to stay competitive in a strongly regulated policy context and competes with 'new' recreational grassland users. The Sand-Ridge Region (Hungary) and Alentejo Region (Portugal) represent landscapes facing critical water scarcity. In Portugal, the irrigation infrastructure has created a 'two-speed' transformation contrasting intensive, irrigated monocultures with declining traditional systems like the *Montado*. The Swiss Alps case examines trade-offs between renewable energy expansion (photovoltaics) and landscape identity and tourism. Denmark addresses the economic and regulatory barriers to large-scale afforestation on private land, while the EU-wide case analyses behavioural drivers in voluntary private land conservation.

One common factor identified across these diverse cases include the possibility of generating a profit from the land, including the EU support through the CAP. Other economic factors such as labour shortages and market volatility also play a role. Land users often perceive an 'unsupportive policyscape', as they frequently report bureaucratic burdens, regulatory disconnects, and 'perverse incentives' that inadvertently discourage sustainable practices. Crucially, the report finds that while financial viability is often a necessary condition for change, it is rarely sufficient; psychological factors - including place attachment, identity, and trust in institutions - play a decisive role in uptake.

Practical implications for policy design are synthesized into four key intervention points: (1) Instrument targeting, ensuring policies address specific causal factors rather than symptoms; (2) Cross-scale alignment, resolving conflicts between national/EU goals and local spatial realities; (3) Transparency regarding the winners and losers of land use transitions; and (4) Flexibility, allowing instruments to accommodate site-specific conditions without compromising overall sustainability objectives. The findings suggest that effective policy must move beyond simple financial incentives to create coordinated 'policy bundles' that address social and structural barriers.

1 The MOSAIC approach to better understand land use decision making

The main objective of **MOSAIC WP3** is to gain 'understanding key drivers behind land use related decisions and their impact of incentives and instruments upon them'. This objective involves both the European scale and the level of the individual Policy Labs (PLs). Policy labs are interdisciplinary, collaborative spaces where researchers, policy makers and other stakeholders come together to develop evidence -based insights and co-design policy innovation. The goals and working of the policy labs in MOSAIC project are explained in Deliverable 2.1 (D2.1): Guidelines for establishing a Policy Lab.

As a preparatory step for WP3, a **research gap analysis** has been conducted on the determinants of European farmers' adoption - and intention to adopt - more sustainable, lower-intensity land use practices (Milestone 4, M4). The gap analysis shows that despite substantial variability across contexts and methods, three determinants consistently exhibit significant effects on adoption decisions: pro-environmental attitudes, perceived/economic viability and past experiences with environmental schemes.

A second set of factors shows generally positive, though less uniform, effects: financial incentives, peer influences, adaptability/flexibility, information sources, income structure, pedo-climatic conditions, farm performance, access to advisory services, and succession. The review identified methodological gaps related to uneven geographic coverage, varying temporal windows, inconsistent treatment of intentions versus behaviours, and limited exploration of interactions among farm, policy, and contextual characteristics.

The next step is this **D3.1 report: 'Identifying drivers of land use change'**. The full description of the Deliverable reads like this: 'Report of the identified European wide and local key drivers behind land use change and the importance of motivation, structural constraints, perceptions, and worldviews'.
As preparation for this deliverable, several preparatory activities have been conducted in all the cases:

1. Assessment of local case-specific **past land use changes** via statistical analysis and from the literature.
2. Based on in-depth knowledge of the cases, booklets with **illustrated narratives** explaining land use changes in the case areas were made (M6). One of the methods used here was the Photovoice method, where land users were asked to take pictures on the issues focussed at in the case study.
3. In the Policy Labs (PL) the **core land use focus** was decided upon and based on a stakeholder mapping exercise the **relevant land user group(s)** was identified (Task 2.1). For the more regional case studies, there was often a need to distinguish different land user groups (but it was proposed to limit to maximum 4 groups). If different land use groups had very similar in logics regarding their land use decision making, then were reported as one group. Where relevant, social inclusive and gender-sensitive approaches were applied to ensure the involvement of diverse voices.

Based on the gap analysis (M4), preparatory steps (see above), literature and interactive WP3 MOSAIC discussions, we designed an **analytical framework** (or 'mind map') for collecting the information related to all the '**factors**' that affect land use decision making (Fig.1) in the six MOSAIC cases (note: 'factor' is used as a generic term which influence decision making). The analytical framework is sub-divided in the following core elements:

- Centrally in the framework is the **land use decision making process** of the focused actor group (blue circle).
- **Land-user motivations**: Around the decision-making circle, the factors that influence decision making and which are (more or less) controlled/under the influence by the land user are visualised. They include the (mostly economic) **land use optimization considerations** (left) and **values** (incl. meanings and interpretations). (Note: In the MOSAIC proposal, the terms 'worldviews, perceptions and motivations' were mentioned, but after consideration the above-mentioned terms in bold were considered more appropriate).
- **Perceived external drivers**: Above the personal motivation box, all the external drivers which are perceived by land users as factors that influence their decision making are visualised. (Note: In the MOSAIC proposal, this factor is also referred to as 'structural constraints', but for this report the term 'external driver' is preferred as it includes both constraints and opportunities). In total 4 type of external drivers are identified: markets & technologies, policies, social environment and climate change.
- Impacts: Below the personal motivation box, changes/maintenance in land use is shown and their consequent impact(s). Impacts of land use (change) are not the main focus of this report, but they are often described in a qualitative way.
- Arrows: The width of arrows could be adapted to indicate relative importance of factors.

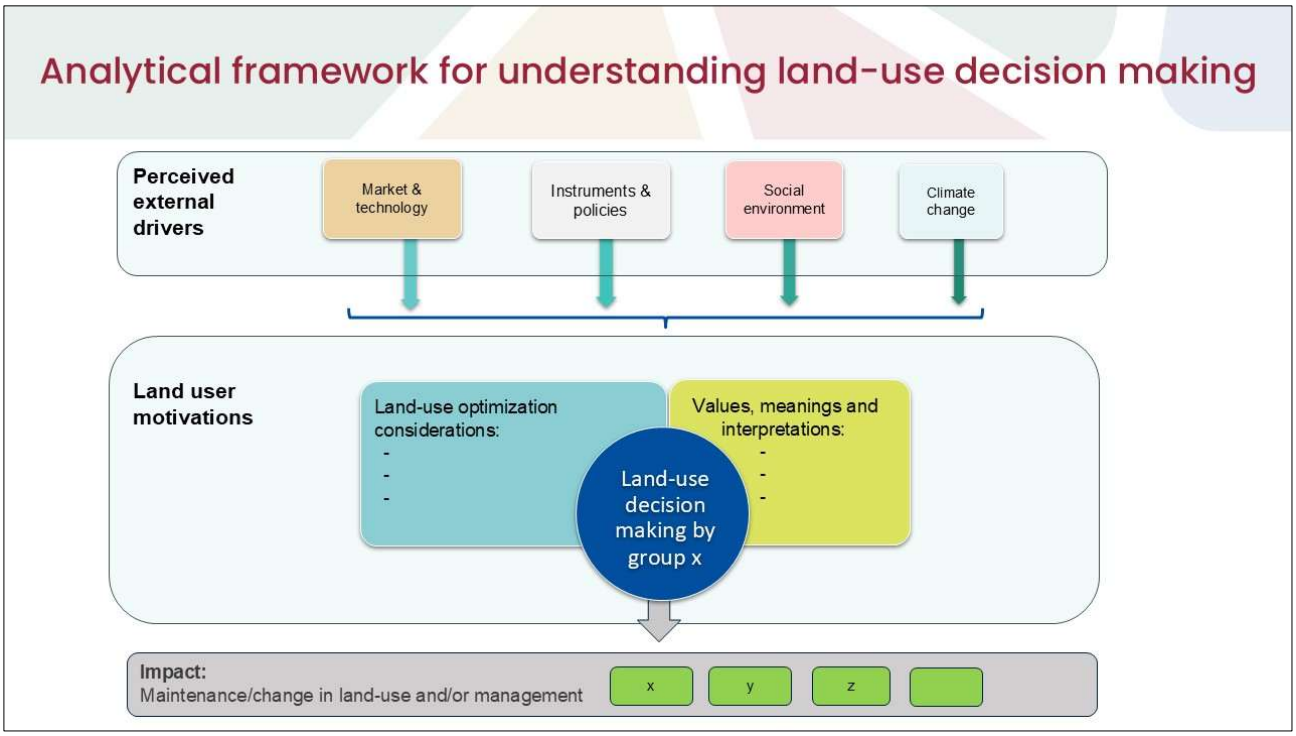

Figure 1: Analytical framework (or 'mind map') for collecting the information related with perceived external drivers and motivations that affect land use decision making.

Researchers in the case studies were free to use to choose their **data collection methods** but were encouraged to use mixed methods that combine quantitative and qualitative data collection. The qualitative methods will be selected and conducted in close cooperation with PLs to ensure local pertinence

Qualitative research methods (Task 3.2) were proposed to assess the following:

- The perceived (environmental, economic, political) drivers as well as (personal) motivations that influence/steer land use change decisions.
- Awareness about the local impact of long-term threats (climate change, biodiversity loss, etc.) and how it affects land use change attitudes and decisions.
- Actual and potential trade-offs of land management decisions.
- How policy mixes (legislation, incentives, agreements, communication, etc.) influence (positively and/or negatively) the motivations to steer land use in a direction aligning with European sustainability goals.

The quantitative research methods (Task 3.3) are mainly applied to assess the following:

- The retrospective uptake of land use change policies and instruments in the case studies.
- Actual and potential trade-offs of land management decisions.
- Willingness to engage in new programmes for sustainable land use.
- The perceived (environmental, economic, political) drivers as well as (personal) motivations that influence/steer land use change decisions.

The next **steps of the D3.1 research process** is illustrated in Figure 2. The gap analysis, the MOSAIC analytical framework and research in the 6 MOSAIC case studies took place more or less simultaneously, and they also inspired each other interactively. This research took place during the period September 2024 - November 2025, and the approach and preliminary results were discussed during the regular WP3 meetings and MOSAIC project meetings. To ensure consistency, the cases were asked to report according to a common agreed table of contents. The case reports can be found in the annex of this report. The core WP3 team used these reports as a basis to detect common themes and diversity of perceived drivers and personal motivations in relation to land use decision making.

This **D3.1 report will provide input** to the overall MOSAIC research objective, and more specifically to the following MOSAIC activities and Deliverables (D) & Milestones (M):

- D3.2 - Uptake of land use policy incentives and instruments. Description: Report on the past and expected future uptake of policy instruments, leading to concrete recommendations on the relative merits of regulatory, market-based, education and other policy instruments and incentives in different land use decision making contexts.
- M8 - Case specific insights from incentive uptake.
- M14 - Publications on uptake of incentives and instruments and drivers behind LU decisions (1 per PL).
- WP2 - It will feed the discussions in the PLs about effective measures for transformative land use change.

- Task 4.3 - Model application and analysis of results in terms of policy objectives.
- Task 5.2 – Co-designing digital model-based services in the PLs.
- M11 - Recommendations on methods to approach the context specific analysis. Trans-national and methodological learning on the analysis of key drivers behind land use related decisions. This task will exchange, synthesise and integrate the methodological findings of this WP. These learnings will be further enriched with relevant insights gained during the processes the PLs went through and the outcomes of the analysis of T5.3.

In chapter 2 the six MOSAIC case studies are explained and the diversity of land use challenges in Europe they address. In chapter 3, the applied research methods in the 6 MOSAIC case studies are discussed. In chapter 4, the common factors influencing decision making of land users in the 6 case studies are summarized. Finally, in chapter 5 reflections are made on the implications for research and policy. This last policy section will be the basis for the next WP3 Deliverable 3.2: 'Uptake of land use policy incentives and instruments'. The report closes with a short conclusion (Chapter 6).

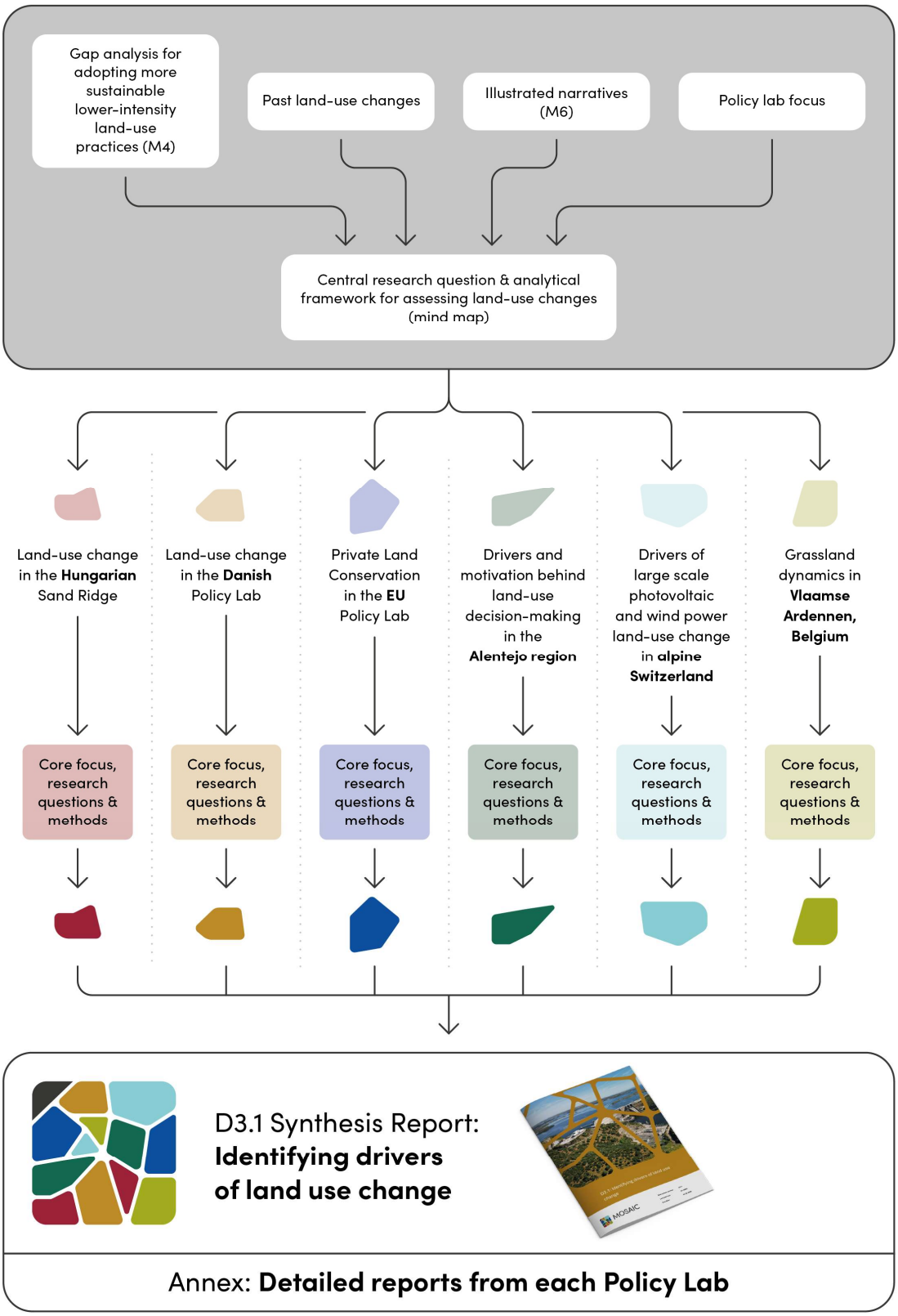

Figure 2: General approach of making this synthesis report based on the 6 MOSAIC case studies.

2 Diversity of land use challenges in Europe

All MOSAIC case studies conducted research to identify the perceived drivers, land use optimization considerations, and values influencing land use decisions (Table 1). Whether it is planting trees in Denmark or managing water in Hungary, the central research question (RQ) revolves around understanding why land users make the choices they do. The spatial scale ranges from a protected landscape to the whole EU.

These six case studies **represent diverse, critical challenges in European land use decision making**. The land use challenges range from water scarcity in Hungary and Portugal, landscape decline due to renewable energy expansion (Switzerland) and due to land use intensification (BE, PT, EU), and biodiversity collapse across the European Union. Here is what each case study represents:

- Vlaamse Ardennen (Belgium): Represents the pressure on grassland ecosystems in peri-urban landscapes. It illustrates the 1) changing management of grassland for livestock, and 2) the competition between grassland used for livestock farming and grassland used for different purposes (such as hobbyists and horse owners, nature conservation) or changing to other land uses.
- Sand-Ridge Region (Hungary): Represents the crisis of farming in a semi-arid, water-scarce landscape. It serves as a test case for drought adaptation where water scarcity is a constitutive condition that defines the boundaries of viable agriculture.
- Alentejo Region (Portugal): Represents a "two-speed" landscape transformation driven by extensive irrigation infrastructure and water access. This led to rapid intensification of irrigated monocultures (olives, almonds), enabled by a dam, in contrast to the decline and abandonment of traditional rain-fed extensive systems, such as the *Montado*.
- Swiss Alps (Switzerland): Represents the land use conflicts associated with the renewable energy transition in sensitive Alpine environments. Specifically, it focuses on the deployment of large-scale ground-mounted photovoltaic (PV) systems to secure winter electricity supply. This case exemplifies the trade-offs between national energy goals and local concerns regarding landscape identity, tourism, and biodiversity.
- Denmark: Represents the challenges of implementing large-scale afforestation on private agricultural land to achieve national climate, water and biodiversity goals. It highlights the tension between intense competition for agricultural land, which drives up prices, and the motivation to convert land for public goods (such as carbon sequestration and water protection).
- European Union: Represents a cross-cutting behavioural analysis of voluntary private land conservation.

The primary **actors** in all case studies are those who directly manage the land - specifically landowners, farmers, and developers. The studies aim to understand the agency of these land user groups, from livestock farmers in Belgium to renewable energy developers in Switzerland.

All cases are united by **policy objectives** aimed at improving environmental outcomes. Common themes include halting declining landscape quality (BE, CH, EU), promoting biodiversity (BE, PT, EU, DK), and adapting to environmental pressures like water scarcity or climate change (PT, HU,

DK). In the large-scale cases, the policy goals are specific environmental targets, such as afforestation in Denmark and voluntary private land conservation in the EU. In the smaller, regional cases, the policy focus is more oriented towards integrated regional and landscape development (BE, PT, CH, HU). The research seeks to identify promising entry points for policies that balance ecological conservation with economic viability. Ultimately, these studies highlight the critical role of human decision making in addressing biodiversity loss and climate adaptation at both local and continental scales.

Table 1: Overview of the 6 MOSAIC land use change case studies.

Region	Country	Surface (km2)	Population	Key challenge of the focus area	Key land use change	Policy objective	D3.1 Key research question	Focussed actor groups
Vlaamse Ardennen	Belgium (BE)	245	100.000	Declining landscape quality	Land use change of grasslands	Maintain grasslands for aesthetic landscape quality, erosion control and biodiversity via sustainable business models for grasslands.	To identify the drivers and motivations for both maintaining and managing grasslands.	1) Livestock farmers 2) 'New' grassland users
Sand-Ridge Region	Hungary (HU)	8.715	623.000	Water scarcity, declining population, lack of capital for small and medium scale farms	Land use change regarding water management, crop selection, agroecological measures	Water retention, flexible and inclusive subsidy arrangements (enabling farmer agency), cooperation platforms and knowledge circulation.	To identify the drivers and motivations for land use change due to the effect of climate change and water management of the region.	Small and medium-scale farms producing livestock and arable crops: 1) conventional medium-scale farm, 2) traditional smallholder farm, 3) regenerative farm.
Alentejo Region	Portugal (PT)	27.339	704.533	Increase in intensive land uses accompanied by landscape simplification	Land use change regarding intensification (olive groves, greenhouses, photovoltaic farms, etc.)	Promote sustainable land use management that integrates nature conservation, farming systems, and energy production.	To identify the drivers and motivations of land use change in the Alentejo region; understanding what motivates the decision making of regional land users.	Farmers and local associations
Swiss Alps	Switzerland (CH)	25.000	2.000.000	Shifting landscape identity of the Alps	Renewable energy land use change (policy led)	To inform policies that balance renewable energy expansion with landscape and biodiversity concerns by clarifying the drivers of land use change and acceptance in alpine photovoltaic development.	Which structural, governance-related, and perceptual drivers influence land use decisions and acceptance of alpine renewable energy projects in the Swiss Alps?	1) Developers 2) Landowners 3) Municipal and cantonal authorities 4) General public 5) Local citizens
Denmark	Denmark (DK)	43.000	6.000.000	Voluntary LUC	Afforestation (policy led)	Afforest 250,000 ha	What levers and barriers are there for landowners to engage in afforestation	Landowners

EU	EU	4.250.000	450.000.000	Biodiversity, land conservation	Towards more biodiversity conservation	Provide insights on land use change behaviour and decision making by landowners	Which behavioural factors influence landowners' willingness and capacity to participate in voluntary Private Land Conservation (PLC) across Europe, based on evidence from pioneering PLC initiatives?	Landowners who are member of ELO or EUROSITE

3 Methodologies applied in the 6 MOSAIC case studies

The methodologies used in the cases display a strong shared commitment to **mixed method approaches** and **participatory research** (linked to the Policy Labs): These are common methodologies across cases:

1. Spatial and document analysis: The cases generally utilised spatial data (e.g. analysing grassland decline in Belgium or solar siting in Switzerland) and extensive document/policy reviews.
2. Land user typologies: Several cases developed specific 'land user typologies' to categorize diverse actors that differ in their land use activities, their motivation and how they react to external drivers. Belgium defined types like 'livestock farmers' vs. 'new grassland users', Portugal identified types such as 'modernizing entrepreneur' or 'ecosystem-dependent', and Hungary distinguished for example between 'traditional smallholders' and 'regenerative transitioners', and Denmark between landowners having small or large areas.
3. Semi-structured interviews: All country-based cases relied heavily on in-depth interviews with land users (farmers, foresters) and experts (organizations, policymakers) to understand motivations, and perceived drivers.
4. Surveys: Some cases used surveys to collect quantitative data on motivations and perceived drivers (DK, CH).
5. Mixed methods approach: All cases combine qualitative insights (interviews, workshops) with other forms of data (spatial analysis, literature reviews, or quantitative surveys) to triangulate findings. The goal is to cross-reference personal perceptions with structural data like land use maps or economic statistics.
6. Policy labs and validation of results: A core component across all cases is the use of 'Policy Labs': iterative meetings with stakeholders to co-design research questions and validate findings. For example, Hungary and Belgium explicitly used these sessions to validate the 'mind maps' created by researchers. Denmark used it to discuss implications of the findings.

On the other hand, **unique tools** were employed tailored to address specific regional challenges but their choice was also influenced by the available expertise and choices made by researchers:

- Photovoice (BE, HU, CH): These three cases explicitly used the Photovoice method. Participants were asked to take or select photos that represent their relationship to the land (e.g. cows grazing, solar panels). These images were then used to facilitate discussions about values and emotions, which often surfaced deeper, non-rational motivations.
- Transect walks (HU): In addition to interviews, the Hungarian researchers conducted transect walks - walking the land with farmers to observe practices and water management structures directly. This allowed them to connect spoken narratives with visible landscape realities.

- Quantitative survey (DK): The Danish case focused on a large-scale quantitative survey distributed to over 6,000 landowners to analyse the motivations for afforestation. This approach was chosen because significant qualitative work had already been done in the region.
- Choice experiment (CH): For the Swiss Alps, a Discrete Choice Experiment (Louviere et al. 2000) (online panel) was conducted to model trade-offs.
- Physiological experiments (CH): This case employed the most experimental techniques. It used cognitive-psychological experiments measuring electrodermal activity (skin conductance) to assess physiological emotional arousal to landscapes with renewable energy infrastructure.
- AI-Assisted Deductive Coding (EU): The EU study is unique in its use of Artificial Intelligence (Large Language Models/Gemini 2.5) to perform deductive coding on a massive dataset of 51 grey literature documents (with thousands of pages in various European languages). It used the COM-B framework (Capability, Opportunity, Motivation) to structure the AI's analysis, acting as a 'research peer' to process multilingual texts.

The case studies provided several **critical reflections** regarding the limitations and challenges of their **chosen methods**:

Sampling and representation bias:

- Gender and demographics: The Portuguese researchers noted a gender imbalance in their interviews, reflecting the male-dominated sector. The researchers in the Hungarian case noted that validation workshops were dominated by middle-aged or elderly men, which limited the discussion of personal/emotional motivations that appeared in individual interviews. The researchers in Denmark noted a low female share in their survey, also reflecting the gender imbalance in the sector.
- "Front-runner" bias: The researchers of the EU report warned that their data (based on LIFE projects) likely represents a 'coalition of the willing' or front-runners, potentially skewing results toward more motivated landowners than the general population.
- Missing actors: The Belgian researchers noted that by interviewing current farmers, they missed those who had already retired or sold their land - the very actors driving land use changes. The Portuguese researchers acknowledged that large corporate investors (who drive olive/solar expansion) were not included, resulting in a missing a perspective of a key actor.

Methodological limitations:

- Qualitative interviews: The Portuguese researchers reflected that their qualitative approach with a small sample, limits generalization to other regions but ensures high local relevance making the findings easily transferable to comparable Mediterranean contexts.
- Stated vs. actual behaviour: The Danish researchers highlight that their quantitative survey measures *stated* preferences (what people say they will do), which may not necessarily match *actual* future behaviour. This likely carries over to other cases as well relying on stated information (interviews + surveys).

- Scoring: In Hungary, the researchers noted that ‘strict scoring’ of factors was unrealistic. Farmers preferred explaining *why* a factor mattered rather than ranking them numerically.
- Physiological disconnect: In Switzerland it was found that physiological bodies reacted strongly to high-infrastructure scenarios even when participants' self-reported attitudes (obtained via a survey) were neutral, highlighting a ‘hidden layer of affective resistance’ that surveys miss.
- AI limitations: The EU study noted that while AI enabled scale, it struggled with ‘contextual ambiguity’ and required human triangulation to ensure precision.

4 Common factors influencing land use decision making

In chapter 4, we discuss the common factors that influence land use decision making in the 6 MOSAIC cases. We follow more or less the logic presented in the analytical framework (Fig. 1). We start with the economic optimization considerations of land users (4.1), as this is most of the time the gate keeper for the choices that land users can make. A related topic is the influence of new technologies impacting land use decision making (4.2). Next in line are the public policies for land use change (4.3), which have a profound impact on land use decision making in all the six cases. The impacts of climate change (4.4) appeared in several cases as an important driver of land use change decision making. Last but not least, the importance of values, meanings and interpretations (4.5) shaping land use decisions are discussed. Although these land use decision factors are discussed here in separate sections, it is important to note that in reality they appear together as (complex) bundles.

4.1 Economic land use optimization considerations

In the section we discuss how changes in profitability drive land use decision making (4.1.1.). Changes in economic factors driving this profitability include: input markets, output markets, new technologies and market risks and uncertainty. Beyond short-term profitability, other factors influence land use decision making, such as succession, identity, and land values (4.1.2).

4.1.1 Changes in economic factors driving profitability

Four main factors influence the relative profitability of different land uses: Input markets, output markets, technology, and uncertainty.

4.1.1.1 Input markets (costs)

A lack of labour is often cited as a key reason for either adopting technological solutions that reduce labour demand, or for moving away from labour-intensive farming systems due to the low attractiveness of farm work (e.g. small farms in Portugal and cattle farms in Belgium). Labour constraints have been mentioned as a driver of the shift from traditional livestock production to dairy farm automatization or to crop production (BE). While this is partly linked to demographic factors (including rural–urban migration), it also reflects increasing labour opportunity costs (higher wages in other sectors) and limited labour productivity, particularly in traditional livestock systems.

Limited access to capital - especially for smaller farms (HU, EU) - is a barrier to adopting new and potentially more sustainable practices that may require high initial investments. In contrast, large-scale farms or companies often have easier access to capital, which can facilitate further scaling-up and intensification of production (PT, EU).

The need of labour and expertise to ensure **administrative demands**, including application for and reporting on CAP subsidies may affect farm types differently and may therefore influence land use indirectly. Small-scale farmers often face relatively higher administrative burdens than larger farms, which may reduce their participation in agri-environmental schemes (PT, HU, EU).

An important factor influencing profitability is **subsidies** and these sending a strong signal to farmers production choices (HU) and may in some cases decouple decision from motivations about development, sustainability and self-dependency in farming.

4.1.1.2 Output markets and demand dynamics

Output markets and demand dynamics are an important driver of land use change across the case studies. For example, the increased demand for renewable energy strongly impacts the Portuguese case, which due to high solar radiation, has the potential for large-scale solar farms that compete with traditional agricultural land use. In the Hungarian case, shifts away from traditional production systems reflect farmers' responses to changing demand conditions, i.e. a stronger exposure to global market dynamics.

To counteract this, **direct sales** and alternative sales canals are considered by farmers as a pathway to reduce dependence on global markets, and/or an opportunity to obtain higher share of value added in the supply chain. However, to which degree such diversification of sales canals is efficient is not clear-cut.

Payment for environmental services can be considered as new output markets for landowners. However, in the Portuguese case such payments were considered insufficient and linked to heavy administrative burdens, and nature or carbon credits are still considered immature for large-scale private land conservation (EU). In the Flemish case, certification - a requirement from the dairy supply chain about environmental-friendly management - was not considered to have a strong impact on management as the price premium is limited.

4.1.1.3 Technology (see also section 4.2 – role of technology)

The case studies show that major **technological and structural changes** can significantly affect the relative productivity of different land uses and land use intensities. In the Alentejo Region (PT), the construction of the Alqueva dam made irrigation water more widely available at lower cost, thereby stimulating more intensive agricultural land use. Another example is the introduction of milking robots, which can make grazing less attractive and encourage a shift towards indoor feeding and mowing-based grassland management.

4.1.1.4 Risks and uncertainty

Changes in risk and uncertainty—driven for example by unregulated global food markets, by climate change, or by vague or conflicting policies, strongly influence land use decisions. In the Hungarian case, such considerations motivate the use of locally adapted breeds to reduce vulnerability and dependence on external inputs. Conversely, the perceived risk of private land conservation activities - in relation to future policies or new policy objectives - may constitute a barrier to voluntary adoption of long-term conservation measures (EU).

Just as decreasing profitability can act as a lever for extensification or nature conservation (see 4.1.1), so can increased variation in return contribute to land use extensification. For example, decreased profitability and increased volatility may lead to an expansion of grassland to produce a larger share of fodder on farm for dairy production (BE).

A particular kind of **uncertainty relates to irreversible decisions**. The long time horizons associated with certain land use changes, which often involve irreversible investments, can represent a major economic barrier. For instance, afforestation on agricultural land is constrained by irreversibility of the afforestation decision while the gain from this forest investment is highly uncertain, not least because of the long time horizon (DK), and similar concerns are experienced with respect to the adoption of new innovative land use options in the Portuguese case.

4.1.2 Beyond short-term profitability: Succession, identity and land values

While much of the economic optimisation at farm level happens within shorter time horizons, the land has a value beyond its current owner. This is reflected in the land prices. Yet, farm profitability cannot be analysed independently of the farmer profile and time perspective. Whether farmers plan for succession (i.e. transferring the farm to their children) or not (PT, BE, HU) can significantly influence investment behaviour. These differences can be interpreted as intertemporal economic optimisation but may also reflect trade-offs between economic outcomes and heritage or identity objectives (PT), such as accepting lower profitability (or refraining from selling land for alternative uses) in order to maintain family heritage, or to obtain private amenity values (BE, DK) (See also section 4.5).

4.2 New technologies impacting land use change

The reason to invest in new land use related technologies revolves mostly around the pursuit of **increased production efficiency and control** (HU, PT, BE). This is a pragmatic response to persistent pressures, such as economic uncertainty, high input costs, labour scarcity, and climatic uncertainty.

At the same time, the adoption of technology often creates **competitive asymmetries**. On the one hand, the first movers are for example large-scale, capital-intensive ventures, exemplified by external capital-funded intensive monocultures in Portugal. On the other hand, smaller farms in Hungary have no access to technologies due to a chronic shortage of capital. This structural imbalance means technological advancement can inadvertently reinforce the dominance of industrial-scale operations and constrain the adaptation options for small and medium-sized producers. Furthermore, technology adoption is not uniformly embraced by all generations, for example in Portugal where younger, formally trained workers embrace innovation more readily than older farmers rooted in traditional knowledge.

In Belgium, a key technological driver is the **milking robot**, which has directly influenced a major trend of shifting grassland management from grazing into mowing. Since the robot system requires cows to stay close to the stable (home plot), farmers opt to mow most of their more remote grasslands and feed the cows (mostly) indoors. This provides higher, more consistent milk yields and reduces labour for tasks like herding and fence maintenance. The use of new heavier **tractors** is also noted, making the management of wet grasslands more challenging.

Technology's impact in Portugal is two-fold. On a large, structural scale, the Alqueva dam project combined with massive **irrigation infrastructure**, has fundamentally reshaped the agricultural landscape. This enabled the widespread adoption of intensive production systems and monocultures, particularly olive groves and almond trees. This public infrastructure acts as a catalyst for large-scale economic transformation. This, however, reinforces water dependency and may prove to be a future risk. On the farm level, technological modernization includes precision tools such as precision irrigation guided by soil moisture sensors for intensive systems. Extensive traditional farmers, while cautious, also adopt technology selectively, using **GPS guidance and soil monitoring** to improve efficiency, without compromising their extensive, resilience-focused logic.

In Hungary, farm technology plays a supporting role in adaptation efforts, focusing on improving **ecological resilience**. Investments are channelled into technologies that enhance the critical need for water retention and soil health, such as more efficient irrigation systems to reduce water loss, and the adoption of regenerative and non-tillage practices to improve humus formation. Despite the utility of these innovations, their widespread impact is limited by the structural barriers of low agricultural returns, volatile markets, and opaque access to credit, which collectively discourage long-term investment and technological renewal for many farmers.

The emergence of affordable **photovoltaic (PV) cells** is a significant driver of land use change, particularly in Switzerland and Portugal, and to a lesser extent in Denmark. The impact of PV manifests as a transformation of traditional or pristine landscapes into ‘energy production zones’, creating competition for land and driving up prices.

4.3 Importance of public policies for land use change

In this section, the impact of public policies for land use decision making is discussed. First we discuss the common mentioned perception of land users who experience an unsupportive "policyscape" and bureaucracy (4.3.1). Next, we reflect upon the discrepancy between higher scale versus local scale policy objectives (4.3.2) and between private objectives versus public goods (4.3.3).

4.3.1 Perception of an unsupportive "policyscape" and bureaucracy

The term "unsupportive policyscape" originates explicitly from the Belgian case study but describes a phenomenon prevalent across all six contexts. It refers to a regulatory environment

perceived by several land users as top-down, bureaucratically burdensome, disconnected from local realities, and sometimes creating 'perverse incentives' that undermine the policies' own environmental goals. Policy also often creates administrative barriers that exclude smaller actors. Here is the evidence of an unsupportive policyscape across the cases:

Regulatory disconnect and top-down imposition: Land users frequently report that policies are designed by distant authorities who lack understanding of practical farm operations, leading to regulations that do not "fit" the reality of land management. For example, Belgian farmers in the case study described regulations are complex and punitive, while objectives are unclear. They feel that policymakers "only see the numbers of reports" and ignore the farmer's reality, leading to a feeling of being targeted by controls rather than supported. Small-scale and extensive farmers in the Portuguese case study perceive a profound disconnection between governance frameworks and their reality. Policies are seen as designed for intensive modernization, leaving traditional dryland farmers without appropriate support tools.

Perverse incentives and 'lock-in' fears: A major structural failure is the creation of incentives that drive land users to destroy environmental features to avoid future regulatory restrictions. An example is the '5-year rule' for grassland in Belgium: farmers frequently plough up grass before it reaches five years of age, in order to prevent land from being legally classified as 'permanent grassland' (which carries strict protection status). This policy, designed to protect grasslands, ironically incentivizes their periodic destruction. The irreversibility of land use change is another perceived barrier to sustainable land use. In Denmark, landowners report in the case area that they are reluctant to convert land to forest because the legal requirement for permanence restricts future options.

Bureaucracy as a barrier for small-scale farming: Detailed regulation exists in many places to ensure that multiple objectives are fulfilled and that public money spent on support is delivering. However, in most of the cases, the administrative burden is emphasized as being heavy, sometimes ruling out certain actors from engaging (EU, HU, PT, BE, DK). In the EU case, "regulatory overload" and a lack of standardized procedures are cited as key barriers.

While subsidies are theoretically universal, complex eligibility requirements (e.g. minimum tillage rules that clash with local crop rotations) and bureaucratic hurdles may effectively exclude smallholders, while privileging large, well-resourced intensive producers (HU, PT, BE, EU). For example, some medium-scale farmers in Hungary withdraw from Agri-Environmental Schemes (AES) as they consider the administrative burden too high (even when their organic practices align with the scheme's goals). The subsidy system is perceived by many to structurally favour large-scale operators who have the administrative capacity to navigate it. Many policies are designed to treat all equal, but when actors start out with very different conditions, e.g. small or big farms, equal conditions may not be equally easy to live up to.

Regulation and administrative burden are a topic that is high on the European policy agenda, also outside the agricultural and environmental agenda and is also emphasised in the Draghi-report. Hence it is not surprising that it draws attention here too. Yet, the multiple policy objectives of land uses make it even more pronounced in the land use sector compared to other sectors of

society. This points at the importance of having emphasis on targeting policies, while keeping administrative burdens low when designing innovative policies (cf. D3.2).

Intensification versus sustainability: Several farmers felt that market logic and policies often incentivize scale over sustainability, forcing farmers to expand or intensify to survive. For example, in Hungary, the subsidy system acts as the 'single most behaviour-shaping mechanism', often overriding ecological reasoning, according to the farmers and experts. Area-based payments are formally crop neutral; however, in practice they incentivise income-optimising farmers to favour large-scale arable monocultures characterised by simple technologies and relatively low input costs. Although a theoretical degressivity applies to area-based payments above 1,200 hectares, large-scale farmers are often able to circumvent or offset these reductions in practice. The construction of the Alqueva dam in Portugal created a 'two-speed' landscape providing water access in a region affected by recurrent drought and chronic water scarcity. Public policy heavily subsidizes intensive, irrigated agriculture (olives/almonds), while traditional dryland systems (like the *Montado*) become economically unviable and face abandonment due to a lack of targeted support. This opens up to questions on the sustainable use of water *versus* water dependency of intensive agriculture. The low profitability of family livestock farming in Belgium combined with strict environmental targets (e.g. nitrogen reduction) provides a push towards intensification (e.g. mowing instead of grazing, planting potatoes).

Uncertainty and Instability: Frequent changes in rules and lack of long-term policy vision create a climate of uncertainty that can paralyze decision making. For example, farmers in Belgium report feeling uncertain due to the complexity and constantly changing rules regarding nitrogen and manure management. The Danish political environment with shifting policies was found to give rise to uncertainty, making landowners reluctant to commit to long-term changes like afforestation. The EU study showed that frequent rule changes or fragmented responsibilities across different levels of government create structural uncertainty, constraining landowners' willingness to engage in long-term conservation. Hence, landowners' biggest fear is to lose autonomy over their property.

4.3.2 Higher scale versus local scale policy objectives

The cases analysed in MOSAIC are all cases where land use changes are ongoing. Some are driven by markets, some by policies, and some by structural changes in society. How land users perceive these changes differs. Some welcome the changes, others want to conserve what was. In the following we will describe some of the high-level changes along with land users' perception thereof as found in the MOSAIC cases.

Both at EU and national levels, there are policies aimed at overall goals – the EU climate law, the nature restoration law just to mention a few. These, and the underlying policies, have quantitative goals that are to be reached at EU or national level. This can for example be reducing greenhouse gas emissions by a given amount or setting aside a certain percentage of land for nature restoration. Yet, land use change is happening at specific places. And that's where the higher-level and lower-level goals start to conflict. The **links between these high-level policies and the**

local ones are not always clear and sometimes result in conflict. This is raised as an important issue in all the cases.

In many of the cases analysed ongoing structural changes in the landscape towards **larger farms** (DK, BE, PT, HU, EU) are reported - a tendency roughly seen all over Europe. While this is partially driven by market forces, including difficulties in attracting farm labour (see 4.1), a part is also incentivised through the European **CAP**, which aims to help the agricultural sector becoming competitive on the world market. This means that land-based subsidies (EU, HU, PT, BE, DK) for production are a key factor.

But this trend comes with consequences locally: larger and more intensive farms typically result in a **lower labour intensity** (larger use of machinery), hence also often a decline in the rural jobs (and accelerating in depopulation of some rural areas). On the other hand, maintaining jobs in the agricultural sector remains a policy objective in most cases (EU, DK), and this is also a concern raised among land users in the case areas (PT, HU, DK). This development also accelerates in a **bifurcation of farm types**: besides large efficient farms, there are the (traditional) small-scale farms (HU, PT), the alternative farms (e.g. agro-ecological farms, HU, PT), and/or the hobby/part-time farms who generate their main income from other sources (BE, DK). These groups can have very distinct views on desired developments.

Broad EU policies with importance for land use change also include different **conservation policies** such as Natura 2000. Additionally, there are local conservation policies. Policies at the two levels may have different details in their goal, despite sharing a common biodiversity agenda. The local ones are often spatially specific and also updated for local changes faster. Thus, when nature restoration is needed, high level conservation policies can act both as a lever and a prohibitor for conservation changes on the ground: currently such policies often have an emphasis on conserving what is already present, and not what could occur under natural conditions. Further, climate change may cause natural habitat changes. Hence nature conservation with emphasis on maintaining e.g. certain habitats can be challenged in a dynamic world. In areas where the hydrological conditions are changed due to climate change, it is difficult to conserve a certain habitat, or where such areas may not be converted into other land uses despite the original habitat de facto being lost. In Denmark, an example was reported where a habitat had changed due to changed hydrology, so that the potential plants and animals could not live there any longer. But because of the conservation status, afforestation was not possible either. In Hungary, the decline in groundwater levels has led to the disappearance of Natura2000 designation species from certain parts of the study area, which may also affect its conservation status in the future. While it may be solved practically in specific conditions (e.g. exemptions), it can create demotivation with land users who feel that they do what is right and wanted politically but encounter that the rules and regulations are not designed to meet it.

Another point of conflict between high level policies and local ones, is the **speed of policy change** that is not coordinated. For example, ambitious national climate targets may not have taken into consideration the need for local hearings (CH) or voluntary engagement (DK). In several of the cases, spatial planning tools are mentioned as crucial enablers as well as barriers. It is raised that their planning cycle is sometimes overly long and difficult to keep up with the

speed of the observed land use changes (PT), or that it conflicts with national goals (CH, HU, DK), or that local support is not present.

4.3.3 Private objectives versus public goods

The potential lack of coordination between local and national policies also points at an overall democratic question: **who has the right to decide on land use**? The owners of the land, the people living there locally, local politicians, national politicians or EU politicians? The cases show that there are clearly different views on this among stakeholders. Many of the cases have a focus on private landowners making decisions on their land. Hence, the ownership structure is relatively clear in most cases.

However, many of the ecosystem services provided are **public goods,** like landscape aesthetics, biodiversity conservation, carbon sinks. The cases show a clear lack of ability to secure the provision of those public goods without conflicts between policies, and also between actors. Examples are the aesthetic consequences of photovoltaic expansion in the Swiss and Portuguese case; the changes in recreational access on land that comes with changed area use in the Danish case; or the water regulation in the Hungarian case. Hence, when looking at innovative policy design options in D.3.2, the provision of public goods needs to be a focus.

4.4 Impact of climate change on land use change

Climate change acts as a fundamental, pervasive, and non-linear driver, impacting agricultural and land use systems across all documented country cases, and especially the south European cases in Portugal and Hungary. For two of the MOSAIC cases, it is clear that climate pressures frequently create compound vulnerabilities when intersecting with human-driven land use patterns. However, during interactions with land users it became clear that climate change is **rarely mentioned** as a driver, but rather the combined impact of past land management decisions with climate change results in an immediate, lived experiences. While participants rarely invoked the explicit "vocabulary of climate change" their stated concerns (e.g. disappearing surface moisture, declining groundwater tables, and spring frost risk) all point toward the cumulative, on-the-ground influence of climatic pressures and past management decisions. It points to the difficulty to make a macro level and long-term driver such as climate explicit in discussions with local stakeholders.

The Hungarian landscape has an historically semi-open vegetation mosaic. Decades of planting of fast-growing closed-canopy forests changed the water cycle. Due to interception and high evapotranspiration, there is almost no groundwater recharge beneath the closed-canopy plantations. The cumulative effect of negative water balance combined with climate change, led to structural water scarcity, and is now framed as the boundary condition of farming.

Similarly in Portugal, the convergence of climate change (rising temperatures and increased rainfall variability) with landscape mono-diversity (the expansion of intensive monoculture of olives and almonds) resulted in "recurrent drought and chronic water scarcity". In addition, it

resulted in other environmental threats, such as soil erosion, organic matter decline and biodiversity loss.

In Belgium, climate change is not spontaneously mentioned as a driver for change in grassland management. However, after probing, increasing variability of grassland production is mentioned. The issue manifests itself as an increasing cumulative precipitation deficit (reaching almost 200 mm in the period 2016-2025), alongside increasingly wet winters and dry summer spells which directly impact grassland production (seasonal length and productivity) and livestock welfare.

Climate change mitigation efforts are in several cases a main driver of land use change. This is often incentivised politically by subsidies, or other market regulation mechanism or market forces itself. In the Danish case, increasing carbon sink is a main driver of the afforestation initiative. In Switzerland and Portugal, photovoltaic installations to produce green energy result in major land use alterations. These changes in land use affect not only the landscape, but also the aesthetic perception of the area, and in some cases even the perceived identity. In Denmark, the identity as a farmer was raised as an issue, while in the Swiss case conflicts between actors having different views on how the landscape should develop was emphasized.

4.5 Values, meanings and interpretations shaping land use decisions

The case reports show recurring evidence that economic expectations appear primary to land use decision making (e.g. decisions to join government-led conservation schemes). In practice, even these external-appearing drivers are processed and acted upon through subjective experience via psychological processes of perception, judgment, memory, and motivation. The case reports also show that social, values-based, and normative concerns are substantial influences on land use decisions. This section synthesizes how land users interpret, evaluate, and legitimate land use decisions beyond economic, policy, environment, and technological drivers. Table 2 synthesises the main psychological dimensions that emerged from the case reports, and specific themes and social science subfields that are most relevant.

Table 2: Values, meanings, and interpretations of land use decisions from the MOSAIC case reports.

Psychological dimensions	Themes and topics
Personal meanings of local land and its use (4.5.1)	Place attachment; lived experience of land; identity linked to land use and practice
Preferences for how local land should be used (4.5.2)	Norms and motivations such as stewardship, autonomy, aesthetics, recreation, and livelihood/profits
Perceptions of regulations and schemes (4.5.3)	Perceptions of land use schemes and interventions; perceived costs and benefits; perceived risks, uncertainties, and acceptability
Social relations and institutional context (4.5.4)	Trust in institutions, intermediaries, experts, and policies; peer networks and social norms; past experiences with regulation and participation

The case reports show that what land represents to decision makers varies widely between sites. This heterogeneity underscores the value of the case method, and reveals differences based on location but also different researcher teams and objectives, which also shape the findings. That is, differences between cases can also reflect differences between researchers and goals between case locations.

In the following we go into the 4 psychological dimensions outlined in Table 2.

4.5.1 Personal meanings of local land and its use

To land users and owners, land is a complex and potent signifier: it can function as a source of identity (how one understands and defines oneself), belonging (one's connection to place, community, and nature), and economic security or autonomy (e.g. as a controllable and potentially fungible asset). These meanings are not fixed but are shaped and modified over time through lived experience and everyday land use practices.

In Switzerland, land is closely tied to local identity, tourism, and cultural symbolism; alpine landscapes, for example, are integral to how places and communities are understood. In the Vlaamse Ardennen (Belgium), land users more often described professional and practice-based identities, such as defining themselves through farming competence or active land management. In these identity-laden contexts, responses to proposed land use changes tend to hinge on whether interventions are perceived as compatible with established self-understandings and place-based meanings, alongside their expected financial implications.

In Portugal, land use also remained linked to identity, but for some land owners this connection is threatened by abandonment, aging ownership, and/or limited control over land use decisions, perhaps in part due to the observation that environmental pressures and changing policies are affecting farmers quite differently depending on their land size and use (see the "two-speed" landscape). In Portugal, land continued to carry symbolic meaning, yet for some farmers identity-based motivations were less able to be consistently mobilized in active decision making than in Switzerland or the Vlaamse Ardennen.

In Denmark and Hungary, land was more commonly represented as a financial, legal, or strategic resource: an asset-oriented framing. Land users emphasized valuation, compensation, contractual conditions, and exposure to long-term risks when discussing land use choices. For example, in Denmark, participation in schemes was often evaluated in terms of reversibility, guarantees, and implications for inheritance, reflecting concerns about control and future flexibility. These generalizations depend on the type of land user. In Hungary, some medium-scale farmers, especially who are operating under restrictive rules, framed land use around security and control in a context of political and institutional uncertainty.

In the EU case, nearly all documents point to the personal side of land conservation. Nearly all reports point to the personal attachment to the land and landscape. In addition, it clarifies that for PLC-pioneers, this is not merely a personal reflection, but also a generational reflection: land as heritage, given by the elder generation and to be passed on to next generations.

In sum, across the cases, land use decisions are shaped not only by material considerations but also by how land is tied to decision makers' identities and feelings of belongingness, and the relative balance of these dependent on the type of landowner/user. The salience and therefore causal importance of these meanings varied markedly across and within EU contexts.

4.5.2 Preferences for how local land should be used

Across the cases, land users reported what they thought the land ought to be used for, often framing these norms in terms of stewardship, care, and responsibility. The form and salience of these norms varied across contexts. In Switzerland, stewardship was articulated in explicitly moral terms, often centred on obligations to protect valued landscapes while balancing climate mitigation with landscape preservation. In the Vlaamse Ardennen, stewardship was framed more instrumentally, referring to norms of appropriate land management such as maintaining productivity, avoiding degradation, and preserving future land use options.

In Portugal and Hungary, stewardship ideals were acknowledged but were more attenuated by structural constraints, including abandonment, limited decision-making authority, institutional uncertainty, or insufficient capacity to implement preferred practices. In these contexts, normative commitments to land care existed but were less important in determining behaviour.

4.5.3 Perceptions of regulations and schemes

Acceptance of land use change and behaviours that support sustainable land use are conditional on how change is framed, implemented, and perceived. This dynamic process better represents

the case study findings than a simple model wherein land use is explained by a single individual difference or attitude, e.g. commitment to environmental protection.

The case studies showed that land users evaluate proposals case-by-case based on their financial outcomes, scale, permanence, governance structure, and other features. For example, a scheme that functionally improves conservation outcomes and landscape beauty will not lead to uptake when land users perceive high risk such as long-term commitment or exposure to future policy or market changes. Concerns about autonomy were pronounced in Denmark and the Vlaamse Ardennen, where schemes were sometimes perceived to limit future control.

In sum, policies may succeed or fail because land users use different evaluation criteria across contexts. Even schemes that are financially advantageous may lack uptake when long-term risks or irreversibility are perceived.

4.5.4 Social relations and institutional context

The final major factor emerging from the case reports concerns who is involved in land use decision making and the degree of trust placed in them. When evaluating land use proposals, individuals commonly attend not only to the content of a proposal but also to who proposes it, who endorses or opposes it, and which intermediaries are involved, such as industry representatives or agricultural liaisons. Across cases, land users distinguished between local and external actors, intermediaries and public authorities, and non-profit organizations and private developers, assigning different levels of credibility and legitimacy to each.

These distinctions were shaped by prior experience, social networks, and perceived alignment of interests. Where institutions were viewed as reliable and governance arrangements as predictable, as in parts of Denmark, trust was more often embedded in formal procedures. In contrast, in Hungary and Portugal - where institutions were perceived as less reliable and policies as more uncertain or in conflict with each other - scepticism toward distant or state actors was more pronounced, and land users relied more heavily on informal networks and personal experience. In Switzerland, the case report highlighted scepticism toward external developers, often attributed to perceived misalignment between developers' objectives and local goals for land and landscape. Likewise, the EU case showcased the importance in the trust towards intermediaries in setting up PLC-activities, which in many EU countries are either public authorities or nature development NGOs.

Across the cases, social networks and trust consistently operated as moderators of informational and social influence, shaping how information was interpreted rather than directly determining outcomes. Higher levels of trust appeared to buffer concerns about uncertainty, loss of autonomy, identity disruption, or financial risk, whereas low trust amplified these concerns and reduced willingness to engage with proposed land use changes.

4.5.5 Psychological factors shaping land use decisions

Psychological factors help explain why similar land use policies yield divergent outcomes across contexts. As shown in this section, such factors operate in interaction with economic, policy, environmental, and technological constraints (Sections 4.1–4.4), shaping how land use options are interpreted, evaluated, and acted upon rather than determining decisions in isolation. Moreover, psychological dimensions—such as meanings attached to land, normative orientations, evaluation criteria, and trust—are likely to interact in complex ways rather than exerting independent effects.

The current state of evidence on the causal role of psychological motivational factors in land use decision making is addressed in detail in Milestone 4. In brief, the existing evidence base does not yet allow for a robust ranking of the relative contribution of specific motivational or psychological factors. Nonetheless, the case evidence presented here indicates that ignoring these dimensions risks overlooking key sources of variation in policy uptake and effectiveness.

5 Implications

In chapter 5 we reflect on the findings of chapter 4 and describe the potential implications for research and policy.

5.1 For theory - Land use frameworks: useful models for better understanding land use (change) decision making

Rational choice models (Hirose et al., 2014) build on the premise that decision makers aim to maximises their utility, which can include monetary and non-monetary aspects. Such models typically assume that decision makers are acting consistently on available information and make decisions that are forward looking. For modelling, this implies that behaviour can be described by characteristics (e.g. economic, social or individual). Examples of rational choice models include cost-benefit analyses at a societal level and discrete choice models at an individual level. Such models are particularly useful when analysing individual decision makers who uniquely weigh trade-offs between characteristics. When markets are present, these models can also be used to elicit implied trade-offs at a larger scale.

However, in many of the cases in this report, choices and trade-offs are made for larger groups of people in the policy area with multiple goods and services that are not marketed. In such cases, the land use choices can also be characterized by decisions made through **conditional reasoning under constraints**, where the relevance of any given factor depends on the configuration of others. Conditional reasoning is compatible with rational choice models, but often not included. With conditional reasoning, context-specific models are preferred over a single, uniform parameterisation. A useful tool that makes trade-offs explicit and potentially visible to a large group of stakeholders is multi-criteria decision making (Grêt-Regamey et al. 2017). Here, decisions are understood as trade-offs among multiple criteria, and each criterion is measured and kept independent from one another. Multi-criteria decision making is especially useful where transparency is desired (e.g. about appropriate weighting between factors) and there are conditions of limited information, attention and cognitive capacity (these assumptions are called **bounded rationality**) (Dessert et al. 2019).

A promising but as yet underdeveloped direction for theory development on land use decisions is to identify two features: **necessary conditions**, which are required factors for a certain action to occur (’must-have factor’), and **sufficient conditions**, which if necessary conditions are in place, are enough for the action to occur (‘guarantee factor’). We interpret across the MOSAIC cases that perceived financial outcomes and limited uncertainty of a proposed land use change frequently emerged as necessary conditions. At the same time, these factors were not always sufficient: even financial outcomes being good and uncertainty being low did not guarantee uptake. For example, in contexts where land use identities were particularly salient and trust in external actors was low (e.g. parts of Switzerland), identity-based concerns could outweigh even favourable financial projections for some actors. These patterns suggest that reductive theories - based on a single ranking of priorities - are unlikely to fit the diversity observed across cases.

A meta-framework that aligns with this logic is **COM-B: Capability, Opportunity, Motivation – Behaviour** (Michie et al., 2011). The central idea is that behaviour only occurs when individuals have sufficient capability, opportunity, and motivation, meaning that these factors are each necessary conditions. Capability is the individual ability to enact the behaviour, and opportunity refers here to the structural and regulatory context making certain decisions available. Finally, motivation can be more or less conscious and reflective and the motivations could be pro-environmental or not (e.g. social belonging). This meta-framework is consistent with the results across the cases, for example that favourable financial projection (motivation) is not sufficient to create a behaviour if identity-based concerns (different motivation) or institutions are weak (opportunity).

One single theoretical approach will not provide the full picture. **Rational choice theory** and **bounded rationality** may be central to the theoretical framework for understanding the motivation and drivers of land use change; necessary and sufficient conditions are a key tool to incorporate in theory development; and multi-criteria decision models can serve to communicate with stakeholders and negotiate priorities. Future quantitative and qualitative research can contribute by identifying how the relative importance and timing of decision criteria vary across land users and contexts, and by specifying how these criteria interact to shape the uptake of schemes or adherence to policies.

The consequences for **policy design** are that single-factor changes, for example to how institutions are trusted, or user goals for the land, are not expected to reliably lead to the same outcomes across contexts. When policies are designed to shift landowner behaviour, such policies should ideally consider contexts and alignment with local perceptions and goals (Knowler and Bradshaw 2007; Swart et al. 2023). Financial incentives and regulatory schemes are often necessary for behaviour shifts, but they may not be sufficient alone (Swart et al. 2023). Coordinated policy bundles that address financial costs, perceived risks such as autonomy, and locally salient preferences for land use will be most effective.

5.2 For policy - Possible intervention points for reaching policy goals and sustainable land use

Land use policy forms the livelihood options of those living of the land. At the same time, land forms the basic resource for the broader society. Hence, balancing interests of different ecosystem services, different actors and different worldviews are inherent for successful and innovative policy design.

While there will always be actors disagreeing with certain political decisions, what innovative policy mechanisms can do are to try and overcome the challenges. Based on the drivers and motivations identified in the MOSAIC cases, we propose the following four points as a systematic way to assess criteria for innovative policies: 1) design instruments that target the goal, 2) ensure alignment between policies at different scales and different targets, 3) ensure transparency, 4) make them flexible enough to accommodate site specific conditions without violating overall objectives. In the following we will elaborate in these:

1) **Design instruments that target the goal:** While it may seem obvious that an instrument should target whatever it is meant to target, it is often found that it may only partly do so – or that perverse incentives counteract it. Hence targeting requires an understanding of the causal factor of a wanted/desired change. Some complications that can be encountered:
    - If an instrument is assuming that decision makers will change their land use only based on necessary (and not the sufficient) conditions, it may not target the right lever. For example, a compensation scheme that is targeting only the opportunity cost, while not considering the underlying issue of identity loss.
    - Another point is that it may be difficult to prove causal effects drivers of land use change and hence design the appropriate policies. Are land use changes for example happening because of a given compensation scheme, or would it have happened anyway?
    - Further, different actor groups may try to influence instrument design in certain direction that target their goal, which may differ from the overall policy goal. It could for example be people interested in biodiversity conservation who want to influence climate policy instruments to prioritize areas with biodiversity conservation benefits too, or specific landowners, who want to influence the money pay out to them.
2) **Ensure alignment between policies at different scales and different targets:** Sometimes policies differ at EU, national and local scales. For example, climate mitigation goals are often national in the land use sector but may interfere with other policies at local level. Hence understanding potential spillover effects and interaction effects between scales are useful before designing policy instruments.

3) **Ensure transparency:** Few land use changes happen that are purely 'pareto efficient' (i.e. sets someone better off without setting someone worse off). Transparency is therefore needed for policies to be accepted and considered fair. Multi-criteria analysis seems a particularly useful tool to create such transparency. Another way to create transparency is by being explicit about who wins and who loses. Then it can be politically decided whether additional redistribution is needed.

4) **Are flexible to local conditions**: The case studies in MOSAIC have clearly shown that there is a large diversity both within and between cases of conditions for people affected by land use change. It is a requirement that instruments are sufficiently flexible to handle that – without losing their effect in reaching the target set.

6 Conclusion

The MOSAIC D3.1 report illustrates that while European land use challenges are diverse - ranging from water scarcity in Hungary and Portugal to renewable energy conflicts in Switzerland and Portugal, and afforestation barriers in Denmark - the factors driving of decision making show striking commonalities. The research highlights that the gap between high-level sustainability targets (e.g. EU climate goals) and local implementation is frequently widened by an 'unsupportive policyscape'. Land users across all case studies report that regulatory environments are often disconnected from local realities, creating administrative burdens and 'perverse incentives' that inadvertently discourage the very practices they aim to promote.

A critical finding for policy design is that economic viability is a necessary - but not sufficient - condition for change. While financial incentives and grants are essential to overcome market volatility and labour shortages, they do not guarantee uptake. Decision making is deeply influenced by psychological factors, including trust in institutions, place attachment, and the preservation of professional identity. Policies that ignore these social drivers often fail, even when they make economic sense. To move from target-setting to effective implementation, our result suggests that policy makers should address the following: instrument targeting, cross-scale alignment, transparency and flexibility. In D3.2 we will look deeper into the design of policy instruments, which have been tried, and how can we design future instruments to address the four aspects.

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Annex: The 6 MOSAIC case studies

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Annex 2 - Sand Ridge (Hungary)

Annex 3 - The two-speed landscape of the Alentejo region: structural external drivers and motivation behind land-use decision-making (Portugal)

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Annex 1: Dynamics and perceptions of grassland use in Vlaamse Ardennen (Belgium)

Francis Turkelboom, Louise Vercruysse, Amaury Sonneville, Dieter Mortelmans, Lotte Mareen, Lien Poelmans, Karl Cordemans, Simon Lox

MOSAIC

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Abstract

This study investigates the role of drivers and farmers' motivations on grassland dynamics in the Landscape Park Vlaamse Ardennen (LVA), where grass-based livestock farming faces increasing pressure from land-use intensification. This is one of the six MOSAIC case studies that study the drivers of land-use change. Spatial analysis showed that the total grassland area declined 5.2% over 10 years, a slight decline of permanent grasslands and a gradual shift from grazing to mowing systems. This is a trend which is representative for most of the intensively farmed lowland regions of Western and Northern Europe.

Analysis of the structural drivers on grassland use in LVA combined with 22 semi-structured interviews, identified four key external drivers and three internal drivers impacting grassland management by farmers. (1) The profitability gap between grasslands and arable crops (especially potatoes) and the difference in value of such parcels incentivizes conversion of grassland, while and at the same time the adoption of technologies like milking robots shifts management from grazing to mowing and keeping cows indoors. (2) Many interviewed farmers report an 'unsupportive policyscape': there are a lot of restrictions which limit their freedom, several policy instruments are perceived as top-down and do not fit their individual farming operations, they feel uncertain due to the complexity and unclear objectives of grassland regulations, and they often report a considerable administrative workload. (3) 'New' grassland users - such as horse owners - who are rather driven by intrinsic motivations are competing for grassland. (4) Although climate change is not often mentioned spontaneously be farmers, it is recognized that it can affect grass productivity and can increase heat stress with cows. (5) While farmers primarily identify themselves as entrepreneurs driven by economic survival and optimization, (6) intrinsic values such as a love for animals and professional pride are also essential motivations for continuing their operations and maintaining specific practices like grazing. (7) Finally, the lack of labour and farm succession accelerates grassland transfer to other actors. Based on these findings, 14 potential policy intervention areas to enhance the quality and distribution of grasslands in the Landscape Park are identified. These intervention areas will drive the analysis in the upcoming report D3.2 and guide future policy recommendations.

Keywords: Grassland, livestock farming, 'horsification', land-use decision making, drivers, motivations, values, Vlaamse Ardennen, Belgium.

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Foto Credit: Vilda

1 Context & framing land-use change

The location of the Belgian case study is within the **Landscape Park Vlaamse Ardennen** (or short: Vlaamse Ardennen). The Landscape Park was recognized by the Flemish government in 2023 (Cordemans et al., 2025). The Park encompasses an area of 245 km^2 and is situated in the south of the Province of Oost Vlaanderen, close to the border with Wallonia (covering (parts of) Geraardsbergen, Horebeke, Kluisbergen, Maarkedal, Oudenaarde, Ronse, Zottegem, Zwalm (en Brakel)). The landscape is characterized by its rugged relief and a mixed, small-scale land use, with forests, arable fields and grasslands, interwoven with small landscape elements. The landscape is rich in natural and heritage values. There are numerous springs, charming villages, family-run farms, water mills and windmills. The area is popular for tourists and recreational users. The Vlaamse Ardennen Landscape Park was established to further strengthen the uniqueness of the landscape of the Vlaamse Ardennen and at the same time to respond to the challenges the region is facing (such as the disappearance of family-run farming, erosion, drought, loss of biodiversity, etc.) (Omgeving, 2023).

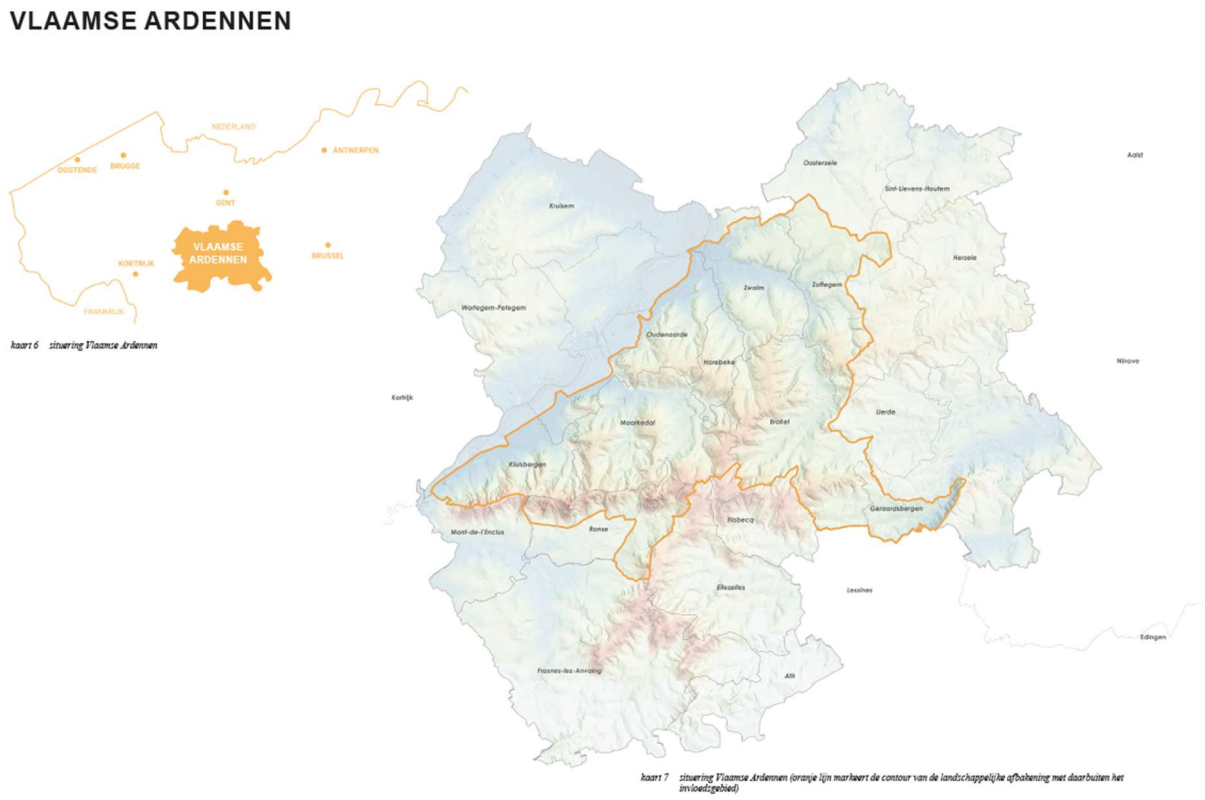


Figure 1: Location and boundary of the Landscape Park Vlaamse Ardennen (Regionaal Landschap Vlaamse Ardennen et al., 2023). This boundary is used for the further calculations, unless mentioned differently.

Agricultural grasslands are an essential part of the diversified 'bocage landscape' (= terrain of mixed woodland and pastures) in the Vlaamse Ardennen, and for the livestock farms that are operating in this landscape. However, these grasslands are under increasing **pressure**. As small-scale, diversified farms are often no longer profitable or face challenges to fulfil all the requirements, farmers have to choose between specializing or halting their farm activities. As a result, typical family livestock farming

is declining in the Vlaamse Ardennen, as in many places in Flanders, while the remaining family farms are becoming larger (Provincie Oost-Vlaanderen, 2025). This increase in scale of farms is leading to greater intensification and mechanization and changes in land use, including a decline of grasslands and an increase in arable farming.

This development is **caused** by many factors, such as fluctuating global market prices for milk, meat and arable crops, competition with other sources of animal fodder, and retirement without succession of livestock farmers. At the Flemish policy level, there are several government administrations that have policies affecting grassland management, such as those of Agriculture, Heritage and Environment (who also employ different definitions for grasslands). Stricter regulations (esp. related to manure management, Nitrogen (PAS)) is likely to put additional pressure on livestock farming, and there seems to be little coherence in the policy goals related to grasslands.

At the same time, new residents are moving to the region, attracted by the landscape and tranquillity. Some of them buy grassland from (retiring) farmers to let their animals (horses, llamas, etc.) graze or to use them as private gardens. Nature expansion, such as afforestation and restoration of biodiversity-rich grasslands, is also putting additional pressure on existing, agriculturally managed grasslands.

Considering this context, it is clear that there are many **actors that influence grasslands** and their use. For this research we focused on the farmers as the main grassland users. These are subdivided into five prototypical categories, based on a typology proposed by two farm experts (K. Sannen, K. Fauconnier) during explorative interviews (based on average data of Flanders, Sannen et al., 2024):

- Intensive dairy farms: On average 90 dairy cows (mostly Holstein breed) and an acreage of 60 ha. They focus on fodder production of grassland, maize and fodder beets.
- Mixed dairy-arable farms: On average 80 dairy cows and an acreage of 70 ha. Beside the specialised dairy breed, they also cultivate arable land, often with potatoes and grain.
- Mixed beef-arable farms: On average 30 suckler cows and an acreage of 65 ha. They cultivate grass, maize, potatoes, grain, sugar beets and vegetables.
- Combined dairy-beef farms with arable crops.
- Arable farms: An average acreage of 53 ha focussing on potatoes, sugar beets, grains and vegetables.

We mainly focused on the livestock farmers (first 4 types) because the (potential) changes of grasslands is more acute with this group of grassland users (esp. after retirement, loss of permit or when a farmer takes an additional job). All external and internal factors that influence the decision making of livestock farmers to maintain or convert grasslands, were considered.

In addition, the ‘new’ grassland users were also considered (the activities themselves are not per se ‘new’, but their increasing popularity is relatively new). There is a growing number of inhabitants who use grassland for ‘new’ activities, such as keeping/breeding horses, llamas, alpacas, sheep, goats, bison, deer, or use grasslands as large gardens (> 1 ha). They carry out these activities mostly as a hobby or a secondary source of income, some do so professionally. Their grassland area is often small, with most grasslands close to their home. Finally, there are also grasslands owned by nature organisations or by public entities. These groups are not the focus of this study.

Through better understanding the drivers of change in grassland management, this study aims to **support the objectives set by the Landscape Park** Vlaamse Ardennen, more specifically the aim to maintain grasslands for aesthetic landscape quality, infiltration, erosion control and biodiversity. Its Masterplan states that a strategy to maintain grasslands is to experiment with sustainable business models for grasslands (Regionaal Landschap Vlaamse Ardennen et al., 2023). The hope is also that by maintaining grasslands, there will be a higher tendency to maintain hedgerows (which have an important function for landscape quality and biodiversity connectivity for e.g. bats).

Our main **research question** is to identify the drivers and motivations for both **maintaining and managing grasslands by livestock farmers** and (to a lesser extent) **by 'new' grassland users**. To achieve a full understanding, we took into account the role of grasslands in the farming system, the trends of grasslands on their farms as well as the perceived trends in grassland acreage and management in the surroundings of these farms. We did this research in close collaboration with the Landscape Park Vlaamse Ardennen and VLM (Flemish Land Agency) to ensure that this report can contribute to their strategy for the Landscape Park. It is expected it will provide some clues to maintain grasslands and increase their quality in the park area, within a complex policy context, in collaboration with livestock farmers and 'new' grassland users.

In section 2 we explain the methodology used for this research, while section 3 gives a short overview of structural drivers for grassland use in Flanders (based on literature and spatial analysis). The main sections are 4 and 5, which explains the factors that influence decision making of livestock farmers and 'new' grassland users based on 23 in-depth interviews. Finally, in section 6 we summarise the results and reflect on their implications.

2 Methodology

For our data collection we relied on the following: a literature study focusing on grassland initiatives in Flanders and on the definitions of grasslands, an analysis of grassland trends and policies influencing grasslands, and interviews with local farmers and 'new' grassland users.

Firstly, we reached out to different experts on grasslands in Flanders. In total, we conducted six so-called **helicopter interviews**. The goal of these interviews was to get an insight on the different types of grasslands in the region, the different grassland users, the factors influencing grassland use and the trends of the overall grassland acreage. These interviews helped us get a better understanding of grassland dynamics in the Vlaamse Ardennen and were used to base our research strategy on.

Secondly, we started off by **delineating the research area**. Local experts recommended that we focus on an area with strong grassland dynamics in the Vlaamse Ardennen. Consequently, the catchment of the 'Peerdestokbeek' was selected. After exhausting the list of Peerdestokbeek farmers that use grasslands, we expanded our search area to neighbouring villages.

Thirdly, as this research aims to shed a light on perceptions of drivers and motivations of grassland land-users, we choose to employ qualitative research techniques, as they are more appropriate then for this purpose then quantitative research approaches. Based on the research needs of MOSAIC and the needs of the Landscape Park, we prepared an interview guide for **semi-structured in-depth interviews**.

To **select potential interviewees**, we relied on a list (provided by VLM) of farmers registered within the Vlaamse Ardennen perimeter. The list contained their acreage of temporary and permanent grassland (as indicated by the farmer on the yearly agricultural application) and the number of grasslands. This information is strictly confidential and was treated as such. We selected farmers who are active in the Peerdestokbeek catchment area and sorted them based on their total acreage of grasslands, their area of permanent and temporary grasslands and the number of grasslands. This way we combined recruiting farmers with many grasslands as well as farmers with large areas of grassland. This resulted in a pre-selection of 29 farmers. The interviewees were randomly selected from our priority list, and about 50% of the contacted farmers agreed to participate. We stopped looking for new interviewees when a representative variation of the different farm-types (explained above) and saturation in the results was found. Finally, we interviewed six dairy-arable farms, four beef-arable farms, three dairy-beef farms, one intensive dairy farm, and one arable farm. Most interviewed farmers were male. In some cases, the farmer's wife joined the conversation or hung around; in one case the wife led the conversation while the farmer was at work outside.

From April to October 2025, we contacted the farmers by telephone and **conducted interviews** with 15 farmers at their farmstead. Each interview was scheduled to last about 1 to 1,5 h and each farmer was given a compensation of 100€ for their time. The interviews themselves were conducted on their own farm by one or two researchers, and if allowed recorded to facilitate transcription. Each interviewee voluntarily signed a GDPR agreement that their information can be stored and used during the duration of the project.

Next, we transcribed all the interviews. Based on the research question and on our interview experience, we abductively (= combination of induction and deduction) composed a **codebook** (this is

a list of recurring themes and topics mentioned during the interviews). This was inserted in Dedoose, a software for qualitative and mixed-methods data, in which the interviews were coded. These excerpts are the empirical material on which we base our perception research conclusions.

In a parallel trajectory the **photovoice method** was conducted to gather information about how farmers perceive and value grasslands in the Vlaamse Ardennen. In collaboration with the Landscape Park's coordinator, we reached out to farmers. They were invited to take pictures which illustrate their relationship with grasslands. After four weeks we met up with 5 farmers and collectively analysed their pictures and discussed the insights. The results can be found here: Booklet Belgium.

For the research on **'new' grassland users**, relevant persons were identified via online search engines, social media, and during our search for livestock farmers. Suitable candidates were contacted and asked whether they were willing to be interviewed. In total 7 'new' grassland users were interviewed via semi-structured interviews. Due to the high variation of 'new' grassland user types, no complete saturation of the results was found. This means that we need to be careful with generalisation of the results. A simplified thematic analysis was performed based on audio recordings of the interviews. Respondents' answers were organized by theme according to a pre-established list of (sub)themes.

The main results of the research were discussed and validated during the **Policy Lab meetings** on 30 September 2025, 19 November 2025 and 21 January 2026.

3 Structural external drivers for grassland change in Vlaamse Ardennen

In this chapter, we briefly describe the structural external drivers that operate externally from the land-user (livestock farmers and 'new' grassland users), based on literature and interviews with experts, and that can influence the conditions in which the land-users operate, and hence can impact land-use changes and management of grasslands.

3.1 Trends in farming and grasslands in Vlaamse Ardennen

In the **Province of Oost-Vlaanderen**, the **number of farms** has fallen by 41% over a period of 20 years (2003-2023). At the same time, the average area of an agricultural holding rose from 23ha in 2013 to 26 ha in 2023 (in Flanders from 25 ha in 2013 to 28 ha in 2023) (Provincie Oost-Vlaanderen, 2025). The proportion of **female farm managers** (2023-2024 data) in Flanders is slowly increasing but is still very low among dairy and beef cattle farms (12%) in comparison to the overall European average of 31% (Eurostat, 'ef_m_farmang' 2020; Brouns, 2025).

The **cattle population** in **Flanders** has declined since 2005. In 2024, the Flemish Region counted 1.18 million cattle. Over the entire period from 2005 to 2024, the dairy cattle population has grown by 11%, while the suckler cow population has decreased by 36% (Statistiek Vlaanderen, 2025). In the 9 municipalities and cities which are related to LVA, the total cattle population had declined with 9% during the period 2019-2024 (37.958 to 34.609). However, the average amount of livestock units per farm has been steadily increasing up to 205 livestock units per farm (a 31% increase between 2014 and 2024, Statbel). For the region of the Vlaamse Ardennen, the average is significantly less (e.g. the municipality of Zwalm has on average between 50 and 75 livestock units per farm).

In 2022, agricultural use covers 62% of the total land of the Vlaamse Ardennen (VA), which is substantially higher than the Flemish average of 49%. **Grasslands cover** 36% of this VA agricultural land, while the other 64% is used as cropland. Most of the grasslands in agricultural use in the Vlaamse Ardennen can be categorised as 'permanent grasslands' (83% of grasslands in agricultural use) according to the definition that is in place since the reformed Common Agricultural Policy (CAP) of 2015.

The area reported in agricultural use in these figures is based on the annual declaration to the Flemish Agricultural Agency. In this Annual Declaration, all agricultural land-use parcels must be registered, as well as certain non-agricultural areas (such as stables and buildings, non-agricultural land that is grazed, and groups of trees), that are used by farmers that either apply for support under the CAP or are required to declare parcels to the Manure Bank. This is required for anyone who uses more than 2 ha of agricultural land or produces more than 300 kg of P_2O_5 from animal manure, which corresponds to more or less 15 horses. This means that a large share of the so-called 'new' grassland users do not fall under this category of agricultural land. To date, there is no comprehensive overview of the extent of land owned and managed by these so-called 'new' grassland users. Part of the land owned and used by these 'new' grassland users is thus recorded as agricultural land (when subject to manure bank reporting obligations), while another part is classified as 'grasslands in gardens' (for those parcels on which a residential use has been recorded) or 'other grasslands (with or without ecological value)' (Fig. 2). The latter is a broad category that also includes other types of grasslands without any agricultural

use, such as road verges, abandoned land, construction land, etc. To date, the necessary spatial data to further subdivide the category 'other grasslands' according to their use are lacking.

The share of grasslands in (the aforementioned strict definition of) agricultural use is substantially higher in the Vlaamse Ardennen (63%) compared to other regions in Flanders (56%). On the other hand, the proportion of grasslands that are managed as nature conservation land is comparatively low (only 1,2% of the total grassland area in the Vlaamse Ardennen vs. 3,4% on average in Flanders) (Fig. 2).

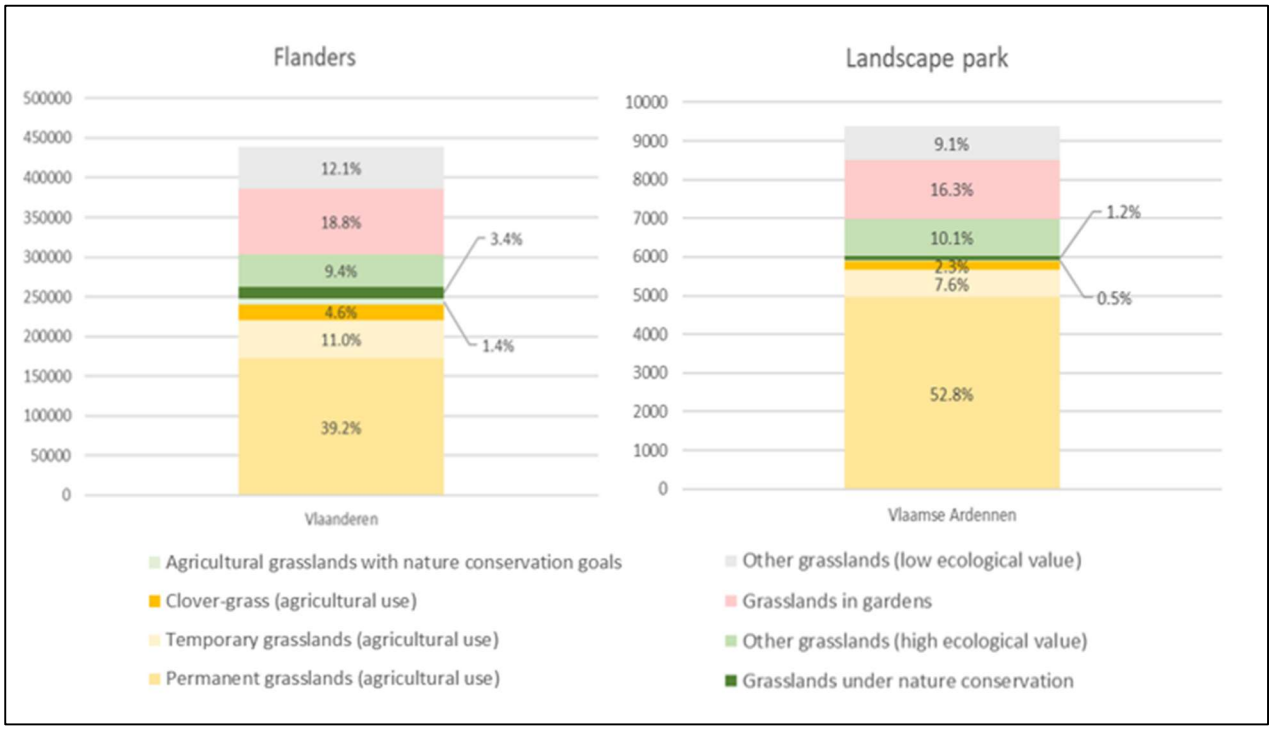


Figure 2: Area (in hectares) and share of different types of grasslands in Landscape Park Vlaamse Ardennen (right) versus Vlaanderen region (left).

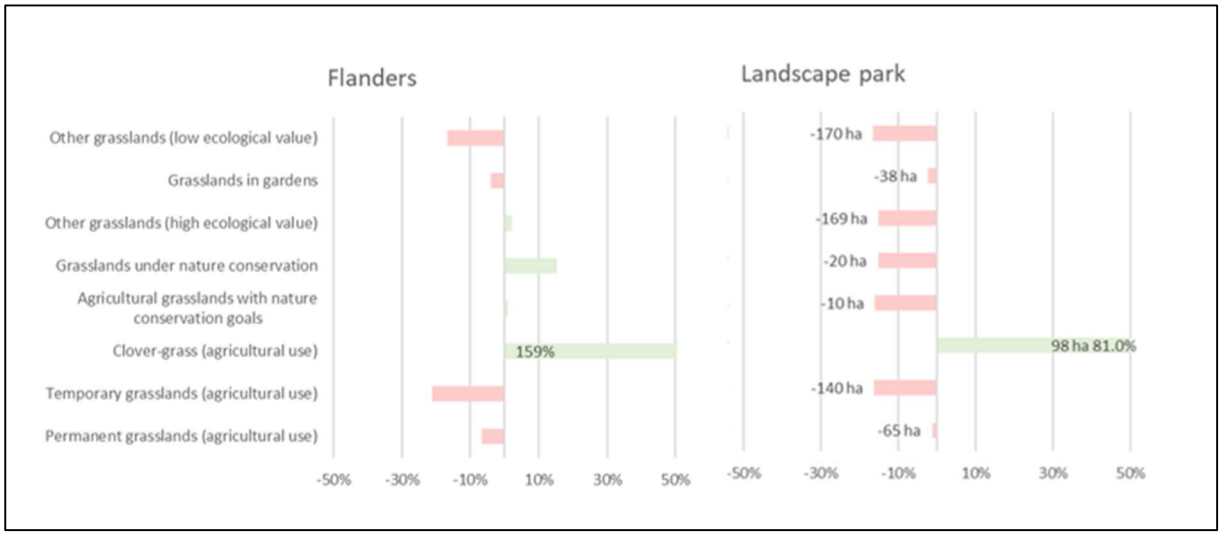


Figure 3: Relative evolution of grassland types in Flanders region (left) and the Landscape Park Vlaamse Ardennen (right) during 2013-2022 (green: area increase, red: area decrease).

Analysis of **grassland dynamics over a 10 year period** between 2013 and 2022 (Fig. 3) indicates that the landscape Park **Vlaamse Ardennen** experienced a net decline in the total grassland area (-5,2%, 513ha), which is similar to the average decline in Flanders (-5,3%):

- In contrast to the rest of Flanders, this grassland decline affected nearly all grassland categories, with the exception of **clover-grass mixtures**, which are mixed pastures composed of grasses and clover species with high nutritional value (Fig. 3) The total share of these clover-grass mixtures in the total grassland area remains however relatively small (Fig. 2).
- While in the rest of Flanders **grasslands with nature value** (grasslands under nature management, grasslands in agricultural use but with nature objectives or grasslands with an unknown use, but with high ecological values) are still showing a slight increase, the area of these types of grasslands is also declining in the Vlaamse Ardennen (Fig. 3). Part of this decline can be explained by afforestation. Some of this afforestation takes place within the Natura 2000 site 'BE2300007' ('Forests of the Vlaamse Ardennen and other South Flemish forests') where the long-term habitat goals explicitly include creating stronger forest habitat networks (e.g. realizing larger forest cores and better connections between them). Further analysis of spatial datasets is needed to determine the role afforestation plays in the disappearance of grasslands in the Vlaamse Ardennen and whether this is limited to Natura 2000 areas.
- The relatively small reduction in **permanent grasslands** compared to the rest of Flanders is particularly noteworthy (-1% in Vlaamse Ardennen vs. -7% in Flanders, Fig. 3). A key challenge addressed in the Landscape Park's master plan, and the central research question of this report, concerns the pressure on grasslands in the Vlaamse Ardennen, where permanent grasslands under agricultural use make up the largest share. For this reason, we take a closer look at the dynamics affecting permanent grasslands. Figure 4 (top) shows the dynamics in permanent grasslands in the Vlaamse Ardennen in the period 2013-2022. More than 80% of the total area of permanent grasslands in agricultural use have not changed during this period. 300 ha (6%) have shifted from permanent grassland to cropland, another 290 ha (5,8%) to other (non-agricultural) land uses. The latter includes the shift from grasslands in agricultural use to 'new' grassland users. The disappearing permanent grasslands are partly offset by new permanent grasslands (+730 ha), which keeps the overall decline in the area of permanent grassland relatively limited to –1%. These new permanent grasslands mainly result from the conversion of grasslands that were classified as 'temporary grassland' in 2013 (+341 ha). This conversion of temporary to permanent grasslands is largely explained by a change in the way permanent grasslands have been registered and monitored since 2015. Following the reform of the Common Agricultural Policy (CAP) in 2015, all grassland parcels that have been in place for five consecutive years automatically acquire the status of "permanent grassland" after the fifth year. At the Flemish level, this has led to a substantial shift in the statistics: a large share of parcels that were previously registered as temporary grassland have since been reclassified as permanent grassland. The observed growth in permanent grassland is therefore mainly the result of a change in registration rules and is therefore not really visible in the landscape (existing temporary grassland is reclassified as permanent grassland, but the grass cover on the ground remains the same). If we assume that the conversion of temporary grassland to permanent grassland is mainly the result of changes in registration procedures, the decrease in permanent grassland would amount to 7,5% (-406 ha).

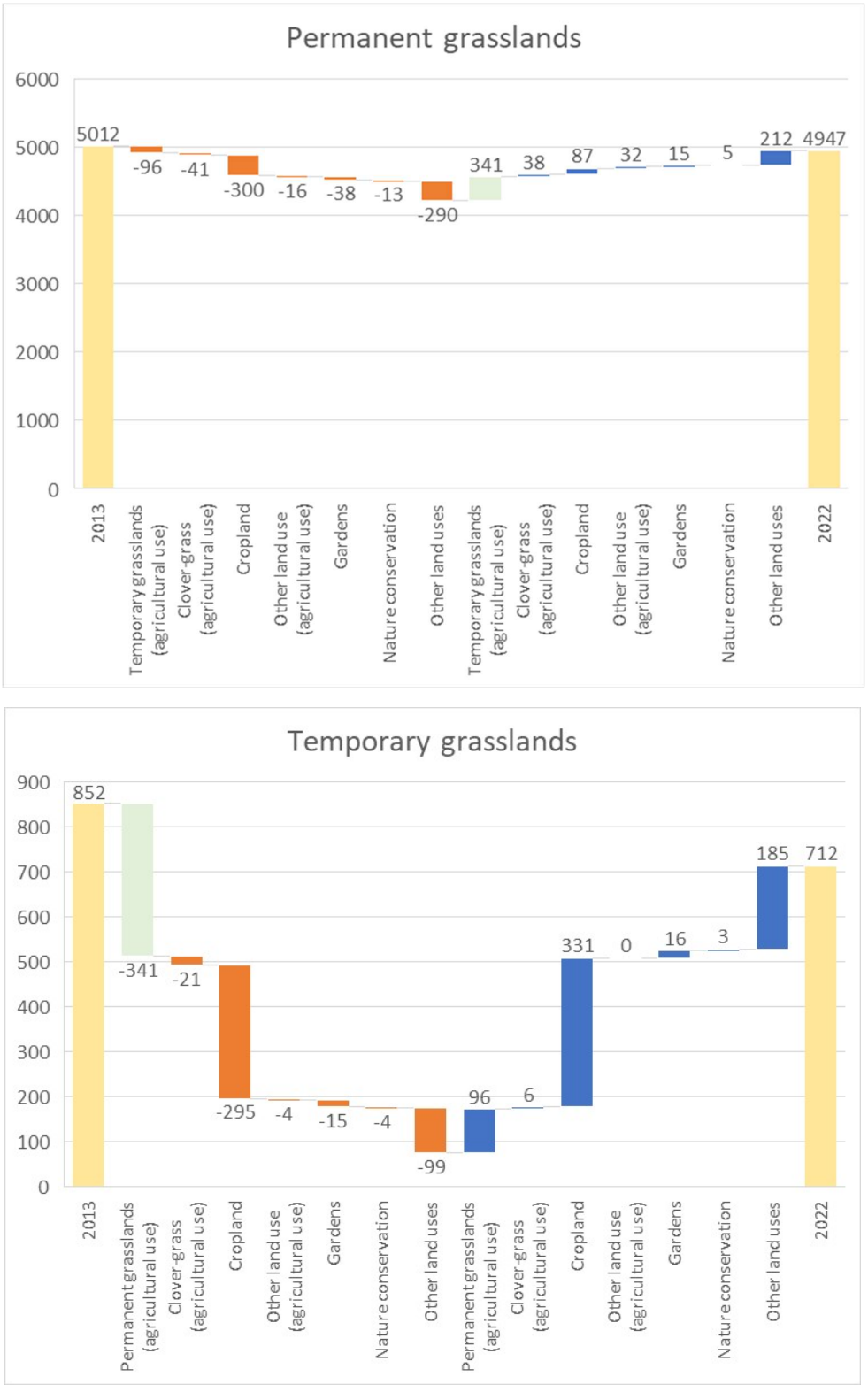


Figure 4: Changes in permanent (top) and temporary (bottom) grassland in Vlaamse Ardennen between 2013 and 2022 (orange = area decrease, blue = area increase, green = administrative reclassification).

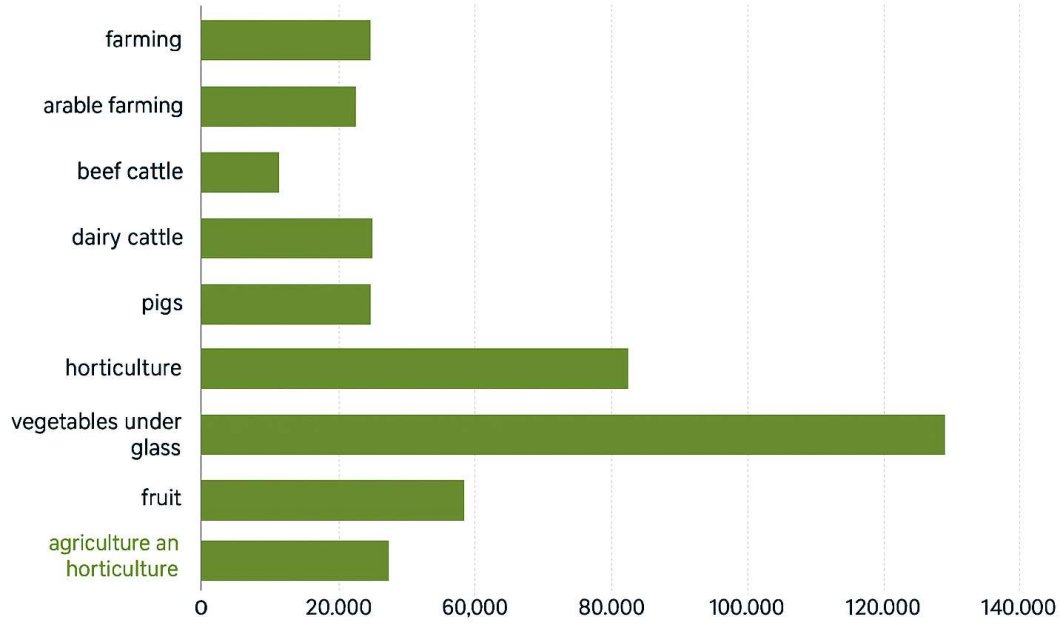
- Figure 4 (bottom) shows a similar representation of the dynamics in **temporary grasslands** in the Vlaamse Ardennen in the period 2013-2022. Since temporary grasslands are part of the crop rotation, their behaviour is more flexible. More than 90% of the temporary grasslands present in the Vlaamse Ardennen in 2013 were converted to another land use. A total of 341 ha was "administratively converted" to permanent grassland (see above). During this period, 295 ha of temporary grasslands were converted to another agricultural crop, while 331 ha of arable land had been converted to temporary grassland. As a result, temporary grasslands in LVA 'reduced' with 16% (-140 ha, Fig. 3).

The combination of factors (intensive agricultural utilisation, limited nature-managed grassland, and an area decline) suggests mounting pressures on the region's grassland ecosystems and highlights their increasing vulnerability within the broader landscape context. The figures, however, indicate that this pressure does not differ greatly from the rest of Flanders, where grasslands are also under considerable pressure. In the Landscape Park, this decline warrants particular attention due to the important role grasslands play in shaping the landscape and supporting associated recreational activities, as well as their function in erosion control and water retention in this highly hilly agricultural area, and their contribution to biodiversity (e.g. through conservation targets for the bocage landscape within the Natura 2000 site).

3.2 Economic & market driver

As farming is primarily an economic activity, an array of factors related to the economic system (such as resource availability, production and consumption patterns and market prices) have a profound impact on the livestock farming systems, and consequently on the grasslands used for livestock. In this section, we aim to briefly enumerate the most important elements that make up the business model of a livestock farm, and some of the most relevant trends.

The average household income - what is left of the income after subtracting all the costs - is different for every agrarian sector (Fig. 5). The household income per labour force is by far the lowest for beef production. The household income for dairy farming is average compared to other agricultural activities in Flanders.



Bron: Agentschap Landbouw en Zeevisserij op basis van LMN

Figure 5: Annual household income per unit family labour (in euro, average for 2017-2021).

The farm business model consists of **costs** and **income**.

Costs

The costs of a livestock farm can be subdivided into variable costs, namely elements that need to be purchased every year, and fixed costs. The **variable costs** include seeds, fertilizer, pesticides, herbicides, fuel, fodder and labour costs. In Flanders, in absolute terms, mainly nitrogen **fertilizer** is used on grassland (47%) and cereal crops (19%) in 2021 (Agentschap van Landbouw en Zeevisserij, 2024). There is a decline in the proportion of family **labour** in relation to non-family labour. In Flanders, the non-family labour of the total labour force on a dairy farm grew on average from 4,3 % in 2003 to 21,5 % in 2023. This has implications for the labour costs.

The **fixed costs** comprise land and larger investments, such as machinery and buildings (e.g. stables). Over a ten year period (2013-2023), the average **price for a hectare of agricultural land** in Flanders has increased by almost 69%. In 2023 the average price was €66.288/ha. In the same period, the lease price has increased by 45%. In 2022, the Flemish average was 424 euros/ha, which is also the average for the Province of Oost Vlaanderen. A hectare of arable land can be 50 % more expensive than a hectare of grassland, which can incentivize farmers to plough up grassland to increase the value. High land prices can also influence farmers to choose for the most lucrative arable crops.

Revenue

The **income** depends on the prices for farming products and on income support and/or compensation. The farm-gate **prices** determine to a certain degree production a farmer will focus on. The index price for milk and for beef has steadily increased since 2010, with a peak for milk in 2022. For potatoes, the index price has more than doubled since 2010. This explains why potatoes have risen to become the

most important arable crop in Flanders and make up to 47% of the total production value of arable farming. Worldwide, Belgium is the largest exporter of frozen potato products and frozen vegetables (Agentschap Landbouw en Zeevisserij, 2024). The second and third main arable crops are cereals and sugar beets. However, the index price for potatoes has dropped by 32% between 2024 and 2025 (Statbel, 2025), showing that prices are very volatile, dependent on a changing world market.

Direct financial support from CAP funds makes up an important part of the farm income, though the proportion depends on the farm type. On average for the period 2017 till 2021, beef farms depend for almost 56% of the farm income on direct income support, while this is only 15% of a dairy farm (Agentschap Landbouw en Zeevisserij, 2024). In addition, **market-initiated certifications**, such as the label "pasture milk" or 'organic milk', can (potentially) provide financial bonuses to farmers.

3.3 Government policy & regulation influencing grassland use

In terms of policy, the most important factors influencing the decision to maintain, ploughing or reseeding grassland are linked to the implementation of European regulations, such as the Flemish interpretation of the conditionalities of the European Common Agricultural Policy (CAP) and agri-environmental climate measures or eco-schemes. Based on expert knowledge and desktop research following policies are regarded as influencing grassland in Flanders:

Policies related to maintenance of grassland:

1. Within the Flemish agricultural policy, there is an **obligation to maintain grassland** and other grass mixtures that have not been in crop rotation for more than four years (GAEC1 of the CAP). However, this means that grassland and alike is often converted to arable farming every few years, in order to prevent it from becoming permanent grassland. This can be interpreted as a (probably unnecessary) avoidance strategy, as farmers can only be obliged to reseed if the 2008 grassland area of the reference area (in this case Flanders region) decreases by more than 3%. According to a parliamentary question (12/12/2022) there was a decrease in reference area of 3,14% in 2022, but no information can be found if some farmers were really obligated to reseed their grassland.
2. Grassland located within the **Natura 2000 network**, the Flemish Ecological Network (VEN) or ecologically vulnerable agricultural areas, may not be ploughed up. Restrictions are also imposed on the use of pesticides and fertilisers, although exceptions are made for residential plots. Municipal, provincial or regional spatial implementation plans may also impose additional conditions regarding the preservation of grassland.
3. The preservation of grassland may be legally mandatory because of for instance the **Heritage** Decree (protected Cultural-Historical Landscape), the **Nature Decree** (for historical permanent grassland or ecologically vulnerable permanent grassland), or as part of a **nature management plan**. In such cases, an exemption or permit for vegetation change is required.
4. **Flemish spatial planning policy** provides spatial implementation plans (regional, provincial or municipal) that may contain regulations for the preservation of grassland, such as a ban on ploughing grassland in agricultural areas of ecological importance.

Note: In Flanders, much of the natural environment is located on land designated for agriculture, and conversely, much of the agricultural land is located in green destinations. Of the registered agricultural area, 11% is not located in an agricultural area: 6.5% is categorised as green (forest, nature reserves and other green areas), 4.2% is categorised as hard (residential, industrial and other), and 0.3% is designated for recreation (link).

Policies related to management of grassland:

5. The **Manure Decree** can also indirectly influence the decision to opt for grassland, as fertilisation standards for grassland are generally higher, and the spreading dates are somewhat more flexible than for most arable crops.
6. The **Nitrogen Decree** may also have an indirect impact on the amount of grassland, as it may result in a reduction in livestock numbers, leading to lower requirement of grasslands.
7. The plot's **susceptibility to erosion** can influence whether or not a plot of grass can be converted to arable land and still comply within the CAP's conditionalities. The obligation to provide erosion strips on steep slopes (as stipulated in the conditionalities of the Flemish agricultural policy and the Decision of the Flemish Government on erosion control) can also influence the choice of crop on the adjacent plots and likely more grassland will be cultivated.
8. To improve **water quality protection strips** along watercourses are mandatory according to the Manure Decree. Buffer strips may vary from 3 to 5 m depending on location, water quality (surface and ground water) in the direct area, and the type of crop (depending on N-loss susceptibility of crop). The use of pesticides and fertilisers in this protection strip ('beschermingsstrook') is prohibited, and only limited soil manipulation is allowed. This will also influence the choice of crop on adjacent plots and likely more grassland will be cultivated since grazing is permitted up to the edge of the watercourse.
9. The Flemish government is encouraging grassland preservation by offering **agri-environment-climate measures and eco-schemes** (link) that compensate farmers for maintaining or developing grassland. In 2024, AECM (botanical grassland) uptake is rather limited (27 ha), while eco-scheme payment were made for 2338 ha permanent grassland (about 50% of registered permanent grassland) (link, incl. 193 ha ecological managed grassland). Also, a support scheme for suckler cows was introduced in 2023. This support is subject to conditions related to sustainable grassland management.

Policies related to conversion to other land-uses:

10. Flanders also actively promotes the **conversion of agricultural land to forest or nature** through subsidies to private individuals and nature organisations.
11. Flemish policy allows for many possibilities for the use of agricultural land that does not align with the designated zoning through a **non-zoning change of function** of farms and surrounding residential plots (Verhoeve and Vanempten, 2026). If this has already been realised without a permit, it can often be regularised retrospectively.

3.4 Urban sprawl and demographic changes in the Vlaamse Ardennen

For a long period, the spatial planning policy (or the lack of it) in **Flanders** enabled urban sprawl, whereby built-up areas have expanded diffusely into peri-urban and rural landscapes (in-situ urbanisation), rather than centrifugally around existing urban cores (Buitelaar & Leinfelder, 2020; Vermeiren et al., 2022; Leinfelder & Buitelaar, 2020). In a region already characterised as one of the most densely populated and spatially fragmented areas in Europe, this dispersed urban development has exerted and still exerts substantial pressure on open spaces. As a cascade system, urban development replaces intensive land-based agriculture land and consequently affects extensive agriculture and nature. This results in both a progressive loss and increased fragmentation of grasslands (Alberti, 2005; Declerck et al., 2017).

The **Vlaamse Ardennen** exhibits a somewhat lower rate of demographic growth in comparison with the broader Flemish region. Between 1985 and 2025, the population of the nine municipalities within the Landscape Park increased by 15% (22% in Flanders). This growth is mainly driven by immigration from other Belgian municipalities, while the natural population growth is negative (Fig. 6).

Despite this relatively modest demographic expansion, the area is characterised by a higher intensity of urban sprawl. Residents of the Landscape Park are proportionally more likely to reside in **dispersed settlement patterns** or **ribbon developments** (42%) compared to the Flemish average (27%, Pisman et al., 2021). In addition, the residential footprint in the region is markedly larger. Approximately 69% of households live in single-family dwellings (64% in Flanders), with a substantial share of these comprising detached housing typologies (42%), with relatively large gardens (Source: provincies.in.cijfers). These patterns highlight the paradox whereby limited population growth is accompanied by disproportionately land-intensive settlement structures, contributing to spatial fragmentation and increased pressure on open space and grasslands in particular.

Another potential contributing factor is the **reuse of vacant farmsteads** into residential housing by private citizens (Verhoeve et al., 2018) when agricultural businesses close. In the Province Oost-Vlaanderen 39% of them are being converted into rural residences, with the surrounding farmland often being used as a garden or pasture for hobby animals. These developments are changing the use of agricultural land and causing a shift in the use of grasslands.

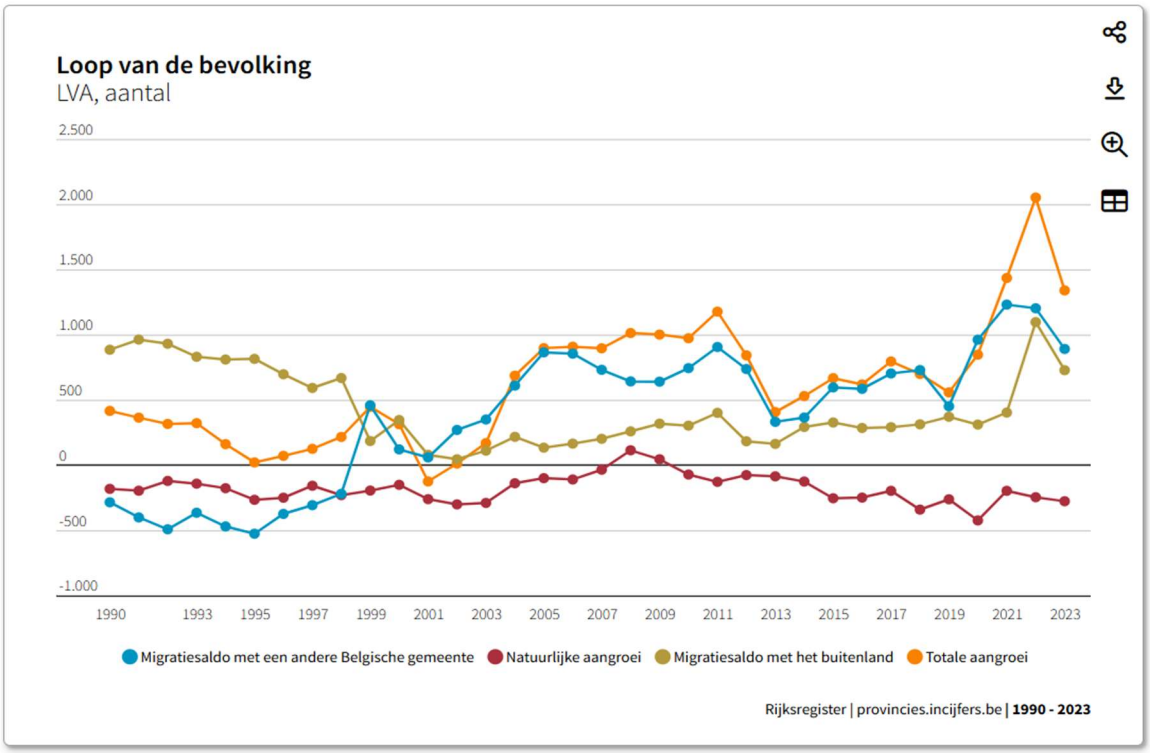


Figure 6: Evolution of population in the municipalities linked to the landscape park during the period 1990-2023, distinguishing natural growth and migration flow.

3.5 Role of climate change

There are two key climate change trends impacting grassland production and livestock raising: increasingly wet winters and dry summer spells resulting in a cumulative precipitation deficit, and increased frequency of heatwaves.

The **precipitation deficit** is the difference between precipitation and the potential evapotranspiration. This difference is determined on a daily basis. However, as stress in plants due to low water availability only occurs over longer periods, the precipitation deficit is viewed cumulatively throughout the entire growing season from April to September. Since the 1980s, there has been a clear increase in precipitation deficit in Flanders. The average precipitation deficit in the period 2016-2025 was exceptionally high and rose to almost 200 mm (which never occurred in the period 1906-2015) (Fig. 7). Increasingly warm summers and wet winters are also expected climate change impacts and already have an impact on farm activities. Figure 8 shows the increasing potential for wetter winters and drying summers. According to this model, the Vlaamse Ardennen are expected to face a 20 to 25% increase in rainfall during winters and a shortage of rainfall of up to 5%.

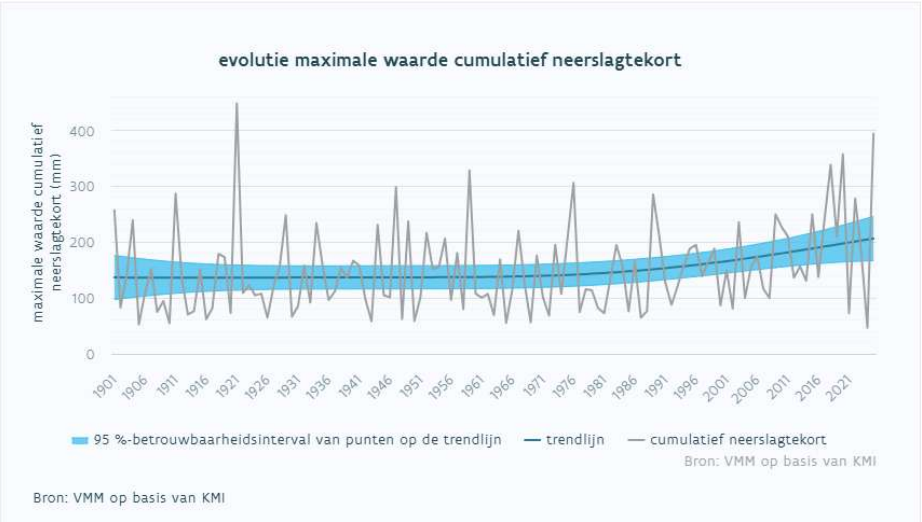


Figure 7: Evolution of maximum value of cumulative precipitation shortage in Flanders (source: VMM website).

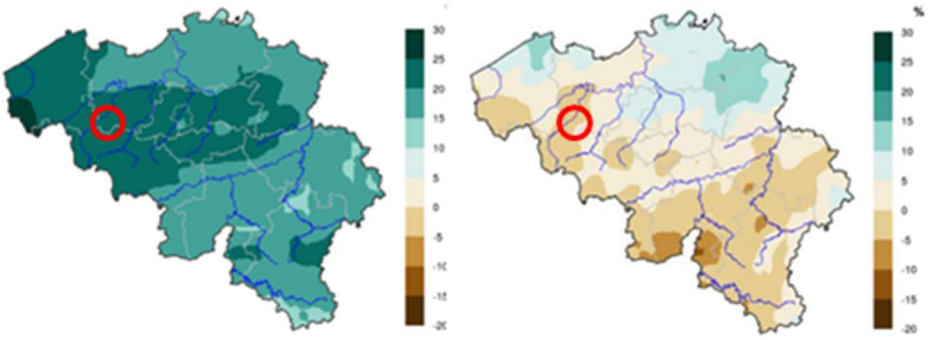


Figure 8: Predicted rainfall in winter and summer in Belgium for the year 2085 in comparison (%) to the reference years 1976 to 2005. The Vlaamse Ardennen area is indicated with the red circle (Source: Serga Zaka, based on KMI ALARD model).

As a result of these trends, climate change in 2070 to 2099 is expected to affect grassland dynamics in several ways. We highlight two expected impacts on grasslands that will likely have an impact on how grassland users will manage their activities (Fig. 9).

- **An increasingly longer growth season for grass with more variation in growth:** The grass production season is projected to lengthen, starting earlier and ending later. Yet grass production will be more irregular and subject to weather impacts (3) (e.g. very wet periods and dry spells). Peak production is expected in spring due to optimal conditions (1), followed by a decline in summer because of heatwaves (2). A smaller production peak is anticipated in autumn. To cope with climate change, adapting grassland management will be crucial. Several strategies are proposed to address these changes: leveraging genetic diversity to maximize the spring growth peak, introducing specific seed mixes to mitigate the impact of summer heatwaves, enhancing the stocking of spring harvests in both quality and quantity to offset summer growth losses, and supplementing with additional feed sources such as hedges or feed crop mixes.

- **An increase in heat stress days for cattle:** Another change expected from climate change is the increase in heat stress days for cattle, especially for dairy. In its codex for animal welfare, the Flemish government already foresees mandatory provision of shade for cattle by 2029. Figure 9 shows the predicted milk production loss (%) for the years 2070 to 2100. For the Vlaamse Ardennen this loss could amount to 10 to 12,5%, according to a strong RCP8.5 scenario. This loss may have an impact on the profitability of grass-based dairy operations if no appropriate mitigation strategies can be found. On the other hand, it is difficult to estimate how the productivity of competing crops will affect the use of grasslands. A lower crop productivity may result in an overall productivity loss without much land-use change. Another possible consequence of milk production loss is the increased use of adapted stables with air cooling through fans or water vapor (or both), which may drive farmers to reducing grazing practices.

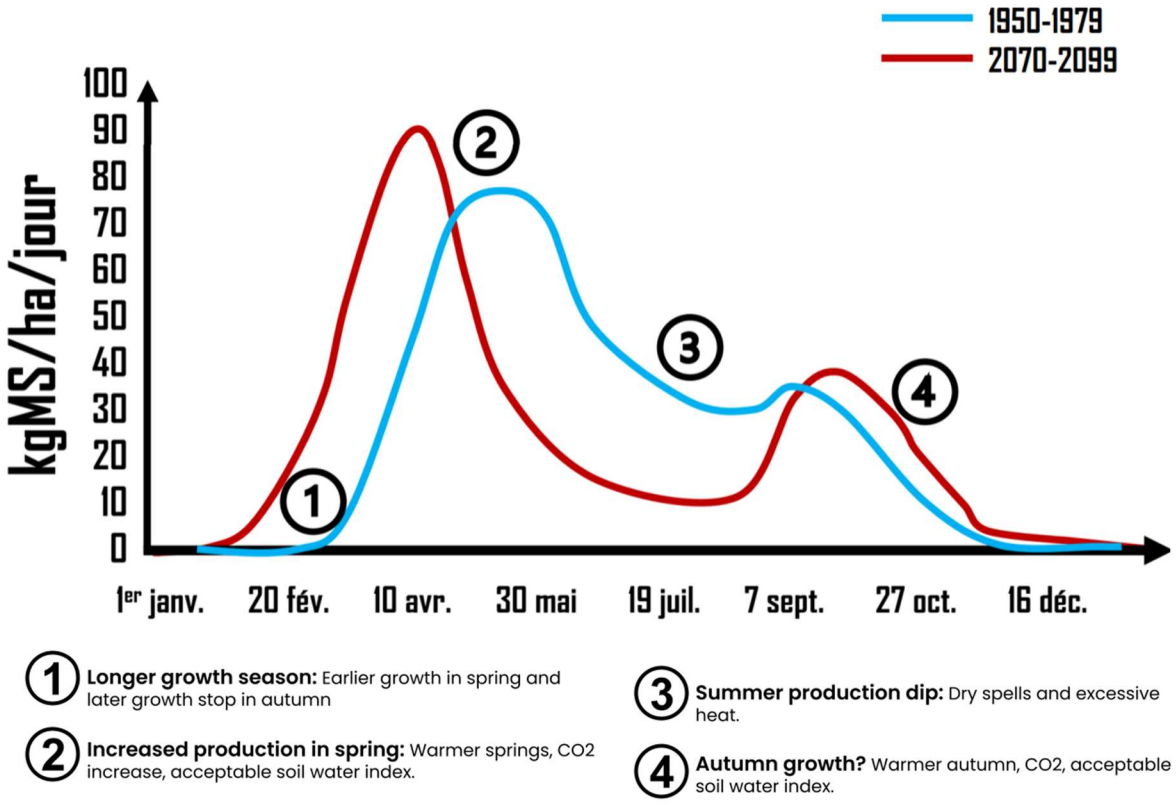


Figure 9: Expected changes in grassland dry matter (kgMS) production up to the year 2100. (adapted from Serge Zaka,CLIMALAIT de L'IDELE).

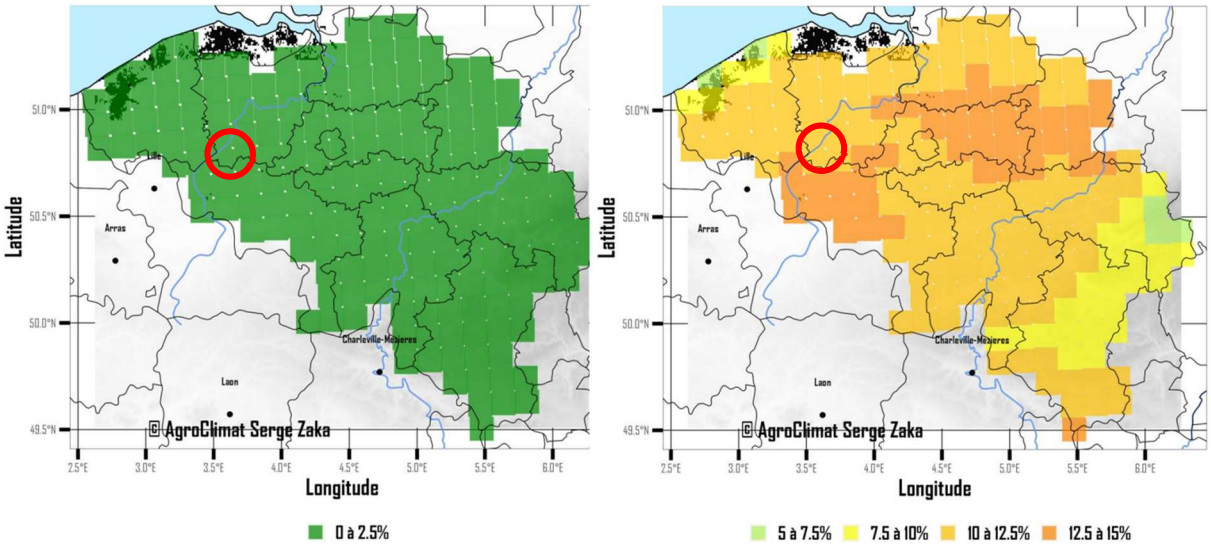


Figure 10: (%) Predicted milk production loss in comparison to reference years 1970 to 2000, based on a strong RCP8.5 scenario and a strong confidence indication. The Vlaamse Ardennen area is indicated with the red circle (Source: Serge Zaka - AgroClimat).

4 Factors influencing grassland decision making of livestock farmers

In this chapter we analyse the farmers' perception on the decision making of livestock farmers regarding their grasslands and their impacts in Landscape parc Vlaamse Ardennen (LVA). This section is based on the 15 interviews, and the results are summarised in the mind map (Fig. 11).

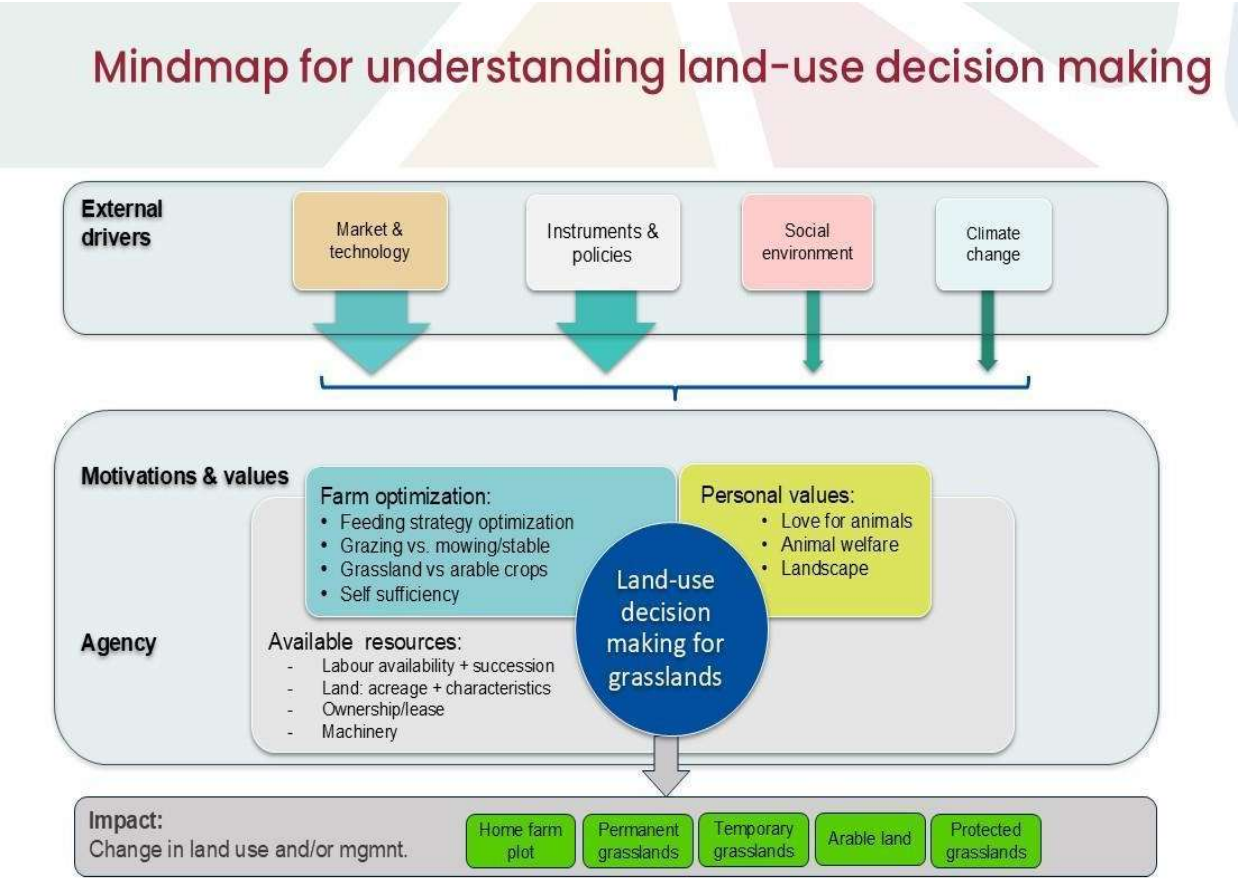


Figure 11: Mindmap of the factors influencing maintenance or changes in grassland use and management by the 15 interviewed farmers in LVA.

4.1 Role of grasslands in the farming system

4.1.1 Farm typology of interviewed farmers

The 15 interviewed farmers with grasslands can be subdivided into five categories (as explained in the section 'Context'):

- The most encountered category (6/15 respondents) are the '**mixed dairy-arable farms**'. Generally, they receive most of their income from dairy farming, but all grow potatoes and sometimes other arable crops that are not used for fodder, such as onions, sugar beets, cabbage. For most of the farmers, potatoes generate a welcome supplementary income, while milk production remains the main source of income (although this varies from year to year).

For one farmer growing vegetables generates the main income. The proportions of land-use differ. Their acreage ranges between 48-180 hectares, and one sixth to almost half of the farmers' land is grassland. One farmer has almost a similar area for potatoes as for grasslands, the others have much less. Holstein is the most common cattle breed. Two of the farmers mentioned they used to have dairy and beef livestock, but have decided to specialize in dairy as it generates a more stable income.

- The second most encountered category are the '**mixed beef-arable farms**' (4 respondents). They have a smaller acreage (7 - 80 ha), of which a third to a fourth is grassland. They all have 'Belgian Blue' cattle. Two of these farmers in this category are of retirement age.
- The third category are the '**combined dairy and beef farmers with arable crops**' (3 respondents). They use between 100 and 170 hectares, of which 30% to 40 % is grassland. One of them has a dual-purpose cattle breed, the others have 'Belgian Blue' and Holstein cows.

For two categories we encountered only one respondent:

- The '**intensive dairy farmer**' has a business similar to the mixed dairy-arable farms. However, the acreage is smaller, with about 55 ha of which three fourth is grassland. It is important to note that this was the only respondent that does not grow potatoes.
- The '**arable farmer with grassland** kept some of his grassland after transforming his livestock farm to an arable farm. Unsurprisingly, this farmer had the smallest proportion of grassland, namely only 2,5 ha of his 100 ha of land.

4.1.2 Grassland typology of interviewed farmers

Farmers differentiate their grasslands in a similar fashion. On the one hand, farmers make some obvious distinctions between their grasslands. For example, some farmers indicate that they just distinguish grasslands that can be **mown and those that cannot**, depending on parcel characteristics (wet or dry, flat or inclined, presence of stones..).

Farmers also mention that they make distinction between their **temporary and permanent grasslands**. Permanent grasslands are meadows or pastures, while the temporary grasslands are rotated with arable crops. Some farmers point out that often the soil quality of permanent grasslands is inferior to the soil quality of arable land.

"If a conversion takes place, it will be grasslands with high quality-soil."

On the other hand, farmers mention several factors that influence the use and management of grasslands. The most common factors are the **biophysical properties of the grassland**. Poor soil quality, stony or steep slopes prevent permanent grassland from being converted to arable land. Also plots that are too wet cannot be worked, or only later in the season.

In addition, farmers put strong emphasis on the **location of the grasslands**. Grasslands near the farmstead (home farm plots) are normally used for grazing, and are considered as a separate grassland type with high value for the farm. In contrast, distant grasslands are mainly mowed, as it requires too much intensive labour to let animals graze there.

A few farmers also report having **legally protected grasslands**, such as 'Historically Permanent Grasslands'. They indicate that due to the limited permitted farm operations (e.g. no fertilizers, no chemical weed control), these grasslands are considered less useful, as they produce low-quality (lower protein content) and declining grass yields (ton/ha). These extensive grasslands often require a too high labour investment in comparison to the yield.

4.2 External drivers influencing grassland use and management

4.2.1 Perceived impact of the market on grasslands

By 'market' we mean the economic system of which the farm is part. This includes, for example, the prices the farmer receives for its production, and the costs s/he incurs to set up and run the business (such as land, machinery, labour).

Competition with arable crops: Most interviewed farmers grow potatoes next to fodder crops to gain an extra income. One farmer mentioned that grass is important, but that other crops would be preferable. Fluctuations in the prices of arable crops such as potatoes can lead farmers to choose to grow more (temporary) grass or protein crops ("*if the price of potatoes falls, I would sow more grass"*).

Costs of investments: The increased costs of investments (e.g. buildings, tractors etc) for livestock farming make farmers feel compelled to increase the scale of their operations and make production more efficient. One farmer mentioned that this is the reason why he chose to keep the cows indoors and not let them graze outside. With the livestock inside, the farmer has more control over feed quality and can keep a close watch on the health of the cattle.

Perceived indirect market drivers of changes

Land prices: In the interviews, the price of land was never mentioned as a direct driver for changes in grassland acreage and/or management. It is more likely a factor when there is a change of user or owner of the grasslands. Land price is certainly an important indirect factor. High land prices make it difficult to expand the area of agricultural land: "*You have to be lucky to be able to buy your own land as a tenant*." Some farmers mentioned that they could not buy a piece of land, as other buyers overbid them (Flemish Land Agency, horse owners). Several interviewees owned about a third of their land. The majority of the land used by farmers is leased (which is close to the Flemish average, around 60% according to the numbers of Landbouw en Zeevisserij). But there was a large difference amongst the interviewees: two interviewees owned almost all of their farmland, while another owned barely 5%. The dependency on leased or rented land puts farmers in a vulnerable position. One farmer mentioned having lease contracts for many small plots of land, owned by different landowners. Every year he loses some, because the owner wants to work the land himself, or because he wants to manage the land himself or to afforest it (to gain subsidies). Another farmer explained that when he took over the business from his father, many landowners did not want to renew the lease contracts. There are also strategic considerations for leasing less suitable grassland. One farmer mentioned that he stopped a lease contract because the land was difficult to work, while another stated that he did not stop it because he is also leasing more qualitative land from the same owner (in this case less productive grassland was located in the Flemish Ecological Network).

Perceived limited influence of the market

Market prices of inputs and outputs: Several farmers indicate that **the market** has little to no influence on the management of grasslands. Costs and prices are unpredictable: two years ago, fertilizer was very expensive and the price of milk was low, but now things are better. Management remains the same: you save during good years and lose during bad years. One farmer indicated that having a mixed farm helps stabilize income, one year the milk price is better, another year the other crops are more profitable.

Labels: A driver to optimize production can be a motivator for farmers to keep their cattle indoors. The question arises as to whether a 'pasture milk label' can command a higher milk price? However, several farmers argue that pasture milk is difficult to market. Some buyers (such as Laiterie Des Ardennes (LDA), "Charte LDA") award more points for grazing, as well as for the participation in agri-environmental agreements and for sowing grass-clover. However, this recognition of a specific use or management of grassland does not necessarily lead to a better price.

4.2.2 Perceived impact of technology

Changes in the use of machineries can also influence grasslands. Nine farmers mentioned 'technology and innovation' as an influencing factor. For two of them, technology led directly to a change in grassland use. More and more machines are being used in livestock farming, such as milking robots, a *Manitou* forklift truck for feeding, and heavier tractors for working the land (which makes it more difficult to work wet grasslands). A milking robot makes it possible for the cows to be milked

throughout the day, rather than at set times. To make the system work, the cows cannot wander too far away from the stable. This leads farmers to decide to mow most part of their grassland instead of having it grazed. By mowing the grass and feeding the cows indoors, the grass is used more efficiently, and milk yield is higher and has a more constant quality. Consequently, grazing is often limited to the farm home plot, while for mowing the proximity of grasslands to the farm matters less. Maintenance and water costs are higher, but less labour is required (for e.g. herding cows, maintenance fences). One farmer mentioned that the robot is the reason why he can keep working longer and maintain his grasslands longer than expected. In one case, the herd was expanded when purchasing one or more milking robots to ensure that the robot(s) are fully utilized. This, in turn, created a greater demand for grass(land).

4.2.3 Perceived impact government laws & regulations

Farmers complain in general about an **unsupportive or overly intrusive policyscape**. They often struggle with the complexity and unclear objectives of grassland regulations, including the restrictive nature of payments like the eco-scheme for grass, which limits farming interventions and creates uncertainty about allowed practices. Many policy instruments do not align with the way farm operations are conducted or decisions are made, and many feel that policies are imposed top-down without practical consideration for how they will be implemented. Another issue which is often reported is the administrative workload and the rigid policy calendars which hinder farm activities. Finally, many farmers doubt whether to innovate and invest in their farm as a result of the factors mentioned previously, but also because of regulation pressure, cattle quotas, pressure from neighbours and uncertainty about regulation. One farmer reported he felt the increased pressure from various sectoral policy objectives on the land. Quotes that illustrate how policy regulations are perceived as top-down by farmers:

> *“That's a bit of a disadvantage. Over there in Brussels, they decide this, that and the other. They don't have a clue what it's like on the ground. They only see the contour lines, and apart from that, little consideration is given to the environment, or to the farmer himself.”*
>
> *“Those are things that are imposed from above. For nature, insects or whatever.”*
>
> *"So those are some of the annoyances we have in the countryside. Someone from INBO insects is coming here, because I see that there are some poles. That person comes from Ghent, from the city. He does his work here, and then he returns to the city. But we are left here with overgrown grass and who knows what else... I have nothing against nature, you know…”*
>
> *“The number of hectares available always remains the same. Yes, definitely, more and more targets are being imposed, which means there is more and more pressure on those same hectares. We are always bringing in more and more people. Yes, it was definitely a pressure."*

Farmers mentioned 13 **specific measures** that hinder their farm activities (Table 1).

Table 1: Overview of specific policy instruments and their perceived impacts which were mentioned by interviewed farmers.

Environmental constraints	
Cattle quota (permitted livestock) per animal type (dairy cows, suckler cows and calves under 1 year)	It has a strong influence on farm development projections and decisions. In theory farmers should follow respective quotas per animal type monthly, meaning they would have to sell or buy animals regularly depending on population dynamics. The permitted livestock is linked to the operational permit which is based on emission rights, cattle manure processing and proximity to housing (for olfactory reasons).
Nitrogen reduction targets	The 30% reduction target for 2030 restricts farm growth perspectives.
Nitrogen decree	Farmers are unsure whether their practices meet the current decree requirements.
MAP, manure and nitrogen regulations	Grasslands are seen as an opportunity to valorise cattle manure. Overall, the nitrogen reduction targets and reported necessary infrastructure changes (e.g. new stables) further constrain growth and operational flexibility.
Fertilizer limits on pastures	One farmer stated that adding excess fertilizer on pastures reduces palatability, hence there is little reason to fertilize them too much. The farmer therefore questions the actual usefulness of limiting fertilizer application on grasslands which are grazed by cattle.
Grassland eco-scheme restrictions (nitrate and pesticide use)	Limited interventions allowed; uncertainty about permitted practices.
Obligation to inject slurry (instead of spraying)	Slurry injection breaks turf and encourages weed growth in grasslands. This seems to be a negative trade-off.
Instruments related to grassland management	
5-year rule for permanent grassland	As farmers want to keep their options open, they often plough a 4-year old grassland to avoid that it will be considered permanent grassland by the government. Several grasslands were converted 5–6 years ago due to expected bans, which also impacted grass production.
Mandatory 5 m grass strips along streams reduce productivity	5 m grass strips lower productivity and encourage weeds. One farmer even questioned whether these strips are useful at all for water quality.
Archaeological value	Historical or archaeological constraints can exclude farmers from compensations.
Agri-environmental measures (AEM)	AEMs are not aligned with farm operations, and do not fit daily workflows. (Note: there were very few mentions of AEMs during the interviews).
Maintenance of hedged grasslands	Hedges require substantial maintenance despite offering benefits to farmers as well. One farmer reported it is simply not possible with the available manpower, even if he wished to. Also, he felt there is no attractive compensation for hedge maintenance.
Instruments related to temporal management	
Fixed farm calendar	Fixed policy-defined farming calendars create constraints for many farmers. Increased seasonal variability enlarges the importance of this barrier.

During the interviews, farmers were asked to provide their views and recommendations, as to how policy could help them manage grasslands. This has at times been intercepted as recommendations to make their farming activity viable. When their current operations are grass based, both aspects (grass management and farm operation viability) are of course highly interlinked. Here is a range of **policy suggestions** that were **made by farmers** during the interviews. These suggestions are based on their respective perceptions:

- In general less policy interference and more flexibility.
- Less administrative workload.
- A clear(er) regulation framework with a 20 year long perspective for example, to reduce uncertainty and unpredictability.
- Less spatial planning changes to ensure continuity in farmlands.
- Desire to be less dependent on subsidies: A farmer is better off with a good price than with income support. With income support, once the funder is unhappy for some reason, you have no room for discussion.
- Get rid of the farm calendar, as it does not work well with seasons that are increasingly variable and require constant adaptation.
- Allow to use more animal manure (instead of chemical fertilizers).
- Issues like fertilizer limits, cattle quotas and slurry injections from the different MAPs disrupt farming efficiency, foster weeds (in case of slurry injections) and impact growth perspectives.
- Allow to structurally apply a combination of grazing and mowing grass in nature reserves (land owned by nature protection organisations).
- A possibility to report a number of 'problematic' plant species (in order to take action where otherwise forbidden). Restricting ploughing -tilling- and fertilization on permanent grasslands leads to the proliferation of invasive and toxic weeds like thistles, dock, and ragwort. Without the option to plough or use targeted chemicals, these plots can become unproductive over time, as manual removal is unfeasible at this stage.
- Support of the young generation of farmers.
- Acknowledge good farmer practices. Farmers often feel targeted by controls highlighting everything they are doing wrong.
- Listen more to farmer knowledge.
- Reduce the focus on moving away from pen-barns, as they are probably better than the very expensive modern barns.

4.2.4 Perceived impact of the social environment on grassland management

There is a limited impact of the social environment on how farmers experience their grassland. In a few cases, farmers mention that they are influenced by what **neighbouring farmers** are doing. For example, when farmers observed other farmers ploughing their permanent grassland, there was a perception that it was still possible, resulting in a peak in ploughing up grasslands 5-6 years ago (2019-2020?).

The most important impact of other actors is probably the competition for grassland with **horse owners** (see Chapter 5). The other side of the coin is that farmers sometimes can sell their hay to the horse owners, or help with the management of the grasslands of horse owners.

"You won't be able to get grassland as easily as you used to, there are lots of horses here... they're everywhere. But those men, they are taking over the land. Belgium is a horse country, you know. You can sometimes sell your hay to those horses."

During the Photovoice, a farmer was critical about how these grasslands are managed:

"There are a lot of 'horsification', riding schools. They speak of erosion, but when you see how much water runs off a horse pasture. That will surprise you."

Recreation can cause 'nuisances' for farmers, but have no direct impact on how farmers manage their grassland. Examples of these nuisances are: litter around walking trails passing through the grasslands, cyclists cutting through wire fences causing cows to wander onto the road, or cycling races resulting in difficult access to roads. However, recreational use is not always perceived as negative. During the photovoice workshop, one farmer was talking about the importance of grasslands for grazing, and mentioned that this value was shared by visitors.

"During Covid, there were many passers-by taking pictures of the cows in the field. 'Wa une vache', they said. That belongs in the image of the landscape, to have animals in the meadow."

Sometimes there are annoyances with **new residents**. Examples are: overhanging branches at farm roads that damage farm vehicles and equipment, limited access of farm roads due to parked cars, complaints from neighbours to the police about noise, residents challenging farmer requests for permits. But again, this has no direct impact on grassland management.

4.2.5 Perceived impact of climate change

Several farmers mentioned that the traditional management of grasslands - through mowing, grazing, and fertilizing - is now being challenged by climate change and that there is a yearly uncertainty about the timing of these activities. Depending on rainfall, wet grasslands can become **drier,** or dry grasslands wetter. In periods of drought, wet grasslands may become workable earlier in the season or even attractive for arable farming, for example in planting potatoes on non-traditional arable land. **Wet periods** during warm summers can produce very high grass yields, but can affect grassland workability and prevent mowing altogether, depending on parcel characteristics. This leads to highly variable yields from year to year, and explains why farmers like to have a diversity of grasslands (wet to dry gradient).

As grassland area and expected yield are aligned with livestock needs, there is a high pressure with often very high workload during very small **time windows**. This can bring mental stress to farmers. When bad weather results in a deficit in grass production, farmers can decide to temporarily convert arable land into **rotational grassland** for feed production. Consequently, the area devoted to secondary crops such as potatoes is reduced. However, major shifts in cultivated areas as a result of climate change are not reported.

In addition to the direct impact on grassland management, climate change is by many farmers also perceived as a factor affecting **livestock welfare**. Hot summer periods and heat waves negatively affect livestock health and reduce milk production. Some farmers mention hedgerows and tree lines

providing shading and cooling. Other farmers prefer to keep their cows indoors - especially in modern dairy farms with high milk production. What is common in these two strategies is the underlying concern for the welfare of their cows.

In summary, farmers in LVA experience a limited yet noticeable impact of climate change on their farm. It does not result in a change in grassland area, but it does affect the management of grasslands and the welfare of their livestock. Most farmers describe that climate change makes farming more complex, while simultaneously accepting that they cannot change the weather.

4.3 Farmer's decision making for grassland use and management

4.3.1 Grassland use and management in the context of the farm optimization

Overall, the **largest costs** for livestock farmers are labour costs (contract workers), infrastructural investments and concentrates.

Grass is the basis of their feeding strategy, and grasslands are only important for farmers because they have livestock. However, a good cattle ration consists of protein on the one hand and energy on the other. Protein is provided by grass, grass clover, cereals and protein crops (such as peas, field beans, clover and alfalfa); while energy is provided by fodder beet, beet pulp, maize, CCM (Corn-Cob-Mix), brewers' grains, cereals, etc. The more maize and fodder beet is added in the ration (compared to grass), the more concentrated feed that need to be given. So, while grass is the basis, maize and fodder beet are also included and supplemented with purchased concentrates (in order to provide a good ration). Maize has the advantage that it is easy to grow and that it has a less strict timing and management demands as grassland, while it has a high success rate and a very high dry matter yield per hectare.

Most farmers are also strongly focused on **self-sufficiency** to meet the feed requirements of their herd. Producing as much as possible on their own farm is cheaper, provides more control over fodder composition, and reduces dependence on global markets in times of economic uncertainty.

Farmers can employ two different strategies to use the grass:

1) Letting the cows **graze** is mostly used for 'dry' dairy cows, beef cows and young stock ('jongvee: vaarzen en kalveren'). It is considered the most extensive and cheapest method, but there is less control on the ration (uptake depends on the grass type and quality, weather, soil, grazing habit cows). Grazing takes place at permanent grasslands.
2) **Mowing grass and feeding indoors** is typically used for milking cows and calves. With indoor feeding, farmers have more control over the ration (protein, energy,..), cow health and milk yield. Also with indoor feeding, cows tend to eat more indoors. In this way, total production increases and farmers have a lower workload. Farmers want to be able to mow as much grass as possible to bring it to the stable or to ensile it for winter. Several farmers stated that anything that *can* be mown, *will* be mown. Especially when using milking robots, grazing is no longer obvious and this can lead to more mowing, more temporary grassland and/or shrinking of the home farm plot. For distant grasslands, some farmers indicated that grazing creates too much workload (transporting animals is labour-intensive) and makes it too difficult to control. Therefore, these plots are mown and ensiled instead.

Almost all farmers explicitly stated that they focus on **grass quantity and high quality** and how it can be improved. Grassland management is intensive Therefore they use the following strategies:

- Productive grasslands require **fertilization**. Manure from livestock is applied on arable land, while mineral fertilizer or slurry is spread on accessible grasslands. Grasslands that are grazed receive less fertilizer (twice per year), while grasslands that are only mown are fertilized 3–4 times per year. Permanent grasslands are allowed to be fertilized more than arable land (Uitrijregeling, Normen en richtwaarden).
- Farmers occasionally **over-sow** permanent grasslands with new grass species, or even plough up and reseed them with perennial ryegrass.
- To obtain high-quality fodder, farmers must **harvest and ensile** at the right moment, which is highly dependent on weather conditions and the growth stage of the grass. To optimize their operations, farmers must take many factors into account and make trade-offs at various stages of the production chain within the limits of their farm.
- Whereas permanent grasslands form the foundation, **temporary grasslands** are mainly used to ensure sufficient grass supply and this acreage is therefore flexible. Particularly in the case of indoor feeding, temporary grasslands are attractive. Many farmers observe higher and better-quality yields in temporary grasslands compared to permanent ones. Another advantage is that when included in a crop rotation, temporary grasslands improve soil quality for the subsequent arable crop. However, a shift to temporary grasslands has not been observed yet among our interviewed farmers as most of them already have enough grass feed from their permanent grassland, and any remaining land not used for other fodder crops is planted with potatoes or other crops.
- Half of the interviewed farmers started using "**grass-clover**" which they maintain for 2 to 3 years. It is perceived positively as grass-clover because of the higher protein content, it can stand drought better, and it improves soil quality (providing a more qualitative crop afterwards). One farmer mentioned that it is better to mow grass-clover and feed indoors than let it graze, as cows tend to leave the clover. The subsidy for integrating legumes such as the 'grass-clover' mix in the crop rotation serves as an incentive for the farmers. Dairy farmers also experience a more positive consumer perception of milk produced from grass-clover mixes.

4.3.2 Personal values in relation with the use of grasslands

Farmers see themselves as **businessmen** who generate income from the market (rather than income support). During the Photovoice workshop one farmer said:

> *"We, the farmers, are not a charity organization; we do not keep pets; we have to earn our living with our work."*

Throughout the interviews, farmers mentioned several personal values that potentially influence their grasslands use and management. First of all, grasslands are kept to feed the cows, and the livestock is kept out of **love for the animals**. During the Photovoice workshop, farmers mentioned the joy that comes with watching your young cattle play outside.

"You grow up with the animals. (…) If I were to say, 'Okay, yes, we're going to stop milking', I would consider choosing another breed, either a beef breed or something else, but still with animals."

"The young cattle are frolicking, playing, and fighting. It's a wonderful feeling every year when the young cows go outside." Another farmer added that "[t]here are two feelings during that time of year: you're happy that they're outside, and you're afraid that they'll break out."

Consideration of **animal welfare** can also influence the use and management of the grassland. Several farmers stated that it is important for them that cows can graze outside. Some farmers mentioned it as a reason to keep the home farm plot and trees on the grassland so it can offer shade for the cows. On the other hand, some farmers prefer to keep the cattle inside, stating it is easier to keep an eye on them and quicker to spot when they are sick. In one case, the grassland around the stable was kept even though the cows stayed inside, just in case of fire.

"A cow should be able to go in the pasture, it's good for their feet. It's a bit an emotion, but a cow that walks outside is still (…) it's better if they can walk outside, and stretch their legs".

The **pleasure of managing grass** is a subjective value that came up, especially during the Photovoice workshop. *"Mowing the ryegrass is the most fun, but most hectic period."* For the farmers, ryegrass speaks to the senses: *"The smell of fresh grass, if you could only bottle that.*"

Several farmers discussed their role in **keeping the landscape** as it is, meaning maintaining a diversified landscape with grasslands both on sloping and flat parcels.

"Everything I do is nature. (...) If we're not there, everything turns to forest. Now there are open spaces between it, if that closes up, the Vlaamse Ardennen loses its character."

"Agriculture and nature can perfectly go together. It is actually the farmers that make the Landscape Park. If you forest it all, you only have forest." (Photovoice)

Perception of nature

We also asked the interviewees how they perceive 'nature' on their farm. These perceptions are not directly drivers for maintaining grasslands, but offer some insights how farmers relate with their environment. Most farmers see **agriculture as nature.** Farmers create nature, as crops are also nature, though one farmer specified that a field full of thistles is not nature for him.

"Farming is the biggest part of nature."

"I think I am more a nature person than most people."

Three farmers talked about **working together with nature**.

"It's strange to say, but nature is actually everything to a farmer. You work with nature, you take care of it. Like I said earlier, there isn't a single farmer who would fertilize his land or do

something wrong, or start working his land too early. You say, it's too wet, we're not going to start. You work with and for nature, that's what I mean."

Some farmers refer to a desired **landscape** quality in the Vlaamse Ardennen and to the role of farmers as creators of the landscape. Some farmers mentioned that they do not want compensation for the actions they take, such as for pollarding trees, managing hedgerows, protecting lapwing's nests or hanging nests for swallows.

"Nature, yes, authentic waterways, pollard willows, everything like it was in the past."

Forests are mentioned by several farmers. The value of forests for nature is considered, but afforestation is considered as a threat for the landscape and for agricultural land. Several farmers say there "*shouldn't be more*". One farmer compared a forest landscape with an open landscape, preferring the second:

"I don't know, that meadow next to the highway is a magnificent meadow, no houses in sight. As a little boy, I thought it was magnificent. Sometimes they want to turn those areas into forest, but when you're standing in a forest, you can only see the first tree behind you and in front of you, and that's it. And I see huge forests in the distance, but I also see pastures with cows. Isn't that nature? Apparently not for some nature lovers."

4.3.3 Labour availability and succession

Grassland management should fit the amount of **available labour** (needed to daily check animals, maintain fences, etc). When farmers take up an additional job, they will reduce their livestock. One farmer mentioned that when his father stopped working in the farm, he decided to mow grasslands instead of letting the cows graze, because herding cows to the desired field required two labourers.

Of our interviewees, two farmers have a **successor**, while three farmers indicated that they do not. For six farmers, the succession is unsure, mostly because the children are too young. Three farmers stated that they are not sure they would recommend the farming business to their children. According to one interviewee, the lack of successors is due to a combination of factors, such as the need for large investments due to high land prices, the cost of materials, and the size of today's farms.

Grasslands are at risk when farmers retire without having a successor. In that case, he either stops or continues to be a part-time farmer, with possibly support of hired labour. What typically happens is that animals are sold (or at least significantly reduced in number) to reduce the work pressure and to have more opportunities to have a day off. In addition, some retirees switch to arable crops, which usually offer higher returns per ha and demand less labour (which even can be outsourced). As a result, grasslands become obsolete for the farmer, and are then sold, leased out or ploughed into arable land. However, this is not always the case, as there was also an interviewee who indicated wanting to start again with beef production after retirement and another interviewee who mentioned that new machinery made the work easier and would allow him to keep up livestock farming longer.

4.4 Perceived ongoing trends and expectations of changes in grassland acreage

Stability of grasslands in optimized farms

For most farmers their farm **grassland area did not change**. Also for the short-term future (5 years), most farmers do not expect significant changes in their grassland area. Grassland area is dependent on the size of the herd, or vice versa. In addition, in the Vlaamse Ardennen, there is a lot of land which cannot (easily) be used for crops (because it is too steep, too wet, close to streams), so keeping grasslands and cows is a logical option. In addition, the home farm plot is essential for milk cows walking in and out, even if it is suitable for arable crops.

Some farms even bought **extra grasslands** and/or seeded new grassland. Mentioned reasons are: increase of the number of cows, need to expand grassland in proximity to the stable, too wet arable land, or the manure quota (when farmer has not enough land to deposit its farm manure). In such cases, grassland is usually bought from retiring farmers who sell their grassland.

But the **management** of their grassland has gradually **changed** over time. Due to use of new milking systems (e.g. milk robot) and/or reduction of available labour, several farmers decided to have their cows only around their farm, and to do more mowing instead of grazing. As a result milk cows spend more time in the stable, and less in the field. Also, there is more rotation with temporary grassland, and there is some experimenting with 'grass-clover'.

But, a declining trend of grasslands in LVA region

Farmers observe that in the LVA region, despite the livestock farms getting larger, the overall number of cows is declining (due to the fast decline of the number of farms). Consequently, most farmers observed a **declining trend of (permanent) grasslands** in de Vlaamse Ardennen. At the same time, it is expected that over time all the **'**good' parcels of grassland will be ploughed and become **arable land**. The main reasons are: retirement (own use or sale), another job, declining meat prices (which encouraged some farmers to stop raising beef cows), shortage of labour, and introduction of a milk robot. On the other hand, arable copping of potatoes and onions is more profitable and it is less labour-intensive. There is also an increasing demand for renting land from potatoes/vegetable farmers. When a grassland is considered not profitable (e.g. too far away, protected status), then farmers stop the lease, sell it or even abandon the grassland (resulting in weedy and bushy fields).

The new generation of landowners is more likely to sell their land. When a (leased) grassland is being sold, chances that a livestock farmer can purchase it are slim, because there are many **capital-rich buyers** who are searching for land (e.g. industrial farmers, horse owners, government agencies searching for reforestation or industrial land, wine growers, camping owners, newcomers searching for houses with big gardens). Many farmers mention the impact of 'horsification', but some farmers assess this impact higher than others (depending on the region, e.g. one farmer claimed that in Horebeke there are more horses than cows). This trend is expected to continue in the future, but buying big farms is now only possible for horse breeders (from the policy point of view it is considered as agricultural activity), and not anymore for equestrian centres. This resulted in the emergence of 'fake-farmers'. On the other hand, renting out grassland to horse owners can yield up to a third more than renting to beef farmers. Wet grasslands in valleys and steep slopes are often earmarked for and

bought for nature development. These grasslands are relatively less profitable for farmers and interesting for nature development. But in this way farmers lose their buffer to cope with dry periods and climate variability.

Government pressure to reduce emissions or the number of cows per farm (in the past: milk quota, now: environmental restrictions) make grasslands either less attractive or irrelevant for farmers to invest in, and will likely result in the gradual decline of grasslands. Also, the 5-year rule for permanent grassland is often mentioned as an incentive to transform them into an arable field (esp. potatoes). In this way, farmers can keep their options open, esp. for their retirement. There was a peak in ploughing grasslands 5-6 years ago, as there was a perception that it was still possible and as farmers observed other farmers were ploughing their grassland. In some cases, government agencies are buying up farmland, or providing subsidies for afforestation to nature organisations. If a farmer is not permitted to change non-useful grassland into arable land, then they have a few options: sell it, rent it out, make a contract with the government (Manure Bank, agri-environmental scheme).

Looking 25 years ahead is difficult as most interviewed farmers will be retired by then, and they find it difficult to assess what will happen to their farm and grasslands. The expectation is that there will be fewer young farmers who want to be milk farmers (as it is not attractive), that animal numbers will decline, and that there will be a decline of permanent grasslands. On the other hand, one farmer stated that steepland will remain grassland.

> *"We have a lot of permanent grassland on our farm, which can only be used for livestock. On the other hand, we are no longer allowed to keep animals? What should we actually do with that grassland?"*
>
> *"No animals, no grass. You can't eat grass, can you?"*
>
> *"Grasslands can be converted to arable farming, but the closer you get to the Vlaamse Ardennen, the more hilly it is, and the more difficult it becomes."*

5 Factors influencing grassland decision making of 'new' grassland users

In this chapter we analyse the factors affecting the decision making of 'new' grassland users regarding their grasslands and their impacts in Landscape Park Vlaamse Ardennen (LVA). These activities are not per se new, but their increasing popularity in the region is a new trend. This section is based on 7 interviews of 'new' users of permanent grassland. The results are summarised in the mind map (Fig. 10).

5.1 'New' grassland users typology and management

Most of the interviewees are originally from the region and some have been living there for many years. They are a very diverse group of land users, and they can be distinguished based on:

1. The main activities taking place on the grasslands: alpacas (2x), sheep (2x), donkeys, horses, bison, and mixed (mowing contracts and recreational use as a garden).
2. The level of professionalism: hobby (2x), second job (4x), main job (2x).
3. The size of their grasslands: Ranging significantly from 3 to 120 ha. Hobby and second job grassland users have between 3 to 15 ha grassland, while professional users tend to have larger acreage (between 28-120 ha).

The official land parcel designation of the users' grasslands was not taken into account. The agricultural status of these users remains unclear due to varied and sometimes confusing terminology regarding agricultural registrations.

The grasslands are mainly located near the home or the main base of their activities. In most cases, they are **owners** of the grasslands. The origin of these parcels varies among the respondents: either the parcels were included when buying the property or were acquired or rented later. When taking into use or purchasing a parcel, local relationships often play a crucial role. Parcels may become available because a farmer stops farming or because a parcel is too difficult to cultivate. This highlights the importance of personal connections and practical considerations in land acquisition processes.

5.2 Perceived drivers and motivations for grassland use

With 'new' grassland users, **intrinsic motivations** are the most prevalent reasons for conducting their grassland activities. An interest or a passion for animals is what drives most of them, and they enjoy being outdoors (Fig. 12).

The 'new' grassland users mostly have a **positive relationship with nature**, even though they view it in different ways. Some appreciate nature intrinsically, for its species of birds, plants or other animals. While others give nature more relational values, such as *"care for nature is care for humans"*, *"experiencing the wonder of nature*" or *"nature is our landscape".* Mostly it was a combination of different values.

The users report having a **good relationship** with people in their surroundings and local farmers. There are almost no major conflicts, only occasional minor complaints (e.g. exotic species, colour of fences, use of pesticides). The majority mentions positive reactions from their social environment, with five explicitly stating that neighbours and passers-by are happy with the presence of their animals. Six respondents collaborate with farmers, for example to dispose of their manure on (other) farmers' fields, winter grazing with sheep on farmers' fields, or temporary management of grassland parcels by farmers. This cooperation reflects a practical and mutually beneficial approach to grassland management in the local community.

Market influences only the grassland users (2x) who have primarily economic motives, such as bison meat production, or renting out grasslands (to other farmers, horse owners).

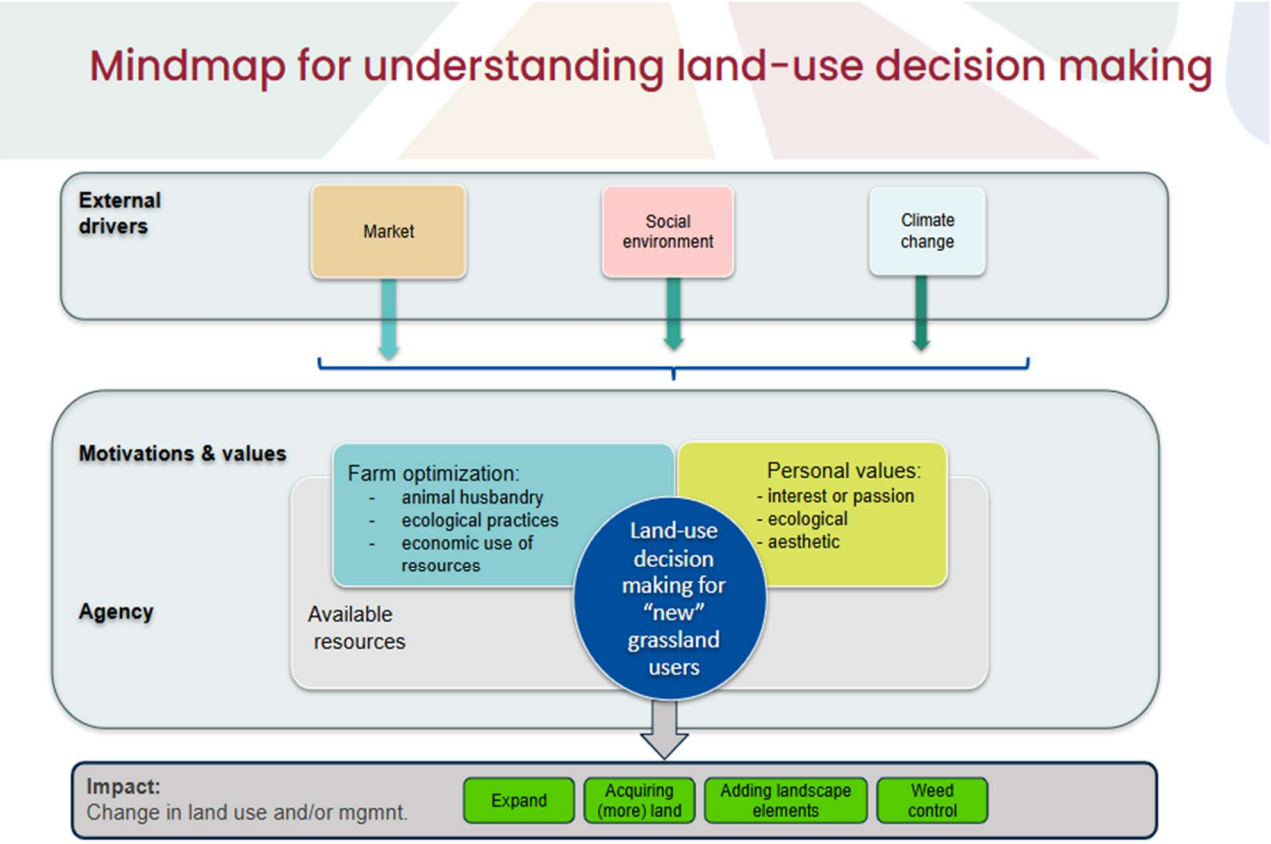


Figure 12: Mindmap of the factors influencing maintenance or changes in grassland use and management by the 8 interviewed 'new' grassland users.

5.3 Changes of grasslands by 'new' grassland users

As this is a new emerging group of grassland users, this type of use is **expanding** in the Vlaamse Ardennen. To reduce the risk of over-grazing (or drought), some of them aim to further expand their grasslands.

The 'new' grassland users want to optimally **manage** their grasslands for their specific animals. Similar as livestock farmers, they let their animals graze, mow, make hay, and add fertilizers to increase grass yield. Toxic plants harmful to animals are removed, by either manual removal or by the use of herbicides. Some more-ecologically oriented grassland users plan to add or maintain landscape elements, such as trees and shrubs in and around the grasslands.

6 Discussion and reflections

6.1 Methodological reflection

We used a mixed methods approach, combining a literature study, quantitative data from historic modelling, with qualitative data originating from semi-structured interviews and the photovoice workshop. Our results, in which we discuss the factors influencing grassland decision making, are based on the perceptions of farmers and 'new' grassland users. These perceptions to some degree

confirm the trends and drivers identified in the quantitative study and the literature. Another iteration, whereby we verify some of these perceptions, e.g. the number of horses, might strengthen the claims made in the report.

The research process was iteratively discussed and coordinated with the Policy Lab, during monthly meetings. Furthermore, our understanding of the topic was broadened during several workshops, where we, for instance, discussed the value, threats and opportunities of grasslands from different perspectives. The results in this report were presented in a Policy Lab meeting, and most members of the Policy Lab also read and thoroughly commented on this report. The iterative process ensures that validation of the results and that the focus of the research is relevant for the Landscape Park. The discussion section will serve as a basis for the development of more concrete policy interventions.

Regarding the selection of participants for the interviews and the photovoice, we had a good variety of types of farmers, and the addition of 'new' grassland users provided a good variety of perspectives. However, by limiting the selection of farmers to those who had or used grasslands in the past five years, we likely missed some farmers who stopped having grasslands before that. Furthermore, with one exception, we only included active farmers. Some factors, such as the impact of retirement, would likely have been more deeply discussed if we included retired farmers and farmers who sold all of their grasslands.

6.2 Major drivers and motivations that steer the maintenance or change of LVA grasslands

On the level of an economic operational farm, there are limited changes in grassland acreage on the short-term, but there are identified changes in the use and management of grasslands. One of the main trends is that lactating dairy cows are increasingly kept indoors and fed mown or ensiled grass, while dry cows and young stock often continue to graze outdoors. As a result, less grassland is grazed and a larger proportion is harvested for mowing. This trend is influenced by new technologies such as the milking robot, and a desire to optimize the feeding strategy and keep a close watch over the cows. Climate change, and more specifically heat stress, are expected to contribute to this trend. Another change is the increased use of grass-clover in temporary grasslands. The drivers for this trend are the higher nutritive value of grass–clover, better adaptability to climate change (drought in particular), and the availability of eco-scheme payments ('ecoregeling').

In our group of interviewees we noticed **increased specialization of farming,** a trend that has been identified in literature (a.o. Schut et al., 2021): mixed dairy-beef-arable farmers had converted to mixed dairy-arable farms, and one dairy-arable farm converted to a purely arable farm. These changes can be economically justified: the average profit of milk production is higher than of beef production, while the average profit from profitable arable crops is higher than of livestock production (with the side remark that there is some fluctuation in profitability between arable production and dairy production). If this trend continues on a larger scale, this certainly must be regarded as a driver for a decline in livestock farming and the loss of grasslands.

Some farmers converted a parcel of permanent grassland into arable land and several farmers rotated temporary grassland with arable crops. These are indications that there is a **competition between**

grassland and productive arable crops. Aside from growing fodder crops, all interviewed farmers - except one - also grow potatoes and sometimes other arable crops next to (or instead of) their livestock activities. On average, potatoes have been the most profitable crop for the past fifteen years, with an increase in price far outweighing the increase in milk or cereal prices. As the historic potato price crash of 2025 shows, this is not a given (De Standaard, 06.08.2025). Still, most of our interviewees, potatoes are considered as a secondary crop limited to parcels which they do not directly need for fodder and grass production. Only one dairy-arable farmer indicated that arable crops, in this case mainly brussels sprouts, became their largest source of income.

Of the total area covered with grassland in Vlaamse Ardennen in 2022, 87% is permanent grassland and 13% is **temporary grassland**. There seems to be a gradual trend towards more temporary grasslands. Temporary grassland offers greater crop flexibility and often higher forage quality in the short term, while permanent grassland excels in carbon sequestration, soil development and biodiversity in the long term.

Many farmers are financially dependent on **direct income support** from CAP funds. Currently, these funds are fundamental for the viability of livestock farms, especially for beef farms, and therefore indirectly lead to maintaining grasslands. Between 2015 and 2021, the average share of direct income support in the gross farm revenue for beef farms is 74% and 13% of the average net income. This is a consequence of a large amount of direct payments and a low average total revenue on these farms. For arable farmers and livestock farmers, the share is on average 35% and 25% of the farm income or 10% and 6% of the revenue. Furthermore, **agri-environment-climate measures** can also provide positive incentives for maintaining permanent grasslands, but they are not very popular (27 ha).

On the other hand, farmers perceive the **policy context** not favourable for livestock farming, putting an increasing pressure on farmers. On one hand, they feel a lot of restrictions (herd quota, nutrient loss reduction, distance to streams, rigid farm calendars) which limits their freedom of operation and reduces their profitability. Moreover, many of the policy instrument mechanisms do not fit the way farm operations are conducted, or farm decisions are made, and many feel that policies are imposed top-down without practical consideration for their operations. On the other hand, they feel uncertain due to the complexity and unclear objectives of grassland regulations and the constant changing of rules (e.g. PAS). Finally, they often reported the administrative workload. All these factors make that their future outlook is not positive, and that farmers are hesitant to invest or take over the farm of their parents.

Personal values and perceptions are important to take into consideration, though they are rarely mentioned as direct drivers for maintaining or changing grasslands. Livestock farmers see themselves in the first place as entrepreneurs who produce food for the market. On the other hand, they are also intrinsically motivated to work with animals and to take care of animal welfare. These types of values influence the choice to either graze or mow grasslands (Van den Pol-van Dasselaar et al., 2020). Furthermore, several farmers see themselves as indispensable for conserving the desired, diversified landscape in the Vlaamse Ardennen, which grasslands are part of.

For the farming system, **changes in labour availability** can also be an impactful factor for grassland management. In our interviews, changes in labour were mainly mentioned in relation to intergenerational collaboration, retirement and second jobs. The moment of **retirement** is frequently mentioned as a fundamental cause for the loss of grassland. Only a few of our interviewees were

certain about having a successor. When there is a lack of succession, due to economic or policy drivers and/or personal choices, farmers often choose to convert their livestock farm to an arable farm, because it requires less labour and can generate more profit. In the next stage, retired farmers without succession sell their land. There is often a fierce competition to buy these grasslands between farmers, government agencies (e.g. nature conservation agency), 'new' grassland users, farmers from (far) outside de Vlaamse Ardennen (who are less familiar/concerned with the local characteristics of the land), and new residents. When these grasslands change hands, there is a high chance of other land management.

At the **regional scale**, although many farmers reported a decline in permanent grasslands in the Vlaamse Ardennen, the spatial analysis over the period 2013-2022 did show only a net 1% decline. However, this can hide internal changes of grasslands. The spatial analysis indicated that permanent grassland has changed into temporary grassland (-96 ha), arable land (-300 ha) and 'other land-use' (-290 ha); while permanent grassland has increased on the expense of 'other land-use' (+212 ha), arable land (+87 ha) and temporary grassland (+341 ha). As the latter is likely a side-effect of new European registration rules, we can assume that the decline of permanent grasslands is around -7,5%.

Another dynamic is the emergence of **'new' grassland users** which can only partly be identified in the spatial analysis (as quite some new grassland users have an official farm number), such as nature conservation organisations (converting agricultural grasslands to biodiverse grassland or forests), horse breeders, people who keep animals as a hobby and residents with large gardens. The group with hobby animals is a particularly expanding group. These 'new' grassland users are primarily driven by intrinsic motivation, acting out of personal interest, passion, and/or ecological convictions. They enjoy being outdoors and value a positive relationship with nature. Markets and policies (e.g. soil management, soil conservation) have less impact on this group, except for those who make an income from these 'new' animals (such as horses, bison, alpaca).

6.3 Relevance of grassland dynamics in Vlaamse Ardennen for other areas in Europe

Grasslands used for **dairy and beef cattle** are **decreasing** most clearly in intensively farmed lowland regions of Western and Northern Europe (e.g. parts of the Netherlands, Flanders in Belgium, northern Germany, Denmark, northern Italy) and in many Central and Eastern European countries where large areas have been abandoned or converted since the 1990s (e.g. Romania, Bulgaria, parts of Poland, Czech Republic, Baltic states, Slovenia, Hungary) (van Vliet et al., 2014).

In Intensive lowland dairy regions (West/North Europe), the share of grassland in dairy farm area has fallen in many regions as maize silage and concentrates replace grass in high-yielding dairy systems (Huyghe et al, 2014). Denmark shows an annual decline of permanent grassland of about 0.5% while temporary grassland is used more flexibly within arable rotations (DairyClim, 2016). Similar patterns of conversion of permanent grassland to temporary leys or arable land are reported in parts of France, Germany, the Netherlands and northern Italy, often despite national safeguards (Huyghe et al, 2014).

One of the main trends observed in Vlaamse Ardennen is the trend of **mowing grassland instead of grazing**. Despite there are few long-term data on grazing available in Europe, researchers in several

countries confirm that this trend also takes place in other Northwestern European countries. There is large variation both between and within countries. In Denmark, dairy cattle did not graze increased from 16% in 2001 to 30% in 2003 and it is still increasing. In the Netherlands the number of grazing dairy cows has been monitored rather intensively from the early 1990s onwards. In Luxembourg, it is estimated that up to 10% of the national herd does not have access to pasture; also the number of grazing animals is decreasing. In the UK, it was estimated that less than 5% of the dairy cattle did not graze in 2005 and this number is increasing. In countries Norway, Sweden and Finland have welfare legislations stating that cattle must have access to pasture or alternative exercise areas outdoors for a minimum period of time during the summer (six weeks to four months depending on location). On the other hand, grass-based seasonal systems of milk production predominate in Ireland. The length of the grass-growing season varies from about 8 months in the northeast to up to 11 months in the extreme southwest (Van den Pol-van Dasselaar et al., 2008). As in the Vlaamse Ardennen, the trend is driven by a complex interaction of structural changes in farm management, technological advancements, nutritional requirements of high-yielding cattle, and environmental pressures (Van den Pol-van Dasselaar et al., 2008).

6.4 Potential intervention areas for the Landscape Park and policy

Based on the topics raised in this study, a number of potential policy intervention areas can be identified to enhance the quality and distribution of grasslands in the Landscape Park. These intervention areas will drive the analysis in the upcoming report D3.2 and guide future policy recommendations.

1. **Matching policy objectives with farm rationale**: More interactions between farmers and policy developers have several advantages:
    - It can help farmers to better understand policy objectives and how these relate to policy instruments (such as regulations and subsidies). By clarifying the purpose of measures, this could foster more acceptance and response among farmers.
    - It will enable policy developers to integrate more farmer knowledge and perspectives (such as how farmers operate and make decisions). This can assist policy to better identify trade-offs and inconsistencies between policy measures, increase the coherence between policy measures, increase their practical applicability, and support the (re)design of policy instruments, making them more actionable.

On the other hand, some stakeholders mentioned that a range of policy measures, such as livestock reductions, result from political rationales and will likely have to be discussed at that level first.

2. **Consistent grassland definitions**: Policy lab meetings revealed that inconsistent definitions of 'grassland' across policy sectors hinder the monitoring of trends. Standardizing these definitions will be essential to effectively measure the impact of any proposed interventions.
3. **Reducing administrative workload:** The administrative burden is a well-known issue and a priority on the European agenda. Two non-exclusive approaches can address this: reducing the administrative requirements imposed by various agencies, and integrating these requirements where possible.

4. **Flexible policy calendars**: Fixed calendars for farm activities often frustrate farmers, especially as they are increasingly incompatible with seasonal variations caused by climate change. A more flexible, season bound alternative is needed here.
5. **Recognizing and rewarding farmers as landscape managers:** Recognizing farmers' efforts by product origin labels, local initiatives or positive feedback from regulatory bodies could improve morale and engagement with policy measures. It relates both to their role of maintaining ecosystem services and biodiversity, and ensuring landscape attractiveness. The landscape park is interested to look further into the potential role of farmers as landscape managers, including the economic conditions that would be needed to operationalize that role.
6. **Adding a new dimension to compliance**: Farm compliance control is carried out by several public agencies and is often perceived negatively by farmers. This is because it directly results in subsidy cuts or fees and is viewed as overly stringent. At the same time, environmental gains resulting from controlled measures or monitoring are not flowing back to the farmers. In that regard, it could be useful to add a learning component and a system of corrective actions for non-compliance before moving straight to sanctions. Communicating the results of (non-)effective measures would also help contribute to greater recognition of their efforts (see also point 4).
7. **Farmer agency**: Farmers have reported a perceived loss of control on their activities. The question arises where and how farmers could increase their influence, either through cooperations, by shortening their value chain (transforming and selling locally) or through the work of the Landscape Park.
8. **Ensuring better farm succession:** The lack of farm succession is a significant trend that could lead to substantial land-use changes. This is already occurring in some cases, such as retiring farmers without successors converting grasslands to arable land, or selling their land. Ensuring continuity by making livestock and grass-based farm activities more attractive and profitable (whether for existing or alternative farm models) should therefore be a key focus.
9. **Addressing market instability and investment security:** Many farmers also expressed ambitions to achieve self-sufficiency in inputs. Doing so increases the control they have over their activities (see also point 6) and makes them less dependent on volatile market prices (e.g. for feed concentrates). Providing income stability by partially decoupling farms from these markets could be a powerful tool for land-use change, specifically by promoting grass-based rationing and ensuring fair, stable prices for meat and milk outputs. Other aspects to address to create more secure investment conditions include renegotiated contracts with the agro-industry, rapid changes in policy requirements, rising land prices, shorter lease durations, and local conflicts (e.g., with neighbours or municipalities).
10. **Valorise grass and clover-based farms:** Some farmers in the Vlaamse Ardennen achieve successful results in dairy farming with high-productive grass/clover systems with minimal maize. Promoting this model and simulating its operational benefits is a crucial step toward maintaining or even shifting the landscape composition towards more grasslands in the short term. This transition would likely require no legislative changes, but a targeted support strategy from the Landscape Park and partners. It is however unclear at this stage to what extent it could be outscaled for farmers with lower land to cattle ratios.
11. **Anticipating the impact of new technologies:** It is important to assess in advance which technologies are potentially harmful and which can offer potential opportunities. Exploring ways to influence technology adoption (preferably before farmers invest) could be beneficial and would

require ex-ante impact assessments. Examples of important past technological innovations are for example milk robots, new modern stables to host cows, increasing milk production per cow through genetic selection, etc.

12. **Resilience to climate change:** Climate resilience is becoming increasingly important for farmers. Adapting grassland management (such as earlier harvesting or using more robust seed mixes) will be essential. This will require innovation, including peer-to-peer knowledge exchange. More emphasis in climate policies on the value of grasslands for carbon storage may also help ensure that this value is appropriately safeguarded or developed.
13. **Working with 'new' grassland users:** Often, 'new' grassland users do not fit within current policy frameworks and thus remain overlooked in policy interventions. However, they could also potentially contribute to the objectives of the Landscape Park. Policy options are: engage them in the maintenance of the bocage landscape, encourage them to plant hedgerows and to develop their pastures into more natural and biodiverse grasslands (Degezelle et al., 2022), and stimulate cooperation with livestock farmers.
14. **Opportunities for multi-species productive grasslands (MSPG)**: MSPG can provide several benefits to the farming system, compared to usual permanent grassland (Janssen and van Eeckeren, 2025; LV link; B3W). With nitrogen inputs, MSPG provides higher and more nitrogen-dense yields than intensively managed permanent grassland (O'Malley et al., 2025). Moreover, the yield of MPSG is less volatile depending on dry and wet years, which make them more resilient during climate change. Finally, many of the herbs have health benefits for the animals (anti-parasitic properties).
15. **Opportunities for semi-natural grasslands:** They are owned by farmers and/or nature organisations). Farmers could maintain these grasslands by mowing or grazing, on condition that the fodder has minimum quality standards (protein, energy) and that the stage of the cows (e.g. 'dry' cows) or livestock breed (e.g. local double purpose breeds, Limousin) is adapted to this type of fodder. These semi-natural grasslands can have an economic valuable role for cattle farms where grazing is an important part of the business operation and where extensive grasslands amount to no more than 1 hectare per 10 productive dairy or suckler cows (for dual-purpose breeds or more extensive breeds this can be 2 hectares or more) (Indeherberg et al., 2018; Sannen et al. 2025).

These policy interventions will be further researched and discussed in Deliverable 3.2, and special attention will be paid to the potential role of landscape parc Vlaamse Ardennen.

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Annex 2: Sand Ridge – The Hungarian Report

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MOSAIC

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Abstract

This report investigates land-use decision-making in the Sand Ridge (Homokhátság) region of Hungary, a semi-arid socio-ecological landscape characterised by groundwater decline, increasingly unpredictable rainfall and high evapotranspiration. Agriculture remains central to local livelihoods, yet production systems face escalating hydrological, economic and institutional pressures. The study draws on 31 farmer interviews, 14 expert interviews, 10 policymaker interviews, transect walks, observations at local water-related events, non-systematic media review, four Policy Lab workshops, three Photovoice sessions, and a fifth validation workshop. Interviews were transcribed and thematically analysed, enabling a mixed evidence base that combines experiential knowledge, participatory mapping and system interpretation.

Three farm types were examined: traditional mixed smallholder systems, conventional medium-scale farms, and emergent regenerative producers. Across these systems, water scarcity emerged as the most decisive driver of land-use change. Participants rarely invoked the vocabulary of climate change; rather, they expressed lived experience of disappearing surface moisture, declining groundwater tables, spring frost risk, and yield instability. Water was consistently framed as the boundary condition of farming—its absence determining not only what can be grown, but whether farming remains viable at all.

Subsidies surfaced as the strongest behavioural mechanism, shaping farmer choices more than ecological reasoning or technological opportunity. State and EU support was perceived as systematically favouring large-scale operators, with mid-scale farms structurally disadvantaged in accessing development incentives. Several medium-scale farmers withdrew from agri-environmental schemes due to administrative burden, illustrating how current funding models can demotivate rather than encourage land-use change. Smallholders displayed high ecological adaptability but low institutional recognition, while regenerative farms exhibited future-oriented practices without stable policy support.

Social drivers proved equally significant. The ageing of the farming population, low succession rates, labour shortages and weak cooperation emerged as key constraints. Although farmers acknowledged the value of collective action, cooperation was widely described as socially impossible, often attributed to historical patterns of mistrust. Meanwhile, region-specific knowledge exists in the region but is under-utilised, and farmers commonly expect solutions to arrive via external actors rather than internal adaptation or collective agency.

A comparative analysis revealed that each farm type holds a different implicit theory of change: smallholders rely on continuity and inherited knowledge; regenerative farmers depend on experimentation and learning networks; medium-scale farms prioritise operational stability and gradual shifts. Yet all are equally exposed to hydrological pressures and equally constrained by policy structures.

One key outcome of the participatory process was a re-ordering of the initial theoretical driver framework. Rather than separate domains (policy, climate, market, knowledge), farmers conceptualised three intersecting fields of influence: (1) water–ecology, (2) governance–subsidies, and (3) cooperation–knowledge.

Drivers such as biodiversity loss or invasive species, emphasised in earlier models, were downplayed when confronted with lived priorities, while previously under-recognised drivers, particularly lack of flexible agricultural strategy and failure of knowledge uptake, rose to prominence.

Methodologically, Policy Labs generated rich insight but required careful facilitation. Time constraints and dominant voices limited exploration of personal motivations, which appeared in interviews and media narratives but were largely absent in workshop discussions.

Overall, the Sand Ridge emerges as a test landscape for European drought adaptation, illustrating that transformation potential lies not in generating new technical solutions but in enabling farmer agency, promoting water retention over extraction, redesigning subsidy structures, enhancing cooperation, and activating existing knowledge systems. The region does not lack innovation capacity; it lacks the social and governance conditions that would allow such capacity to scale.

Key words: Water scarcity, Agricultural policy, Knowledge transfer

1 Socio-economic, ecological and hydrological context of a semi-arid landscape

The Danube–Tisza Interfluve, known as Sand Ridge (Homokhátság in Hungarian), is one of the driest and most climate-sensitive regions of Hungary, where the lowering of groundwater levels, the increasing frequency of droughts, and the vulnerability of agricultural systems have long shaped landscape functioning. Precipitation and water distribution are increasingly unbalanced, while formerly extensive marshes, wetlands and small lakes have either contracted significantly or disappeared altogether. The 8715 km^2 region is home to 623,386 inhabitants, representing 6.6% of the national population, with a relatively low population density of 71.53 people per km^2 typical of rural areas, although nearly 15% of these residents live in outskirts of settlements (Farkas et al., 2024). Climate change has intensified extreme undermining agricultural production and reducing environmental security in a landscape where nearly two-thirds of the area is under agricultural use. At the same time, the proportion of the population engaged in traditional small-scale farming and the number of agriculturally active farmsteads are declining. Despite these processes the share of farmsteads remains high in both national and European comparison, and pronounced territorial disparities persist, particularly in the southern and border regions, where several districts are characterised by weak functional centres and structural disadvantages (ibid.). Taken together, these dynamics point to a region where environmental vulnerability, shifting land use practices and socio-spatial inequalities reinforce one another, making the Homokhátság a critical case for understanding how climate stress and agrarian change shape rural livelihoods in Hungary.

The negative water balance is the outcome of decades of cumulative processes: evapotranspiration regularly exceeds the recharge that can be supplied by precipitation, and groundwater reserves cannot regenerate at the pace required by agriculture, forest cover and climatic stressors. Almost ten years ago the area was described as a semi-arid region facing complex hydrological and socio-economic stressors (Kovács, Hoyk, and Farkas 2017), indicating that aridification is not a recent phenomenon but a well-documented long-term trajectory. Water scarcity is therefore structural rather than episodic, and it will strongly shape future land-use decisions.

The original vegetation of the region was forest-steppe, characterised by mosaic grasslands interspersed with scattered tree stands. However, in the 19th–20th centuries, large-scale afforestation was implemented to stabilise shifting sand. Tölgyesi et al. (2021) demonstrated that these closed-canopy plantations intercept a significant proportion of rainfall, and their evapotranspiration exceeds natural input, resulting in almost no groundwater recharge beneath forests, whereas recharge still occurs under native grasslands (Tölgyesi et al., 2021, p. 133). This finding is reinforced by groundwater recharge research on the Great Hungarian Plain, which confirms that closed forest cover significantly reduces infiltration and contributes to long-term groundwater decline (Szabó et al. 2023). Historically, the landscape

was therefore not a continuous forest but a semi-open vegetation mosaic that aligned more closely with the region's hydrological regime.

Hydrological dynamics are further detailed by Szkolnikovics-Simon (2022). Winter infiltration is the only substantial source of groundwater recharge, yet forest cover and intensive soil disturbance limit percolation; in summer, evapotranspiration may exceed infiltration by a factor of three to four (Szkolnikovics-Simon et al. 2022:37). Water scarcity is thus not purely a biophysical condition, but also a function of land-use, soil management, and institutional decisions. The hydrological system of the Sand Ridge currently displays low inertia: it loses water rapidly and regains it slowly, making all interventions long-lasting in effect. Past decisions, drainage, afforestation, field consolidation, are therefore still visibly embedded in the present landscape.

This hydrological context directly influences social and economic structures. Large-scale arable agriculture remains dominant, mainly based on wheat, maize and sunflower monoculture, yet its high input and water demand render it increasingly fragile. Fruit cultivation has declined in some areas while re-emerging elsewhere with new varieties and technologies (e.g., apricot, small tomato cultivars). Many holdings rely on poultry, sheep and cattle husbandry, occasionally aquaculture, viticulture or small-scale winemaking. This indicates high livelihood diversification, where income is often stabilised through supplementary activities such as workshops, machinery services, rural tourism or seasonal labour. Farm structures can be grouped into three broad types:

- **Conventional medium-scale farms:** This is still the prevailing agricultural model in the Sand Ridge, based on cereal – oilseed rotations, high fertiliser and pesticide input, heavy machinery use, and strong integration into commercial markets. Such farms provide short-term income stability when yields are high, but they are vulnerable to drought. A growing subset of farmers have already recognised that long-term irrigation development is uncertain or unfeasible, which may open pathways toward more adaptive soil- and water-saving practices, though adoption remains gradual.
- **Traditional mixed small farms:** These post-peasant smallholdings combine livestock and crop production grounded in local ecological knowledge. They operate with low capital and mechanisation yet often display high ecological flexibility. Production focuses on self-sufficiency: vegetables, fruit, fodder, small orchards; while surplus is sold locally or informally, contributing modestly but continuously to household income. Economically fragile, culturally resilient, these farms remain important to local social fabric and agrobiodiversity.
- **Medium-scale farms transitioning to regenerative farming:** These holdings increasingly adopt soil-conserving methods, no-till, minimal disturbance, diversified cover crops, and in some cases the re-integration of livestock, with the explicit aim of retaining water and rebuilding soil structure. They are typically innovative and experimental, trying new crop varieties and marketing channels, but remain socially marginal: while respected, most

farmers in the region still view regenerative practices with caution or scepticism, perceiving them as risky under current subsidy and market conditions.

In addition to the farm types described above, three further farm types were identified: large-scale arable crop farms, waterfowl breeding facilities, and intensive greenhouse vegetable production systems. The latter two currently face pronounced economic pressures: waterfowl farms are increasingly exposed to risks associated with avian influenza outbreaks, while rising energy prices have significantly reduced the economic viability of greenhouse vegetable production. Large-scale arable farms showed limited willingness to engage in Policy Lab activities; as a result, the validation of findings for this farm type could not be carried out.

Ecosystem services are increasingly recognised as central to regional wellbeing. Kelemen et al. (2015) found that locals identified water availability as the most important ecosystem service (p. 116–118), followed by pollination, soil fertility and genetic resource maintenance. This indicates that water scarcity is not only a scientific or policy concern, but it is also a lived experience. People observe the disappearance of ponds, declining hay yields, weakening bee colonies and reduced forage biomass. In this sense, water functions as a foundational ecosystem service, upon which others depend. When water declines, every associated service, provisioning, cultural, regulating, weakens accordingly.

Recent media and policy discourse reflects this shift in perception. Sand Ridge is no longer portrayed merely as a marginal agricultural zone, but as a real-time test site for climate adaptation in the Carpathian Basin. Three municipalities appear prominently as pilot territories: Jászszentlászló, Szank and Móricgát, where farmers and local actors have initiated bottom-up water-retention solutions, including weir construction, sluice restoration and small-scale impoundment along the Dong-ér-Kelő-ér water system. These micro-projects represent a conceptual departure from earlier drainage-driven thinking: water is no longer an excess to be removed, but an asset to be retained. The guiding question for the coming decades is therefore not how to bring water back, but rather, how not to lose it again.

Policy goals at local/regional level

While the formal government programme currently targets land-use transition or drought adaptation in the Sand Ridge - as the existing proposal is merely a techno fix: a large-scale water replenishment of the area - an emerging vision is taking shape among researchers, municipalities and farming communities. The most clearly articulated objective is *the creation of landscape-scale planning and governance,* replacing fragmented plot-level responses. The proposal emphasises water retention as the primary design principle and calls for agricultural subsidies to shift away from uniform hectare-based allocation towards incentives for small and medium-sized farms, soil-conserving practices, and hydrologically adaptive land-use. Instead of large-scale water transfer infrastructures, the envisioned approach prioritises keeping water within the landscape through infiltration enhancement, micro-reservoirs and cooperative management of drainage channels. In this interpretation, the Sand Ridge is not primarily an unbalanced system to be repaired, but a region

where integrated hydrology–agriculture policy could stabilise ecosystem services and rural livelihoods.

2 Methodology

Between December 2023 and August 2025, we conducted extensive qualitative fieldwork in the region. In total, 31 interviews with farmers, 14 expert interviews (independent specialists, National Park representatives, civic organisations, and public institutions), and 10 interviews with policymakers (Agricultural Chamber, Water Agency, County Council, Local Councils) were completed. In several cases, interviews were accompanied by transect walks, allowing direct observation of farming practices, water management structures, and landscape-level decision making. The research team also attended local events, particularly those addressing drought and water challenges, engaged with parallel research projects, and conducted non-systematic media analysis to capture wider public discourse and general attitudes surrounding land use and resilience. In addition to interviews, we organised four Policy Lab (PL) meetings and three Photovoice workshops, enabling participatory reflection, peer-learning, and multi-level knowledge exchange across farmer communities and institutional actors.

All interviews were fully transcribed and analysed using qualitative thematic coding. Recurring drivers, narratives and perceptions were identified inductively and then compared with outputs from PL sessions, Photovoice discussions and transect observations. Triangulation across these methods—individual interviews, collective deliberations, field observations, and external societal signals—enhanced both analytical depth and interpretive validity. This mixed-method approach enabled us not only to identify key drivers but also to understand how these dynamics manifest within the analysed part of the Sand Ridge farming system, and under which ecological, social and institutional conditions they gain significance.

To ensure robustness, a fifth Policy Lab meeting was conducted after the analysis, dedicated to validating and discussing the results with participants. Insights from this final workshop exercise were incorporated directly into the interpretation of findings. A detailed description of the full methodological process of the validation workshop; including participants and workshop design, can be found in Section 6 and in the Appendix.

2.1 Structural external drivers for land-use change

Figure 1: Mindmap for understanding land-use decision making in the case study area – external drivers

Based on the interviews, the first four Policy Lab workshops and the reviewed literature, we identified a broad set of drivers that shape climate-related land-use change in the Sand Ridge region. These drivers reflect both long-term structural forces and more immediate pressures influencing farmers' decisions, production strategies and adaptation pathways. The complete list of drivers is presented in the Appendix, grouped according to the typology proposed by the MOSAIC framework. We visualise the full driver structure in Figure 1. to offer an integrated overview of how the individual drivers relate to one another and cluster into broader domains.

In the section below, we provide a concise analysis of these drivers, focusing on how each category influences land-use decisions in general, and how they collectively influence land-use decisions in the case study area. Rather than isolating individual factors, the aim is to illustrate the web of interacting pressures: economic, regulatory, social and climatic, through which landscape transformation occurs. By briefly unpacking each category, we highlight not only the sources of vulnerability, but also the potential leverage points for future adaptation.

Structural external drivers comprise the socio-economic, political, technological and ecological forces that operate outside the direct control of land-users, yet fundamentally shape the conditions under which they make land-use decisions. In the Sand Ridge region, these drivers were grouped into four main categories — Market & Technology, Instruments & Policies, Social Environment, and Climate Change — each exerting distinct but interacting pressures on farming strategies, land allocation and long-term viability.

Market & Technology drivers reflect persistent economic uncertainty and structural capital constraints. Farmers describe agricultural returns as low and unpredictable, with high input prices, volatile product markets and limited bargaining power. Access to credit remains problematic: loan conditions are often opaque, bureaucratic, and difficult to meet, particularly for farms without collateral or formal financial literacy. This combines with a chronic shortage of capital, preventing technological renewal, farm infrastructure development or diversification toward higher-value crops. Agriculture therefore struggles to provide a stable livelihood, reinforcing outward migration and discouraging long-term

investment. Input-cost inflation — especially fertilisers, fuel, and feed — intensifies vulnerability to global market swings, making land-use decisions more risk-averse and short-term oriented.

Instruments & Policies exert both enabling and restrictive effects, divided into three subcategories. Subsidies play a decisive role: afforestation schemes historically encouraged forest planting, while support for native species helps conserve biodiversity but involves strict compliance procedures. Land-based payments are influential because large farms secure substantial income purely through area size, which can reduce incentives for innovation or conversion. Technology development support is welcomed, yet only accessible for farmers with matching capital. The legislative environment is similarly double-edged. EU accession fundamentally reshaped market functioning and subsidy logic, increasing regulatory density. National Park and Natura 2000 designations protect ecological assets but restrict land conversion, building, and ownership, placing farmers on a constrained development path. Meanwhile, administrative burden has grown steadily; uniform rules treat small and large farms alike, and the volume of inspections fosters compliance fatigue.

The *Social Environment* further influences the trajectory of land-use change. Rural demographic ageing reduces generational renewal — many heirs leave agriculture, and only a small number of young farmers take over existing holdings. Labour shortages limit the management of livestock, orchards and labour-intensive crops. Cooperation remains weak, diminishing collective bargaining capacity, while recreational animal keeping introduces alternative land uses with low economic relevance. Local residents have limited influence over land-use decisions, and past oil exploratory drilling has raised concerns regarding groundwater impacts.

Finally, *Climate Change* introduces both adaptation pressures and heightened vulnerability. Warmer winters facilitate the survival of pathogens and invasive species, demanding new pest-management strategies. Extreme spring frosts increasingly damage orchards, while avian influenza destabilises livestock systems. The most systemic issue is atmospheric drought combined with declining groundwater and soil moisture, leading to rapid disappearance of precipitation and accelerating water deficits year-on-year. Biodiversity loss and reduced ecosystem stability feed back into productivity decline, reinforcing risk-sensitive land-use choices.

Collectively, these drivers shape land-use change not through single impacts but through interlocking constraints and opportunities, where economic uncertainty, regulation, social capacity and climatic exposure continually redefine what farming is possible, and for whom.

3 Factors influencing land-use decision making

Based on interviews, document analysis and insights from the earlier Policy Lab meetings, we also developed a visual summary that synthesises how land-users understand and respond to landscape change. In the following section, we present the perceived drivers of land-use decisions, emphasising that not all factors reflect direct biophysical or economic pressures, several are rooted in farmers' interpretations, values, memories and judgements, rather than external constraints themselves. These internal drivers therefore shape how structural forces are experienced and translated into action, revealing not only what influences farming decisions, but how farmers make sense of change in the Sand Ridge environment. The schematic figure of the factors influencing land use decision-making can be seen below (Figure 2), the full list of factors can be found in the Appendix.

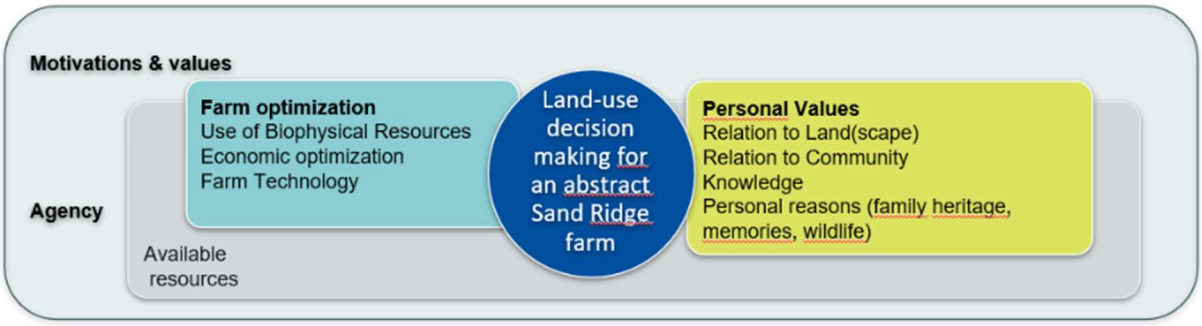


Figure 2: Mindmap for understanding land-use decision making in the case study area – motivations and values

The analysis of land-use decisions in the Sand Ridge region reveals a complex constellation of drivers that operate across personal, social, ecological, economic, and technological dimensions. Rather than acting in isolation, these drivers interact and reinforce one another, shaping how farmers perceive constraints, opportunities, and responsibilities in a landscape increasingly characterised by water scarcity and environmental stress. The categorisation of drivers highlights that land-use change is not only a response to biophysical pressures but also deeply embedded in values, memories, knowledge systems, and social relations.

Personal values emerge as a foundational layer influencing decision-making. Many farmers articulate a strong commitment to preserving family heritage, reflecting long-standing intergenerational ties to land and place. Land is not viewed merely as a productive asset but as a carrier of family history, identity, and moral obligation. This sense of stewardship is often reinforced by personal memories, particularly recollections of childhood experiences when water was more abundant and landscapes were perceived as healthier and more resilient. Such memories function as reference points against which current degradation is assessed, shaping both loss narratives and aspirations for restoration. In some cases, personal values also translate into concrete actions aimed at helping wildlife, such as the creation of wildlife ponds, motivated by emotional responses to visible ecological decline and suffering.

Closely linked to personal values is the farmers' relationship to land. Habitat protection appears as a significant driver, where land-use decisions are guided by the intention to conserve biodiversity and maintain ecological functions, even at the expense of short-term productivity. At the same time, respondents point to the disappearance of the traditional farmstead lifestyle as a major structural change. The erosion of this landscape-adapted way of life is associated with the spread of industrial agriculture, standardisation of practices, and the loss of locally embedded ecological knowledge. This shift is perceived not only as an economic transformation but also as a cultural and environmental rupture that constrains more adaptive and place-sensitive land-use strategies.

Relations to the local community further shape decision-making processes. Trust-based relationships within the community are repeatedly highlighted as enabling factors for certain land-use choices, particularly those involving cooperation, informal exchange, or shared risk-taking. Where trust and long-standing social ties exist, farmers are more likely to coordinate actions, share resources, and align practices. Community action also emerges as a distinct driver, illustrating how collective responses can be mobilised when environmental changes—such as declining water availability or wildlife loss—are perceived as shared threats. These collective initiatives demonstrate the latent potential of local social capital, even if such cooperation remains uneven and fragile.

Knowledge plays a central role in shaping adaptive behaviour. Learning from experience is frequently cited, with farmers emphasising that land-use decisions are informed by trial-and-error processes, observation of outcomes, and reflection on past mistakes. This experiential knowledge is complemented by learning from each other, where successful local examples and peer practices serve as important reference points. Rather than relying primarily on formal advisory systems, farmers often draw inspiration from neighbouring farms or trusted individuals, underscoring the importance of horizontal knowledge exchange in the region.

Personal constraints also exert a strong influence on land-use trajectories. Health reasons, including physical strain and age-related limitations, can directly lead to the abandonment or simplification of certain activities, such as livestock keeping. Overwork and lack of time further restrict the capacity to maintain diversified farming systems, pushing farmers towards fewer, less labour-intensive activities. These personal factors highlight that adaptation capacity is not solely determined by awareness or motivation, but also by embodied and temporal limits.

Farm optimisation strategies reflect attempts to align production with changing environmental conditions. Conscious breed selection and the preference for native animal species are cited as adaptive responses to climatic stress, based on the perception that locally adapted breeds are more resilient and require fewer external inputs. These choices indicate an effort to reduce vulnerability by working with, rather than against, ecological constraints.

Biophysical resource conditions form a critical structural layer of decision-making. Poor soil quality is identified as a fundamental constraint that limits viable land-use options, often making crop production economically unfeasible. Overuse of land exacerbates water management

problems, reinforcing the need for uncultivated or water-retaining areas. At a broader scale, the dryness of the Danube–Tisza floodplain is recognised as a key determinant of water availability in the Sand Ridge, linking local land-use decisions to regional hydrological management. In this context, afforestation is sometimes preferred over production, as water scarcity renders arable farming increasingly unviable. Water retention emerges as a unifying concern, reflecting widespread recognition that maintaining existing water resources is essential for any future land-use strategy.

Economic optimisation drivers reveal how farmers seek to remain viable under tightening constraints. Cost-cutting measures, such as reducing soil cultivation, are adopted to lower expenses without significantly reducing yields. Direct-from-farm sales and alternative supply chains are used to bypass intermediaries and mitigate price manipulation, while cost-effective procurement through global markets reflects continued integration into wider economic systems. These strategies illustrate the balancing act between local adaptation and global market dependence.

Finally, farm technology plays a supporting role in adaptation efforts. Investments in more efficient irrigation technologies aim to reduce water loss, while organic fertilisation is preferred to improve soil condition and reduce reliance on synthetic inputs. The adoption of new agricultural technologies, particularly regenerative and non-tillage practices, reflects growing interest in approaches that enhance water retention and humus formation. Together, these technological choices signal a gradual reorientation towards practices that align economic viability with ecological resilience.

4 Drivers and factors influencing land-use decision making

To validate and refine the results of the previous analytical phase, we invited participants of the Policy Lab alongside local farmers, municipal representatives and domain experts to a structured validation workshop. The objective was not only to verify whether the identified drivers accurately reflect local realities, but also to understand how different types of farming systems prioritise and interpret these drivers in practice. The workshop was designed to test the robustness of our abductively derived driver framework and to compare how land-use decisions are shaped across varied operational contexts. Validation was carried out for three farm types representing the spectrum of agricultural systems in the Sand Ridge region:

- a conventional medium-scale farm open to agroecological approaches,
- a traditional smallholder mixed farm,
- and a regenerative farm.

In the following section, we present the outcomes of the workshop in the context of these three farm profiles, highlighting where perceptions align with or diverge from the original driver analysis. We asked the participants of the three groups to think about their own experience and farm practice while answering the questions and contributing to the discussion. At the centre of the board, the guiding question: *"Which factors shape land-use decisions among farmers in the Sand-Ridge region?"*. This helped structure the discussion and anchor the subsequent mapping of interconnections. Most drivers were deemed as highly influential, suggesting that the set of drivers distilled from interviews, literature and media analysis adequately reflected the realities experienced by farmers.

The workshop lasted around 60 minutes and consisted of three main parts:

- *Part 1. Driver assessment and grading.*

  Participants first reviewed a set of drivers that possibly influence their current land-use generated through abductive analysis of interview material. Each driver was then collectively evaluated and scored on a 1–3 scale based on perceived impact (using a 1-to-3-star scale, and additional option of non-relevant). The drivers were colour-coded according to category (external (drivers), internal (factors)), although this categorisation was not disclosed during the exercise to avoid influencing prioritisation.

- *Part 2. Mindmap construction.*

  Participants collaboratively organised the drivers into clusters, forming a mindmap structure that represented perceived relationships, causal linkages and thematic proximities. This exercise made visible how farmers themselves conceptualise the complexity of land-use decision-making. The mindmaps created by the 3 groups were translated and digitalized by us, and are analyzed in chapters 5.1., 5.2. and 5.3. The set of drivers in the original mindmap framework for each case can be found in the Annex.

- *Part 3. Identifying drivers of change.*

  Finally, participants selected the drivers that most strongly motivate or compel land-use change within their farming context. These were graded on a 1–5 scale, allowing for a more fine-grained assessment of influence and enabling comparison between farm types.

4.1 Drivers and factors influencing land-use decision making: the case of a conventional medium-scale farm

This section summarises the validation workshop for a medium-scale conventional farm in Sand Ridge. The focal farm consists of 50 ha cereal–oilseed rotation combined with livestock. Although conventional in structure, input levels are lower than typical conventional farms, the farmer uses manure rather than much synthetic fertiliser, and he is open to agroecological techniques, including future product processing. The system provides income stability in good years, yet drought creates vulnerability, irrigation prospects are uncertain, and adaptation is increasingly necessary. Together with neighbours, s/he participates in a water-retention cooperation, signalling a slow transition within conventional production systems.

The importance of drivers

Drivers influencing land-use decision-making were evaluated through discussion and mapping. Compared to smallholders, influences here appear more structural than cultural. The impact of the global market economy places medium-scale farmers at a competitive disadvantage, as they cannot achieve the volume-based efficiency of large-scale producers. Shortage of capital and low payoff reduce investment capacity, while livelihood remains the threshold condition: the farm must be profitable to continue. The farmer's interest in processing suggests a shift toward value-added strategies.

Policy instruments were considered central. Administrative burdens were regarded as disproportionately heavy, leading the farmer to exit the Agri-Environment Scheme despite organic management. Land-based support and technology-development subsidies currently benefit large-scale farms, not medium-sized ones. While EU influence was recognised as strong, responsibility between EU and member-state implementation was debated. The group introduced the lack of flexible agricultural strategy as a new key driver, describing it as a systemic limitation that restricts adaptation to drought and market volatility.

Climate-related conditions were discussed without using the term climate change. Instead, farmers refer to water scarcity as the primary driver, with groundwater decline reinforcing long-term risk. Water retention was seen as the most important future-oriented strategy. Frost damage influences sowing decisions, biodiversity loss is acknowledged but less urgent, and invasive species were not considered impactful due to their manageability.

Social drivers reflect structural change in agrarian culture. The ageing farming society, labour shortages and the lack of successors pose significant risks. Cooperation is weak, despite recognition of its potential power. Learning from each other remains superficial rather than knowledge-based. The workshop added another new driver: lack of region-specific knowledge. Although such knowledge exists, uptake is limited, suggesting behavioural, not informational, barriers. Poor soil quality requires adaptation, species shifts are increasingly relevant, and no-till was rejected as unsustainable in the long term. No-till agricultural practices are emerging in the region as part of the adaptation pathway. This farmer is open to agroecological techniques, fighting biodiversity loss is one of his main endeavours. However he obtains certain scepticism towards the agenda of regenerative farming as a holistic approach, deemed unsustainable and monoculture-like by him on the long term. Across all domains, three overarching levers stand out:

- water scarcity
- lack of flexible agricultural strategy
- lack of cooperation and knowledge-exchange.

Links among the drivers, the mindmap

Instead of discussing each driver individually, participants grouped them into an interconnected structure. Figure 3 represents the mindmap created by the participants, indicating the titles they gave to each cluster and the connections they found between them.

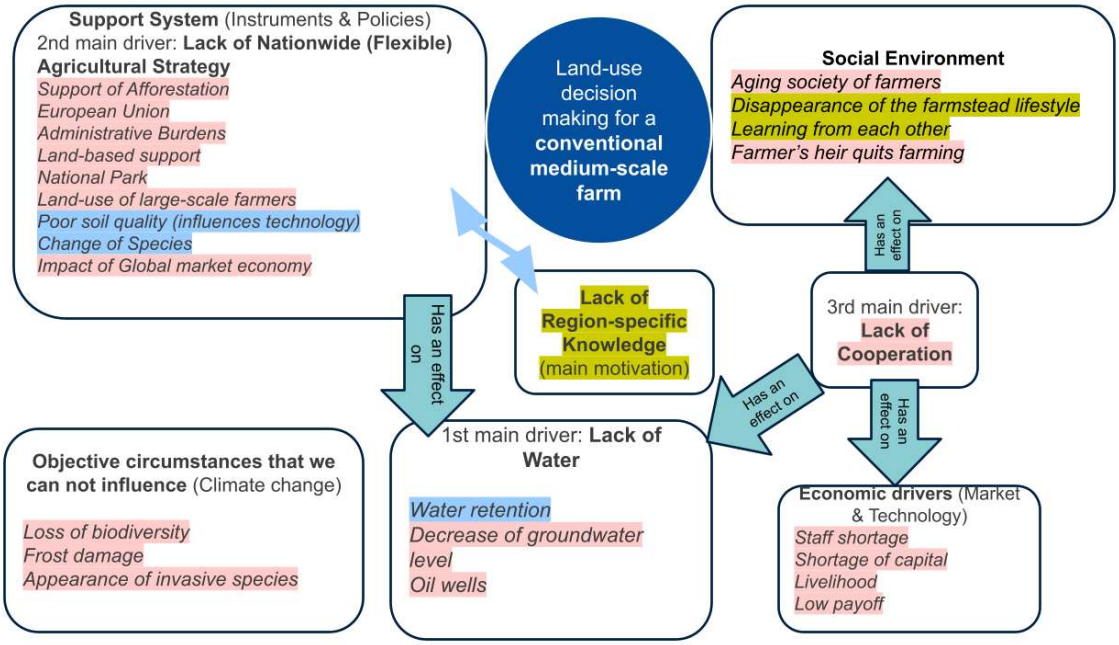


Figure 3: Mindmap for understanding land-use decision making of a conventional medium-scale farm on the Sand-ridge (created by participants)

Water scarcity formed the first and strongest cluster, linked to groundwater loss, oil wells, frost exposure and the need for retention measures. The group perceived groundwater loss, oil wells and water retention initiatives as subcategories of the main driver: *Lack of Water*. A second cluster grouped policy and institutional factors, subsidy distribution, administrative requirements, EU frameworks, discontinued afforestation support and the limited accessibility of technology development. These were perceived as powerful structural forces that shape what kinds of decisions are economically rational. A third cluster centred on cooperation and knowledge: ageing, succession gaps, labour shortages, lifestyle shifts, limited peer learning and the missing uptake of region-specific knowledge. Smaller drivers relating to biodiversity, species change, soil and invasive plants sit at the edges of this structure. The mind-map therefore visualises a decision space shaped not by isolated pressures, but by overlapping climate, policy and social systems.

Most impactful drivers

When asked which drivers genuinely induce change rather than merely influence planning, the group placed the subsidy system at the top. Farmers adapt to funding frameworks more than to ecological or technological reasoning. Because most support mechanisms reward scale, medium-sized farms adjust behaviour around eligibility rather than long-term resilience. Limited access to technology development intensifies this dependency on the subsidy system. In practice, subsidies function as behavioural signals; directing effort, investment and crop choice, rather than guidance toward development, sustainability and self-dependency in farming.

Water scarcity forms the second major change-driver. It accelerates crop abandonment and pushes production toward extensive or alternative forms. The group noted that maize and sunflower are already disappearing in some areas. Water-driven change is incremental yet cumulative: as availability declines, it erodes the viability of conventional rotations, forcing diversification, process innovation or scaled-back production. The cooperative approach to water retention indicates collective awareness of the need to change an approach to farming that dates back generations.

A third driver, knowledge, remains latent but potentially transformative. If region-specific knowledge were more actively shared and applied, adaptation could accelerate quickly. The workshop revealed that knowledge exists but is not accessed. This implies that institutional support, cooperation structures and advisory systems could unlock change more effectively than technical innovation alone. The role of media reinforces this dynamic: public narratives on inland water or drought management shape perceptions and may alter collective expectations. Communication therefore acts as an amplifier, capable of shifting land-use norms before economic pressure makes land use change unavoidable.

Together, these impact findings suggest that land-use change in medium-scale farms is shaped less by agronomic conditions themselves and more by the systems through which farmers navigate them: subsidy logic, market structure, knowledge access and the capacity to organise collectively.

4.2 Drivers and factors influencing land-use decision making the case of a traditional smallholder mixed farm

This traditional smallholder mixed farm (~5000 m^2 arable, goats, cows, poultry, orchard and grassland) represents a post-peasant household system combining livestock and crop production with strong reliance on local ecological knowledge. Operating with low capital and limited mechanisation, it focuses primarily on self-provisioning, selling surplus vegetables, fruit and dairy locally. Though economically vulnerable, the system remains culturally resilient and ecologically adaptive, contributing to agrobiodiversity and the social fabric of the community. The following section presents how drivers of land-use change were perceived within this farm type.

The importance of drivers

During the participatory mind-mapping exercise we first collected from the previously prepared list the drivers influencing the land use change and their relevance in the case of traditional smallholder mixed farms producing vegetables, fruits and dairy products for self-provisioning and sell in the Sand Ridge region. In the second step, we explored the interconnectedness of these drivers and finally we asked the participants to assess how much those impact land use change.

The most dominant drivers of land-use decisions in small mixed farms are the decrease of soil water level, atmospheric drought, and the resulting water shortage. These hydrological changes reinforce each other, leading to increasing aridity, reduced productivity, and heightened annual risk in cultivation. Climate change intensifies this system further by worsening water scarcity and increasing weather unpredictability.

Personal and cultural drivers are also highly influential. Personal memories: especially childhood experiences and knowledge inherited from parents and grandparents; strongly shape land-use choices. Closely related is the motivation of preserving family heritage, which reflects long-term emotional attachment to land and the wish to pass it on to the next generation.

At the same time, the disappearance of the farmstead lifestyle marks the erosion of traditional ecological knowledge, while urban consumers increasingly lose familiarity with the sensory quality of real, locally grown produce. A further key driver is the land use practices of large-scale farmers, perceived as having a strong (mostly negative) effect, connected to global market incentives and EU subsidy systems, and often resulting in inefficient or wasteful water use.

Among the relevant but less dominant influences are frost damage, water retention, and conscious breed selection, all of which affect annual planning and adaptation. Poor soil quality and the appearance of pathogens also directly shape production decisions. Learning plays an essential role — both learning from each other and learning from experience — through community events, field visits and conferences.

Trust and social ties appear as important enablers: trust-based relationship with the community and direct-from-farm sales/alternative supply chains support farm viability, particularly within short supply chains. Health reasons were also widely emphasised — farming ensures access to chemical-free food and supports physical or mental well-being, including family health and therapeutic values of working with land.

Economic context is significant. European Union opportunities and funding influence operational choices, while livelihood remains a crucial baseline condition — farmers continue only as long as the activity remains viable and meaningful. The impact of the global market economy stands out within this group: year-round supply expectations, fluctuating prices and unstable sales channels push producers toward informal exchanges, CSA-type box communities or individual market strategies.

The workshop also identified several drivers with minor influence on land-use decisions. These included support for irrigation, cutting costs by reducing soil cultivation, change of species, irrigation development, organic fertilisation, and the appearance of invasive species such as *Ailanthus* or *Wisteria*, which persist independently of water conditions.

Social and organisational factors, lack of cooperation, community action, and the influence of local residents, were acknowledged, but perceived as weak unless efforts are coordinated collectively. Source of information follows a similar pattern: limited in individual effect, but potentially powerful in awareness-raising and knowledge transfer.

Other low-impact drivers in this category included recreational animal husbandry, keeping native animals, aging, young farmer taking over the farm, the heir quitting farming, administrative burden, low payoff, support for technology development, land-based support, support for native species, overuse of the land/water resources, and measures of helping wildlife (e.g. wildlife ponds), sometimes generating unintended outcomes such as increased predation pressure.

Links among the drivers, the mindmap

Participants collaboratively organised the drivers into clusters, forming a mindmap structure that represented perceived relationships, causal linkages and thematic proximities. Figure 4 represents the mindmap created by the participants.

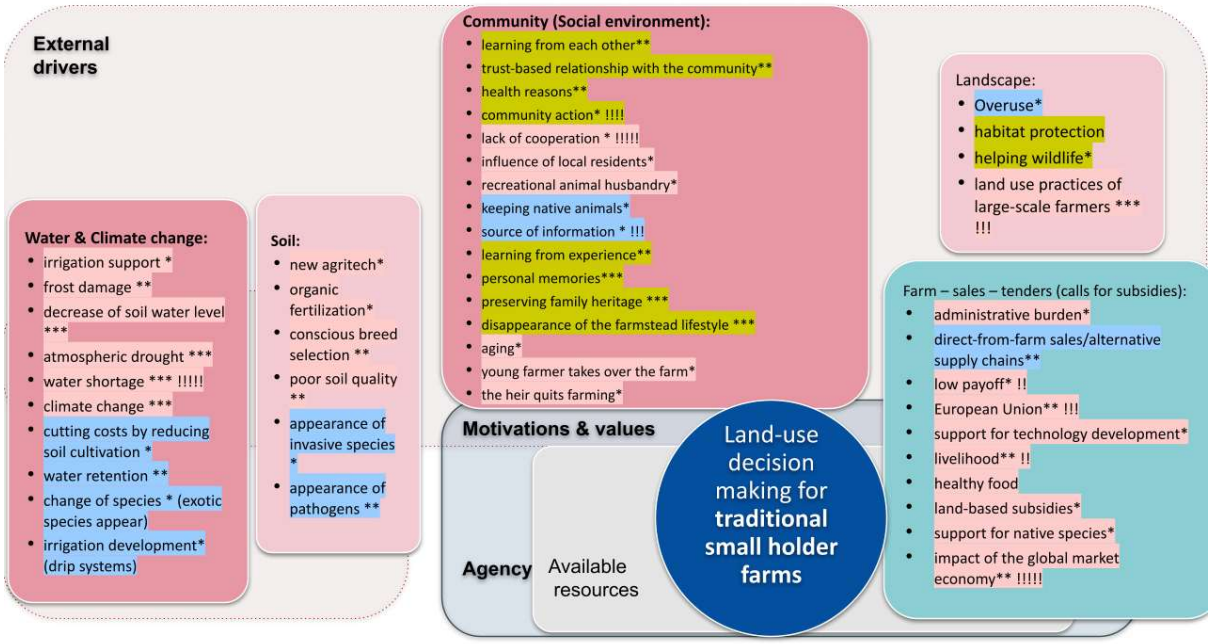


Figure 4: Mindmap for understanding land-use decision making of a traditional smallholder farm on the Sand-ridge (created by participants)

According to the small group of participants on traditional smallholder farms, these drivers were grouped together in a way that suggests they perceive connections between them, even if they did not explicitly articulate these links. They defined five main groups: water & climate change, soil, community, landscape and farm (sales & calls for subsidies). We kept the names for the categories given by the participants of the workshop. Having a closer look at the categories one might observe that sometimes the drivers are loosely or not linked to category names.

For example, new agricultural technology (e.g., regenerative agriculture, no-till), use of organic fertilisers, conscious breed selection, poor soil quality, the appearance of invasive species, and the appearance of pathogens were seen as related factors. While participants primarily referred to soil as a reference point, the grouping indicates an implicit recognition that these drivers are

connected to the broader natural environment and, to some extent, to climate change. The way these factors cluster together in their discussions suggests that farmers intuitively understand their interdependence, even if they did not formally reflect on it.

According to the group discussion water & climate change and community play a central role in land use decision-making, other drivers are less relevant. It is also worth noting that our original clustering of the drivers was overwritten during the group discussion.

Most impactful drivers

Finally, we asked the participants about the influence of the different drivers on land use change. Among the factors that most strongly motivate farmers to adapt or change their practices, water shortage emerged as the single most critical driver. Its effects are immediate and pervasive: without sufficient water, traditional cropping and livestock practices cannot be sustained, and farmers are forced to reconsider what, when, and how to cultivate or manage the land.

Closely linked are social and market dynamics that only achieve their full potential through coordination. Lack of cooperation and the impact of the global market economy have particularly strong influence. Individual farmers may feel limited effect from these drivers alone, but together they can push for significant adaptation; the cooperation among the farmers could counterbalance the negative effects of the global market economy. The global market's influence is multifaceted: it demands year-round supply, sets price pressures, and introduces uncertainty in sales channels. Farmers respond with individual strategies, such as bartering, local box communities, or short supply chains, to compensate for these pressures.

Community action also plays a crucial role in driving change, although it is slightly less influential. When local initiatives prioritise local products and foster conscious consumption, through cooperative marketing, CSA-style box schemes, or consumer engagement, they can strongly motivate farmers to adapt their land-use practices.

Another set of powerful motivators are linked to information, policy, and institutional frameworks. Information sources are critical in raising awareness among consumers and transmitting local knowledge, helping farmers make informed decisions about production, sourcing, and marketing. Similarly, the European Union serves as a strong driver through funding and programmatic support, encouraging adoption of new practices, innovation, and alignment with regulatory standards, while also shaping the market orientation between local consumption and export.

Large-scale farmers' land use practices exert strong indirect influence: their resource-intensive and globally oriented operations create pressures on smallholders, particularly regarding water use and local competition. This driver is amplified by the structure of global and EU-supported agricultural systems, often compelling smaller producers to innovate or change to remain viable.

Economic viability remains a central, although moderately influential driver. Livelihood and low payoff influence decisions in a direct, practical sense: farmers are more likely to change practices if their current methods are not profitable, or if they perceive that market prices and consumer demand do not justify continued effort. The consideration of what is "worth doing" often includes the dual lens of economic sustainability and the production of healthy, high-quality food.

4.3 Drivers and factors influencing land-use decision making: the case of Medium-scale farms transitioning to regenerative farming

This section summarises the validation workshop dedicated to medium-scale farms that are either transitioning toward regenerative practices or already experimenting with them in the Sand Ridge region. The discussion brought together five participants, four of them directly involved in farming. In contrast to other tables where experts and land-users were mixed, this group was more cohesive in terms of background. Yet beneath this apparent homogeneity lay substantial diversity in their production systems: some participants manage orchards, others operate livestock-based enterprises, while several focus on no-till or otherwise low-input arable farming on underutilised soils. Their farms share medium scale and an orientation toward ecological regeneration, but differ in resource availability, market exposure and strategic priorities. The following section outlines how they perceived the structural external drivers shaping land-use decisions within this emerging regenerative farming pathway.

The importance of drivers

Although drivers emerged in a non-linear order during the workshop, they are presented here according to their respective categories. Among the external drivers, several stood out as particularly influential. The most critical were shortage of capital, the impact of the global market economy, the role of the European Union as a regulatory power, the combined effects of atmospheric drought and the decrease of soil water level. These drivers were described as shaping both the economic viability and ecological limits of farming in the region. Social pressures such as the heir quitting farming and staff shortage were likewise highlighted as decisive, pointing to long-term structural challenges in generational renewal and labour availability. Biodiversity loss, avian flu, and the appearance of invasive species further underscored the growing ecological vulnerability faced by regenerative-oriented farmers.

Drivers receiving two or one star such as loans, administrative burden, aging, the National Park, or specific climatic stressors like frost damage were seen as relevant but less central. Their influence is uneven: important in certain farm types or years, yet not consistently decisive across the group.

Turning to the internal drivers, participants again emphasised a small number of highly influential factors. Preserving family heritage, the disappearance of the farmstead lifestyle, overwork, learning from experience and learning from each other were described as shaping everyday decision-making as much as external structural conditions. Ecological adaptation strategies

such as conscious breed selection, keeping native animals, change of species and water retention were similarly prioritised, even if the latter was accompanied by the note: *"it would be important, but there is no water."* New approaches, including regenerative agricultural technologies, reflected an openness to innovation within the constraints of local conditions.

Internal drivers marked with two or one star such as helping wildlife, afforestation instead of production, personal memories, or irrigation development were acknowledged as relevant but situational, either dependent on available resources, farm structure or the personal motivations of individual farmers.

Finally, few drivers were identified as not relevant for this group. These included technological development in the conventional sense, financial support for irrigation (due to insufficient water resources investment in such infrastructure is not meaningful), and cost-effective procurement through the global market, which did not align with the scale or production logic of the participating farms, even if the broader effects of the global market were discussed elsewhere and marked with special emphasis and high relevance.

Overall, the discussion revealed that external or structural and personal considerations, aligning in tone with insights from the other groups while reflecting the specific realities of medium-scale farmers shifting towards regenerative practices. One participant also introduced a new driver "human greed" highlighting that behavioural motives can influence land-use choices just as strongly as formal economic or ecological factors.

Links among the drivers, the mindmap

In the second task, participants were asked to organise the identified drivers into groups based on their own understanding of how these factors relate to one another. Unlike in our preparatory work where drivers were synthesised into predefined categories derived from interviews, literature and media analysis we did not provide any structural guidance during the exercise. Instead, the aim was to observe how farmers themselves conceptualise linkages and categories. This approach allowed us to capture their implicit logic of connections, revealing patterns of association that may diverge from expert-derived classifications and offering insight into how they perceive the dynamics shaping land-use decisions.

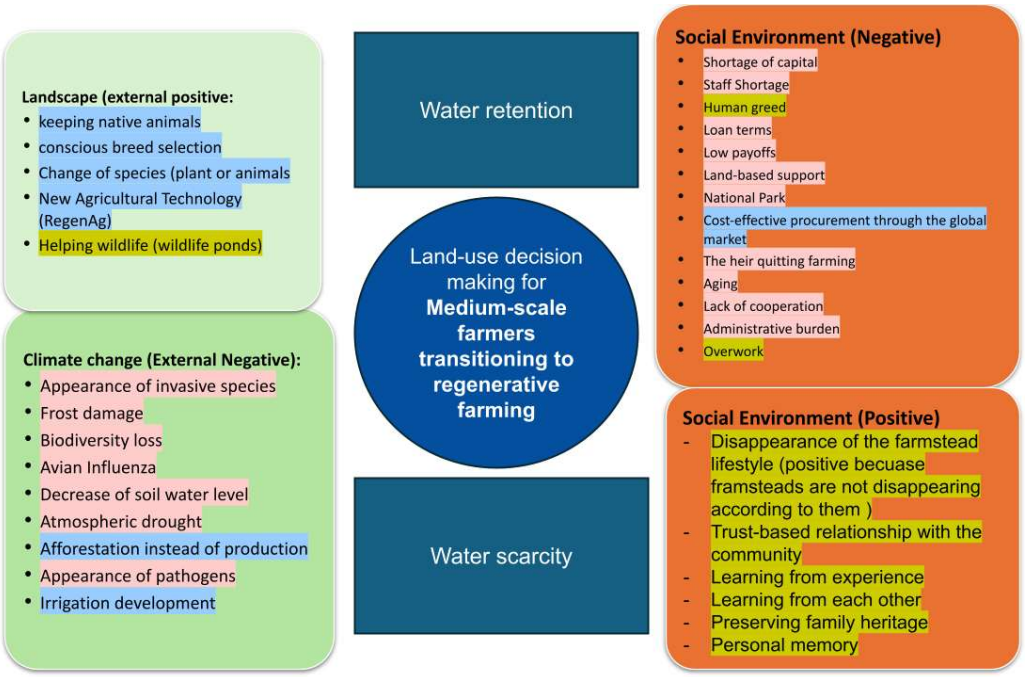


Figure 5: Mindmap for understanding land-use decision making of a medium-scale farm transitioning to regenerative farming on the Sand-ridge (created by participants)

During the grouping exercise, participants first emphasised the need to distinguish between a landscape's interests perspective and a human's considerations perspective, which led them to separate the drivers into two overarching domains: *Natural* and *Social*. A second organising principle emerged from their everyday farming experiences, namely the differentiation between *positive* and *negative* influences. This resulted in four operative categories: Landscape (external positive), Climate change (external negative), Social environment (positive), and social environment (negative). Notably, the two positive clusters closely reproduced the structure of our preparatory categorisation (as also reflected by the colours on the mind-map), whereas the negative clusters showed partial alignment with some meaningful deviations. For example, cost-effective procurement through the global market which we had preliminarily classified under "economic" drivers was placed by farmers within the negative social environment, indicating a different interpretive logic than expert frameworks typically apply. Two drivers were given special prominence and placed as standalone elements: water scarcity, identified as the single most decisive constraint, and water retention, repeatedly raised throughout the discussion despite its limited feasibility. The resulting mind map therefore reflects an ordering principle that is grounded in farmers lived experience.

Most impactful drivers

The last part of the validation workshop was marking the already categorised drivers according to their impact factor. When reflecting on which drivers most decisively shape their own farming practices, participants immediately identified water scarcity as the dominant force. They described it not as one issue among many, but as the condition that connects and amplifies all

others, determining what can be grown, how systems must be adapted, and ultimately whether farming remains viable at all. One participant illustrated this starkly by recounting how all three of his children chose to leave agriculture after witnessing the struggle to maintain the farm. They live in the city now and learned other professions, he and his wife are now considering selling their land and moving to the city as well, a decision he linked directly to the worsening situation connected to water. Although "climate change" had not appeared explicitly on the cards, it surfaced immediately in the discussion, with farmers emphasising the cumulative influence of climate-related pressures: drought, declining groundwater, extreme weather and biological stressors on their everyday decisions.

Technological factors were also regarded as influential, particularly the limits of access to new agrotechnologies. Participants stressed that promising innovations exist yet remain out of reach for medium-scale farms like them due to the high investment costs. As one farmer put it, *"A lot of things are not profitable for a farmer with 100 hectares. I can't buy a 40-million-forint tractor, it wouldn't pay off even for my grandson."* These constraints were further illustrated through anecdotes about invasive species, a topic that became more prominent as the discussion shifted toward personal experiences. In parallel, the role of the global market was repeatedly underlined: price volatility, input costs and market expectations all exert substantial pressure, shaping both what farmers attempt and what they abandon.

Toward the end of the conversation, attention turned to the personal motivational drivers in the social- personal and "positive" corner of the map. Participants acknowledged that this identity, attachment to land, and the satisfaction derived from meaningful work remain essential for sustaining their commitment. Yet they also pointed to the lack of trust and weak cooperation as major obstacles preventing collective action, even though cooperation was broadly recognised as one of the few viable pathways out of their current difficulties.

5 Discussion and Reflections

The Sand Ridge functions as a semi-arid socio-ecological system in which water scarcity is not a temporary disturbance but a structural condition. Its hydrological behaviour is characterised by low buffering capacity, meaning that historical land-use decisions, particularly afforestation and drainage, continue to influence groundwater decline today. This long ecological memory of the area underscores how past policy choices remain embedded in current environmental constraints.

The final Policy Lab meeting reinforced a core insight repeatedly seen in the wider research: water is not just an environmental variable but the principal organising logic shaping how farmers think about land, risk and the future. Participants did not use the vocabulary of climate change, yet their concerns, groundwater depletion, disappearing surface moisture, frost damage, soil desiccation, all point toward lived experience of climatic change. Water was consistently framed as the condition of possibility for farming: its absence dictates what can be grown, its potential

return motivates interest in water retention, and its unpredictability drove a shift away from input-dependent irrigation aspirations, particularly among small and medium scale farmers. While large-scale producers could benefit more from greater irrigation support, it cannot deliver high yields or stable incomes due to limited water availability. In this group, water became the central reference point for adaptation discourse, displacing technological modernisation or market diversification as strategic anchors. This points to high local awareness but limited systemic interpretation of climate dynamics.

Across stakeholders, also the subsidy regime emerged as the most influential behavioural driver, often outweighing agronomic reasoning or ecological pressures. Farmers respond primarily to compliance opportunities rather than to longer-term ecological adaptation, because existing policies favour large-scale production and offer limited incentives for mid-scale farm transformation.

Farming systems in the region are far from homogeneous. Regenerative pioneers exist but represent a small proportion of producers; conventional medium-scale farms dominate economically yet are increasingly vulnerable to drought; meanwhile, traditional mixed smallholders retain ecological flexibility and cultural continuity but operate under significant economic fragility. Traditional mixed smallholders approach land use through heritage, identity and ecological resilience but lack economic stability. Regenerative innovators experiment with systemic adaptation but remain socially marginal and institutionally unsupported. Medium-scale conventional farms hold the largest leverage potential, financially stable enough to innovate, yet structurally constrained by subsidy incentives, ageing demographics and low knowledge circulation. This triangulation reveals that each farm type possesses a different theory of change: smallholders rely on continuity and memory; regenerative farms on experimentation and networks; medium farms on stability and incrementalism. Yet all are equally exposed to water scarcity, and none feel institutionally empowered to initiate collective action; reinforcing water's primacy as a shared risk but not a shared coordination mechanism.

Social and knowledge conditions further constrain adaptive capacity. An ageing farming population, labour shortages, low cooperation and weak knowledge circulation all restrict collective action. Region-specific agronomic knowledge is available in the area, but farmers do not actively seek or exchange it, suggesting a failure of knowledge uptake rather than knowledge production.

5.1 Methodological Reflections

The workshop validation reinforced these insights: it did not contradict earlier classification of drivers, but it sharpened priority relationships, elevating subsidies, knowledge access and cooperation deficits while downgrading biodiversity concerns and invasive species.

Through the workshop, farmers blended the original categories into three intersecting influence fields: water – ecology, governance – subsidy, and cooperation – knowledge. Drivers such as biodiversity loss or invasive species, emphasised earlier in the theoretical framework, were downgraded when confronted with farmers' lived experiences. Conversely, drivers absent or weak in the original model, especially lack of flexible agricultural strategy and knowledge uptake failure, arose as dominant meanings. Rather than contradicting earlier theory, workshops reweighted and relationally reorganised the system, showing water and governance as systemic attractors around which other drivers orbit.

As workshop participants worked in three parallel groups at different tables, we wrote methodological reflections accordingly. The lessons learnt below therefore follow the logic of the three tables, reflecting the distinct dynamics, priorities and forms of knowledge that emerged in each discussion.

Lessons learnt - Conventional medium-scale farms

The workshop was highly dynamic and rich in knowledge exchange, though less linear than originally planned. Participants, including a farmer, advisor and decision-maker, brought deep practical and policy insight, making moderation challenging but productive. Debate often moved beyond validation toward co-construction of understanding, especially when subsidy allocation and legislative responsibility were discussed. For this reason, strict scoring proved unrealistic. Participants were much more interested in explaining drivers than in ranking them. They often rejected simple categorisation and instead elaborated on why a driver matters, how it intersects with others, and under what conditions it becomes impactful. As a result, strict scoring was rarely followed, but the qualitative depth we gained far exceeded what a numeric rating would have produced. Through this process, we were able to capture both high-importance drivers (such as water scarcity, lack of flexible agricultural strategy and poor cooperation) and drivers that were considered relevant but not decisive.

Moderation required flexibility. Rather than asking participants to evaluate each driver individually, we adapted by presenting groups of 6–10 drivers at once, allowing participants to choose what to prioritise, debate or discard. This method worked well, it preserved momentum, engaged participants' expertise, and revealed which drivers naturally drew attention. Where consensus was strong, drivers quickly proved to be both important and impactful; where views diverged, the discussion itself exposed structural tensions and knowledge gaps. The final mind-map therefore reflects not only which drivers matter, but how they became meaningful in conversation.

Lessons learnt – Traditional small holder mixed farms

In retrospect, the workshop did not deliver strict validation in a narrow methodological sense, but it produced something arguably more valuable: a knowledge-rich, co-interpreted framework that aligns well with participants' lived experiences.

An importance - impact analysis shows that only a small number of drivers are simultaneously highly important in everyday small-scale farming and strongly influence land-use

change. These core determinants are water shortage, climate-driven aridification, and the landscape impact of large-scale farmers, indicating that hydrological constraints and external market-structural pressures currently shape both daily practice and adaptation.

In contrast, personal memory, family heritage and health-related motivations are central to why farmers remain active in agriculture, yet they have limited power to trigger land-use transformation on their own. These values sustain continuity rather than push change.

Several drivers have low-importance in this type of farming but still have a high-influence; these could be hidden leverage points. Although less present in everyday thinking, global market forces, lack of cooperation, community action, and information flows can rapidly induce behavioural change when activated or coordinated.

Finally, a broad set of drivers have both low-importance and low-influence, including subsidies, invasive species, succession, and administrative burden. These form the background environment of farming but currently do not determine land use or innovation trajectories.

Lessons learnt - Medium-scale farms transitioning to regenerative farming

The medium-scale regenerative farming group developed a working rhythm that differed from the more linear discussions. Participants frequently moved between focused engagement with the task and moments of storytelling or anecdotes triggered by drivers. We created categories or compare drivers, then an example or memory emerged, which made others to share similar experiences, before the group naturally returned to the main thread of the workshop. This flow characterised the entire session. Rather than interrupting the process, it revealed how closely everyday practice, memory and interpretation are intertwined for the participants.

What became clear through this dynamic is that personal drivers carry substantial weight for these farmers. Their relation to the landscape is direct, emotional and grounded in daily experience, which shaped how they prioritised and explained the drivers. While other tables tended to stay closer to institutional reasoning, here experiential knowledge guided the conversation. Ultimately, this interplay of structured analysis and lived experience enriched the workshop outcome, with a layered understanding of how medium-scale regenerative farmers navigate and make sense of the forces influencing land-use decisions.

What we learned from the process

The final Policy Lab meeting continued a pattern seen earlier in the research: participants were exclusively middle-aged or elderly men. This demographic concentration limited the discussion of personal motivations and identity-related drivers — even though such aspects appeared prominently in media narratives and interviews with other actor groups. Instead of emphasising household-level values or wellbeing aspects, participants focused on landscape characteristics, technological constraints and structural barriers. This suggests that personal drivers are present in the wider system but not articulated by the medium-scale male farmers who dominate decision spaces.

Interestingly, one of the most productive sources of “best practice” came not from the group itself but from media examples: local actors forming a water association to deliberately flood multi-owned fields to increase infiltration and retention. This was recognised as promising, yet such initiatives did not spontaneously emerge within workshop discussions; again, hinting at low self-efficacy and an expectation that solutions must come from outside the farm unit. Participants acknowledged that collective action is valuable but repeatedly described cooperation as impossible, often attributing this to long-standing cultural and historical patterns of distrust.

The Policy Lab activities unfolded in a constructive and respectful atmosphere, but several methodological lessons emerged. Role distribution among facilitators could have been clearer, particularly when group dynamics required redirection. Time pressure occasionally curtailed deeper probing into latent motivations. Moreover, some tables required stronger moderation to keep discussions anchored and ensure all participants engaged, especially when dominant voices steered topics away from driver validation. Overall, the process worked well, but these insights suggest refinements for future sessions, particularly where demographic homogeneity magnifies interpretive blind spots.

5.2 Major Drivers influencing land-use decisions

Based on interviews, four Policy Lab workshops, and a targeted literature review, the analysis identifies a broad set of drivers shaping climate-related land-use change in the Sand Ridge region. These drivers operate across multiple scales and combine long-term structural forces with more immediate pressures that influence farmers’ decisions, production strategies, and adaptation pathways. Rather than acting in isolation, economic, regulatory, social, and climatic drivers interact to redefine what forms of land use are viable and for whom.

Structural external drivers operate largely outside the direct control of land users but fundamentally shape their decision-making environment. These drivers were grouped into four main categories: Market & Technology, Instruments & Policies, Social Environment, and Climate Change. Market and technology drivers are characterised by persistent economic uncertainty, volatile input and output prices, limited bargaining power, and restricted access to capital. These conditions discourage long-term investment, technological renewal, and diversification, reinforcing short-term, risk-averse land-use strategies.

Instruments and policies exert ambivalent effects. Subsidy schemes strongly influence land-use decisions, often favouring land-based payments and afforestation, while innovation-oriented support remains accessible mainly to farms with sufficient co-financing capacity. At the same time, regulatory frameworks linked to EU accession, protected areas, and Natura 2000 designations impose development constraints and increase administrative burdens, particularly for smaller producers. Uniform compliance requirements and frequent inspections contribute to compliance fatigue and disengagement.

The social environment further conditions land-use change through demographic ageing, weak generational renewal, labour shortages, and limited cooperation. Declining livestock keeping, recreational land uses, and concerns over groundwater impacts from past extractive activities also shape local perceptions of land-use risks and opportunities. Climate change intensifies these pressures through increasing atmospheric drought, declining groundwater and soil moisture, extreme weather events, biodiversity loss, and growing instability in crop and livestock systems.

Alongside these structural drivers, land-use decisions are strongly shaped by internal factors rooted in values, knowledge, and lived experience. Personal values such as preserving family heritage, memories of past landscape conditions, and concern for wildlife influence how farmers interpret environmental change and justify their choices. Relations to land, community trust, and collective action shape cooperation potential, while experiential learning and peer-to-peer knowledge exchange guide adaptive practices. Personal constraints—health, ageing, and overwork—limit adaptive capacity, while farm optimisation, resource conditions, economic strategies, and technological choices reflect ongoing efforts to align production with ecological constraints.

Together, the findings show that land-use change in the Sand Ridge emerges from the interaction of external structural pressures and internally mediated responses, highlighting both vulnerabilities and potential leverage points for future adaptation.

5.3 Reflections of the specific context of the decision making

Land-use decision-making in the Sand Ridge is shaped by a distinctive combination of structural constraints, socio-ecological conditions and historically embedded perceptions of agency. Farmers operate in a context where water scarcity functions as a constitutive condition rather than an external shock: declining groundwater, atmospheric drought and soil desiccation define the boundaries of what is considered feasible farming. Decisions are therefore made within a narrow horizon of perceived options, where adaptation is framed less as transformation and more as damage limitation.

A key contextual feature is the strong externalisation of responsibility. Although interviews and prior research highlight the importance of personal values, identity and attachment to land, these motivations rarely surface explicitly in collective settings. Instead, farmers predominantly interpret drivers as external—policy frameworks, subsidies, markets and ecological constraints—and expect solutions to emerge from institutional or technological interventions rather than from collective or individual agency. This orientation is closely linked to historically rooted mistrust and weak cooperation, which continues to limit confidence in joint action despite emerging examples of successful water-retention initiatives.

Scale plays a decisive role in shaping how land and risk are perceived. Farm size not only determines economic viability but also influences farmers' sense of relevance within policy

schemes and their engagement with support instruments. Medium-scale actors, in particular, often perceive existing subsidies as mismatched to their operational reality, reducing their motivational impact and shifting attention toward landscape conditions, soil quality and incremental technical adjustments.

5.4 Policy pathways and recommendations

The analysis confirms that water scarcity is not simply a stressor but a constitutive force shaping decision horizons, risk perceptions and adaptive thinking in the Sand Ridge. The lack of usable water is already altering cropping patterns, pushing producers toward extensive land use, cooperative infrastructure and soil-based retention approaches. Crucially, farmers perceive water as a boundary beyond which neither innovation nor production is possible, making hydrological conditions the most reliable predictor of future land-use change.

In parallel, the report highlights that the subsidy system is the single most behaviour-shaping mechanism, more influential than climate information, agronomy or technology availability. Farmers adjust their actions to align with subsidy logic rather than ecological forecasts, but perceived ineligibility among medium-scale actors also means that these farmers disengage rather than transform. Thus, subsidies act as both incentive and exclusion mechanism, determining who can participate in innovation and who internalises stagnation.

When considering the three farm types, the research suggests that their capacity for change is differentiated not by awareness but by structural positioning. Smallholders possess adaptive culture but lack capital; regenerative farms possess vision but lack institutional traction; medium-scale farms possess potential but lack enabling policy frameworks. Collectively, workshops showed that the initial deductive model of drivers underestimated this differentiation and overestimated climate-awareness discourse, while participant-led modelling elevated governance, cooperation deficits, and hydrological constraints as systemic levers.

Cooperation and knowledge circulation appear to be the most underused but potentially powerful drivers of change. The findings indicate that technological availability is not the primary barrier; rather, it is the lack of mechanisms that enable farmers to learn, organise and act collectively. To support transition, interventions should therefore prioritise four strategic entry points: strengthening water retention capacity; increasing flexibility and relevance within agricultural policy; enhancing cooperative structures and trust between actors; and activating region-specific knowledge exchange systems.

Overall, the results point toward a dual transformation agenda: hydrological stabilisation and governance redesign. Water retention, flexible and inclusive subsidy arrangements, cooperation platforms and knowledge circulation emerge as the actionable pathways. The reflection remains valid: solutions are not absent in the region, the conditions for mobilising them are. Future practice, research and policy must therefore focus not on generating more

drivers or technologies, but on enabling farmer agency, fostering cooperation, and redesigning subsidy mechanisms that unlock adaptation rather than merely reward scale.

The discussion revealed that farmers hold deep contextual knowledge but often externalise responsibility, expecting solutions to arrive through policy change rather than collective agency. This diversity illustrates that adaptation potential exists within the system, although it is unevenly distributed and conditioned by institutional and financial factors.

Appendix

In the appendix we provide the list of drivers, notes and photos from the validation workshop as well as the original mindmap filled out by us based on the interviews and workshop for each farm type.

Appendix 1: List of the drivers

List of structural external drivers

Categories	Drivers	One-sentence definitions
Market & technology	Low payoff	The return on agricultural activity is uncertain and low.
Market & technology	Loan terms	Credit terms are difficult to understand and difficult for farmers to meet.
Market & technology	Shortage of capital	Farmers do not have sufficient capital.
Market & technology	Livelihood	Agriculture does not provide adequate income.
Market & technology	Impact of the global market economy	Input materials are constantly becoming more expensive, while the prices of agricultural products fluctuate unpredictably.
Effects of subsidies	Support for afforestation	Support schemes directly influence the types of crops farmers plant, such as forests or vineyards.
Effects of subsidies	Support for native species	Subsidies linked to native species encourage their preservation, but strict controls make it difficult for farmers to operate.
Effects of subsidies	Land-based support	Land-based subsidies strongly influence farmers' decisions because they represent significant income for large areas, while limiting opportunities for change.
Effects of subsidies	Support for technology development	Farmers rely on technological development subsidies to replace their old machinery with modern, more efficient equipment.
Effect legislation	European Union	The introduction of EU regulations and subsidies has fundamentally transformed the functioning of the market
Effect legislation	National Park	National Park regulations severely restrict farmers' freedom of action, for example, they cannot buy land, only lease it, which puts them on a forced path.
Effect legislation	Natura 2000	The Natura 2000 regulations restrict the use of the land because farmers cannot build facilities and certain activities are prohibited due to landscape protection regulations.
Administrative burden	Administrative burden	Excessive administration and rigid rules place a significant burden on farmers, especially because small and large farms are

		treated equally and are subject to an increasing number of controls.
Social environment	Aging	Due to the aging of the farming community, fewer young people are entering agriculture because they are not attracted to a difficult and uncertain livelihood, so there is no one to take over family farms.
Social environment	Lack of cooperation	The lack of cooperation and solidarity among farmers weakens the representation of their interests and joint action.
Social environment	Recreational animal husbandry	Non-commercial animal husbandry.
Social environment	Land use practices of large-scale farmers	
Social environment	Oil wells	Previous test drillings may also have had a detrimental effect on groundwater.
Social environment	Influence of local residents	Local people have little influence over land use issues.
Social environment	Young farmer taking over the farm	
Social environment	Staff shortage	Unable to find workers for a range of activities.
Social environment	The heir quitting farming	
Climate change	Appearance of pathogens	Due to warmer winters, pathogens and pests are no longer destroyed, so they appear earlier and in greater numbers, directly influencing farming decisions.
Climate change	Appearance of invasive species	Climate change and lack of cultivation make it easier for invasive species to take over and displace native vegetation.
Climate change	Frost damage	Extreme spring frosts have become more frequent, regularly destroying blossoming orchards, thus fundamentally influencing cultivation decisions and species selection.
Climate change	Avian influenza	The regular recurrence of avian influenza has crippled livestock farming for a long time, making farming unpredictable.
Climate change	Atmospheric drought	Due to atmospheric drought, precipitation simply "disappears" over the region, so the landscape cannot absorb or retain moisture, which severely hinders farming.
Climate change	Biodiversity loss	The decline in species and habitat diversity weakens the ecosystem and makes farming more vulnerable.

Climate change	Inland water	The presence of groundwater used to cause problems in farming, but now it is its absence that causes problems.
Climate change	Decrease of soil water level	Due to the persistent decline in the groundwater level, the landscape is unable to retain water, so surface precipitation disappears quickly and farming activities start with a greater water shortage year by year.

List of personal drivers (motivations and values)

Categories	Drivers	One-sentence definitions
Personal values	Preserving family heritage	It expresses a connection to a place and land that spans generations, which is why land use decisions are often guided by family tradition and heritage preservation.
Personal values	Personal memories	Personal memories are a motivating factor, stemming from people's recollections of their childhood, when there was still water in the landscape.
Personal values	Helping wildlife (wildlife ponds)	Action in response to the suffering and destruction of wildlife, with the aim of changing the situation.
Relation to land	Habitat protection	It describes the intention to preserve ecological values and biodiversity when land use decisions are motivated by the protection of living organisms and the maintenance of habitats.
Relation to land	Disappearance of the farmstead lifestyle	It marks the decline of the traditional, landscape-adapted farmstead lifestyle, which is linked to the spread of industrial agriculture and the loss of local ecological knowledge in land use decisions.
Relation to community	Trust-based relationship with the community	It emphasizes the role of community trust and local relationships in land use decisions, where shared values and mutual cooperation are key.
Relation to community	Community action	It shows the power of community action and cooperation when locals respond together to changes that threaten the landscape and wildlife, and work together to find solutions to environmental problems.
Knowledge	Learning from experience	It refers to learning from practical experience, where land use decisions are shaped by knowledge gained from one's own mistakes and observations.
Knowledge	Learning from each other	It highlights the role of learning from and inspiring each other, where land use decisions are influenced by successful local examples and good practices of others.

Personal reasons	Health reasons	Physical strain and health limitations can directly influence land use decisions, for example, leading to the abandonment or conversion of certain activities such as livestock farming.
Personal reasons	Overwork	It refers to limitations arising from overload and lack of time, when land use decisions are influenced by the farmer's inability to maintain multiple activities simultaneously.
Farm optimization	Conscious breed selection	Switching to animal and plant species that are adapted to climatic changes.
Farm optimization	Keeping native animals	This means giving preference to native species, because, in the farmer's experience, they are more resistant and require less external intervention.
Farm optimization	Source of information	
Use of biophysical resources	Poor soil quality	Poor soil quality fundamentally determines land use options, as low crop yields make it almost impossible to make a living from crop production.
Use of biophysical resources	Overuse	Overused areas cause water management to deteriorate, so uncultivated, water-retaining areas are needed.
Use of biophysical resources	Dryness of the Danube-Tisza floodplain	The water conditions of the Danube-Tisza floodplain determine water retention in the Sand Ridge region, so land use decisions depend on the management of the floodplain.
Use of biophysical resources	Afforestation instead of production	Instead of production, it is better to reforest, as the arable land is not viable due to water shortages.
Use of biophysical resources	Water retention	This indicates the need to retain existing water resources.
Economic optimization	Cutting costs by reducing soil cultivation	Reducing soil tillage lowers costs without compromising crop yields.
Economic optimization	Direct-from-farm sales/alternative supply chains	The producer sells directly from home to avoid price manipulation by wholesalers.
Economic optimization	Cost-effective procurement through the global market	He sources the necessary raw materials from the global market and always buys at the most favorable price.
Farm technology	Irrigation development	The producer switches to more efficient irrigation technology in order to manage with less water loss.

Farm technology	Organic fertilization	The farmer prefers organic fertilization to improve soil condition and reduce fertilizer use.
Farm technology	New agricultural technology (RegenAg)	The farmer is using new, non-tillage technologies because they result in better water retention and humus formation in the soil.

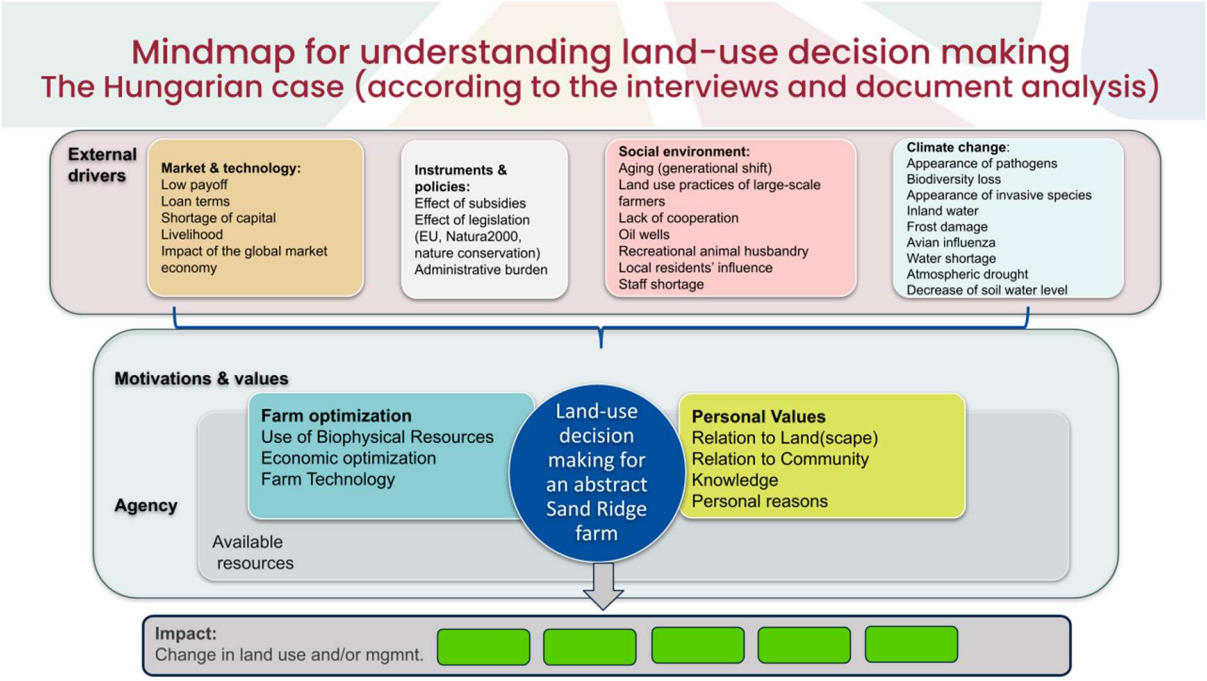


Figure 6: Mindmap for understanding land-use decision making: The Hungarian case (according to the interviews and document analysis)

Mindmaps of the 3 Farm types (based on the interviews & workshop, created by the research team):

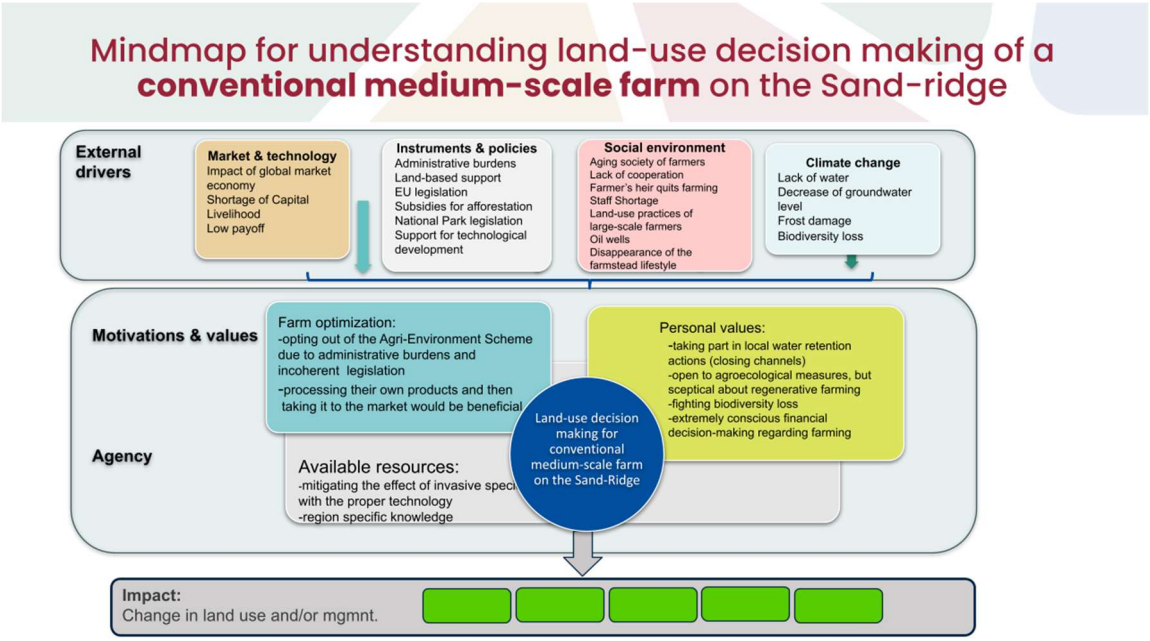


Figure 7: Mindmap for understanding land-use decision making of a conventional medium-scale farm on the Sand-ridge

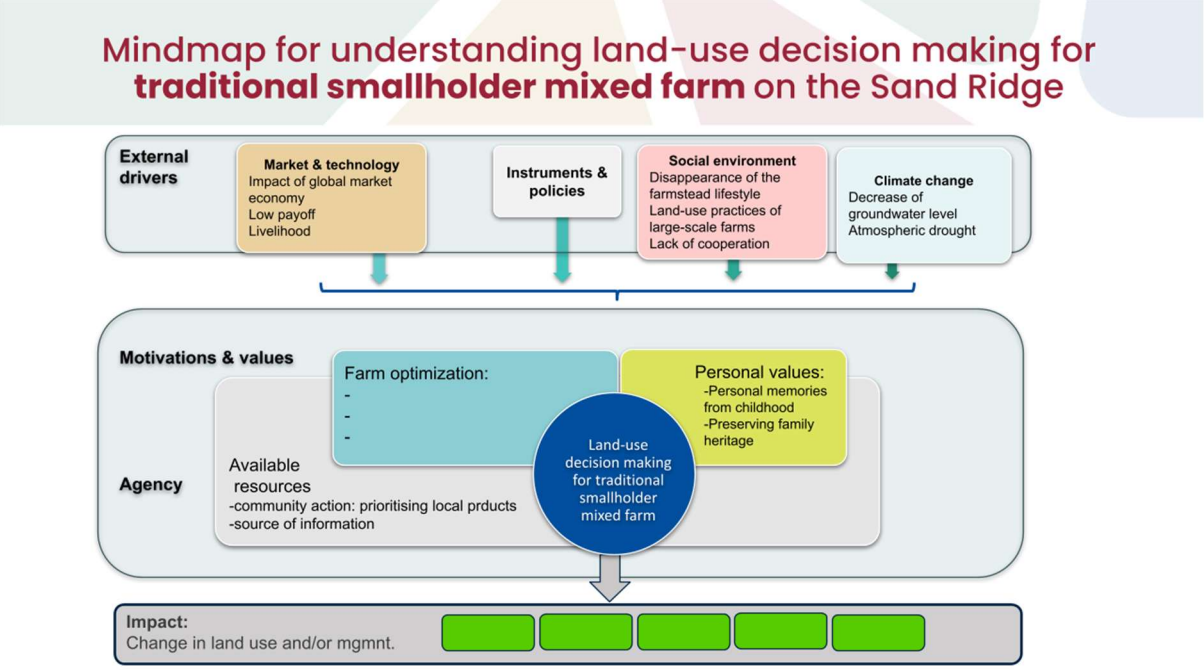


Figure 8: Mindmap for understanding land-use decision making of a traditional smallholder mixed farm on the Sand-ridge

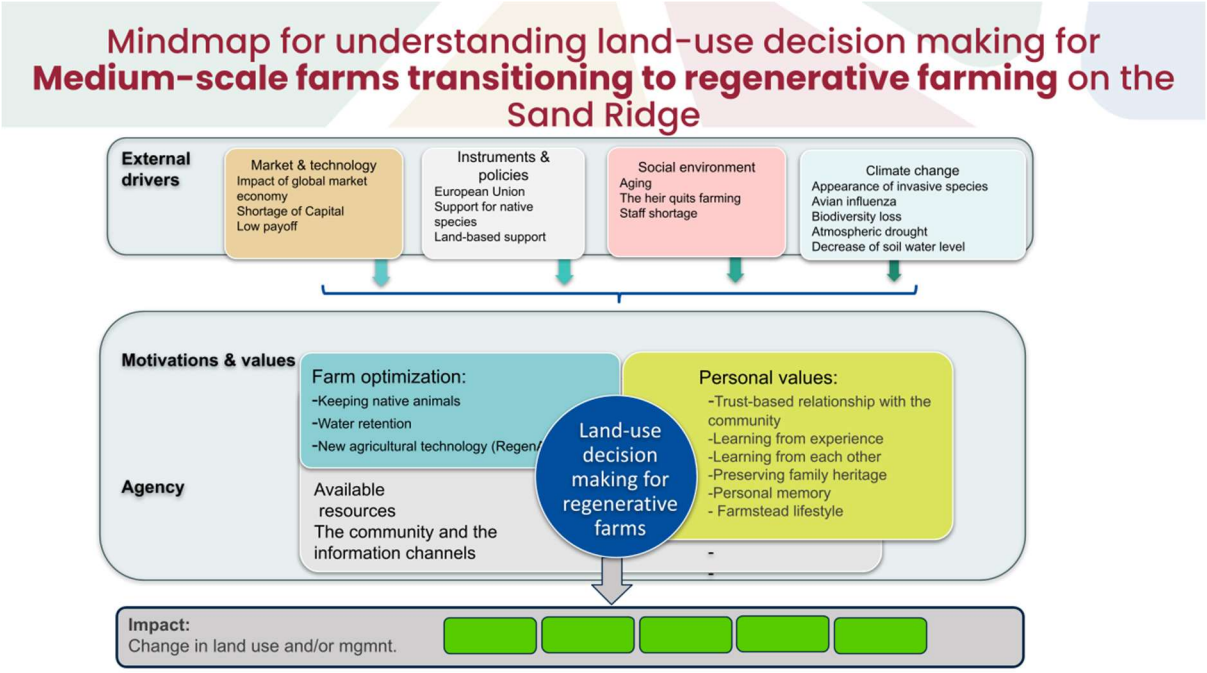


Figure 9: Mindmap for understanding land-use decision making of a medium-scale farms transitioning to regenerative farming on the Sand-ridge

Appendix 2. Notes from the validation workshop conducted as part of the 5th policy Lab meeting, on the 19th of November 2025.

1stValidation group: Medium-scale farms transitioning to regenerative farming

Members of the group

Farmer1: Is a regenerative, no-till farmer who cultivates a diverse range of legumes and continually experiments with new species to adapt to changing conditions. He applies advanced regenerative farming practices and is an active member of the regenerative farming association.

Farmer2: Kiskunok a Vízért Association founder and member, farmer who has recently given up agricultural activities because of the water scarcity and low payoff. Active member in organising the community.

Farmer3: Has a dynamic way of thinking, drawing on his background as a teacher and his experience in municipal politics. He primarily manages orchards he is familiar with a wide range of farming activities.

Farmer4: He also has a background as a teacher and plays an active role in community organisation. He is primarily a livestock farmer but maintains a broad and diverse set of agricultural interests. Interested in no-till and regenerative practices.

Expert1: He is a sociologist, social worker and recognised as an expert on traditional farmsteads. As an active member of the local community, he contributed thoughtfully to every discussed topic.

During the workshop the farmers connected their responses to their own farming experience and practices, such as the expert who is familiar with traditional farmstead practices.

Overall group dynamics

The group engaged with enthusiasm from the outset, creating a lively and open atmosphere that sustained the discussion throughout. Their exchanges frequently moved between focused discussion and anecdotal storytelling, reflecting a natural way of articulating challenges and making sense of complex issues. At times they drifted into extended narratives, yet they consistently returned to the guiding questions with clarity and intention. We, as organisers, allowed space for these stories, recognising that this oscillation between personal experience and structured reflection supported a deeper and more grounded understanding of the drivers under discussion.

2nd Validation group: experts & farmer – conventional medium-scale farming

Members of the group

Farmer: older farmer with political affiliation in the past and a degree in agricultural engineering. His farm is 50 hectares, he describes it as complex farming (livestock and crop farming), with an open attitude towards agroecological farming techniques.

Expert1: retired farmers' advisor of the Hungarian Chamber of Agriculture who worked in the Sand-ridge region

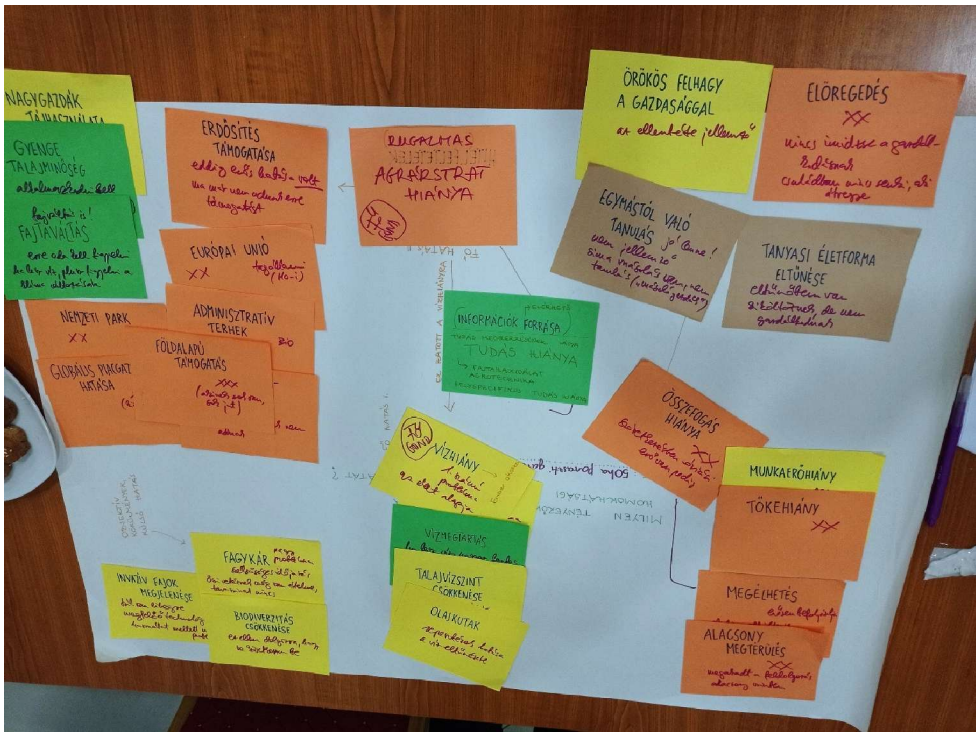
Expert2/Decision-maker: member of BirdLife Hungary, oversees and takes part in legislative processes (such as agricultural state subsidies)

Expert3: member of WWF Hungary

During the mindmap task the idea was that the group will focus on the perspective and experiences of the farmer in the group, discussing the drivers from a point of view of that farm type.

Overall group dynamics

Being grouped together provided a great opportunity for discussion between the farmer and experts that they were eager to exploit, therefore the focus often shifted from the land-use of the group's specific farm type towards discussing matters of wider agricultural issues. The farmer and Expert2 lead the group discussion, often disagreeing on the topics, Expert1 sharing personal experiences and stories from his past as an active farmers' advisor, and Expert3 taking an observatory stance.



3rd Validation group: small scale farmers

Members of the group

Participants: Farmer 1.: traditional smallholder mixed farm (less than 1 hectares), also an employee of the county council, as climate referent

Farmer 2. elderly vineyard owner (1 hectare, other 4-hectare former vineyard, now abandoned land)

Expert: member of WWF Hungary

Local cultural referent

Discussed farm type: small-scale mixed family farm (or traditional smallholder mixed farm), with ~5000m2 arable land, goats, cows, poultry, orchards and some grassland producing vegetables, fruits and dairy products for self-provisioning and sale.

Overall group dynamics

The group worked effectively despite meeting for the first time, quickly focusing on the selection of the farm type and completing the mind-mapping exercises with clarity and engagement. Participants were familiar with the smallholder mixed farms under discussion, which enabled a productive assessment of the drivers

influencing land-use decisions. the discussion was slightly dominated by one of the farmers, but still the other farmer, and the cultural referent of the settlement had some words. The expert defined this role, as an observatory role.

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Annex 3 - The two-speed landscape of the Alentejo region: structural external drivers and motivation behind land-use decision-making (Portugal)

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MOSAIC

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Abstract

This study investigates the external structural drivers and motivations behind land-use decision-making in the Alentejo region, where significant socio-ecological transformations over the past thirty years have shaped a two-speed landscape. By combining interviews with land users and organisations, cartographic analysis, and policy review, the study reveals how land-use changes emerge from the interaction of economic–technological, socio-demographic, political–institutional, and environmental–climatic drivers. The construction of the Alqueva dam and the respective irrigation system is recognised as the region's key transformation. By facilitating large-scale irrigated agriculture, it has promoted permanent intensive monocultures, such as olive and almond groves, consequently attracting external capital. These irrigated areas contrast with the region's rainfed areas, which face abandonment, ageing populations, labour shortages, declining profitability, and landscape simplification, making them more vulnerable to climate change and market volatility. As a result, a territorial divide has emerged between investment-driven irrigated areas with dynamic economic activity and marginalised rainfed areas struggling to sustain traditional farming. These findings reveal a "two-speed" landscape shaped by water availability, depopulation, policy contradictions, uneven environmental impacts, and ambivalent motivations, both individual and collective. Final reflections highlight the importance of designing land-use policies that account for drivers and motivations, alongside integrated regional planning, to promote sustainable intensification and balance agricultural productivity, biodiversity, and landscape. The current study provides an empirical contribution relevant to Portugal, which could be expanded to other Mediterranean regions facing comparable socio-ecological changes and climate change challenges.

1 Context

The Alentejo region, covering approximately 27,000 km^2, represents nearly one-third of Portugal's land area with only 5.2% of its population (INE, 2021). This vast region encompasses 47 municipalities characterised by low population density, ageing demographics, and a rural identity shaped by farming practices that generate not only material outputs, but also social relationships perceived as sustaining local community life (Carolino, 2010). Biophysically, Alentejo's landscape transitions from coastal areas to the semi-arid interior, resulting in a heterogeneous land-use mosaic of cereal plains, open pastures, dryland farming, agro-silvo-pastoral systems, and forested areas (Figure 1).

Figure 1: Examples of Alentejo's heterogeneous land-use mosaic

A central element is the *Montado*, a traditional cork and holm oak agro-silvo-pastoral system, covering approximately 10,000 km^2 in the region (Winkler & Pinto-Correia, 2026). As a socio-ecological system, it combines extensive grazing with woodland management, sustaining key ecosystem functions (e.g., soil fertility maintenance and water regulation), supporting biodiversity, while shaping the region's cultural identity.

Over the past three decades, Alentejo has undergone profound changes in land use, reshaping both its spatial patterns, landscape and social structure. Traditional extensive dryland agricultural systems have been gradually replaced by irrigated, intensive, and super-intensive farming systems, including olive and almond monocultures, as well as energy-related land uses, such as large-scale solar farms. This transition was driven by the construction of the Alqueva dam in 2002, which expanded the irrigation perimeter (from 52,000 ha in 2012 to 120,000 ha in 2016) and unlocked access to water in previously semi-arid areas (Costa et al., 2025). The combination of water security, mechanisation, and external capital investment has positioned Alentejo as a focal region for export-oriented agriculture and renewable energy development. External capital

(national and international) has been pivotal in financing large-scale irrigated farming, oriented toward global markets and value chains (Silveira et al., 2018).

In contrast, small and traditional land-users face increasing pressure from rising costs, market uncertainty, and a complex policy framework. This has led to a divergent landscape along a soil-water suitability gradient, with intensification concentrated where fertile soils and irrigation access converge and decline where they do not. At the same time, structural demographic decline and land concentration have reconfigured the agrarian system. Ageing and youth migration have led to farm abandonment in some areas, while land consolidation and investment-driven acquisitions have accelerated intensification in others (Almeida, 2013). Despite these changes at the socio-demographic level, other demographic features, such as the gender imbalance in the agricultural sector, remain essentially unchanged, with the predominance of men in the sector largely intact.

Women comprise only 26% of the agricultural workforce in the Alentejo, and approximately 27% of farm owners are female (INE, 2021), slightly below the EU average of 31% (Eurostat, 2020). Female representation in high management positions within farming associations is, however, low (Gomes et al., 2022), as evidenced by the fact that, for example, among the 16 organisations mapped in the Portuguese Policy Lab, only two include women in executive positions. Gender and minority dynamics influence land-use decision-making in Alentejo in subtle yet structurally significant ways. The interviews reveal a marked gender imbalance, with women significantly underrepresented, among land users and farm owners. This reflects long-standing structural patterns in the region, where agricultural property and decision-making roles are predominantly male. As a result, the perspectives shaping land-use strategies often stem from male-dominated experiences, potentially overlooking the priorities and values that women bring, particularly those related to social well-being, landscape care, and community cohesion. In organisational interviews, however, women appear in key technical and leadership positions, demonstrating high expertise and long tenure. Their presence suggests that gender barriers are less pronounced in the institutional sphere than in land ownership, though still limited. Women in these roles tend to emphasise integrated planning, environmental stewardship, and social concerns, offering more holistic perspectives on territorial development.

This case study focuses on the intensification of land-use systems in Alentejo, particularly the expansion of permanent irrigated monocultures of olive groves and almonds, as well as large-scale solar farms. These shifts have significantly impacted soil quality and fertility, landscape heterogeneity, and biodiversity (Ribeiro et al., 2016). Within this context, our aim is to understand land-use decision-making in a diversified socio-ecological system. We recognise that decisions are shaped by interactions among biophysical conditions (climate, soils, water availability), socio-economic factors (markets, labour), institutional and political drivers (governance, policy instruments), and cultural values (land stewardship, family legacy).

The study adopts a comprehensive systems focus, examining land-use change not only from economic, environmental, and technological angles but also from institutional, cultural, and emotional perspectives on decision-making. This integrated approach enables an understanding of how individuals and organisations interact with structural constraints, revealing the

entanglement of economic, ecological, and identity-based rationalities that inform land-use decisions. By combining institutional interviews (a regional or helicopter perspective) with land-user interviews (a local, actor-centred perspective), the study systematically connects regional narratives with local on-farm realities and explores how both levels co-evolve under shifting climate, environmental, and market pressures.

At the regional policy level, the case study is contextualised within the ongoing elaboration of the Regional Spatial Planning Plan for Alentejo (PROT-A) and related sustainable development strategies. In this sense, the present study aims to contribute to the central MOSAIC research question of the Alentejo Policy Lab:

How can we promote sustainable land-use management that integrates nature, farming systems, and energy?"

This study addresses the overarching question by exploring how external structural drivers and motivations influence land-use decision-making in the Alentejo. Specifically, it investigates:

- What are the external structural drivers of land-use change in the Alentejo region?
- What motivates the decision-making of regional land users?

2 Methodology

The study employs a qualitative, interpretive methodology to understand how land-use decisions in the region emerge from the interplay between structural external drivers and individual agency, underpinned by value-based motivations. Semi-structured interviews with land-users and organisations constitute the core of data collection, eliciting the cognitive and affective dimensions of decision-making: what actors consider, value, and envision when maintaining or modifying their land-use and, consequently, the landscape of the Alentejo region. The interview questions were guided by WP3's conceptual categories, structural external drivers, perceived external drivers, and values and beliefs, to ensure coverage of key domains. The open-ended format encouraged respondents to express not only their reasoning but also their emotional and symbolic connections to the land, thus providing rich qualitative material for analysing how and why land-use transformations occur. Two complementary interview guides structured the fieldwork according to the following:

- **Land-users guide:** Target group: farmers, beekepers, livestock managers, rural landowners and tenants. The guide is organised in five thematic blocks: (1) profile and land ownership; (2) motivations and perceptions; (3) management practices and change dynamics; (4) institutional/social relations; (5) visions for the future. The guide captures decision criteria, constraints and enablers (e.g., water access), values (heritage, stewardship), and perceived impacts/adaptation strategies.
- **Organisations guide**: Target group: associations/cooperatives/local bodies. It mirrors the same blocks at a regional scale: organisational profile and territorial scope, evolution of aims, perceived regional dynamics (demographic decline, intensification, renewable energy expansion), interfaces with public policy, governance challenges and needs.

Interview guides were pilot tested with the Policy Lead from ADRAL, adjusted to ensure contextual adequacy and coherence, and reviewed by the NOVA FCSH Ethics Committee, which raised no ethical concerns. The two-level approach enabled cross-referencing between the individual/local and organisational/regional scales, thereby enhancing the dataset's interpretive capacity. Moreover, interviews with the organisation's representatives provided a helicopter's-eye view of the region, offering an integrated, system-level perspective on the dynamics across the Alentejo area in which they operate. This institutional tier also functioned as an antechamber to the land-user interviews: orienting sampling, refining prompts, and identifying key themes for further exploration. In turn, interviews with land users captured individualised perspectives, decision-making logics, constraints, and values through which structural signals are interpreted and translated into management choices at the farm level. We started by interviewing the land users already involved in the policy lab. As part of the interview, we asked for recommendations of other relevant stakeholders. This snowball process allowed us to assemble 13 interviews: 7 land users and 6 organisations, comprising 3 women and 10 men, striking a balance between individual and collective levels and reflecting the gender imbalance characteristic of the regional farming sector.

The interview data were analysed through a multi-stage thematic procedure. We first co-constructed a coding framework in MAXQDA to establish the overarching analytic architecture.

We then conducted several rounds of hand-coded, iterative refinement, drawing on close interpretive readings. In this stage, an artificial intelligence tool (ChatGPT-5.2) was also used to support the systematisation of the final interpretive readings. This combined strategy ensured both analytical coherence and sufficient depth to capture the nuances of stakeholders' perspectives.

Qualitative insights were triangulated with cartographic evidence of land-use change, and agricultural/demographic statistics (e.g., INE, Agricultural Census). This enables comparison with verified trajectories (e.g., the expansion of irrigated permanent crops, the proliferation of solar farms) against observed spatial patterns and indicators. Policy and planning documents (e.g., CAP measures, regional planning instruments, energy siting frameworks) provide the framework for interpreting reported constraints and incentives. The interview design supports analytic triangulation: organisation narratives are corroborated or challenged by land-user accounts, which are then cross-verified with maps and statistics. The analysis proceeds through systematic thematic coding of interview transcripts, identifying recurrent patterns, contradictions, and stakeholder-specific emphases. Direct quotations are bracketed and identified by interview numbers to enable traceability and the rendering of narratives, while ensuring anonymity of the land-users, providing distance from the person representing each institution and maintaining analytical focus on structural mechanisms and main patterns. The gender dimension has been considered through a review of regional statistics and relevant literature. Interview-based gender insights remain limited due to the number of respondents.

Finally, we developed exploratory types of land users following a theoretical sampling approach (Glaser & Strauss, 2017) to maximise variation in scale of operation, production systems, and land tenure relationships. The types prioritise analytical generalisation—i.e., the capacity of each type to capture a distinct logic of land-use decision-making under environmental and policy pressures. The strength of those types lies in the theoretical coherence of each category; the clear differentiation between types based on agency, structural constraints, and motivations; the solid empirical anchoring through rich interview evidence; and the triangulation with regional-scale interviews and secondary data on structural contextual factors, including policies, economic frameworks, and social and environmental change.

3 Characterization of actor study case

As described in the methodology, our exploratory qualitative approach was designed to privilege diversity, involving organisations and land users, over representativeness. Accordingly, this results in a diversified, though not exhaustive, group of land users and organisations (**Fout! Verwijzingsbron niet gevonden.** and **Fout! Verwijzingsbron niet gevonden.**), embodying analytically significant types with meaningful variation and spatial distribution across the region. In fact, the interviewed land-users are part of the major group managing farms in the Alentejo region. Of the 31,131 farms in Alentejo, 26,657 (86%) are managed by individual producers, and only 4,371 (14%) by companies, and 103 (0.3%) by other legal entities (INE, 2019). In this context, it is worth noting that companies related to solar farms and large agribusiness investors associated with olive groves were not directly included, as the study prioritised the voices of individual land managers actively engaged in production and management decisions rather than corporate or institutional operators. However, their influence is acknowledged as a structural driver for shaping land markets and policy frameworks, for example, by affecting land availability and prices through acquisition strategies and by influencing investment capacity. This leads to reconfigured surrounding land uses and management priorities, making it harder for smaller land managers to maintain diversified, low-input practices.

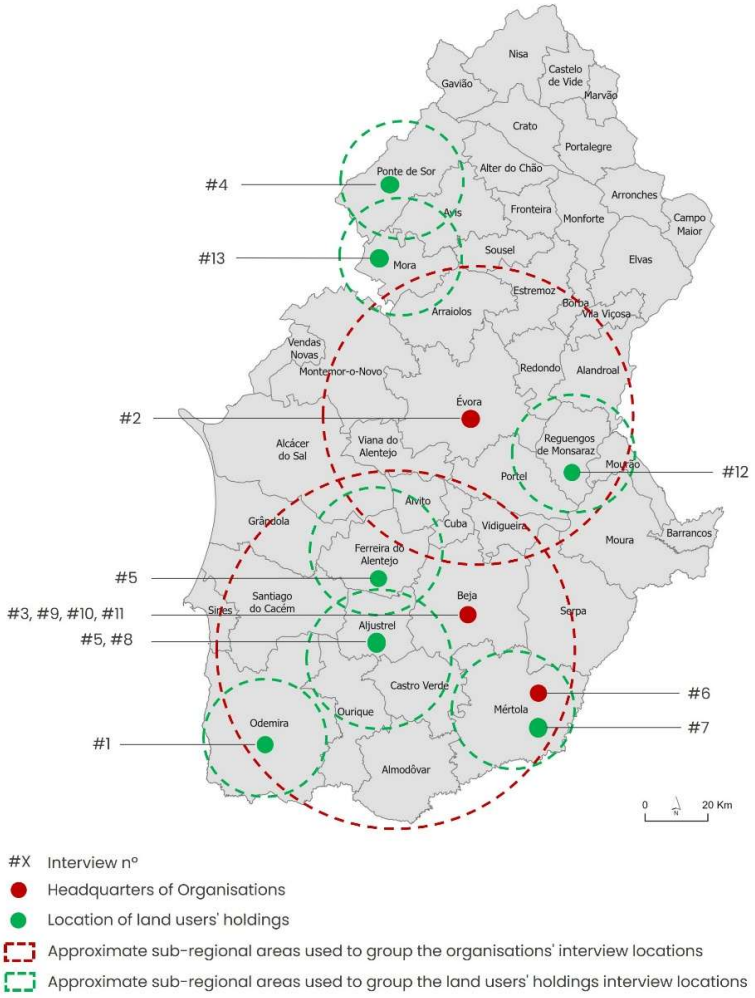

Figure 2: Localisation of the *interview (organisations and land-users) in Alentejo*

Table 1: List of organisations (O) and land users (LU) interviewed in this study

Interview Nº	O	LU	Territorial Dimension	Scope (O)/Activities (LU)
#1		x	30 hectares	**Irrigated agriculture** (sweet potatoes and berries in greenhouse), livestock.
#2	x		The entire national territory (30 farmers)	Development of **soil conservation** practices and the specific adoption of regenerative agriculture.
#3	x		The entire national territory (different farmers' associations, municipalities and universities)	**Knowledge transfer** to promote and support irrigated agriculture.
#4		x	874 hectares	***Montado system*****,** Eucalyptus, Pine Forest, Cattle.
#5		x	800 hectares (400 landowners; 400 tenants)	**Intensive agriculture,** Olive grove in hedge, corn.
#6	x		The entire Alentejo region	Promote **territorial development**, the recognition, and appreciation of local resources (human, cultural, heritage, and environmental).
#7		x	NA	**Beekeeping**.
#8		x	960 hectares (200 landowners; 760 tenants)	***Extensive livestock*****,** Olive groves, Cereals, Cork, Sheep, Cows, *Montado*.
#9	x		1 million hectares	**Manage** the region's main irrigation **infrastructure**.
#10	x		53 000 hectares	**Promotion** of the **olive** grove sector.
#11	x		South of the Alentejo region (2,000 farmers)	Defence and **promotion** of the development of **agriculture**, livestock, forestry, agroindustry and all rural activities.
#12		x	10 hectares	**Extensive agriculture,** Vineyard (main), Olive Grove, Orchard
#13		x	600 hectares	**Intensive agriculture,** Olive groves, Corn, Cattle, Forests

3.1 Organizations

Our interviews were conducted with representatives from six diverse organisations (Appendix B): four private non-profit, one mixed public-private entity, and one public institution. This diversity reflects the complex, multi-actor transformation of Alentejo's land use, spanning local territorial development organisations, national-scale sectoral associations, and state infrastructure management. The interviewed organisations' reach varies from local (focused on the Mértola municipality) to regional (serving southern Portugal or covering Central and Lower Alentejo) to national. Their membership and dimension range from approximately 30 to over 2,100 members, with one association representing 70% of national olive oil production and a public institution managing 130,000 hectares of irrigation infrastructure. The organisations represent distinct but complementary domains, addressing multiple dimensions of agricultural development, from infrastructure provision to sectoral representation to environmental sustainability advocacy. Target publics vary significantly: farmers, territorial communities, an entire region, and a mixed group of farmers, technicians, and academics. Service provision models range from direct technical assistance and sanitary services to knowledge transfer and demonstration, to infrastructure management, and sectoral representation and communication. Four of the six interviewees hold agricultural engineering degrees, demonstrating the technical and scientific

foundation for leadership in the region's agricultural sector. The remaining two professionals have expertise in law and geography.

Among our six interviewees, only two are female. Both women hold significant leadership positions: one as association president for almost 25 years (#2, soil conservation), and the other as project coordinator and technician (#6, territorial development). Leadership tenure varies considerably, from 3 to 25 years, with three interviewees serving in their roles for substantial periods (25, 11, and 8 years since 2016), indicating institutional stability and accumulated regional knowledge. The age distribution (mostly over 40) reflects experienced professionals in mid-to-late career stages who have witnessed and actively participated in Alentejo's agricultural transformation over the past few decades. And finally, most interviewees combine institutional leadership with direct land use or ownership, providing practical grounding to their organisational perspectives. This pattern of dual roles (institutional and land user) is characteristic of Alentejo's agricultural land-use decisions and suggests an intimate knowledge of both policy implementation challenges and on-the-ground farming realities.

3.2 Land-users

Our interviews were conducted with seven land users (Appendix A), representing several agricultural realities and activities across Alentejo (Figure 3). The sample includes small-scale quality producers, extensive traditional farmers, modernising entrepreneurs, and ecosystem-dependent users, capturing the heterogeneity of land-management logics and operational constraints in the region. Property sizes range from 10 hectares in small vineyards to nearly 1,000 hectares in mixed intensive systems, while the beekeeper, our ecosystem-dependent type, operates across 17 apiaries without land ownership, reflecting a very different form of territorial engagement.

Figure 3: Examples of agricultural realities and activities identified through interviews across Alentejo

Geographically, interviewees span the main subregions of Alentejo, from the coastal southwest (Odemira) to the semi-arid interior (Mértola, Aljustrel) and the northern *Montado* landscapes (Ponte de Sor). Their production systems encompass a wide spectrum: sweet potato and cattle, cork oak *Montado*, intensive olive hedgerows, maise under pivot irrigation, livestock–cereal rotations, vineyards, and professional beekeeping. This diversity mirrors the broader territorial mosaic that characterises Alentejo and allows the analysis to capture both irrigation-enabled intensification and dryland-based extensive systems. The profile of interviewees reflects a predominantly male, middle-aged farming population, consistent with regional demographic patterns. Most work full-time on their land or in related activities, combining inherited knowledge with varying degrees of technological adoption. Notably, the group includes both landowners and mixed owner-tenant arrangements, illustrating how land tenure influences investment capacity, risk perception, and exposure to structural constraints. Together, these land-user interviews provide a grounded, actor-centred understanding of the motivations, constraints, and value systems shaping land-use decisions in Alentejo. They complement the interviews with organisations by revealing how regional drivers, water access, market dynamics, policy frameworks, and environmental change are interpreted and operationalised at the farm level.

4 Structural external drivers for land use change

In the Alentejo region, structural external drivers have been systematised based on the literature, interviews with organisations (#2, 3, 6, 9, 10, 11), and a preliminary questionnaire survey, revealing how the convergence of long-term structural factors and recent market-policy shifts has reconfigured both agricultural systems and landscapes. From this framework, the following structural external drivers emerged: 1) Economic-Technological; 2) Socio-Demographic; 3) Political/Institutional, and 4) Climatic-Environmental (Figure 4).

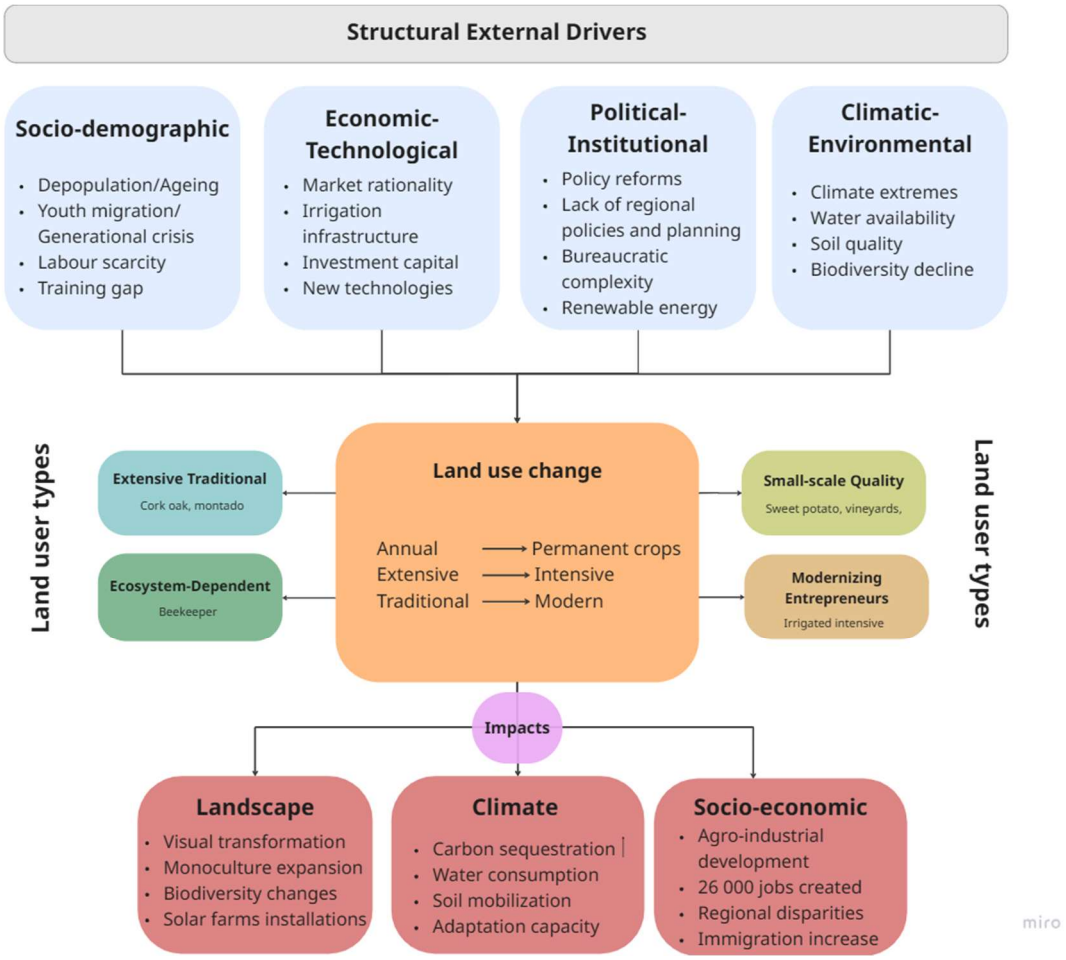

Figure 4: Synthetic visual of structural external drivers, land use change, land user's types and impacts

The interviews with organisations highlighted a range of perceived impacts, both positive and negative, across the same thematic areas, including landscape transformation, socio-economic dynamics, and environmental outcomes. Regarding landscape transformation, the negative impacts identified include monoculture expansion, deterioration and reduction of the *Montado* system, proliferation of greenhouses and solar farms, and rural abandonment. At the same time, interviewees identified positive outcomes, including increased productivity through irrigation, technological development enabling greater resource efficiency, land revitalisation, valorisation of heritage landscapes, potential of agro-industrial and tourism development, and opportunities for ecosystem restoration.

4.1 Economic-technological drivers

Economic rationality and market-driven risk-return calculations drive major land-use changes in the Alentejo region. According to the representative of a public company operating in the irrigation sector (#9, infrastructure manager), the Alqueva dam, which provides extensive irrigation infrastructure and water access to 130,000 hectares, reshaped agriculture and the landscape in the region, with broader economic and ecological effects extending across nearly one million hectares. These processes include the stabilising effect of consistent water availability enabled by irrigation, the spread of irrigation infrastructure and intensive practices, and the gradual reorganisation of the surrounding landscape into larger, more homogenous areas.

This scale of intervention creates a structural transformation as access to water fundamentally alters the viability of production systems and generates a multiplier effect across the rural economy. Agricultural intensification has thus attracted agro-industrial development, creating self-reinforcing dynamics that consolidate intensive irrigated production as a regional model. The intensification of irrigated agriculture has been amplified by significant inflows of external capital, both national and international. The public company responsible for the irrigation system is a major actor in this transformation:

> "[Public company] *has the mission to build, manage and promote the great Alqueva project. Therefore, in this action, we are catalysts for the change that has occurred and is occurring in Alentejo, because we have, fundamentally, built the infrastructure that distributes water. This enables landowners and farmers to engage in different types of agriculture that they could not before." (# 9, infrastructure manager)*

Land-use decisions reflect economically rational responses to profitability differentials across production systems. Olive grove monocultures, in particular, demonstrate superior risk-return characteristics due to relatively stable output prices, high levels of mechanisation and automated production capacity, and resilience to weather events. In contrast, although horticultural crops are of high value, they may incur catastrophic losses when extreme weather events occur or when market oversupply drives prices to negligible levels, whereas olive cultivation is described as remaining consistently profitable across variable conditions. In this sense, the observed convergence toward olive monoculture can be interpreted as a pragmatic response to uneven and structurally produced risk exposure, rather than as a culturally driven reluctance to diversify. Export competitiveness performance further amplifies these dynamics: a strong market performance of olive oil enables reinvestment and expansion, reinforcing the dominance of olive groves despite well-recognised sustainability concerns. Interviewee 10, representing an association of the olive sector, emphasizes the role of technological modernization, including precision irrigation guided by soil moisture sensors, integrated/biological production certifications, and inter-row vegetation management to preserve soil structure. At the same time, he notes that significant barriers to knowledge transfer remain. Traditional small-scale producers often show limited engagement with technical assistance, whereas younger, formally trained workers embrace innovation more readily. Older farmers, by contrast, often resist abandoning practices rooted in traditional ecological knowledge. This gap also reflects differences in investment horizon: younger farmers may be

more inclined to invest in new technologies when they foresee continuity, whereas older farmers may be reluctant to undertake costly upgrades close to retirement, especially where succession is uncertain.

4.2 Socio-Demographic drivers

Alentejo's agricultural transformation occurs amid severe demographic decline, marked by very low population density, an ageing farming population, and weak generational renewal. The latter two are the most critical socio-demographic challenges for the region's future. Interview findings confirm that demographic decline acts as a structural constraint on land use as the human foundation of traditional and diversified farming systems progressively disappears. Labour-intensive agricultural systems, such as extensive agriculture, become economically unviable if workers are unavailable, even when market prices are favourable. Stakeholders highlight that sector modernisation needs younger, skilled, and innovative participants, but local youth, especially the most educated, continue to leave rural areas. Interior areas of the region face particularly acute pressures from this demographic decline, experiencing the compounding impacts of depopulation, low regional attractiveness, and weak public investment (#6, territorial development).

Agricultural intensification has, however, changed labour patterns since 2018, generating substantial demand that is met mainly through international immigration. The intensification of migration flows, from the 2000s onward, to supply agricultural labour can be summarised in two different sub-regional dynamics: 1) In the Alqueva irrigation perimeter, mechanisable permanent crops (olive groves, vineyards, and almonds) created seasonal labour demand, attracting temporary workers from Eastern European countries. 2) In the Mira irrigation perimeter, labour-intensive berry production requires year-round workers, resulting in the permanent settlement of over 9,600 foreign workers by 2021, predominantly from Nepal, India, and Thailand (Carvalho, 2021).

4.3 Political-institutional drivers

Interviews reveal that policy reforms have acted as structural drivers reshaping Alentejo's land-use patterns. Interviewee 2 (soil conservation) emphasised the pivotal role of the 1992 CAP reform, which exposed dryland cereal producers to global commodity competition, systematically eroding the profitability of traditional crops (such as wheat, barley, corn (maize), oats, rye). This generated an economic push toward permanent irrigated crops with superior price stability (such as olive crops) and a policy-orchestrated structural adjustment rather than a purely market-driven transformation. Agri-environmental measures, while designed to incentivise sustainable practices, often contain implementation barriers that exclude intended beneficiaries. For instance, conservation agriculture requirements mandate continuous five-year adherence without soil mobilisation, effectively prohibiting rotations necessary for crops such as tomatoes or horticultural species, which require occasional tillage (#2, Soil conservation). These requirements tend to favour larger, well-resourced farms: smaller farmers who are most in need of support for efficient water use frequently cannot access corresponding subsidies, whereas well-resourced "frontlines" are the primary beneficiaries (#3, knowledge transfer). Administrative

thresholds and technical requirements thus function as gatekeeping mechanisms that limit equitable participation.

Nature conservation-oriented organisations highlight that policy gaps, such as the absence of mandatory environmental mitigation for private agricultural land. They argue that large-scale, homogeneous cultivation should be held to obligations for riparian restoration, ecological connectivity, and settlement buffer zones, comparable to urban planning regulations (#6, territorial development). These tensions reflect competing development narratives, revealing fundamental contestation over the policy discourse that shapes land-use decisions:

> *"One of our concerns is that the vision most widely transmitted and disseminated is that irrigated areas are the engine of the economy. And this vision significantly harms our country, which is predominantly dryland. Therefore, intensive production systems have their place in the market and national production, but dryland systems—that is, production and products from dryland—are not about intensity but about identity. From there comes double the product with great qualified value. Therefore, they are a guarantee of our culture and our market differentiation." (# 6, territorial development)*

Stakeholder interviews reveal a governance gap between the speed of land-use change and regional planning capacity. Without strong criteria, such as exclusion zones or impact caps, large solar farms or intensive monocultures often proceed, externalising impacts on rural landscapes and ecosystems. This compounds governance fragmentation: agricultural, water, energy, and conservation policies operate in parallel rather than within a coherent territorial framework for mediating trade-offs and sequencing investments.

Agri-environmental measures, including integrated production, biological certification, inter-row vegetation, and cereal incentives, retain relevance for the adoption of environmental practices. In this context, some agricultural associations have strategically prioritised open knowledge dissemination over exclusive member services, deliberately accepting lower formal membership in exchange for broader practical impact (# 2, soil conservation #11, agriculture promotion). However, bureaucratisation has altered the roles of associations. Interviewee 6 (territorial development) notes that organisations initially designed for knowledge transfer are now primarily engaged in bureaucratic tasks, which reduces their capacity for territorial intervention.

4.4 Climate-environmental drivers

Environmental adaptation in Alentejo agriculture reflects a mix of proactive institutional initiatives and reactive responses to intensification pressures. Climatic-environmental drivers include rising temperatures, more frequent heat extremes, and increased rainfall variability, which lead to recurrent drought and chronic water scarcity. These pressures intersect with landscape-scale environmental degradation, such as soil erosion and organic matter decline, salinisation risk in irrigated areas, and the simplification of ecosystems, thereby increasing exposure and vulnerability to climate extremes.

Conservation agriculture practices, including reduced tillage, permanent soil cover, and crop rotation, have gained adoption as climate adaptation strategies that enhance soil organic matter, carbon sequestration, and water retention and resilience (# 2, soil conservation). Water use

efficiency emerged as an institutional priority as early as 1999, preceding broader discourse on water scarcity. Subsidy programs incentivised efficiency practices (# 3, knowledge transfer). Soil management modernisation replaced historical deep summer ploughing with direct seeding and minimum tillage across both dryland and irrigated systems. Inter-row vegetation management reduces erosion, improves soil quality, and prevents nutrient runoff, supported by agri-environmental mechanisms (#11, agriculture promotion). Infrastructure development establishes ongoing environmental surveillance through mandatory baseline soil characterisations and decadal monitoring of soil and land-use evolution into practice (# 3, knowledge transfer). Despite these measures, economic imperatives dominate decision-making hierarchies. As one producer association representative stated:

> *"When discussing decisions regarding our properties, among economic, social, and environmental factors, it is always economic" (#11, agriculture promotion).*

This economic primacy fundamentally shapes responses to environmental challenges. Monoculture expansion exacerbates landscape-scale environmental pressures, including water scarcity and soil degradation. Nevertheless, crop diversification remains a landowner's prerogative, with limited regulatory enforcement (# 9, infrastructure manager). Intensive monoculture also generates negative externalities, including the loss of ecological connectivity and riparian degradation, that require buffer zones and riparian restoration. (#6, territorial development). Divergent narratives emerge regarding biodiversity impacts. Sector representatives argue that intensive olive groves still support species/wildlife such as the Iberian lynx, while acknowledging ecological community transformation (#10, olive promotion). These debates reflect the tension between productionist and conservationist perspectives in interpreting the environmental consequences of agricultural intensification.

5 Factors influencing land-use decision making

Based on a thematic analysis of interviews with land users (#1, 4, 5, 7, 8, 12, 13) and the existing literature on agricultural transformation in the Alentejo, four land user types emerge, characterised using a capturing logic for motivation and diverse decision-making pathways. The types are the following:

Extensive Traditional - consists of landowners and stewards of cork and holm oak systems (e.g., cork extraction and extensive livestock grazing, often complemented by hunting and other multifunctional activities) who provide key ecosystem services, but face challenges linked to demographic ageing, succession bottlenecks, and lower profitability than irrigated agriculture. These users generally own large properties (>50 hectares) and work on them part-time or full-time.

Ecosystem-Dependent - includes land-users who are highly dependent on ecosystem health and biodiversity for their livelihoods (e.g., beekeeping, mushroom and aromatic plant harvesting and other nature-dependent activities). Their economic viability relies on maintaining ecological integrity, making them highly vulnerable to land-use changes such as intensive monocultures or pesticide use. These land-users customarily operate full-time across multiple sites.

Small-Scale Quality - includes land users oriented toward niche and high-quality production (often under PDO/PGI labels). These producers uphold values such as cultural and landscape diversity but remain financially constrained by scale, certification costs, and exposure to climatic variability. These users generally own medium-sized properties (5-20 hectares) and work on them full-time.

Modernising Entrepreneur - represents the main agents of post-Alqueva land-use conversion, leveraging water availability, technology, and external investment to establish intensive permanent irrigated crops (e.g., super-intensive olive groves and almond orchards) and shape regional supply chains. These land-users generally own large properties (>50 hectares) and work on them full-time.

Land-use decision-making process across these different land-user types reveals a common structure:

Assessment: Farmers evaluate the viability of different land-use options across multiple dimensions. As highlighted by Interview 8 (*Extensive livestock*), adopting new or innovative approaches requires “at least five years” to observe their performance under shifting climatic conditions.

Enablers and constraints (factors): Access to water infrastructure emerged as the primary decisive differentiator. Interview 1 (irrigated agriculture) emphasized that farm survival depends on access to water, while producers with Alqueva irrigation connections pursue intensification. Other constraints include labour availability, market volatility, and administrative burdens, but these factors remained secondary to water access in differentiating viable pathways.

Pathways Decision: Four key land-use trajectories emerged:

- **Intensification**: Enabled by irrigation access and driven by profitability goals. (#5, intensive agriculture)
- **Diversification**: Used as a risk management strategy to buffer climatic and market uncertainty. (#8, extensive livestock)
- **Maintenance:** A commitment to preserving heritage landscapes and traditional systems, despite financial losses. (# 12, extensive agriculture)
- **Abandonment**: Economic unviability and demographic decline (Interlocutors of Interview 1 (irrigated agriculture) expect the neighbour farmers to retire within 10 years)

Decision-making is associated with the external structural drivers discussed in Section 4, as well as with specific motivations and values identified in the land-user interviews. Across interviews, land-use decisions were strongly influenced by cultural and emotional motivations that extend beyond economic rationality:

- Family heritage: Farms and land are kept within the family to maintain generational continuity.
- Land attachment. Strong emotional and symbolic ties to place, often resisting market pressures, and continuing family farming activities.
- Traditional knowledge: Preservation and transmission of local farming practices and agro-ecological knowledge.
- Identity preservation: Land and landscape as central elements of personal and cultural identity, often linked to *Montado* and vineyards.

5.1 Extensive traditional land user

The **Extensive Traditional** land-user type is characterised by large-scale, low-intensity land use, ecological stewardship, and resistance to pressures to convert to intensive monoculture (Figure 5). Their practices integrate extensive forestry (*Montado*), grazing, and rotational cereals, reflecting a commitment to both ecological sustainability and intergenerational continuity.

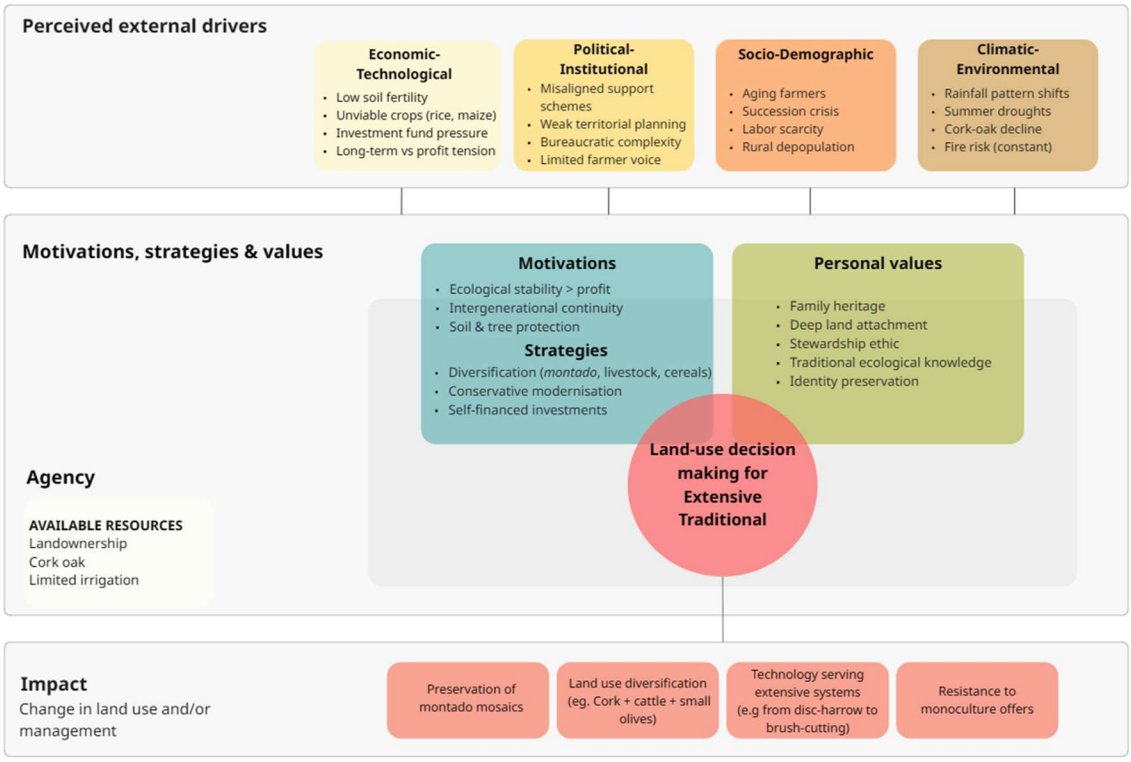

Figure 5: Synthetic visual for the land-use decision-making process for the Extensive Traditional Land User type.

Perceived external drivers

Socio-demographic drivers are a central constraint. Interviewees 4 and 8 (*Montado* system and extensive livestock) emphasised ageing and lack of generational renewal, leading to land abandonment or rental to external operators. This demographic decline limits labour availability, the capacity for labour-intensive improvements, and discourages long-term investment. Interviewee 4 notes that attracting younger workers requires making agricultural work appealing through technology and better equipment, highlighting that modernisation is not rejected but depends on creating conditions that make rural life viable. Interview 8 (Extensive livestock) points to structural isolation, reinforced by poor mobile connectivity, as a factor that discourages settlement and modernisation and contributes to demographic stagnation.

Economic viability is a persistent challenge for extensive systems of production. Farmers operate on low-fertility soils, and where irrigated crops quickly become unprofitable. Interviewee 4 explains that cultivation of crops such as rice, maize, and tomatoes was gradually abandoned due to declining returns. Extensive farmers adopt **technology selectively**, with precision tools (GPS guidance, variable-rate input systems, and soil monitoring) that improve efficiency without altering the extensive logic. Investments are frequently financed privately, as public programs are slow or poorly adapted. Simultaneously, large-scale, capital-intensive ventures backed by investment funds create competitive asymmetries. These actors prioritise rapid returns through monocultures of olive and almond trees, reshaping land markets and exerting pressure on traditional producers to either rent or sell. Interviewee 8 highlights that extensive farmers resist short-term profitability strategies that compromise soil health and tree longevity, opting for incremental improvements aligned with ecological constraints.

Political-institutional frameworks are widely perceived as disconnected from extensive systems of agricultural production. Interviewee 4 (*Montado* system) criticises current support schemes for confusing "responsible management" with routine operations. This misunderstanding leads to incentives that are difficult to access and poorly suited to the long timeframes required for soil recovery and tree growth used in extensive agriculture. He advocates for three pillars: long-term investment programs co-designed with academia, structured knowledge transfer, and targeted support for responsible management. Interviewee 8 (*Extensive livestock*) stresses the lack of effective territorial planning, identifying it as a key driver of monoculture expansion and associated environmental risks, including erosion, biodiversity loss, and fire. Both Interviewees 4 and 8 point to bureaucratic complexity and fragmented governance as major obstacles, with limited channels for farmer participation and weak continuity in policy design.

Climate variability directly impacts extensive systems that rely heavily on rain-fed regimes and ecological resilience. Interviewee 4 observes an increasingly concentrated winter rainfall and reduced spring precipitation, resulting in prolonged summer droughts that weaken cork-oak stands and increase vulnerability to pests and diseases. Interviewee 8 (Extensive livestock) highlights the unpredictability of weather, which complicates sowing and harvesting schedules and forces case-by-case adaptation rather than quick fixes. Where irrigation exists, it is managed with precision tools to minimise losses. Fire risk is constant and addressed through associative networks and preventive practices, yet it remains a structural vulnerability due to the property's scale and limited emergency response capacity.

Motivations, strategies & values

These factors collectively steer extensive traditional producers toward prudence and resilience. They prioritise soil conservation, tree protection, and diversified land-use mosaics combining forestry, grazing, and rotational cereals. Technological adoption is cautious and purpose-driven, aimed at sustaining ecological functions while improving operational efficiency. Where institutional programs fail, investments are self-financed according to risk tolerance. In the absence of effective territorial planning, producers articulate the need for regulatory limits and resist speculative offers that would convert traditional systems into intensive monocultures.

> *"My management is based on protecting the soil (...) and protecting the trees... It's necessary to mix all of this and make decisions that sometimes harm one part, but overall, we try (...) to have increasingly healthy soil and increasingly healthy trees." (# 4, Montado system)*

Extensive traditional land-users express a strong attachment to their land and a commitment to intergenerational continuity, combined with an ethic of stewardship. Interviewee 4 (*Montado* system) acknowledges the transitory nature of ownership while striving to maintain ecological integrity. Interviewee 8 (*Extensive livestock*) emphasises that he was "raised into" farming and values diversification to minimise environmental impacts, even at the cost of short-term profitability. Both stress the importance of knowledge and learning through universities, trials, and associations, and frame responsible management as a public good that depends on

economic viability. For these producers, biodiversity, soil health, and cork-oak vitality are inseparable from stable income for farmers and workers. Interviewee 8 (*Extensive livestock*) captures the economic-ecological tension:

> "*Profitability (...), today there is no crop that yields more income than olive groves or almonds. And people go for the income, not for the landscape." (# 8, Extensive livestock)*

Extensive traditional producers consciously reject strategies that would affect long-term sustainability, positioning themselves against the short-termism that dominates intensive models.

Impact

Regarding **land-use decisions**, including whether to change or maintain current land use, five main outcomes emerge:

Maintenance and refinement of extensive mosaics - On poor, sandy soils, producers have **preserved the core structure of extensive systems**: *Montado* (cork and holm oak), grazing, and rotational cereals. The shift has been away from historically broader irrigated crops toward land uses adapted to soil limitations and ecological functioning. Interviewee 4 maintains a diversified property and practises rotations to reduce erosion and maintain organic matter.

Selective reductions and exits - discontinued activities - Producers have **discontinued activities** that became unviable under market conditions or regulatory changes such as irrigated rice and maise, and a complete Iberian pig cycle production was abandoned after stricter production rules collided with local acorn variability and cost structures.

Management innovations within an extensive logic - Aim to improve ecological quality, e.g. replacing disc-harrow understory control with brush-cutting to protect shallow cork oak roots, adopting precision input tools, and organising fire-response networks. These measures reflect "conservative modernisation": technology serving extensive systems rather than transforming them into intensive regimes.

Resistance to conversion - Faced with offers to rent or sell land for intensive olive grove plantations, one interviewee (#5, intensive agriculture) declined, citing biodiversity and soil protection as priorities. He views **large continuous plantations and fund-driven models as incompatible with territorial suitability** and ecological resilience, advocating for binding planning rules and mandatory set-asides

Anticipated trajectories - Producers anticipate increasing climatic stress, demographic decline, and persistent policy misalignment unless long-term, science-based programs and fine-grained territorial zoning are implemented. In response, they plan to maintain diversified, extensive mosaics, deepen soil-care practices, and rely on associative infrastructures for knowledge and risk management, accepting slower returns in exchange for ecological stability.

5.2 Ecosystem-dependent land user

The ecosystem-dependent land-user is a distinctive type within Alentejo's agricultural transformation, as he operates without land ownership while remaining fundamentally dependent on landscape biodiversity for economic viability (Figure 6).

The interviewee 7[1] is a beekeeper from Mértola, who manages 700 hives across 17 apiaries. He is the third generation of honey producers in his family, and he relies on beekeeping as his main activity.

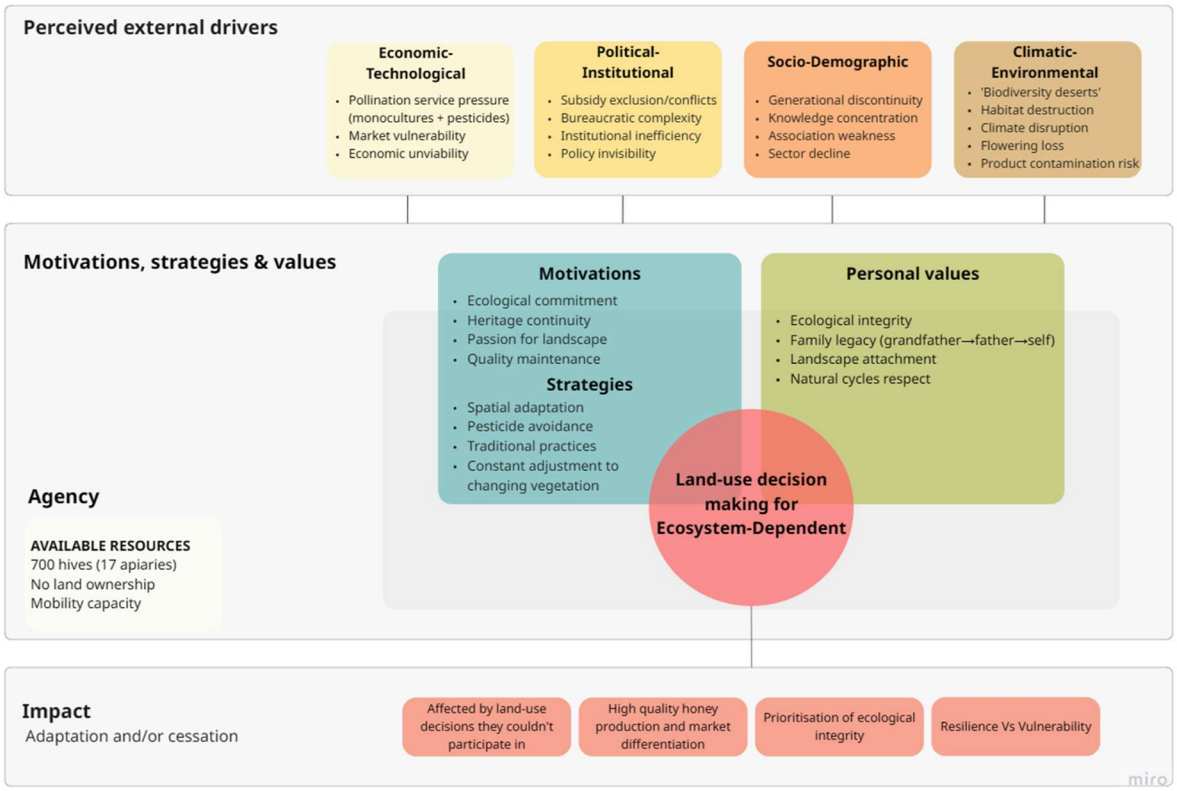

Figure 6: Synthetic visual for the land-use decision-making process for the Ecosystem-dependent Land User type

Perceived external drivers

The ecosystem-dependent land user's perception of **socio-demographic drivers** focuses on the broader context of territorial abandonment in Alentejo and the progressive isolation of beekeepers' activity. For our interviewee, the small number of professional beekeepers is a result of generational discontinuity and of the economic unviability of the model. His role as an informal technical advisor to beekeeping associations underscores how knowledge concentration among remaining practitioners cannot compensate for the sector's systemic decline.

In his view, demographic hollowing creates a situation in which traditional knowledge becomes increasingly concentrated and institutionally marginalised. In this type, the narrative about

[1] Our exploratory qualitative approach was designed to privilege diversity over representativeness.

economic-technological drivers manifests primarily through indirect mechanisms rather than direct market pressures. The expansion of intensive monocultures, notably olive groves occupying more than half of irrigated areas, creates what the interviewee perceives as "biodiversity deserts" that eliminate the productive capacity of activities that depend on pollinators.

The economic rationality driving neighbouring land-use decisions of intensive farming, mainly the pursuit of stable returns and profit through permanent crops, generates negative externalities that constrain ecosystem-dependent operations. The emergence of pollination services for intensive almond plantations represents a particularly revealing dynamic, in which ecosystem services are commodified within production systems that simultaneously degrade the ecological base supporting them. Interviewee 7's rejection of these "pacts with the devil", resulting in pesticide-laden environments, demonstrates his resistance to economic incentives that would compromise both ecological integrity and the quality of the wax and honey.

In the absence of land ownership, our interviewee becomes vulnerable to landscape changes beyond his direct control. Operating across others' properties without formal agreements depends on informal social relations and traditional access rights, increasingly challenged by intensification pressures.

In this type, **political-institutional drivers** operate through both active intervention and the systematic neglect of the needs of ecosystem-dependent land users. Existing subsidy mechanisms require complete vegetation removal, which creates direct conflicts with pollinator habitat requirements, while bureaucratic complexity hinders the possibility of adaptive responses. His four-and-a-half-year struggle to secure approval for facility expansion illustrates how institutional inefficiencies compound operational pressures. Our interviewee also highlights that associations created to support beekeepers now primarily serve as administrative requirements for hive registration and medication access rather than providing support systems. This institutional context reveals a fundamental disconnection between policy frameworks designed for land-based agriculture and the spatial requirements of ecosystem-dependent activities such as beekeeping.

Climate changes have profoundly disrupted traditional apicultural cycles, with shortened flowering periods and erratic precipitation patterns forcing operational adaptations. Consequently, a critical shift in the hierarchy of structural drivers in the decision-making process occurred: while environmental factors were always present, they have become overwhelmingly determinant.

> *"Ten years ago, environmental and climatic considerations were my primary concern. Since then, I have had to make decisions and come to terms with the fact that the climate has completely changed." (#7, Beekeeping)*

Motivations, strategies & values

The convergence of climate change with landscape mono-diversity creates compound pressures that transform environmental factors from manageable challenges into existential threats. According to our interview, family legacy implies a profound attachment to the landscape, transcending purely economic considerations. Third-generation continuity represents not merely

occupational inheritance but cultural transmission of ecological knowledge and territorial connection. Interviewee 7 articulates a deep emotional investment rooted in childhood experiences:

> *"[...] besides being a family heritage [beekeeping] is also my childhood life...every holiday, every long weekend I spent in Alentejo... It is a passion!" (# 7, Beekeeping)*

This affective dimension sustains the activity's persistence despite deteriorating conditions, distinguishing ecosystem-dependent operators from market-oriented producers. Decision-making reflects explicit prioritisation of ecological integrity over profit maximisation. His categorical rejection of pollination services demonstrates value-based resistance to lucrative opportunities that compromise environmental and product quality. This ethical stance extends to production methods, refusing artificial feeding practices that would boost productivity at the expense of natural cycles. Anticipatory thinking about desertification trajectories reveals adaptive capacity grounded in a realistic assessment of ecological trends rather than optimistic policy expectations. Land-use decisions manifest through continuous spatial reconfiguration rather than fundamental transformation of practices.

Impact

The beekeeper maintains traditional practices, emphasising that it promotes quality over quantity, and produces 10 to 12 tons of honey annually through extensive methods. The refusal to adopt intensive feeding regimes or engage with contaminated environments preserves product integrity and market differentiation. This quality-focused strategy provides economic viability in niche markets while maintaining ecological practices, though market premiums remain insufficient to fully offset productivity losses from environmental degradation. The experience of our interviewee reveals how ecosystem-dependent users become "collateral damage" in agricultural transformation, affected by land-use decisions in which they have no participation. This structural marginalisation extends to policy processes where ecosystem services remain unrecognised and uncompensated within agricultural support frameworks.

5.3 Small-scale quality land user

The small-scale quality producer type is characterised by territorial rootedness, quality-oriented production, and economic marginalisation within policy frameworks privileging larger operations (Figure 7). Examples are:

Interviewee 1 (irrigate agriculture) was held with a couple managing 30 hectares in São Teotónio, within the Southwest Alentejo Natural Park (the region's coastal area), combining sweet potato production, cattle rearing, and partial land rental to greenhouses. As third-generation farmers, they maintain the land without public subsidies.

Interviewee 12 (extensive agriculture) manages 10 hectares of vineyards near Reguengos de Monsaraz (interior, central region), within the Alqueva irrigation perimeter, with supplementary olive groves, and continues a family viticultural tradition linked to the local cooperative.

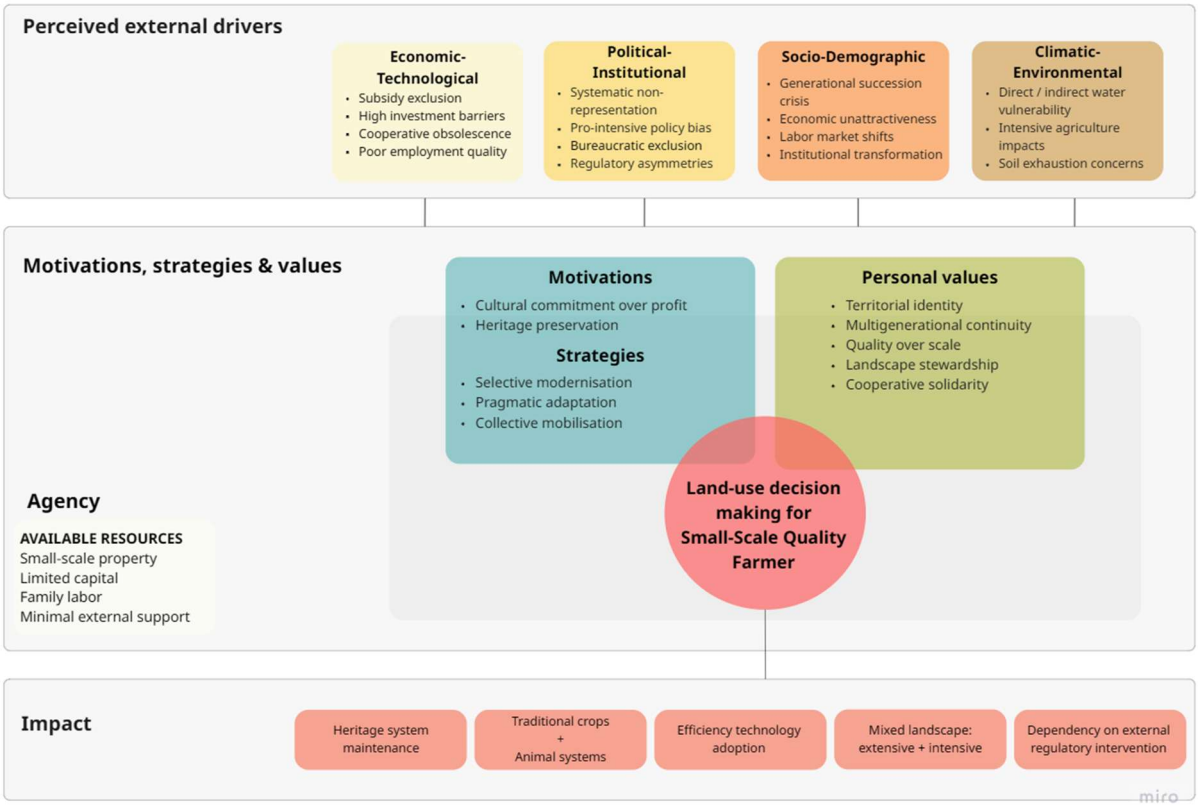

Figure 7:Synthetic visual for the land-use decision-making process for the Small-Scale Quality Farmer Land User type

Perceived external drivers

The small-scale land user's perception of **socio-demographic** drivers centres on the generational succession crisis and labour constraints intersecting with territorial transformation. Succession concerns are justified by economic unattractiveness, rather than cultural rejection. As expressed by Interviewee 12 (extensive agriculture), agriculture has become "unattractive", and younger generations are likely to choose alternative livelihoods rather than inherit productive patrimony, which is less rewarding.

Economic pressures threaten the long-term survival of small farms. Interviewee 12 (extensive agriculture) adopts technological solutions, such as mechanical harvesting or drip irrigation, evidencing efficiency pragmatism motivated by labour scarcity and streamlining rather than productivity maximisation. He critiques cooperative degradation, which no longer effectively supports small producers. Interview 1 (irrigated agriculture) similarly critiques intensive agriculture for creating low-quality, **precarious** jobs, failing to foster sustainable territorial development, and failing to create skilled employment that would justify investment in agricultural education.

The **economic-technological** and the **political-institutional** drivers are deeply intertwined. Both farmers express a sense of profound disconnection between governance frameworks and small-producer realities. This disconnection manifests in bureaucratic exclusion and regulatory asymmetries that favour intensive operations. Interview 1 (irrigated agriculture) articulates the systematic non-representation of small producers: the government actively supports intensive

greenhouse expansion while failing to implement regulatory frameworks that would protect extensive systems or establish landscape capacity limits. To organise resistance, they created an advocacy organisation.

One of our interviewees articulates institutional evolution through changes in the management of cooperatives:

> *"Cooperatives exist, or existed, to allow, especially small producers, to market their product (...) Today they make sense, but for large producers and not for those with ten hectares like me, or even less." (# 12, extensive agriculture)*

This reflects a perceived institutional drift that disadvantages small farms independently of their management capacity. Interviewees in interview 1 (irrigated agriculture) 1experience regional demographic growth driven by a greenhouse migrant worker influx, while remaining economically marginal from the benefits. They see themselves positioned outside dominant land-use trajectories — neither benefiting from labour availability nor participating in intensive agriculture.

Interviewee 12 (extensive agriculture) is critical of the CAP reform, highlighting that subsidy schemes are perceived as universal but remain structurally inaccessible to small-scale farmers due to literacy asymmetries and administrative burdens. In both interviews, demands for preventive regulation to contain the expansion of intensive agriculture are expressed, and it is stated that small producers are landscape conservation advocates whose territorial embeddedness generates systems-level awareness, absent in capital-intensive operations.

Climatic-environmental drivers operate asymmetrically, with land users in Southwest Alentejo experiencing water scarcity directly through rainfall dependency. On the other hand, Interview 12 (extensive agriculture) anticipates irrigation infrastructure and external decision-making dependency, creating additional vulnerability once the Alqueva connection arrives. Small-scale land users, such as Interviewee 1, operating entirely under rainfed conditions within a natural park, are directly exposed to climatic variability, water scarcity, and the absence of technological buffers. Their primary environmental concerns focus on the effects of greenhouse expansion: water competition, biodiversity displacement, and landscape homogenisation.

Motivations, strategies & values

Interviewee 12 (intensive agriculture) understands environmental change through the lens of landscape evolution. He associates the expansion of intensive olive and almond groves with risks of soil degradation, showing clear environmental awareness. He highlights landscape preservation as an economic foundation, framing environmental quality as a competitive regional asset rather than a production constraint. As he states:

> *"I would invest in maintaining the landscape because it would retain value for another sector very important to us: tourism". (# 12, extensive agriculture)*

Both producers' motivations combine emotional attachment to land with the pragmatic need to ensure economic survival.

"It made complete sense for us to farm, but without any subsidies. It was really for emotional reasons, perhaps, and maybe because of the land's characteristics. That's it—doing the agriculture of the territory we belong to has a lot to do with our identity." (# 1, irrigated agriculture)

Impact

The previous statement reveals how crop choices, such as sweet potato cultivated by previous generations, reflect territorial identity and inherited knowledge more than economic optimization. They show two contrasting logics: economic rationality, acknowledging they earn no subsidies, versus cultural-emotional commitment to farming tied to family heritage, territorial identity, and maintaining "the agriculture of the territory". They deliberately preserve farming practices that made sense decades ago rather than adopting contemporary intensification pathways. Interviewee 12 (extensive agriculture) continues viticulture partly to support the local cooperative and maintain family tradition, despite increasingly marginal returns. Both producers prioritise territorial identity and quality production over maximum profit, accepting financial sacrifice to preserve agricultural heritage.

5.4 Modernizing entrepreneur

The modernising-entrepreneur land-user group is exemplified by Interviewee 5, whose trajectory combines infrastructure-enabled scale expansion and technological intensification with strategic crop diversification (

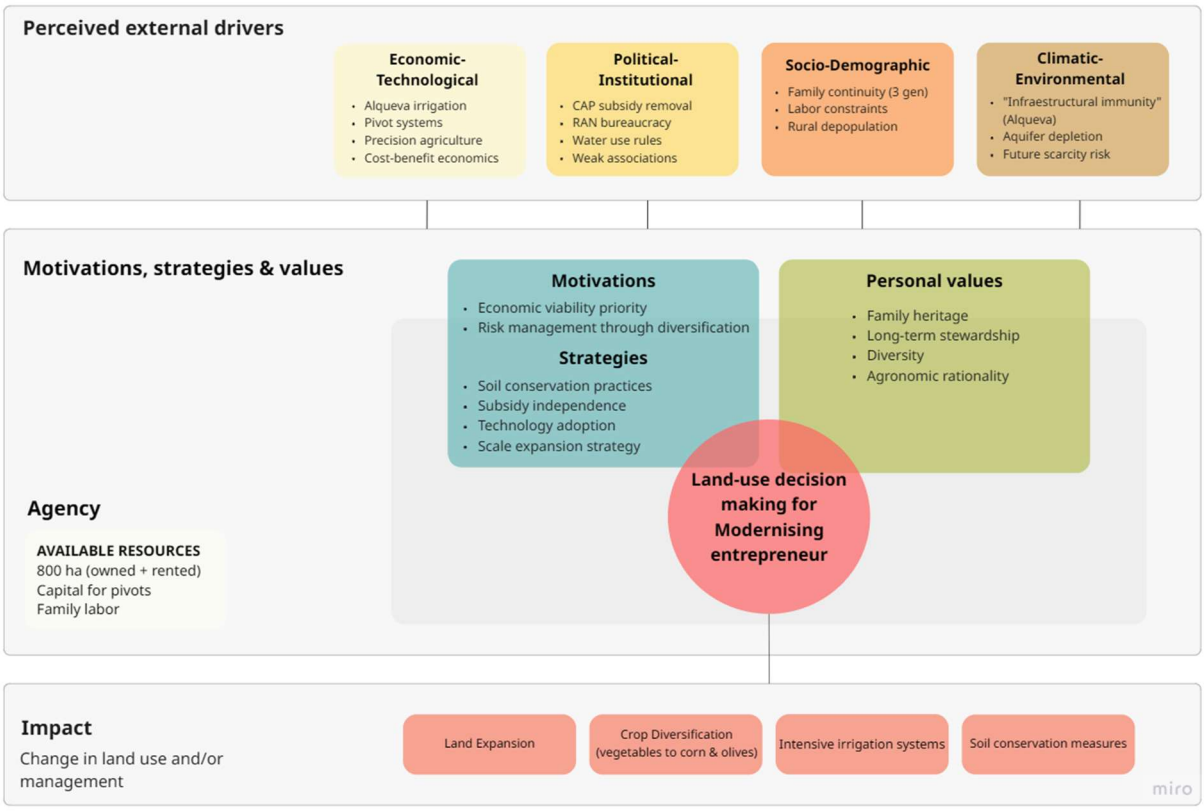

Figure 8).

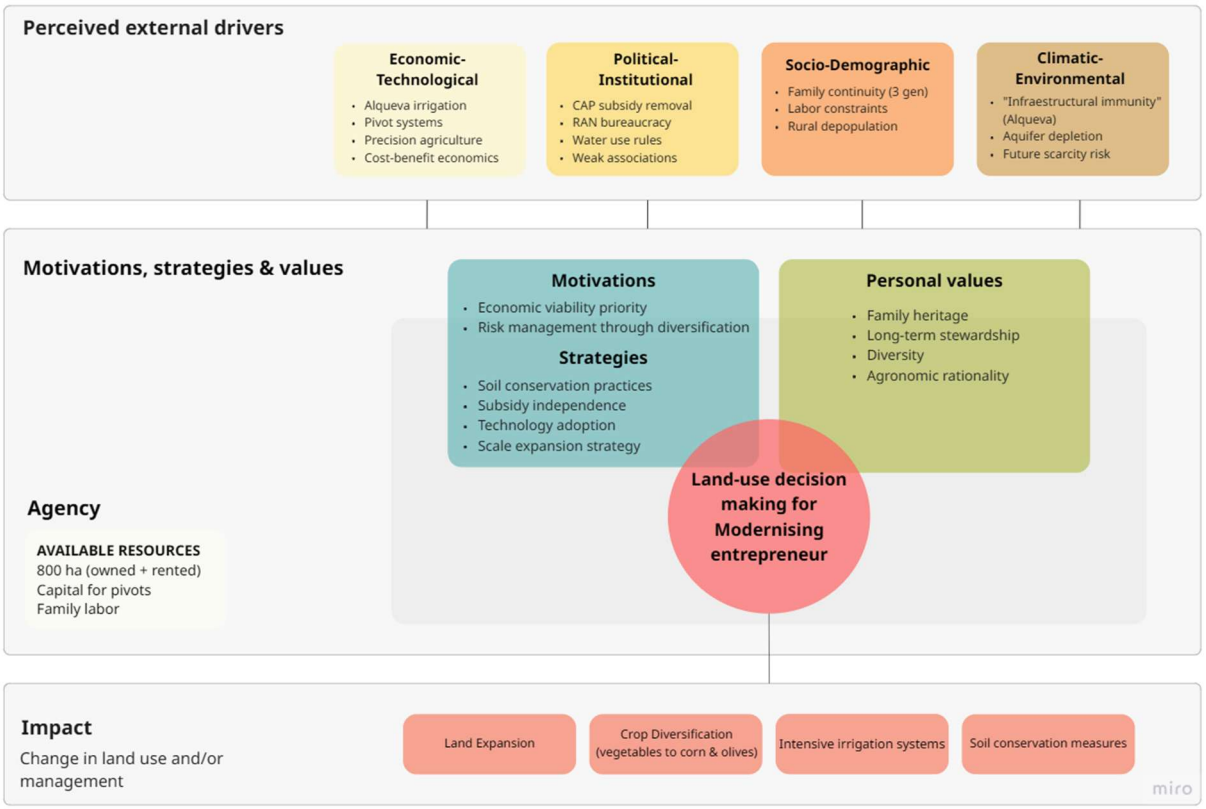

Figure 8: Synthetic visual for the land-use decision-making process for the Modernising Entrepreneur Land User type

This third-generation farmer operates approximately 800 hectares across owned and rented lands, transforming an inherited vegetable-based farm into 50% intensive hedged olives, 45% pivot-irrigated corn, and 5% cereals following the arrival of the Alqueva irrigation system. Operations are managed within a family structure, combining multi-generational agricultural knowledge with economically rational decision-making and scale-oriented growth strategies made possible by public infrastructure investment.

Perceived external drivers

The Alqueva irrigation system's arrival 15-20 years prior constitutes the major **transformative economic-technological driver** in his perception:

> *"[...] the biggest transformation occurred when in Alqueva (region), permanent crops started". (#5, Intensive agriculture)*

His decision-making reflects a pragmatic assessment of investment efficiency:

> *"Investing in one hectare of tomato could match four or five hectares of corn, demonstrating how access to infrastructure fundamentally restructured production economics by reducing per-hectare investment requirements and enabling scale expansion." (#5, Intensive agriculture)*

The interviewee installed pivot irrigation systems across multiple lands, representing capital-intensive **technological modernisation**, distinguishing entrepreneurial operators from traditional farmers lacking financial capacity and/or risk tolerance for such investments. He implemented precision agriculture techniques and soil conservation practices, including no-till agriculture, cover cropping, and crop residue retention, well before CAP requirements. His pragmatism means direct seeding is used whenever possible, but minimum tillage or conventional methods are deployed in case of soil compaction or drainage problems.

Political-institutional drivers manifest through perceived bureaucratic dysfunction and policy misalignment. He criticises the bureaucratic processes for the National Agricultural Reserve (RAN), particularly those related to the approval of expanded storage infrastructure.

His strongest critique targets the removal of CAP subsidies for permanent crops, which he argues harmed medium-sized farmers the most. Funds investing millions annually are largely unaffected by subsidy caps of €300–350k, while medium family operations lost essential financing for installing permanent crops. The interviewee distinguishes his own farm from investment fund operations increasingly dominating Alentejo olive production (as funds of stock-market shift from petroleum to agricultural commodities). He holds directorship positions in three irrigation associations (two traditional, one EDIA representative body), but characterises this role as largely symbolic, with minimal decision-making power, describing the associations as having advocacy capacity but lacking decision-making authority. His frustration extends to EDIA's water management approach, which he criticises for prioritising reduced usage over water productivity.

His perception of **climatic-environmental drivers** operates through "infrastructural immunity" from direct climate impacts, with 100% of operations within the Alqueva irrigation influence area. However, infrastructural mediation does not preclude environmental awareness. He observes reduced aquifer levels and diminished stream flows in non-irrigated areas, while his irrigated zones maintain year-round water flow from continuous irrigation, creating artificial perennial streams through irrigation return flows. Environmental risk perception focuses on the future allocation of water, with apprehension about potential water transfers to the Algarve or Spain. He critiques permanent crop expansion for creating inflexibility during drought, distinguishing his mixed annual-permanent system from olive monocultures, which are vulnerable to water restrictions. He advocates strict water allocation rules and permanent crop licensing, and perceives diversified annual-permanent systems as flexible when water becomes scarce. Regarding renewable energy, he accepts photovoltaic expansion but advocates its placement on marginal rather than productive agricultural land:

> *"I do not chase funding. I do my activity. If there is support, I will take it. If not, my activity continues the same." (# 5, intensive agriculture)*

Motivations, strategies & values

This reflects confidence in the structural robustness of his production model and a deliberate refusal to depend on subsidy frameworks. Economic primacy coexists with a strong cultural attachment to annual cropping systems inherited from his father's vegetable production tradition, which explains why olive expansion occurred only in "leftover" areas despite superior profitability, rather than replacing corn pivots. Family continuity supports this strategy, with the

recruitment of his nephew providing specialised labour for olive grove management, allowing the interviewee to maintain focus on annual crops.

Diversification is described as an inherent value, reflecting risk-management logic in which a balanced crop portfolio reduces vulnerability to market fluctuations and production failures. His emphasis on soil as the principal asset and commitment to long-term conservation practices demonstrate a stewardship-oriented approach that frames as agronomic rationality rather than ecological ideology.

Social responsibility emerges in concerns about employment and the decline of the rural social fabric. He contrasts his family's operation with investment funds, criticising the depersonalisation of agriculture when absentee capital replaces resident farmers. What started as an inherited farm of 180 hectares in the 1990s, focused on tomato and sugar beet production, evolved to a farm of approximately 800 hectares with intensive hedge olive systems (≈ 360 ha), pivot-irrigated corn (≈ 360 ha), and rainfed cereals (≈ 80 ha). This mirrors the broader regional transition from cereal to permanent crops, while maintaining a deliberate annual-permanent balance. This distinguishes his trajectory from pure intensification models typical of investment fund operations.

Impact

Expansion involved sequential decisions informed by risk management: first abandoning unprofitable vegetables when Alqueva arrived; then massively scaling corn production through the installation of pivots on rented and purchased lands to achieve economies of scale; finally, adding intensive olive production once operational scale and specialised family labour were secured. Olive groves were placed around existing pivots rather than replacing them, using parcels unsuitable for pivot geometry, producing spatially fragmented olive blocks (parcels of 10-20 ha distributed across properties) that reflect both land constraints and diversification principles.

Soil management outcomes include cessation of burning practices, retaining crop residues, introducing cover crops (vetches and legumes), and adopting direct seeding where feasible, resulting in visible improvements in soil structure. Hydrological impacts include year-round stream flow maintenance within irrigated zones, contrasting with severely depleted flows elsewhere, creating localised artificial wetlands from irrigation return flows that paradoxically support riparian vegetation and associated biodiversity in otherwise drought-affected landscapes. Visual landscape transformation involves geometric pivot circles and linear olive hedgerows replacing traditional extensive cereal and *Montado* systems, though this maintenance of crop diversity moderate's homogenisation compared to pure olive monocultures. Employment impacts include workforce expansion, though constrained by labour availability, particularly skilled agricultural positions, and the maintenance of social infrastructure through continued local residence and community engagement. His explicit resistance to regional-scale monoculture positions him as a critical moderniser rather than an uncritical intensifier. He recognises that collective vulnerability arises when individual rational decisions aggregate without coordination mechanisms to ensure landscape-scale resilience and water system flexibility during inevitable future scarcity periods.

6 Discussion and reflections

Across the four structural domains, distinct dynamics emerge. Economic–technological drivers, particularly Alqueva-enabled water access combined with market integration, create opportunity structures that favour intensive, permanent crops. Socio-demographic shifts (ageing, succession crises, labour scarcity, immigration) limit the continuity of extensive systems and constrain the capacity to adopt knowledge-intensive sustainable alternatives. Political–institutional architectures generate contradictory pressures: subsidies promote intensification while environmental regulations impose contested mitigation requirements. Climatic–environmental changes function both as drivers (water scarcity, precipitation variability) and consequences (biodiversity loss, soil degradation) of current transformations.

Organisations highlight excessive bureaucracy, insufficient compensation for ecosystem services, and weak integration between water, agricultural, energy, and environmental policies. While consensus exists on the ongoing expansion of permanent crops and renewable energy infrastructures, major uncertainties persist regarding future water availability, evolving markets for sustainable products, and the continuity of farming through generational renewal.

Organisations framings further shape these dynamics: production associations emphasise economic viability and technological solutions; conservation entities foreground regulatory gaps and the undervaluation of ecosystem services; public infrastructure organisations operate within legal mandates that balance development and environmental safeguards; rural development associations advocate for spatial planning interventions. These contested narratives actively constitute rather than merely describe land-use transformations.

Land-user interviews provide grounded insights with important implications for the region's future. As Interview 12 (extensive agriculture) observed:

> *"Maintaining traditional landscapes is essential for tourism, as intensive cultivation brings nothing economically to communities."*

Interview 7 (Beekeping) stressed that intensification is creating:

> *"biodiversity deserts", undermining ecosystem-dependent livelihoods such as beekeeping.*

Extensive traditional users embody a stewardship logic rooted in heritage, identity, and ecological prudence, calling for aptitude-based territorial planning and long-term, knowledge-oriented support. Ecosystem-dependent operators—acting as ecological sentinels—highlight how vegetation clearing and pesticide use erode the ecological matrices necessary for pollinators and other biodiversity. Small-scale quality producers reveal the tensions between heritage and survival: maintaining traditional systems while leasing land to greenhouses to secure income—an emblematic example of mixed, adaptive land-use mosaics. The trade-offs identified, access to water, scale-dependent policy effects, and cascading ecological impacts, show how policies

designed for modernisation can unintentionally reinforce the bifurcation between intensification and abandonment. As Interview 1 noted:

> *"Bureaucratic barriers disadvantage small farms, while subsidies favour large-scale transformation." (#1, irrigated agriculture)*

It also indicates that sustainable land-use policy must account for user heterogeneity, address scale-dependent barriers, and recognise the cascading impacts of individual decisions on collective landscape outcomes.

6.1 Methodological reflection

The study adopts constructivist-interpretivist epistemology, recognising that stakeholder accounts represent positioned knowledge claims shaped by institutional roles, professional backgrounds, and material interests. Nevertheless, convergent testimony across divergent stakeholder positions regarding certain structural factors suggests empirical robustness of key findings. Land-use changes in Alentejo are shaped by a complex interplay of factors, with the Alqueva irrigation project acting as a key catalyst for transformation. These drivers have created a "two-speed" landscape, generating both positive and negative effects: irrigated areas show socio-economic dynamism, including tourism and heritage landscapes valued as alternative economic assets, but also bring significant environmental pressures. Severe labour shortages are fuelling mechanisation and dependence on immigrant workers, while generational renewal remains a critical challenge.

Some methodological limitations arise from the two-level qualitative approach adopted in this study. First, the sample size, although diverse, remains relatively small, limiting the generalisation beyond the Alentejo context. Second, the gender imbalance among interviewees reflects the structure of the agricultural sector itself, but it reduces the diversity of perspectives captured. Third, this study did not include large agribusiness investors or corporate actors involved in olive and almond groves, or solar expansion, whose decisions significantly influence land markets and territorial dynamics.

Additionally, the high heterogeneity of land-user profiles, ranging from beekeepers with no land to modernising entrepreneurs managing over 800 hectares, makes systematic comparison challenging and requires careful contextual interpretation. The emotional and identity-based narratives expressed by traditional and small-scale producers also demand caution to avoid normative bias. Finally, the study's strong territorial focus means that the results are deeply rooted in the specific biophysical and socio-political conditions of Alentejo, providing transferability while strengthening local relevance.

6.2 Major Drivers and motivations influencing land decisions

Back to our case study-specific research questions:

- What are the external structural drivers of land-use change in the Alentejo region?
- What motivates the decision-making of regional land users?

Key factors include the decisive influence of the Alqueva irrigation system, the continued presence of dryland farming and *Montado* systems, persistent regional labour shortages, and the rapid expansion of the renewable energy sector. Although some patterns may resemble those found in other Mediterranean regions, certain dynamics, such as the "two-speed" landscape shaped by unequal access to irrigation, the interaction between agriculture and solar development, and the deep cultural and emotional ties to the land, are uniquely characteristic of Alentejo.

Across both levels addressed by our interviews, external economic and technological drivers, in combination with land users' motivations, emerge as the most influential forces shaping decision-making in Alentejo. The region's historical and cultural legacy, deeply rooted in agricultural traditions, intersects with current socio-demographic vulnerabilities, including depopulation and ageing, which create pressure to promote market-driven, profitable activities, such as intensive farming and tourism. This framework interacts with the political and institutional drivers, as the lack of regional policies and planning has led to the rapid expansion of monoculture and large-scale solar farms, which have become a defining factor in land-use transformation. To steer these trends with sustainable land-use goals, **policy and market instruments** must directly target the factors that land users identify as most decisive. This includes:

- Water governance and irrigation policy - water availability determines where agricultural intensification is viable and can therefore promote ecological intensification, crop diversification, and efficient irrigation practices.
- Simplification of funding mechanisms - farmers, especially small and medium producers, are unable to access EU and national subsidies due to administrative complexity. Improving accessibility and transparency could trigger substantial uptake of soil conservation, agroforestry, biodiversity measures, and climate-adaptive farming.
- Regional planning and regulatory frameworks - strong, ecologically grounded territorial planning could play a decisive role in supporting sustainable land-use decisions by guiding land allocation toward green infrastructure, biodiversity conservation, and nature-based solutions within both intensive farming and renewable energy projects. The current absence of such ecological planning tools has led to the uncoordinated expansion of monocultures and large-scale solar farms. By contrast, a strengthened, ecologically grounded territorial framework could align land-use transformation with landscape resilience, ensuring that agricultural and energy transitions contribute to ecosystem integrity rather than undermine it.
- Market incentives for sustainable practices - supporting high-nature-value farming, regenerative practices, diversified production, and ecosystem-service provision can make sustainable models economically viable.

As such, sustainable land-use management requires regional policies that reshape economic incentives, regulate land-use pressures, and ensure that agricultural, ecological, and energy systems evolve in an integrated way, rather than competing for land and resources.

6.3 Role of how specific context influences decision-making

Context is a decisive factor shaping every land-use pathway in Alentejo. It encompasses ecological and climatic, socio-demographic, historical, cultural, and institutional dimensions, all of which interact to define the feasibility, risks, and attractiveness of different land-use options. Ecological context is fundamental because it determines soil, climate, biodiversity, and land-use suitability for different agricultural.

- These transformations are enabled mainly by the availability of **water resources,** particularly through the Alqueva irrigation system. Water access functions as a critical enabler, buffering drought risk, stabilising yields, and defining the suitability of land for specific crops. This creates a sharp territorial divide between highly productive irrigated zones and rainfed areas in decline, where soil constrains and water availability limit intensification.
- Alentejo's exceptionally high **solar radiation** further shapes land-use possibilities, increasing the viability of renewable energy development and greenhouse agriculture. These solar-driven opportunities attract investment, reshape land markets, and introduce new territorial pressures—especially in areas where rainfed agriculture is marginal or where land can be easily converted to alternative uses.
- **Soil** is both an ecological foundation and a structural constraint. It defines where intensification is viable and where extensive systems are more suitable. When soil quality is poor, fertiliser-dependent or high-input systems are usually economically unprofitable. Interviewees noted long-term risks, such as loss of fertility under permanent monocultures; compaction from mechanised pivot-irrigated corn areas; and degradation of *Montado* soils under drought stress. Mismanagement of intensive systems, particularly Intensive olive and almond monocultures, accelerates soil erosion, organic matter loss, and compaction. Soil degradation is thus a cumulative outcome of policy and land-use choices.
- **Biodiversity** constitutes another critical feature of the ecological context. For the ecosystem-dependent users (e.g., beekeepers), the rise of "biodiversity deserts" caused by monocultures, pesticide regimes, and brush removal associated with CAP subsidies directly threatens their livelihoods. These shifts shape not only the viability but also the existential continuity of some ecosystems and land-based activities.

Socio-demographic trends in depopulation, ageing, and labour scarcity create a distinct decision environment in Alentejo. The collapse of local labour supply pushes some systems toward mechanisation and exit, influencing long-term investment, land-use choices, and the need for migrant labour.

Alentejo's **historical and cultural heritage** is associated with family legacy, territorial identity, traditional *Montado* management, and attachment to place, particularly among extensive

traditional stewards, who maintain landscapes and practices across generations despite economic pressures.

Regarding minority groups, immigrant workers, primarily from South Asia, Eastern Europe, and African countries, play a crucial role in labour-intensive agricultural sectors, such as horticulture, berries, and super-intensive olive production. While they sustain the functioning of intensive sectors, these workers remain absent from strategic decision-making, land ownership, and representation structures. Their marginal position shapes land-use decisions indirectly: labour scarcity and reliance on migrants influence crop choices, business models, and mechanisation strategies. However, despite their centrality to the agricultural economy, their voices and needs are not integrated into land-use policy debates.

6.4 Potential policy options

The **institutional and governance** framework, characterised by complex bureaucracy, fragmented planning, and a scale-biased regulatory framework, produces unequal effects across actors. For instance, CAP subsidy schemes and agri-environmental measures formally apply to all, but in practice favour actors with administrative capacity, financial liquidity, or dedicated staff, conditions more typical of large farms than of small-scale or ecosystem-dependent producers.

However, the interviews reveal surprising and sometimes ambivalent perspectives:

- Although economic–technological drivers are the most decisive, many farmers are unable to access EU and national subsidies because of bureaucratic complexity. This limits innovation and reinforces inequalities.
- Paradoxically, the interviews also revealed that land-user decision-making does not rely entirely on CAP funding. The CAP fails to function as an enabler, not only because of its bureaucratic burden but also because of the design of the subsidies.
- Interviewees in land-user types demonstrated awareness of the importance of protecting soil integrity and quality, recognising it as the foundation of their productivity.
- The ecosystem-dependent type (beekeeper) can be seen as an “ecological custodian”, whose livelihood viability provides a sensitive indicator of landscape simplification and biodiversity loss. However, his essential activities in promoting pollination remain almost invisible in policy design.
- The strength and persistence of emotional and identity-based motivations among all but the most financialised actors, even in a highly market-integrated region.

In the future, land-use decision-making frameworks (Cunha & Magalhães, 2019; Pena et al., 2025) may help promote sustainable intensification and balance agricultural productivity, biodiversity, and landscapes. This means combining intensive land uses associated with farming and renewable energy with ecological practices, soil conservation, efficient irrigation, landscape protection, and biodiversity promotion, offering a promising pathway to reconcile economic growth, social inclusion, and environmental stewardship. Such an approach can offer a potential policy option to explore, ensuring that intensification does not occur at the expense of ecological integrity or cultural landscapes. When aligned with local motivations and structural constraints,

these approaches can strengthen rural well-being, foster employment opportunities, and attract younger generations, helping counteract outmigration trends and reinforcing long-term territorial resilience.

6.5 Final Reflection

Addressing our umbrella research question: “How can we promote sustainable land-use management that integrates nature, farming systems, and energy?” implies placing ecosystem integrity, biodiversity conservation, and soil health at the core of territorial planning. Sustainable land-use in Alentejo must begin with safeguarding ecological functions, ensuring that both intensive farming and renewable energy expansion operate within the limits of landscape resilience. For intensive agriculture, this means promoting models of sustainable intensification that couple productivity with soil preservation, efficient irrigation, landscape heterogeneity, and reduced chemical pressure. Practices such as inter-row vegetation, organic matter restoration, regenerative soil management, and diversified cropping systems can maintain ecosystem services while supporting economic viability. Similarly, renewable energy development must be integrated in ways that do not compromise habitats, ecological connectivity, or the cultural landscape. Through integrated regional planning, ecological intensification, and nature-compatible renewable energy models, the region can move toward a land-use future in which economic development reinforces rather than undermines biodiversity, landscape identity, and long-term ecosystem resilience. Final reflections highlight the importance of designing land-use policies that account for drivers and motivations, alongside integrated regional planning, to promote sustainable intensification and balance agricultural productivity, biodiversity, and landscape. The current study provides an empirical contribution relevant to Portugal, which could be expanded to other Mediterranean regions facing comparable socio-ecological changes and climate change challenges.

Appendix

Appendix 1: Characterisation of land users interviewed in this study

Interview	Gender	Age	Land User Type	Subregion	Dimension	Main Activities
1* (*two interviewees)	F/M	47/46	Small producers	Odemira - Costa Vicentina (Litoral)	30 ha	Sweet potato (5-6 ha), livestock (limousine cattle), 6 ha rented for berry greenhouses
4	M	40-65	Owner/manager	Ponte de Sor (Alto)	874 ha	Cork oak *Montado*, eucalyptus (~10%), pine, small irrigated area, cattle
5	M	58	Mixed owner-tenant (60% own, 40% rent)	Aljustrel (Baixo)	~1,000 ha	Intensive olive hedgerow (45%), maise (45%), barley (10%), conservation practices
7	M	50	Professional beekeeper (no land)	Mértola (Baixo)	17 apiaries	Honey and pollen production, beekeeping services
8	M	56	Mixed owner-tenant (family property)	Rio de Moinhos e Aljustrel (Baixo)	~960 ha	Livestock (sheep/cattle - primary), olive grove, cereals, cork
12	M	41	Co-Owner (with brother)	Reguengos de Monsaraz (Central)	~10 ha	Vineyard (primary), olive grove (2 ha), small orchard

Appendix 2: Characterisation of organisations interviewed in this study

	Organisation				Interviewee						
Interview Nº	**Broad Characterisation**	**Main public**	**Main Activity**	**Main Objectives**	**Role**	**Tenure**	**Age Group**	**Gender**	**Training**	**Land User**	**Activity/Land Use**
3	National irrigation competency center; mixed public-private entity	Irrigated agriculture farmers across Portugal (national scope, based in Beja)	Knowledge transfer, technical support for efficient water use in agriculture, soil characterisation and monitoring for EDIA irrigation perimeters	Support efficient agricultural water use and irrigation management; promote transformation to irrigated agriculture	Director/ President	Not specified	60-64	Male	Law (Jurista)	Yes	Owner and Manager: Olive grove and manages a small irrigation perimeter in Alandroal
11	Agricultural and livestock farmers association; private non-profit	2,100+ agricultural and livestock producers (southern Portugal, primarily Lower Alentejo and Algarve)	Sanitary services for 6 municipalities, technical support, Ovibeja fair organisation, laboratories (veterinary and olive oil), sheep shearing with Uruguayan teams, wool concentration, livestock commercialisation, small ruminant cadaver collection	Support and defend interests of agricultural and livestock producers; provide comprehensive services to members	President	Since 2016 (8 years)	65+	Male	Agricultural Engineer	Yes	Owner and Project Manager: Agricultural farm and agricultural projects office
2	Soil conservation and conservation agriculture association; private non-profit with national scope and international partnerships	~30 members including farmers, technicians, and academics	Knowledge transfer and dissemination through publications (manuals, guides, newsletters), demonstration fields, conservation agriculture promotion, research projects on carbon sequestration and climate change mitigation	Promote soil conservation and conservation agriculture practices; demonstrate environmental and economic benefits of minimal soil disturbance, permanent soil cover, and crop rotation	President	Almost 25 years	60-64	Female	Agricultural Engineer and Postgraduate in Farm Management	Yes	Owner and Farmer: irrigated annual crops, dryland oak *Montado*, livestock (cattle and pigs)
9	Public company managing Alqueva multipurpose project	Alentejo region (Central and Lower Alentejo, covering Évora and Beja districts); 130,000 hectares of irrigated area + 250,000 hectares for public water supply	Water distribution, irrigation infrastructure construction and management, environmental monitoring and impact minimisation, regional development catalysation, cultural heritage preservation, natural area management	Construct, manage, and promote Alqueva project for integrated regional socio-economic development; ensure environmental compliance with impact assessments	President	11 years	50-54	Male	Agricultural Engineer and Master's in Business Management	No	NA
6	Local development association focused on Mértola territory; private non-profit with international projects (Mozambique, Cape Verde, São Tomé and Príncipe)	Mértola municipality population and stakeholders (associates are primarily local residents)	Sustainable development in dryland/sequeiro extensive production systems, soil erosion combat, climate change adaptation, extensive livestock promotion, *Montado* preservation, water resource management; activities in environment, culture, and social support	Promote sustainable territorial development through resource valorisation (human, cultural, patrimonial, environmental); increase farmer income and environmental sustainability of extensive production systems	Technician and Project Coordinator	Not specified	-	Female	Geography degree and Master's in Ecosystem Restoration	Yes	Farmer: in a traditional olive grove and involved in extensive pastoralism promotion initiatives
10	Olive oil producers association; private non-profit representing major sector share nationally	Olive grove producers managing ~53,000 hectares of olive groves and 20 oil mills (representing 70% of national olive oil production)	Sector defense and representation, communication and knowledge dissemination, promotion of modern intensive olive farming practices, technical support for producers	Defend olive oil sector interests; promote communication between producers, industry, and society; support adoption of modern, sustainable olive farming techniques	Project Manager	3 years	45-49	Male	Agricultural Engineer	Yes	Owner: 600-hectare property in Ourique with Alentejo pigs and sheep in an extensive dryland farming system

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Project Partners

MOSAIC

MOSAIC is an EU-funded project working to understand and influence how land-use across Europe is managed.

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Annex 4 - Drivers and motivations for land-use change in the Danish case

Clara Ryge and Jette Bredahl Jacobsen

MOSAIC

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Abstract

This chapter has investigated drivers and motivation of afforestation in Denmark. It is based on literature from the case area, two MSc theses, a qualitative study done in parallel to MOSAIC by colleagues, and a quantitative study inspired by the qualitative. Additionally, interpretations have been related to discussions in the policy lab, especially the event "Skovkonventet 2025" where the ambition of how to reach a policy goal of afforesting 250.000 ha was heavily discussed.

The development in land prices is a main driver identified as both a motivational factor and a barrier: there are many competing land uses, and this drives up land prices. At the same time, private amenity values play an increasing role, and this is found to be capitalised in the land price. Hence it can also act as a lever.

Competing land uses is also reflected in competing incentives (e.g. subsidies for afforestation and for extensive grassland) which compete for the same land. This can act as a barrier for the individual goal – here afforestation.

Turning to the motivations, private amenity values in the form of joy of ownership, nature interests, hunting and own outdoor recreation are found as main motivational factors in both the qualitative and quantitative studies. Potential forest income only play a smaller role. Among the barriers, the need of land for agricultural production is found to be a main barrier, along with the associated opportunity costs. Afforestation in Denmark comes with a permanence restriction. This is also seen as a main barrier among landowners and other stakeholders. Not least in the uncertain world, where both market and policies may change in the future. This latter point is hence investigated further in D3.2.

1 Context and framing of the land-use change

The Danish policy lab (LP) is situated in a context of currently politically driven land-use changes. During centuries, Danish forests were overexploited, resulting in very little forest cover and largely degraded forests (by grazing and overharvesting) by the beginning of the 19th century (Sand-Jensen & Møller, 2017). A forest law was made in 1805 with the aim of protecting and restoring remaining forest. Hence, requirements of permanence were implemented – forests could not any longer be converted to other land-uses. This restriction is still present today. Since 1805, afforestation has taken place, with different policy motivation – in the beginning soil conservation (preventing inland dune creation) and wood production, then from the 1980ies utilisation of less productive soils, and later on motives like outdoor recreation, biodiversity conservation and carbon sequestration as been main drivers. The last 30 years or more, it has been possible to obtain subsidies for afforestation on private land. The entire country is divided into zones where afforestation is wanted or not wanted (e.g. due to landscape conservation). In the autumn 2024, a political deal was established between agricultural NGOs, nature conservation NGOs and the government on reducing GHG and nitrate emissions from agriculture. A key element of this agreement is afforesting 250.000 ha of agricultural land (or 6% of the surface area of Denmark) and setting areas aside for extensive land-use (The Danish

Government, 2024). The afforestation ambition is the key object of interest in WP3. The reason for this is that the goal is so ambitious in terms of size, that it can only be reached if most of the barriers are overcome. The scale of the project is the entire country (approx 43.000 km2)

A part of the political agreement is, that land-use changes is to be decided by local tripartite groups. There are 23 of these – one for each watershed (as N leakage is a main policy objective too). In each group, local stakeholders (the government, municipalities, local farmer organisations, and green NGOs) agree on how to fulfull the goals (primarily assiging potentials for afforestation, reduced N leakage into surface water, sensitive drinking water areas and areas for biodiversity conservation). Further, voluntary incentives are key, i.e. private landowners cannot be forced to change management. Hence, understanding the motivations and drivers for the landowners is key, and is focus of this study.

72,5% of the Danish area is agriculture (as of 2016, Statistics Denmark statistical code AREALAN1) of which the largest share is privately owned. Again, this points at the importance of understanding motivations and drivers as seen by private landowners.

In 2020 there were 7500 full time farmers of which men constitute 94%, 50% are 55 years or more (Pedersen et al., 2022). Hence the key research objectives is to understand private land owner motivation for afforestation - what drivers and barriers affect their choice of afforesting or not.

2 Methodology

In order to understand drivers and motivation of land-use change, we started out with an overview of the literature as also reported in T3.1, combined with a literature search on specific Danish studies looking at land-use change. This search was conducted in both English and Danish.

Parallel to MOSAIC, various other reports have been made investigating the drivers and motivations of afforestation (Broch & Vedel, 2012; Guyard & Lundhede, 2023; Vedel et al., 2015) . In particular Guyard et al 2023 conducted an inductive qualitative study where 19 landowners and forest consultants were interviewed to understand barriers and drivers for afforestation on private agricultural land. Building on this study, a quantitative survey has been carried out, to better understand and quantify the drivers and barriers for afforestation and to allow for generalisations. The details of the survey development is reported in Ryge et al (2025), but brief details given here. The survey was carried out from October to December 2024 and distributed to 6.231 landowners which were randomly selected from The Danish Agricultural Agency's list of all 29.654 CVR-numbers of landowners who in 2022 received the basic income support for sustainability (EU based subsidy). The questionnaire was approved by the ethical committee at Faculty of natural science and Faculty of health before distributing it. The sample consisted of 50% "large landowners" who were defined as landowners getting basic income support for sustainability on more than 50 ha and 50% "small landowners" who were defined as landowners with a registered area below 50 ha. The sample was randomly drawn within the two groups. Gender, and other socio-demographic factors are therefore represented according to the population. While we do not know the true gender distribution in the population (numbers above

are for full-time farmers only), we know it is male dominated. Surveys of the kind used here (choice experiments) often have a slight over-representation of females (often attributed to higher tendency to responding). We don't know if that is also the case here. But we observe a low female proportion. 786 landowners responded to the survey, giving a response rate of 12,6%. The distribution of respondents on socio-demographic factors are presented in Appendix A. Data are pseudo-anonymised and stored on a secure server, hosted by University of Copenhagen and living up to legal requirements of GDPR.

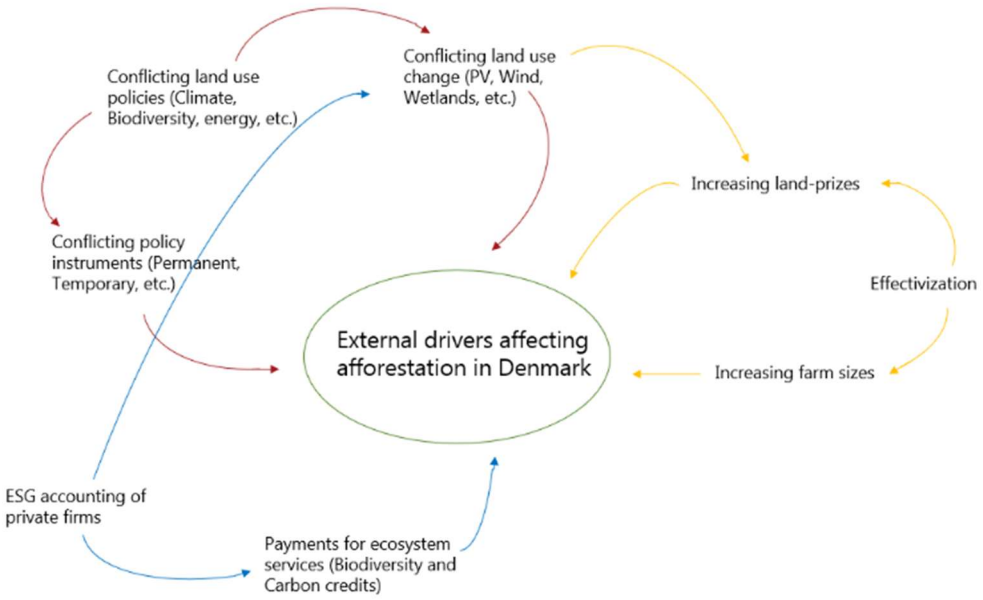
The questionnaire is comprised by three main sections, a section where the respondents are asked a line of questions regarding their property and definition of it in the context of farming, their relation to afforestation, whether they have previously done afforestation on their land and reasons for and against and whether they have plans to do afforestation and reasons for and against. The second section is a choice experiment where different contracts are presented, and the landowners are asked to choose between them or a business-as-usual scenario. The third section contains questions regarding their attitude to different statements and some socio-demographic questions. This report consists of result from the first and last section of the questionnaire. The middle section about the choice experiment relates to the uptake of incentives and will therefore be reported in D3.2.

Additionally, two MSc theses have been directly associated with MOSAIC: Kennedy (2025) conducted an analysis linking which motivational factors different land-use change policies in Denmark addresses. This is based on a document analysis of the policy instruments themselves linking the characteristics of the instrument to motivational factors identified in the literature. Lehner (2025) relied on the quantitative data from Ryge et al (2025) and combined it with qualitative interviews conducted after analysing the quantitative ones. This allowed for an ex-post analysis to supplement the causal interpretation of the results.

Finally, results from Ryge et al (2025) were presented at a stakeholder workshop and findings were discussed by practitioners. The purpose were two-fold: to provide feedback on whether results reflect practioners' understanding of the broad picture, and to provide an input for practioners in their decision making regarding the green three partite, and especially the local negotiation and coordination between landowners that were to be initiated.

3 Structural drivers of land-use change

Land-use changes continuously with societal changes. Figure 1 illustrates some of the main external drivers as identified in the project. The main input for these is a literature review, but also discussions with the policy lab partners.



1. *Figure 1 llustrating some of the main external drivers affecting landuse change for afforestation in Denmark. Colours of the arrows are only meant to make links more visible.*

Following the theoretical von Thünen model, forest is an extensive land-use, and hence afforestation will often take place on land of lower productive value and further away from markets (Rogers et al., 2013). Production should in 2025 be seen as both production potential for agriculture, but also urban development, industrial development, energy infrastructure, etc.

Campell et al (2014) estimate large welfare economic values of public goods from forests (recreation, biodiversity conservation, water provision). But not all ecosystem services from forests are public – some are also private. For example, Lautrup et. al (2023) show that private forest amenity values influence land prices positively, especially for small properties. Thorsen (2010) show how forest land prices have developed over a 50year period compared to the productional value showing a much higher increase in forest land prices than production value increases can explain, and he uses this to discuss whether amenity values or land price speculation (or both) is the main driver. Hence looking at land price development is a starting point for understanding the structural drivers of afforestation.

Starting at the right side of Figure 1, the yellow arrows indicate aspects related to **land prices**. A key factor here is agricultural production. Seen in a time perspective since the second world war, we have seen an increased intensification, and a trend towards larger farm sizes. This has also

led to increases in land prices. If we zoom in on the more recent development, from 2015-2024, a lans price increase of 16% can be observed (Statistics Denmark 2025, LPRIS37). The increase in prices is not solely driven by a demand for agriculture. Figure 2 shows the development in the price index for agricultural properties, and as is seen, it is not showing the same increase as the land prices per se.Hence, other competing interests for land is also driving up the land prices.

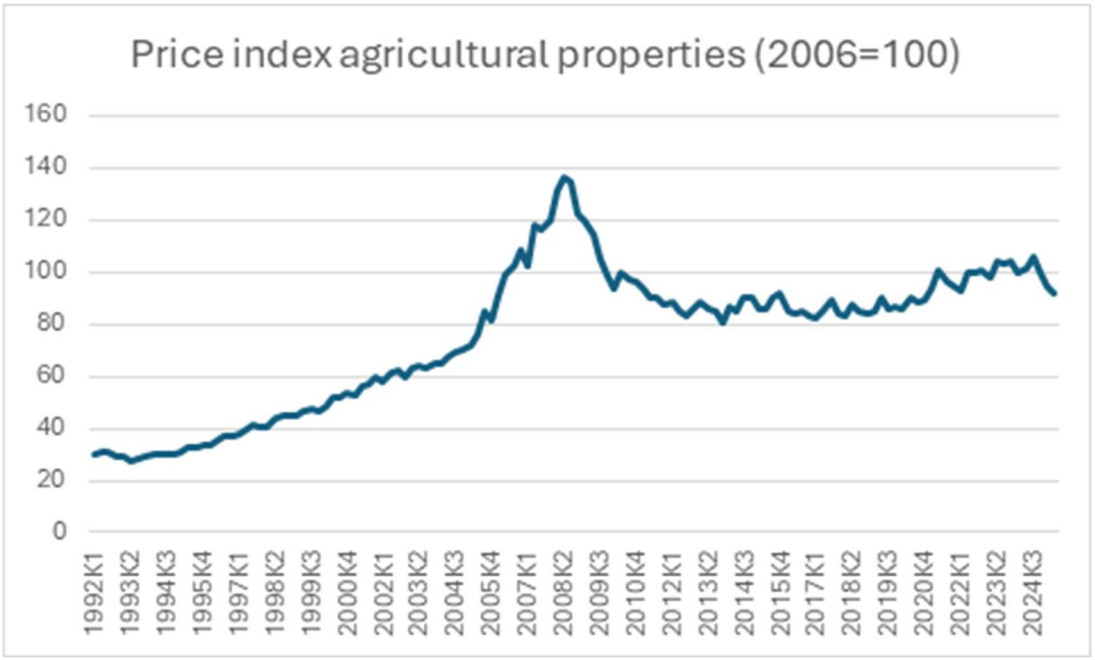


Figure 2 Price index for agriculture in Denmark, 1992-2024 for each quarter (K). This includes both the pure land value and the value of the farm (infrastructure, etc) per se.

While we do not have the price statistics yet to document it, some stakeholders in the policy lab are saying that they see large increases in land prices after the green tripartite agreement from 2024.

Forest production also provides a financial benefit. Jørgensen et al (2025) have shown soil expectation values for forestry in the range of -40.000 DKK to 500.000 DKK, depending on which afforestation type, soil condition and interest rate we are looking at. This should be combined with capital value of opportunity costs in form of lost agricultural production of 40.000-150.000 DKK (Jørgensen et al., 2025).

Another factor influencing afforestation is **competing land-uses**, c.f. the red arrows in figure 1. In recent years photo-voltaic development has become important, as well as private land conservation . For example, large private foundations are buying up land for nature conservation This also affects land prices. But it also leads to policy interventions as indicated by the red arrows. Here we see various conflicting instruments and conflicting land-use changes. As Kennedy (2025) shows there are many policies with some degree of overlap, cf. figure 3, and as Jørgensen et al (2025) argue, this also lead to competing policy instruments.

The increasing land-use prices combined with the competing land-use policies and national Danish goals of afforestation (The Danish Government, 2024), provide a large share of uncertainty for landowners and are some of the external drivers that make them reluctant in joining into permanent schemes as afforestation, where there is no irreversibility in terms of land-use change (Bisgaard, 2024; Hansen, 2023). This was also backed up at the stakeholder event February 2025, where a conclusion from a discussion of barriers concluded that the political environment with shifting policies give rise to uncertainty and reluctance to enroll.

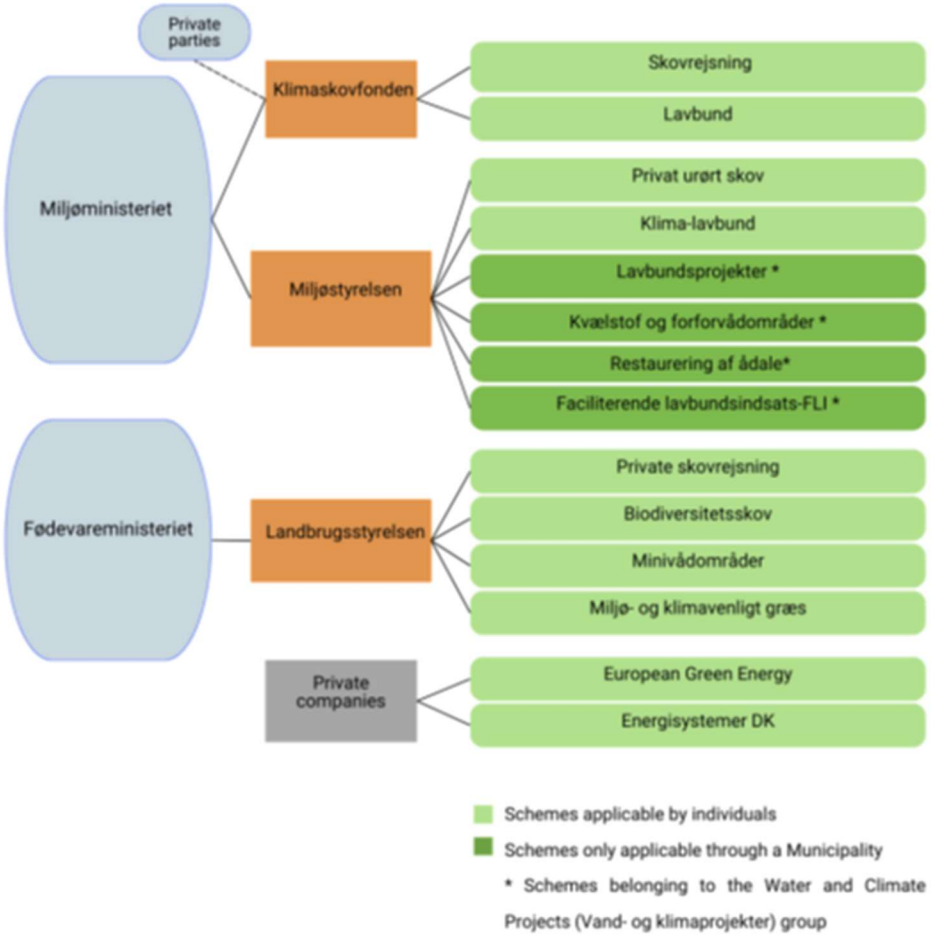


Figure 3 Land-use change related policies are organized under two ministries (environment and food; left part of the figure), a number of implementing institutions (Middle) and specific instruments (green to the right) Source: Kennedy (2025).

The last set of arrows in the figure comes from an increasing **ESG reporting requirement** for private companies, including farms. As climate change is becoming more visible, many companies do not only comply with required regulations but want to show that they take a larger responsibility. Afforestation is one of the few ways where CO2 can be removed from the atmosphere, and at the same time provide various co-benefits (ESABCC, 2025). Hence it is attractive for CO2 emitters - both farmers emitting greenhouse gasses from other parts of production, and for other actors (such asindustries with hard-to-abate emissions) wanting to show contribution. This is the basis of the Climate Forest Fund (see WP2 of the project) but also

of a number of other actors selling voluntary carbon credits. Despite an emerging market for voluntary carbon credits, the current possibilities for companies to benefit from amenity values as carbon or biodiversity from afforestation are limited and unsecure and might prevent companies from investing. This was backed up at the stakeholder event February 2025, where stakeholders reported that an external barrier for doing afforestation as a company was the lack of structural incentives for companies to fund such activities since possibilities to report of synergy-effects from afforestation are lacking.

4 Motivations influencing land-use decision making

The actors analysed in the Danish PL are land owners as the land use changes analysed are planned to be implemented by volumtary agreements with individual landowners.

Figure 4 provide an overview of the external drivers as describe above and the motivations and values. A key driver for the land-use change in focus, afforestation, is the external policies and policy instruments, and their alignment or lack of so with personal values and motivations is key (cf Kennedy, 2025). Likewise, climate change is increasingly being observed and hence a direct driver for action. Social surroundings also play a role. The motivation and values of farmers is in the figure split in two – one called farm optimisation, and one called personal values. The personal values are largely relational values, but may hold both instrumental and intrinsic values as well. The points mentioned under farm optimization is to a larger degree instrumental values. This points at all three types of values being present for the individual farmer. In the following, we will elaborate on the motivations and values.

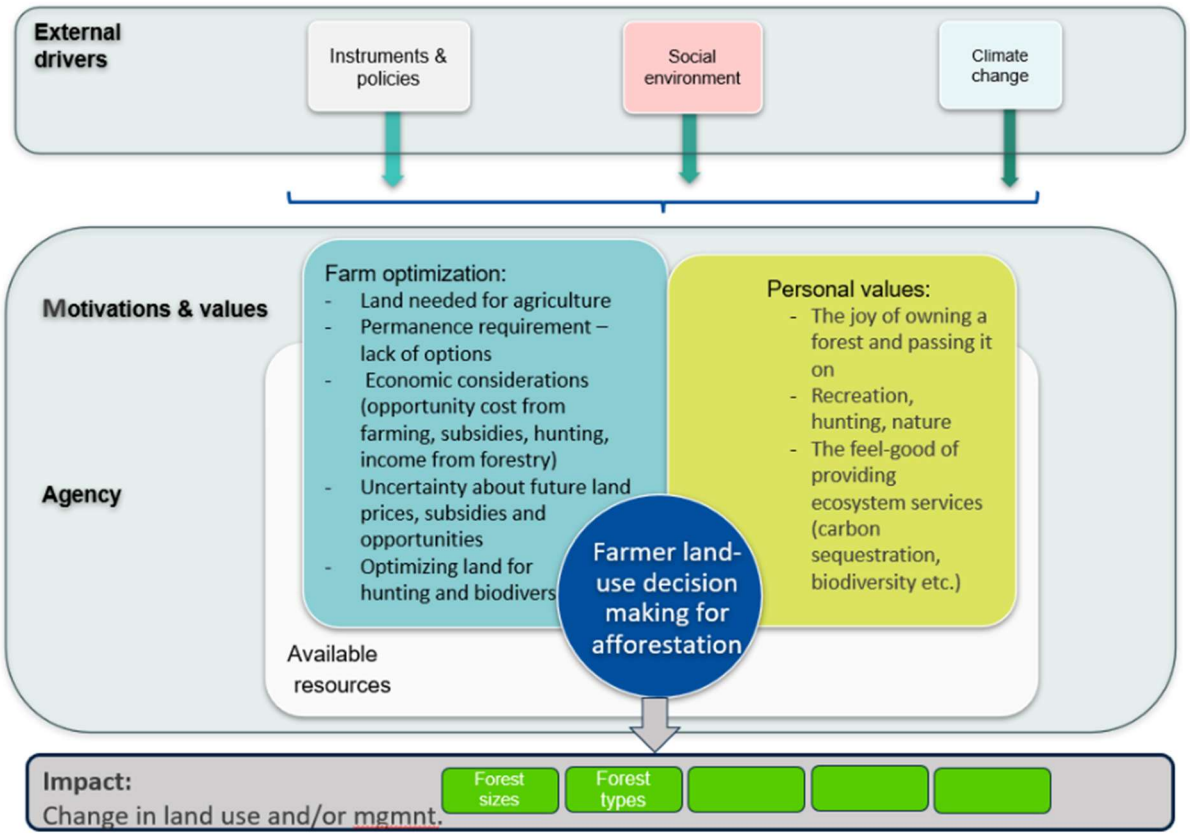


Figure 4 Motivational drivers and barriers for afforestation in Denmark

In the **qualitative study** from 2024 Guyard et. al. found that the main drivers for landowners to do afforestation on their property were the joy of owning a forest, private recreational values and hunting. Common for the interviews was, that the respondents emphasised on the amenity

values and that the values tied to the forest as a production system, producing timber, were not a main driver for doing afforestation. In the study they also investigated barriers for afforestation on private land and here the landowners mentioned the length of the process for applying for the afforestation schemes as a financial barrier. Such a barrier is supported by the MSc thesis associated to the project by Kennedy (2025) emphasizing that the smoothness of policy instruments applications is a main factor for action following on motivation. Other barriers mentioned by Guyard et al (2024) were restrictions in the contracts, restricting certain forest types and structures, but also the aforementioned permanence restriction – that forest land cannot be converted, i.e. there is no option of cancelling the contracts.

The **quantitative results** of drivers and barriers are somewhat in line with what was found in the qualitative study. Of the total 786 landowners 41% had some interest in doing afforestation on their land and correspondingly 59% said that they had no interest in doing afforestation on their land. The landowners were asked about their main reasons for and against afforestation. Each respondent who had confirmed interest in afforestation could choose three main drivers. The drivers which most respondents chose as was the joy of owning a forest, the value of passing on something positive for next generations, the value of increasing biodiversity on their property and hunting. Other drivers which were mentioned but by a smaller share of the landowners were the value of carbon sequestration/carbon credits, wood production and recreational values besides hunting. The drivers which only a small share of the landowners chose were groundwater protection and protection of water ways.

The main barriers which were chosen amongst the landowners who said that they were not interested in afforestation in their property were that the land were needed for agricultural purposes, land restrictions which will be put on the land, when enrolling in a subsidy scheme, and the limited income from afforestation. This was backed up at the stakeholder event in February 2025 where a discussion concerning barriers circled around the Danish Forestry act and its restrictions. Of other factors affecting the motivation, Lehner (2025) finds the importance of what neighbours think about your management an important issue, and it was mentioned as a potential barrier.

Looking at the heterogeneity in motivations among farmers, we do see a **large heterogeneity** reflected in both the qualitative and quantitavie parts, but it is difficult to associate it with specific characteristics. Broch et al (2013) have investigated heterogeneity related to spatial location and the provision potential of the ecosystem services, such as groundwater interest, species richness, human population density, forest cover in the area and hunting. They find that human population density affects willingness to afforest negatively. A similar result is found in Lehner (2025) who point at the problem raised by farmers who have done afforestation in densely populated areas – that they don't like people walking in the forest (public access is allowed if the area is larger than 5 ha). On the other hand, possibilities of hunting affect the likelihood of doing afforestation positively – i.e. supporting the conclusion we also have in the study of Ryge et al. Sociodemographic heterogeneity is less studied. In our quantitative study, as a result of the random sampling with only a small share of female participants, we did not have enough information to see statistically significant differences between male and female perceived drivers and barriers.

When comparing the drivers for landowners who have already made afforestation and the ones who say they are potentially interested we find that biodiversity and climate sequestration/carbon credits have been increasing drivers. This is in line with two of the three motivations for the green tripartite agreement (water quality, climate and biodiversity) which was in its last part of negotiation at the time of the survey, but not yet agreed on. This indicates some alignment between private land owner motivation and policy. And may also indicate a trend in these. In an older study, Boon et al (2004) did not find climate and biodiversity as the main motivations for owning a forest. Of course there could be a difference between the motivation for forest owners and for those wanting to establish forests (afforestation Yet, it may be an indication of a change. The awareness of the climate debate has been raised in the Policy lab as a possible explanation.

In the current study (Ruge et al., 2025) no clear difference can be seen in the identified barriers between those who have done afforestation and those who are potentially interested.

Turning to the **afforestation subsidy scheme** and its link with motivational factors, Kennedy (2025) rate 5 different motivational factors depending on how well the scheme fulfil them. Four of these, risk attitude, self-efficacy, social norm and the potential for regretting entering the scheme rate negative, meaning that these factors affect the willingness to enrol negatively, and only one, pro-environmental attitude rate positive for the scheme from the Danish Climate Forest Fund, meaning that this factor motivates people to enrol. This positive relationship, aligns with the findings mentioned above in Ryge et al (2025) of the main motivations for afforestation. That the potential for regret is negative supports the finding from the other studies that the forest permanence requirement is a main barrier. Lack of self-efficacy may have to do with forestry requiring a different set of skills than agriculture – an aspect also mentioned in Broch and Vedel (2012). That social norms weigh negative is also indicated by Lehner, but interestingly it is not mentioned in any other studies. Kennedy also assess the ministerial subsidy for afforestation (cf Figure 4) and find somewhat better alignment with the motivational factors. This is surprising, given that the Danish Climate Forest Fund aims for exactly aligning better with the motivational factors. Kennedy also compare the support of different motivational factors of other subsidy schemes, see figure 4. As is seen, many score negative on the 5 criteria she assesses. Afforestation is somewhat in the middle, indicating that some of the schemes aligns better with motivational factors, and others worse.

Scheme	Risk Attitude (RA)	Pro-Env. Attitude (PEA)	Self-Efficacy (SE)	Social Norm (SN)	Potential for Regret (PFR)
1. Skovrejsning	-5.5	1.5	-5.5	-3.5	-5
2. Lavbund	1.5	1.5	1.5	3.5	2
3. Privat urørt skov	-5.5	1	-5	-5.5	-5
4. Lavbundsprojekter	-6	1.5	-7	-4.5	-6
5. Kvælstof og forforvådområder	-6	1.5	-7	-4.5	-6
6. Restaurering af ådale	-5	1.5	-6	-3.5	-6
7. Faciliterende lavbundsindsats-FLI	2	1.5	2	2.5	2
8. Klima-lavbund	-2.5	1.5	-3.5	-2	-1.5
9. Private skovrejsning	2.5	1.5	1.5	3	1.5
10. Biodiversitetsskov	-3.5	1.5	-6	-4.5	-6.5
11. Minivådområder	-1.5	1.5	-2.5	-2.5	-2
12. Miljø- og klimavenligt græs	-2.5	1.5	-3.5	-2	0
13. EU Green Energy	0.5	1.5	1.5	2	0
14. Energisystemer DK	-3	1	-2	-2	-3

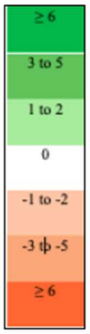


Figure 4 Scheme characteristics and how they affect different motivational factors. The two related to afforestation is number 1 and number 0. Colours indicate alignment (green) or disalignment (red). Source: Kennedy (2025).

Risk and uncertainty play a large role in all the sources of data we have investigated. Kennedy (2025) rates it negative, Jørgensen et al (2025) and Ryge et al (2025) mentions uncertainty of future policies as an important barrier and also earlier studies such as Thorsen (1999) mentions it as a potential barrier of conservation or land use changeuncertainty, though looking at it more broadly as market uncertainty. Because of the limitations in changing land-use once The fact that afforestation is done, irreversible, it is perceived as ility comes in as a main barrier. This will be investigated in relation to incentive design in deliverable 3.2

The focus in this report has been on doing afforestation per se. But obviously, these different values and motivations play a role for **which kind of afforestation** is being made – how large a forest is being established, which type of forest etc.

5 Reflections

5.1 Methodological reflection

Motivations and barriers has in the Danish case been analysed qualitatively by a number of studies already when MOSAIC started, and supplemented by Master theses. This caused that the **emphasis could be more on the quantitative side**. The quantitative study has confirmed the qualitative findings, but has further allowed to assess the question of how widespread given opinions are, and how important they are relative to each other (see Ryge et al., 2025 for details).

The quantitative part is based on a **stated preference study**, where respondents consider what they may do in the future. Whether they will in fact do it at the end of the day is not given. Therefore, in the next part of WP3, we will also look retrospectively at similar incentive schemes to assess to which degree it carries over to concrete land-use changes.

5.2 Major drivers and motivation influencing land-use decisions

Land price development is a main driver for land-use: it can both act as a barrier and a lever for afforestation. Historically we have seen increasing land prices, also for forest land, which cannot be explained by production. Instead amenity values are suggested in the literature to play a large role. This is confirmed by the studies conducted here in MOSAIC on the motivational factors – hunting, own outdoor recreation, biodiversity and the intangible "joy of ownership" are considered the main motivational factors in both the qualitative and the quantitative studies. Through discussions in the Policy Lab, it has also been suggested that a wish to take personal responsibility for public goods like biodiversiy and climate may play a role.

The main barrier identified is the need of land for **other purposes**. Second, the restriction that **afforestation is a permanent land-use change** is identified as a main barrier. Last, in population dense areas, the access of the general public is raised as a concern by many.

5.3 Case specific characteristics that may influence decision making

The drivers and motivations for the afforestation analysed in the Danish PL are, like in any case, specific to the setting.

First of all, it is a **national policy**. And it is centered around a narrative of green transition, where all sectors have to contribute. This is a rhetoric that has been articulated in the **climate debate** for at least 10 years: we do not reach the national policy ambitions without. This need, is similar in other EU countries, but our (subjective) impression is, that the debate is more advanced in Denmark – the Danish agricultural sector has realized that they play an important role. A driver of this is, that the emission heavy industry in Denmark is relatively small and the agricultural emissions relatively big – compared to many other European countries. As emissions continue to reduce throughout Europe, emissions from agriculture will play an increasing relative role. Hence, there is much to learn from the Danish case.

Another characteristic that play an important role are **the many small hobby/parttime farmers and few large farmers**- who then manage large parts of the area. This uneven distribution is also

seen in other European countries, but the fact that the small farmers are not dependent on the farm income is more pronounced in some countries than others. This means that designing incentives may target one group more than another. Many of the learning points may be easier adoptable in countries that are also facing this divide between "horsification" and "intensification" like in Belgium. Yet – the development towards few larger farms is seen Europe wide.

Finally, a characteristics of the Danish agricultural landscape is, that it is to a large extend, the **landowner who manages the land**. This is as opposed to the many countries where the farmer rents the land.

5.4 Possible policy options

The Danish afforestation policy goal is ambitious – if it is to be reached, it requires that a lot of landowners enter. While compensation that covers the marginal opportunity costs seems feasible, the need for agricultural land is an issue.

We see farms getting bigger and bigger in order to be competitive. Hence, allocating land, even small shares, is not only a question of marginal costs, but on the whole economy of a farm. Hence it is not surprising that the need of land for agriculture is a main barrier. At the same time, we see smaller farms, especially closer to cities, being bought by hobby-farmers. These properties are bought for private amenity values, and hence it is not surprising that afforestation seems a better option on these farms. However, small forests fulfil the goals of the policy less: despite the target being a measure in hectares, the underlying ecosystem services targeted are biodiversity, carbon sequestration and water quality. Biodiversity requires larger coherent areas. You don't get that with a few hectares here and there. Public access is only allowed if the forest is above 5 ha, again: size matters, and public access may not be attractive for a small farm – not least if it is a property that serves more as an extended garden close to a larger city. Carbon sequestration is easier in an afforestation mosaic – but makes it administratively more expensive. And likewise with water, where the precise location matters. Hence the motivations of private land owners may conflict with the underlying goals which will **require larger coherent areas**.

However, it is important **to align the policies with these motivations** if the afforestation goal is to be reached by the use of voluntary incentives. Hence, designing policy instruments that takes this into consideration is key. And will be the topic of D3.2.

Appendix

Appendix 1: Distribution of answers to the quantitative survey

	Share of respondents who have answered the questions
Sex	
Men	83.0
Women	4.6
Other	0.3
No answer	12.1
Age	
20-39 years	4.3
40-59 years	31.7
60-79 years	49.4
80+ years	14.4
No answer	0.3
Household income	
0-24,9 t DKK	6.9
25-49,9 t DKK	20.6
50-69,9 t DKK	16.4
70-89,9 t DKK	11.4
90-99,9 tDKK	3.3
More then 100 tDKK	14.2
No answer	27.2
Regions	
Hovedstaden	6.1
Midtjylland	26.2
Nordjylland	16.0
Sjælland	14.4
Syddanmark	24.6
No answer	12.6

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Annex 5 - Drivers of large scale photovoltaic and wind power land-use change in alpine Switzerland

Marc Reusser, Jonas Schwaab, Jan Hartman, Adrienne Grêt-Regamey

MOSAIC

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Title Image: *Solar PV Austrian Alps,* CC-BY-SA-4.0, Mr ccep, https://commons.wikimedia.org/wiki/File:Solar_PV_Austrian_Alps.jpg

Abstract

This case study examines the drivers of land-use change linked to alpine photovoltaic (PV) development in Switzerland, a key component of the country's strategy to expand winter electricity production. Ground-mounted PV projects in high-elevation landscapes raise tensions among national energy goals, landscape identities, tourism, agriculture, and biodiversity protection.

Using a mixed-method approach combining stakeholder workshops, Photovoice, choice experiments, cognitive-psychological experiments, spatial analysis, and municipal voting data, we identify the structural, perceptual, and governance factors that shape decisions about alpine PV.

Developers prioritize cost-efficient and technically feasible sites, particularly those close to existing roads and grid infrastructure, while biodiversity considerations play almost no role in early-stage site selection. Municipal approval decisions, by contrast, depend mainly on local acceptance and governance conditions such as ownership models, economic benefits and voting formats. Across methods, landscape type strongly influences acceptance: infrastructure is tolerated in already modified landscapes but faces resistance in pristine alpine regions, where place-protective values are strong. Physiological data reveal that high-infrastructure scenarios trigger stronger emotional responses, highlighting an affective dimension that is not fully captured by stated preferences alone.

These findings show how structural conditions, values, emotional responses, and institutional arrangements jointly shape land-use trajectories. The Swiss case illustrates that sustainable energy transitions in mountain regions require the deliberate integration of biodiversity considerations and acknowledgment of landscape meanings, both factors that are currently not integrated in site-selection. The Swiss case also shows that governance arrangements must be designed that foster trust and local benefit. These insights are relevant for alpine and mountainous regions across Europe facing similar trade-offs.

1 Context + Framing of Land Use Change

The Swiss Alpine region represents a complex social-ecological technical system where national energy transition goals intersect with local livelihoods, cultural landscapes, and sensitive ecosystems. Switzerland's commitment to phase out nuclear energy and increase renewable electricity production has generated strong pressure to expand photovoltaic (PV) installations, including large-scale ground-mounted plants in high-elevation areas. These projects promise substantial winter electricity output that are crucial for closing a possible winter energy supply gap. However, higher-altitude alpine installations have a direct impact on land use in the Alps, where tourism, agriculture, and conservation of pristine landscapes and prone ecosystems are highly interconnected. As a result, decisions about installing PV farms depend not only on technical feasibility and economic viability but are also deeply embedded in land-use conflicts involving landscape services, biodiversity, and local perceptions of landscape change.

The land-use change at the centre of this case involves converting alpine open land into energy production zones through the development of ground-mounted solar parks. While these sites are chosen for their strong solar irradiation, especially in winter, they represent a transformation from traditional toward energy producing landscapes, altering both the visual and functional role of Alpine landscapes in Switzerland.

Several actor groups play a key role in shaping these land-use changes. Developers, predominantly national or regional energy companies, initiate projects and negotiate with local authorities. Landowners (including municipalities, cooperatives, or private alpine corporations) act as critical gatekeepers by leasing land or co-developing projects. Municipalities, through assemblies or referenda, hold the authority to approve or reject projects, making local citizens central actors in the decision process. Cantonal governments are increasingly influencing outcomes by drafting spatial plans and aligning projects with cantonal energy strategies, while the federal level provides overarching policy instruments, such as the "Solar-Express," which offers subsidies and streamlined approval until the end of 2025. Taken together, these actors can be grouped into four categories: developers, landowners, citizens, and public authorities (municipalities, cantons and state).

Policy goals at local, cantonal, and federal levels align on expanding renewable energy while ensuring compatibility with other land uses. At the federal level, the "Solar Express" aims to accelerate alpine PV deployment for projects submitted by the end of 2025, thereby aiming to secure winter electricity supply. Cantons are tasked with drafting spatial plans that balance the expansion of PV farms with environmental and landscape protection. Local municipal policy goals often relate to ensuring democratic legitimacy (through assemblies or referenda) and reconciling development with local economic interests such as tourism or agriculture. Together, these policy goals create both incentives for rapid PV deployment and constraints to safeguard other land-use functions.

The goal of the WP3 case study in Switzerland is to generate evidence on the drivers and motivations of land-use change linked to alpine PV development. By combining stakeholder workshops, photovoice, choice experiment studies, cognitive-psychological experiments, spatial analyses, and voting data, WP3 aims to systematically identify how socio-economic,

perceptual, and governance factors drive the transition towards renewable energy landscapes in the Swiss Alps. With this approach, we aim to disentangle the structural and actor-specific drivers of land-use change linked to the siting and acceptance of alpine PV. Findings from this WP also feed into the MOSAIC Policy Lab to inform how energy transition policies can be better aligned with land-use values, and directly feed into the development of the Swiss SolarWind Explorer in WP5, a tool to support siting of renewable energy landscapes.

2 Methodology

2.1 Workshops to identify structural factors influencing land use change

To identify structural factors influencing land-use change related to renewable energy expansion, we organized a series of three stakeholder workshops between December 2022 and September 2023. The objective was to co-develop criteria for locating ground-mounted PV installations that minimize conflicts with landscape quality and biodiversity.

The first workshop (15 December 2022, 20 participants) brought together experts from federal and cantonal administrations and academia. Participants gathered and discussed existing legal constraints, planning instruments, and scientific evidence, focusing on exclusion criteria (where PV should not be built) and priority criteria (where expansion should be favoured). The collected criteria were refined after the workshop to clearly describe the requirements of potential development areas.

The second workshop (8 May 2023, 48 participants) expanded the group to include municipalities, the energy sector, and civil society. Through rotating group work across four thematic stations, participants revised and consolidated the draft catalogue of criteria, rated their usefulness, and highlighted disagreements between stakeholder groups. Participants were encouraged to propose new criteria where they felt the list from the first workshop did not meet their perspectives. The outcomes highlighted the need to consider solar and wind energy sources separately.

The third workshop (25 September 2023, 18 participants, online) focused on translating the criteria into practical parameters and datasets for cantonal spatial planning, with emphasis on PV installations. Discussions addressed implementation challenges and documented persisting divergences.

Across all workshops, the criteria catalogue was iteratively refined and validated, then circulated for consultation and final review. The process resulted in a consolidated, stakeholder-informed set of criteria to guide conflict-minimizing PV siting in Switzerland.

2.2 Photovoice experiment to identify drivers and motivation supporting land use change

To capture perceptions of alpine land-use change, we conducted a Photovoice exercise with stakeholders directly or indirectly affected by planned PV projects. Participants were invited to either provide their own photographs or select from a set of 17 images depicting existing or planned PV installations in alpine landscapes. Using these visual images, participants responded to a set of questions about their perceptions, hopes, and concerns regarding land-use change through solar infrastructure.

The sample included residents of a municipality where an alpine PV project is under discussion, as well as natural hazard scientists, climate and landscape NGOs, municipal administrations, federal authorities, energy companies, and farmers. Although not all groups responded, the diversity of perspectives provided a broad picture of how PV is interpreted across social, scientific, and professional domains. The guiding questions explored (i) first impressions and symbolic meanings of the landscapes, (ii) perceived risks and opportunities

of alpine PV, (iii) fears of loss (e.g. habitats, retreat areas, scenic value), (iv) conditions for acceptable development, and (v) the actors who should be central in decision-making.

The Photovoice method thus provided a qualitative, actor-centred view of how land-use change is perceived and negotiated in the Alpine context, as well as the motivations of actors involved, highlighting both potential sources of conflict and pathways for more accepted projects.

2.3 Choice experiment: to identify individual drivers and motivations to choose land use change

An online panel survey of Swiss citizens (N=844) was used to assess people's preferences for transforming the landscape with solar panels, windmills, and energy infrastructure (Salak et al., 2021; Salak et al., 2022). The questionnaire had two parts: (1) a discrete choice experiment (DCE) and (2) questions on meanings/experiences. Respondents completed 15 choice tasks comparing two renewable energy systems landscape scenarios, plus an opt-out option. Attributes were defined through literature and an expert workshop. Four key attributes were varied: landscape type, wind infrastructure, PV infrastructure, and high-voltage power lines. Fractional factorial D-optimal design (NGENE v.1.2.0) reduced 224 possible combinations to 30 alternatives across 15 randomized tasks. Analysis used a Multinomial Logit Hierarchical Bayes (MNL-HB) model. The model was estimated via Markov Chain Monte Carlo. Individual utilities from HB were then used as input to a Randomized First Choice (RFC) simulation. The two-stage approach (HB + RFC) produced estimates of the likelihood of choosing each scenario, enabling inference on Swiss citizens' preferences for renewable energy landscapes.

2.4 Cognitive-psychological experiment: to identify individual drivers and motivations to support land use change

To gain a spatially explicit understanding of the affective drivers underlying support for the implementation of renewable energy infrastructures within specific landscapes, we measured participants' physiological (electrodermal activity) and behavioural (landscape preference)

responses to virtual stimuli depicting land-use changes across different renewable energy implementation scenarios (Spielhofer et al., 2021). The visual stimuli consisted of either a low or a high number of wind turbines and photovoltaic systems across seven landscape types of representatives of the main landscape types in Switzerland. The seven landscape types allowed to extrapolate the results across Switzerland. Participants were asked to choose their preferred landscape image from pairs of sequentially presented images while we recorded their electrodermal activity. The study recruited 101 young, mainly well-educated and environmentally oriented German-speaking students. Fourteen 30-second panoramic videos were created from 3D reconstructions of seven typical Swiss landscapes. LiDAR point clouds were coloured with high-resolution photographs and rendered in CINEMA 4D under constant atmospheric conditions. Each landscape had two versions, showing low- and high-renewable energy scenarios. Ambient sounds were recorded and standardised. Testing occurred individually in the Mobile Visual Acoustic Laboratory, a sound- and light-controlled aluminium cabin with three projection screens and surrounding sound. Skin conductance electrodes were attached to the non-dominant hand to record electrodermal activity (EDA). After consent and baseline measurement (reading a short story), participants completed one practice trial followed by three randomised testing trials comparing pairs of landscape videos (high–high, high–low, low–low RES). After each trial, they chose their preferred landscape. Post-experiment questionnaires measured environmental attitudes, neighbourhood perceptions, and socio-demographics. Results were analysed using nested linear mixed models and Spearman rank correlations (Bonferroni-corrected) related both dependent variables to the high- and low-level visual features of the stimuli. The results provided a Swiss-wide map of citizen preference levels for renewable energy systems.

2.5 Spatial analyses to identify drivers and motivations to implement land use changes

In this analysis, we aimed to examine the drivers and motivations of decision-makers involved in the implementation of renewable energy systems, rather than stated preferences or affective factors influencing preferences, as investigated above.

Several stakeholders are involved in the implementation process: developers aiming to construct the PV systems. Most often, the developers are energy companies. Second, there are landowners who cooperate with the developers to sell or lease their land for the installation of the PV systems. In some cases, the landowners themselves are developers. Third, municipalities can accept or reject projects planned within their administrative boundaries. As a fourth actor, the cantons will soon become highly relevant, as they are in the process of creating spatial plans that define where PV systems can be installed and where they cannot.

We used, on the one hand, the structural factors assessed in the workshops (see 1) that are relevant when selecting sites for PV systems. On the other hand, we collected spatially explicit data showing where the installation of PV farms has started, is planned, or where it was planned until it was rejected by a municipality (Fig.1). This data can be used in combination with the normative set of spatial criteria to assess whether the criteria influenced the decision-making process.

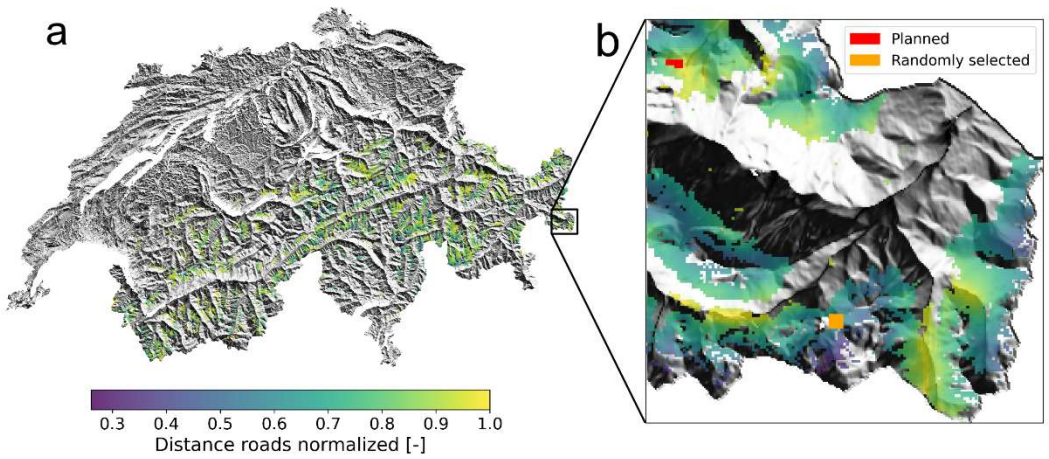

Figure 1: a) Map of Switzerland showing the distance to roads for all areas that are available for the installation of ground-mounted PV-farms. b) Clipped area of eastern Switzerland showing the patches of a planned PV farm (red) and a randomly selected patch for a PV farm (orange).

We combined this spatially explicit data to understand how developers selected sites for the installation of PV farms. We analysed the characteristics of each site planned for installation based on the defined spatially explicit criteria (e.g., “distance to roads” or “winter power production potential”). To better understand which criteria were taken into consideration when these sites were selected, we compared them against a set of randomly selected locations. To test for significant differences, we computed the distribution of the means and the medians based on bootstrapping (resampling 10’000 times with replacement) of the planned and the randomly selected sites.

Second, we used the data to determine whether some of the normatively defined spatially explicit criteria were relevant to municipalities' decisions on whether to approve or disapprove the installation of a PV farm on their territory. In our dataset, there were 26 sites on which the installation had been approved by the respective municipalities and 20 sites on which the installation had been rejected. For 5 municipalities, there has not yet been a decision. To test whether there was a significant difference between accepted and rejected sites, we again used a bootstrapping approach, calculating the distribution of the means and the medians (based on resampling 10’000 times with replacement).

2.6 Voting analyses to identify drivers and motivations to implement land use changes

A recent study led by Prof. Stadelmann (Stadelmann-Steffen et al., 2025) aimed at identifying how the type of decision-making (public vs. secret voting) and the ownership model (distant/private vs. local/public) affects acceptance for renewable energy systems. The study analysed 40 alpine photovoltaic projects in Switzerland that were subject to municipal votes between June 2023 and December 2024. Using cross-sectional Bayesian beta regression models, they examined the proportion of “yes” votes in these local decisions. The key explanatory variables were the type of voting (public versus secret) and the ownership structure (local/public versus distant/private). Additional control variables included project size,

municipal support for a 2024 national energy referendum, and time trends. The models used non-informative priors and are estimated with the *brms* package in R (10'000 iterations with 5'000 burn-in), allowing the analysis of the entire population rather than a sample.

3 Structural external drivers for land-use change

Structural drivers shape the opportunity space for alpine PV development by creating incentives, constraints, and spatial feasibility conditions. In this case study, the major structural drivers can be grouped into (1) policy drivers, (2) market/technical drivers, (3) environmental drivers, and (4) social-environment drivers.

3.1 Policy drivers

At the federal level, policy incentives, such as the "Solar Express" act, serve as a strong accelerator of alpine PV development by providing time-limited financial and procedural support for projects submitted by the end of 2025. Cantons are increasingly relevant as they are developing spatial plans that define where PV systems can be installed and where they cannot. Local municipal processes (assemblies or referenda) create additional institutional constraints and opportunities by shaping how decisions are formally made.

In the voting analysis, time trends also mattered: support slightly decreased over 2023-2024 as the 2022 fear of winter energy shortages faded, showing that wider energy-supply conditions can act as a temporary policy-context driver of acceptance.

3.2 Market and technical drivers

Market- and feasibility-related drivers are particularly visible in developers' site selection. Our comparison of 51 planned and 51 randomly selected PV farm locations shows clear differences in location characteristics. Developers' siting decisions were significantly associated with proximity to roads and the electric grid, as well as with land-use intensity of open spaces and wilderness. These criteria reflect cost-efficiency and technical feasibility, such as easier grid connection, lower construction costs, and better winter power production potential.

Municipalities' decisions to approve or reject PV farms showed fewer structural drivers. Only land-use intensity of open spaces remained significant for them, suggesting that once projects reach the municipal level, most technical site characteristics have already been pre-filtered by developers.

3.3 Environmental drivers

Environmental drivers operate both as motivation (climate/energy transition goals) and as constraints (biodiversity, ecosystem sensitivity). The alpine PV policy push is strongly linked to the goal of increasing winter electricity production and supporting the broader energy transition. However, biodiversity considerations were not relevant for developers' site selection: randomly selected PV farm sites were significantly better for biodiversity than the planned sites (See Connectivity in Fig. 3). This indicates that, at present, ecological quality aspects such as

biodiversity play little role in the selection of PV farm locations. This absence may stem from a lack of clear data, uncertainty about how to account for biodiversity, or weak incentives to integrate ecological values in early-stage planning and permit routines.

3.4 Social-environment drivers

Beyond formal policy, the broader social environment structures decisions through institutionalized arenas (e.g., municipal votes) and contextual conditions (e.g., local economic expectations and project scale). The voting analysis showed the role of project size: smaller projects received higher "yes" shares than large-land-use projects, echoing the general pattern that intensive infrastructure can face stronger resistance.

4 Factors influencing decision making

Building on the structural drivers outlined in Section 3, this chapter examines how land-use decisions are shaped by different stakeholder groups. While policy, market, environmental, and social-environment conditions define the general opportunity space, land-use change ultimately depends on how actors interpret these conditions and anticipated reactions. To make these processes explicit, the chapter is structured by key actor groups involved in alpine PV development.

Figure 2 shows a simplified representation of the land-use change process around alpine PV installations: developers anticipate public acceptance of projects, which is then also directly reflected in the municipal approval process. Pre-existing conditions, such as land-use intensity, and demographics mediate landscape valuation and place-protective attitudes. The ownership structure of a proposed project also impacts public acceptance.

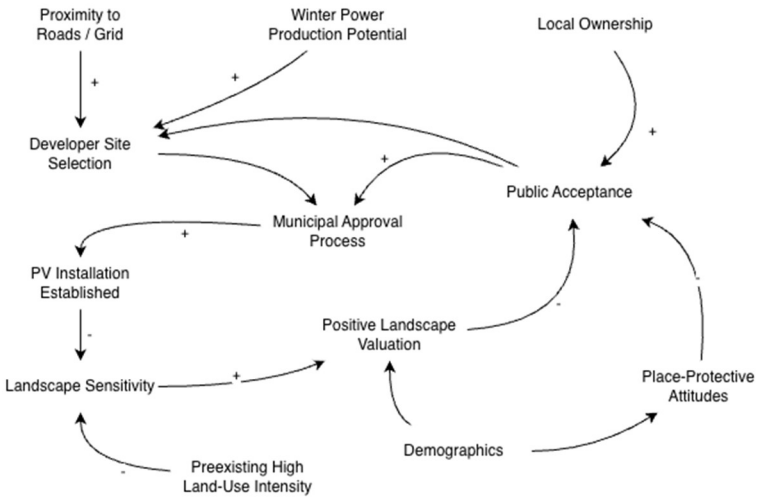

Figure 2: Land-use change processes for alpine PV

4.1 Developers and landowners

Figure 3 highlights how developers' site selection decisions are shaped by technical feasibility and market considerations, while also anticipating public acceptance and potential approval risks. Developers prioritize cost-efficient and technically feasible sites, particularly those close to existing roads and grid infrastructure, while biodiversity considerations play almost no role in early-stage site selection. Developers appear to internalize local preferences and avoid siting PV farms in landscapes perceived as sensitive, even though these landscape criteria are not directly related to cost-efficient energy production. As a result, municipalities mostly review projects that have already been screened for higher acceptance potential.

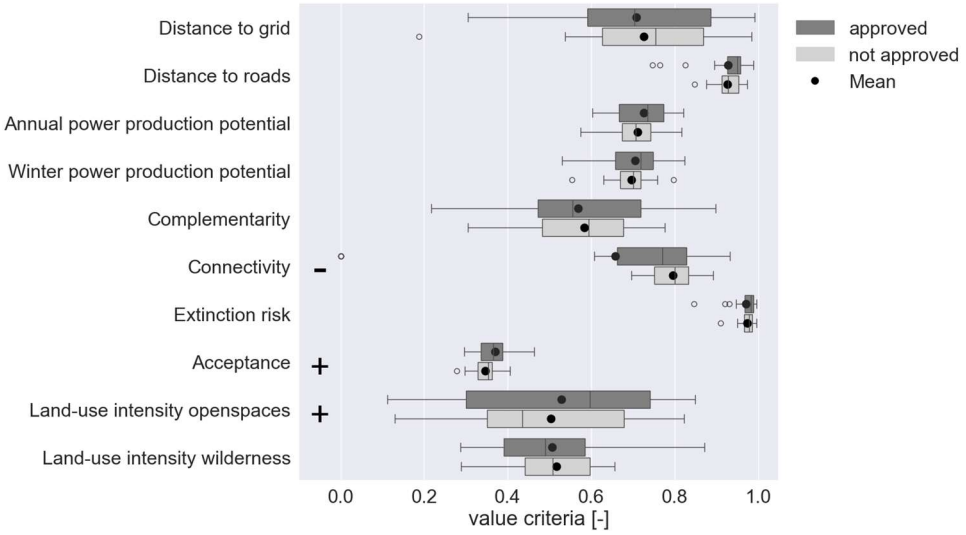

Figure 3: This figure indicates whether there are significant differences in the criteria between "approved" and "not approved" PV farms. The boxplots indicate the distribution of the "approved" and "not approved" sites for each criterion. The plus sign "+" indicates that PV farms were more likely to be approved by the municipalities if they were at locations where the criteria "Acceptance" and "Land-use intensity open spaces" were high. If there is no plus sign, it means that the criteria did not seem to be relevant for the selection of the sites. If there is a minus sign "–" it means that there was a significant difference between "approved" and "not approved" sites. However, this difference is negative, meaning that the "approved" sites even had a lower value for the criteria Connectivity than the sites that were "not approved".

In the spatial analysis (Fig. 3), acceptance already influenced site selection: projects were more likely to be planned in areas with higher expected public or political support, probably to avoid costly rejections later. This points to an anticipatory logic in which developers respond to perceived local acceptance and governance risk (e.g., likelihood of rejection), in addition to land-use intensity.

Landowners act as critical gatekeepers by leasing land or co-developing projects. In some cases, landowners themselves are developers. Their willingness to cooperate can depend on expected local benefits, perceived reputational risks, and whether governance arrangements are likely to be seen as legitimate.

4.2 Municipalities and cantons

As illustrated in Figure 2, municipal approval processes represent a key decision point where structural conditions intersect with public acceptance. Governance conditions such as ownership models, economic benefits, and voting formats also play an important role. In our dataset, municipalities' decisions to approve or reject PV farms showed few significant differences in spatial criteria; only land-use intensity of open spaces remained significant (Fig. 3). This suggests that, once projects reach the municipal level, most biodiversity or technical site characteristics have already been pre-filtered by developers and that municipalities judge projects primarily through the lens of social legitimacy and local fit.

Governance choices emerged as decisive. Municipal votes conducted in public assemblies were systematically associated with higher approval rates than votes held by secret ballots, reflecting the role of deliberation and the emphasis on the common good. However, public voting alone did not create majorities; it was most effective in municipalities where residents had already expressed support for renewable energy in previous national-level votes. Likewise, ownership mattered: projects owned exclusively by distant private companies were far less likely to pass than those including municipalities or local energy providers as co-owners. The highest "yes" shares occurred where both local ownership and public decision-making combined, indicating that governance factors jointly activate a collective-action logic (Stadelmann-Steffen et al., 2025).

Cantons will soon become highly relevant, as they are creating spatial plans that define where PV systems can be installed and where they cannot. This emerging planning layer is expected to shape municipal decision contexts by pre-defining feasible areas and formalizing the balance between expansion targets and protection goals.

4.3 General public

Across methods, landscape type strongly influences acceptance: infrastructure is tolerated in already modified landscapes but faces resistance in pristine alpine regions, where place-protective values are strong. Preferences for land-use changes during the energy transition are strongly shaped by factors such as the type of landscape and the characteristics of the infrastructure. Settlement-dominated areas, such as the Swiss Plateau, are the most acceptable locations for renewable energy systems, followed by agricultural areas and intra-mountain valleys, whereas pristine high-elevation Alpine regions consistently receive the lowest acceptance. Touristic mountain areas are tolerated only where tourism infrastructure already exists, and mid-elevation Jura and Pre-Alps elicit neutral reactions.

Infrastructure characteristics also matter: increasing numbers of wind turbines lead to a steady drop in preference across almost all landscapes, and high-voltage power lines are uniformly disliked. Photovoltaic installations display a more complex pattern; respondents rate scenarios without any PV lower than those with a minimum amount, but preferences decrease again as PV moves from medium to maximum levels. Across the board, a balanced, low-to-medium mix of wind and PV outperforms high levels of either technology, indicating that both the type of infrastructure and its quantity jointly drive acceptance.

Photovoice results highlight place-based meanings and motivations that help explain these patterns. Participants associated alpine landscapes with meanings such as home, identity, retreat, and untouched nature, and expressed concern that new infrastructures could undermine these qualities, especially in pristine alpine areas. At the same time, many participants welcomed PV installations when they were integrated into already-used landscapes such as dam walls, ski resorts, mountain passes, or agricultural zones, where the added impact was perceived as limited. Acceptance was closely tied to trust and legitimacy, with a preference for transparent and participatory decision-making and for local or public forms of project ownership.

Physiological data add an affective layer that is not fully captured by stated preferences alone. Skin conductance responses were significantly higher when participants viewed videos with high renewable energy infrastructure impact compared to low impact, indicating stronger physiological arousal to more intensive installations. This effect was consistent across six of the seven landscapes. Participants preferred low-renewable energy scenarios, especially in Alpine regions, whereas Plateau landscapes were the only landscapes where high-renewable energy scenarios received slightly more support. This indicates that although high-renewable-energy scenarios raise physiological arousal everywhere, the acceptability of that arousal differs across landscape contexts.

Respondents' own characteristics and perceptions also influence preferences. Many people display strong place-protective behaviour, rejecting renewable energy development in near-natural or culturally valued landscapes regardless of the infrastructure level. Landscapes perceived as strongly "arcadian" (natural, traditional) are judged to have a poor fit with renewable energy infrastructures and are less likely to be chosen, whereas landscapes viewed as "utilitarian" (already used) are more likely to be chosen. Respondents who see renewable energy systems as contributing to sustainability report a better fit between infrastructure and landscapes, while those who associate renewable energy systems with mechanisation report a poorer fit.

Perceptions of landscapes vary systematically with experience and demographics: living or recreating in a landscape increases the likelihood of seeing it as arcadian or utilitarian, depending on context. Urban landscapes are rated least arcadian and most utilitarian; near-natural Alps remain the benchmark for arcadian character. Swiss-Italian respondents perceive near-natural landscapes as less arcadian than Swiss-Germans do, and Swiss-Germans view them as more utilitarian than Swiss-French or Swiss-Italian respondents do. Men are somewhat more likely than women to rate a landscape as arcadian, and membership in an environmental organisation raises both arcadian and utilitarian perceptions. Exposure to renewable energy systems in one's living or recreational environment also alters the meanings attributed to them, lowering their mechanistic connotation and, in some cases, strengthening their sustainable connotation.

Integrated synthesis

Acceptance emerges as a key social driver across both public perception and municipal decisions. For municipalities, acceptance was one of only two significant criteria (alongside land-use intensity), indicating that local social or political sentiment strongly shapes the

approval process. Developers anticipate these dynamics by strategically siting projects in areas where they expect greater political and social acceptance. The interplay between developers, municipalities, and public perceptions underscores how anticipated community reactions feed back into project planning and approval.

Figure 4 synthesizes how land-use decisions for alpine PV development emerge from the interaction of structural pressures and social dynamics. It illustrates a system of negotiation where technical feasibility and national energy policy collide with local identities and landscape values. Developers and authorities act within enabling but constraining frameworks, while municipalities and citizens infuse decisions with social legitimacy and emotional meaning. This interplay reveals a shift from purely rational planning toward value-laden governance, where acceptance and ownership become decisive drivers. Overall, the Figure portrays land-use change not as a technical outcome but as a collective socio-political process embedded in place and perception.

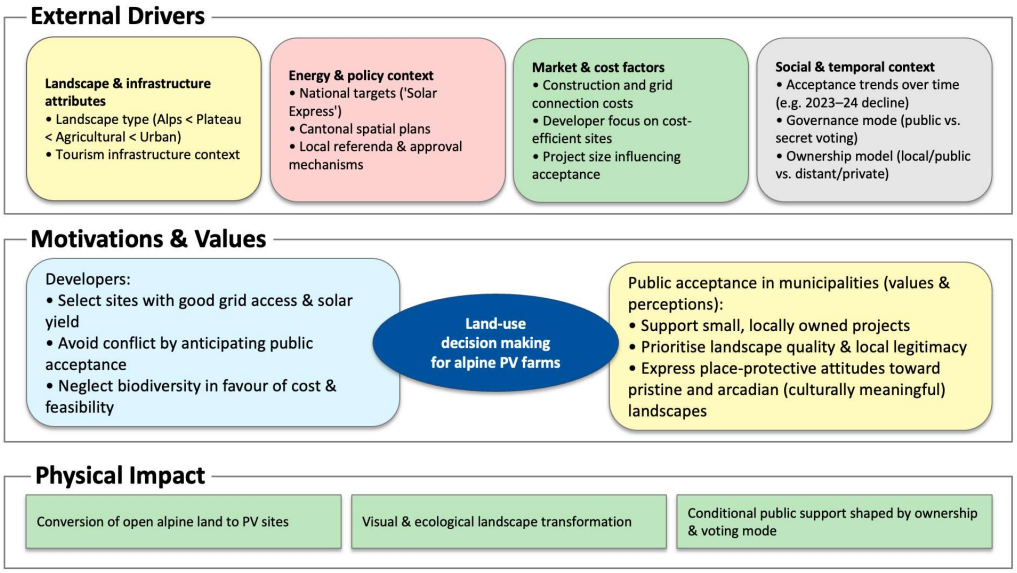

Figure 4: Mind-map for understanding land use decision making for alpine PV farms.

5 Discussion and reflection

5.1 Methodological reflection

Across the substantially different methodological approaches, a consistent picture emerges. Spatial modelling, Photovoice, discrete choice experiments, physiological data, and voting analyses all point in the same direction: acceptance, landscape meaning, and governance conditions collectively shape land-use trajectories. Each method contributes an additional layer of understanding of structural drivers, emotional reactions, social norms, and political processes, together providing a more complete picture than any single method could offer. This underlines the importance of a mixed-method approach for understanding socio-ecological transitions, as land-use change emerges from the interplay of technical feasibility, social legitimacy, emotional responses, and institutional structures.

One particularly interesting observation comes from the physiological and behavioural experiments. Participants' bodies reacted strongly to high-infrastructure scenarios even when their self-reported attitudes were relatively neutral. This highlights a hidden layer of affective resistance that may not be fully captured by surveys or stated-preference methods alone. Emotional and symbolic attachments to alpine landscapes influence responses to landscape change more strongly than people sometimes acknowledge, and these emotions can shape acceptance long before formal decisions are made.

5.2 Major drivers and motivations influencing land-use decision making

Across methods, a consistent pattern emerged: context matters. Landscape type, project ownership, and decision-making format jointly determine whether energy projects are embraced or rejected. Developers' site selection is primarily guided by economic criteria, whereas municipalities' decisions hinge more on social and political acceptance than on ecological or technical parameters.

Acceptance is highest where renewable energy infrastructures "fit" with the existing landscape, i.e. in already "infrastructured", touristic, or lowland landscapes, while pristine and culturally meaningful landscapes elicit strong emotional opposition. The data reveal conditional support for renewable energy transformation: people are willing to accept it if it is concentrated in already altered landscapes and designed as a balanced mix of technologies that align with their mental models of a fitting landscape.

The integration of ownership and governance dimensions is particularly decisive. Projects with local or public ownership and open, participatory decision-making received significantly higher approval rates than distant, privately driven projects. This highlights that collective benefit and procedural fairness are as important as technical performance for sustainable land-use transitions.

One of the most striking findings across most methods is the systematic absence of biodiversity considerations in both developer and municipal decision-making. Despite strong ecological concerns expressed in public debates and policies (e.g., the Biodiversity Strategy, Swiss Federal

Office for the Environment, 2024), biodiversity rarely influenced actual site selection. This points to a significant policy–practice gap: although biodiversity is a stated priority at the national level, it is not embedded in the practical routines of planning and decision-making for alpine PV projects. Poor accessibility of related data to decision-makers, inconsistent guidance, or limited incentives may contribute to this gap, and addressing it will be essential if future renewable energy development is to be aligned with broader environmental objectives.

A key implication of this gap is that biodiversity risks are not necessarily "rejected" in decision-making; rather, they tend to be invisible when decisions are made. When biodiversity criteria are not translated into decision-ready indicators, or when responsibilities for biodiversity assessment remain unclear across stages (developer screening, cantonal planning, municipal approval), biodiversity can remain marginal even when actors express general support for conservation goals. This suggests that integrating biodiversity is less a matter of changing values and more a question of operationalization of biodiversity goals across decision stages.

5.3 Role of specific context and relevance for other areas in Europe

While our study focuses on Switzerland, the underlying dynamics shaping land-use decisions, particularly the trade-offs between national energy goals and local landscape identities, are highly relevant for other Alpine and mountainous regions in Europe. Similar tensions between renewable energy expansion, landscape protection, tourism, biodiversity, and local identity are present across the Alps and other rural, landscape-sensitive areas. The conditional acceptance pattern we observe in Switzerland, where people are willing to support renewable energy only where it "fits" existing landscape character or builds on existing infrastructure, is likely to occur in many comparable European contexts as well.

Alpine regions across Europe likely face similar tensions between energy production, landscape protection, tourism, and local identity (cf. Iversen et al., 2021 for Norway). The symbolic value of alpine landscapes is often high, and the acceptance of new infrastructure is strongly influenced by how people perceive their landscapes, what they fear losing, and how fairly they feel included in the decision-making process. Acceptance increases when projects are built on or around existing infrastructure, when governance is transparent and participatory, and when benefits are shared locally. These principles hold beyond Switzerland and can inform European strategies to expand renewable energy in sensitive mountain environments.

While the Swiss case is shaped by specific political and cultural conditions, most notably Switzerland's strong direct democracy system and local voting rights, many of the underlying dynamics are relevant for other European mountain regions. In Switzerland, municipalities and local citizens play an unusually direct role in approving or rejecting energy projects. This can lead to very visible expressions of local acceptance or resistance. In other European countries, such direct local voting may be less common or less binding, and decision-making may rely more on administrative procedures and planning authorities.

Despite these institutional differences, the core insight remains the same: local acceptance is essential for the long-term success and social legitimacy of renewable energy development, regardless of national governance structures. Even where formal local vetoes do not exist, low acceptance can slow projects through opposition, legal appeals, political pressure, or

reputational damage. Likewise, high acceptance can help stabilize the expansion of renewable energy and improve public trust in the energy transition.

Overall, the Swiss case shows that planning for renewable energy in sensitive landscapes requires more than identifying technically suitable sites. It requires acknowledging landscape meanings, addressing emotional responses, improving biodiversity consideration, and designing governance arrangements that build trust and local benefit. These reflections underscore the need for integrated approaches that recognise both the structural and psychological dimensions of land-use change.

5.4 Potential policy options

The long-term implications of our findings point to both opportunities and challenges for sustainable energy transitions in alpine environments. Projects that build on existing infrastructure, involve local ownership, and incorporate participatory processes demonstrate higher levels of legitimacy and are more likely to be accepted by the general public. This suggests that governance choices constitute powerful levers for supporting sustainable land-use change. At the same time, the systematic neglect of biodiversity in both planning and decision-making processes reveals a structural weakness that could compromise long-term national ecological targets.

Based on these insights, potential policy options include:

- **Strengthen participatory and transparent decision-making** to increase procedural legitimacy and reduce conflict, especially in landscape-sensitive regions.
- **Promote local and public co-ownership models** (or benefit-sharing mechanisms) to increase perceived fairness and collective benefits.
- **Integrate biodiversity assessments earlier in planning and site screening**, including improving accessibility and usability of biodiversity data for decision-makers and clarifying how biodiversity evidence should be applied in spatial planning and project evaluation.
- **Prioritize development on or near existing infrastructure** (e.g., ski resorts, dam walls, transport corridors, already modified landscapes) where acceptance is higher and added landscape impacts are perceived as lower.

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ELO European Landowners' Organization

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Environmental
Social Science
Research Group

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

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ILVO
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Annex 6 - Drivers and motivation for Private Land Conservation in the EU-case

A Behavioural Analysis of Practice-Based Evidence from European PLC Initiatives

Floris Huyghe, Anna Verhoeve, Jeroen De Waegemaeker

MOSAIC

Version number: 002

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Table of Contents

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List of Figures and Tables

Abbreviations

LLM	Large Language Model
PLC	Private Land Conservation
COM-B model	Capability, Opportunity, Motivation – Behaviour model

1 Introduction

1.1 About MOSAIC

For many decades already, the scientific community warns about the detrimental impact of current land use practices on biodiversity, soil fertility, water reserves, climate change, to name a few, eroding the safe operating space for humanity on Earth (Richardson et al., 2023; Rockström et al., 2009). Yet, despite the piles of reports with irrefutable evidence, not much change can be seen on the ground. Facts, figures and scenarios of the future we are heading for appear not to be enough to convince land use decision makers to make more sustainable choices.

MOSAIC therefore wants to contribute to a better understanding of why this is the case, and, more importantly, contribute to the solutions. To that effect MOSAIC investigates the drivers behind land use choices. Are farmers, business managers, nature conservationists, policy makers and other land use decision makers aware of what is at stake? And what role can they play in finding a solution? What kind of land use do they favour and why? What motivates them to go for their choice? How can their decisions be aligned or reconciled with policy targets in the fields of climate change mitigation and adaptation, biodiversity and renewable energy? What tools and incentives can help to align these individual land use decisions on the ground with high-level policy targets and international agreements aimed at the conservation of our common home?

To investigate these questions, six Policy Labs, comprising a diverse array of decision makers in Belgium, Denmark, Hungary, Portugal, Switzerland, and a European Lab, are set up as pivotal platforms for MOSAIC's transdisciplinary research. Each one is linked to a specific case of land use decision making. These Policy Labs help the researchers investigate these questions and allow practitioners to co-create relevant knowledge, so the gained knowledge becomes truly actionable for them.

MOSAIC's modelers will build upon this knowledge about drivers and motivations to characterize expected future land use patterns – an indispensable tool in land use policy processes. Based on spatial, social and economic insights, potential displacement effects can be made visible, as well as evolutions jeopardizing European biodiversity, climate and renewable energy goals.

To enable this, the Policy Labs receive support from a digital learning environment in which MOSAIC bridges the siloes of researchers' and practitioners' worlds. During the project, this environment allows for knowledge transfer, learning, evaluation and collaboration between researchers and practitioners, both within the cases and in cross-case settings. After the project, this learning environment will live on to give answers to the research questions outlined above, questions about the practical implementation of these learnings; and will it function as a source of inspiration for those wanting to render land use more sustainable in other places as well.

This way, MOSAIC will showcase in six cases how policy, science and society can work hand-in-hand on concrete solutions to accelerate the transition towards more sustainable land use.

1.2 About this report

This report presents one of the first systematic, cross-European analyses of the behavioural determinants shaping voluntary Private Land Conservation (PLC). As Europe experiments with new conservation instruments such as easements, stewardship agreements, habitat markets and compensatory schemes, policy development has outpaced behavioural understanding of voluntary actions for land conservation. Little is known about how landowners perceive, navigate, and respond to these emerging tools. This report addresses that gap by synthesising a uniquely broad body of grey literature produced by pioneering PLC initiatives and analysing it through the structured lens of the COM-B behavioural framework (Capability, Opportunity, Motivation – Behaviour) (Michie et al., 2011).

The study advances three core objectives. First, it aims to map the behavioural landscape of PLC in Europe by identifying the drivers and barriers that consistently shape landowner participation. Second, it seeks to organise this highly diverse practice-based evidence into a clear analytical structure, using COM-B as a deductive coding framework. Third, it explores how AI-assisted qualitative analysis can enhance reproducibility, comparability, and transparency in large-scale behavioural evidence synthesis. Together, these objectives position the report as both a methodological innovation and a substantive contribution to emerging PLC scholarship.

At the heart of the report is an extensive coding process applied to thousands of pages of project reports, evaluations, testimonies and practitioner documentation. These sources, although not published in scientific journals, constitute the most immediate repository of empirical knowledge available: they capture real-world interactions with PLC instruments, including the frictions, misunderstandings, risks, and opportunities encountered by landowners and intermediaries. By treating these documents as legitimate behavioural evidence and analysing them systematically, the study reveals patterns that are often invisible in more formal academic literature.

Across this material, three key insights emerge. First, economic viability functions as the decisive threshold for PLC participation. The analysis consistently shows that when structural economic conditions (risk, return, and transaction costs) cannot be overcome, behavioural intentions fail to translate into action. Opportunity, understood as the external conditions enabling action, therefore dominates the behavioural equation. Second, social trust acts as the principal relational mechanism shaping participation. Trusted intermediaries, peer networks, and local legitimacy appear more influential than formal incentives or information-based interventions. Third, intrinsic motivations rooted in identity, stewardship, pride and legacy are widespread among landowners and conservation organisations. Rather than needing to be created, these motivations require enabling conditions to become behavioural drivers.

While confirming well-established findings from broader land-use behaviour research, particularly the centrality of economic constraints, the report also highlights less documented determinants, including the behavioural weight of autonomy, trust, and social cohesion in voluntary conservation. These insights refine our understanding of PLC as a distinct behavioural

field: highly relational, strongly context-dependent, and shaped as much by social legitimacy as by financial design.

Methodologically, the report demonstrates that COM-B offers a transparent, accessible framework for structuring diverse behavioural evidence. It facilitates the separation of what landowners can do (Capability), are allowed or enabled to do (Opportunity), and want to do (Motivation). At the same time, the study recognises COM-B's limitations: its simplicity risks masking broader institutional, legal and market structures that strongly influence land-use decisions. For this reason, COM-B is presented not as a stand-alone model but as a complementary lens that can strengthen broader socio-economic and ecological approaches.

The report also reflects critically on the use of AI in large-scale qualitative analysis. While AI enabled the processing of a far larger, more multilingual dataset than would have been feasible manually, it also introduced challenges related to precision, contextual ambiguity, and potential omissions. These limitations were addressed through triangulation and consistency checks, culminating in the creation of a transparent PLC-database that underpins the findings presented.

Although not a policy evaluation, the report offers several actionable insights for PLC policy and practice. These include the need to de-risk participation, professionalise intermediaries, combine financial and social incentives, and strengthen local legitimacy through bottom-up governance models. The findings also provide behavioural parameters for integration into MOSAIC land-use modelling, enabling more realistic scenario development.

Overall, this report establishes a behavioural evidence base for voluntary PLC in Europe and demonstrates how structured behavioural frameworks and AI-assisted analysis can enrich both research and policy design in an emerging conservation landscape.

2 Making a case of Private Land Conservation in the EU

2.1 Private Land Conservation

Across Europe, achieving the ambitious goals of the EU Biodiversity Strategy for 2030 requires conservation efforts that extend well beyond areas under public protection. While statutory conservation and state-led initiatives to protect and develop nature areas, e.g. national parks, nature reserves, and Natura 2000 sites, remains the cornerstone of biodiversity policy, they alone cannot address the ecological gaps that persist across the wider landscape. A significant proportion of Europe's most biologically rich land is privately owned, meaning that the protection of species, habitats, and ecological connectivity depends heavily on the stewardship of private landholders. Private Land Conservation (PLC) therefore represents a vital complement to statutory conservation frameworks: it mobilizes voluntary actions by landowners, organizations, and communities to protect, restore, and sustainably manage biodiversity on private property. These initiatives, ranging from conservation easements and stewardship agreements to privately protected areas, enhance ecological coherence and resilience by bridging fragmented habitats and fostering collaboration between public and private actors.

Engaging private landowners through supportive policies and incentives enables conservation to operate at the landscape scale required to meet Europe's environmental objectives.

2.2 European scale

The European scale of this report adds both significance and complexity. Unlike regional or national case studies that focus on single governance contexts, this analysis spans a continent characterized by diverse land-use systems, ownership structures, policy frameworks, and cultural attitudes toward land stewardship. These regional differences shape the opportunities to address the biodiversity challenges via the private land conservation strategies, from economic incentives and legal recognition to emotional attachment and cultural heritage. While such variation complicates the identification of universal patterns, it also offers a unique opportunity to capture the richness of (drivers for) PLC practices across Europe. Despite these contextual challenges, this report aims to provide a comprehensive overview of the underlying behavioural drivers and motivations that influence conservation engagement among European landowners. Their drivers and motivations are analysed through the Behaviour Change Wheel (BCW) framework to understand how capability, opportunity, and motivation influence conservation behaviour.

2.3 Land user groups

This research draws on a dataset of reports and deliverables produced by a group of Private Land Conservation (PLC) front runners in the European Union. The group comprises both individual landowners who entered PLC schemes and the non-governmental organisations (NGOs) and public authorities involved in the design, facilitation, or implementation of these initiatives. In many cases, the pioneering PLC projects in the dataset target large landowners whose properties consist of heterogeneous estates, often combining arable land, grassland, wetlands, forests, and/or other semi-natural habitats. As a result, it is frequently impossible to attribute these land users to a single land-use category (e.g., “farmer”, “forester”, “hunter”). Importantly, this is not merely a classification difficulty but reflects a defining feature of PLC: it often seeks to challenge siloed approaches to rural governance that treat land use as a set of distinct, sectoral groups (e.g., separating forestry from agriculture). Therefore, this analysis does not draft divisions of land users groups since any attempt to impose singular categories would risk misrepresenting the land managers’ actual practices and the integrative rationale of PLC.

A second limitation concerns the level at which the data is reported. Except for illustrative examples and case study descriptions, most of the available material is oriented toward the collective or cross-case level, where conclusions are drawn beyond the level of the individual landowner. Consequently, this research is constrained in its ability to generate robust individual-level conclusions, such as comparing outcomes or motivations across distinct types of land users. In short, within this dataset, systematic differentiation between individual land users is not possible, and any claims at that level would exceed what the evidence can support.

It is also critical to note that the land users included in this dataset represent only a subset of European land users. The sample is shaped by two major forms of selection:

1. Front-runner bias: The dataset focuses on pioneering PLC initiatives rather than typical or average land management contexts.
2. Ownership and scale bias: Compared to the broader population of land users in Europe, the dataset over-represents actors who own their land (as opposed to tenants or those operating under short-term/annual contracts) and tends toward larger landholdings, rather than small-scale farms and forests.

2.4 Policy goal

As clarified in Section 1.1, the underlying policy objective of the European MOSAIC Policy Lab is to supplement existing conservation strategies, such as statutory conservation and state-led initiatives for the protection and development of nature areas, with policies that facilitate voluntary conservation efforts by private landowners, commonly referred to as private land conservation (PLC). PLC functions as an umbrella concept encompassing a wide range of innovative policy instruments that regulate, facilitate, or financially support conservation efforts by private actors. These instruments include, but are not limited to, conservation easements, privately protected areas, and conservation stewardship schemes.

The ambition and prioritisation of specific **PLC instruments are inherently context-dependent**, as they must align with local levels of support, existing policy frameworks, and broader cultural and institutional traditions within EU Member States. Consequently, PLC does not represent a single, uniform policy model, but rather a flexible policy approach that adapts to diverse socio-geographical contexts.

2.5 Research Questions

To guide systematic examination of the factors shaping private land conservation (PLC) in Europe, the following research questions were formulated.

Main Research Question:

- What behavioural determinants shape landowners' willingness and ability to engage in voluntary Private Land Conservation (PLC) across Europe, as revealed through the practice-based evidence generated by pioneering PLC initiatives?

Substantive behavioural questions (COM-B components) (Michie et al., 2011)**:**

- Sub-RQ1 — *Opportunity* (structural conditions). What external and structural conditions enable or constrain landowners' participation in voluntary PLC, and how do these conditions shape the feasibility of conservation behaviour?
- Sub-RQ2 — *Motivation* (intrinsic and extrinsic drivers). What intrinsic and extrinsic motivations influence landowners' willingness to engage in PLC, and under what conditions do these motivations translate into action?
- Sub-RQ3 — *Capability* (skills, knowledge, competences). How do landowners' skills, knowledge, and perceived competences affect their capacity to participate in PLC, particularly in relation to structural constraints?
- Sub-RQ4 — *Interactions* across COM-B. How do Opportunity, Motivation, and Capability interact to determine whether landowner intentions lead to actual PLC behaviours?
- Sub-RQ5 — *Policy and Actionability*. How can insights on behavioural determinants, structural constraints, and motivational drivers be translated into actionable strategies and policy recommendations to enhance participation in voluntary Private Land Conservation in Europe?

Methodological questions:

- Sub-RQ6 — *COM-B as a deductive coding framework*. How can the behavioural determinants reported in PLC-focused EU initiatives be systematically mapped using the COM-B framework to organise diverse practice-based evidence?
- Sub-RQ7 — *AI-assisted qualitative analysis*. How can AI-assisted coding support the identification of recurring behavioural themes, cross-cutting challenges, and potential leverage points for strengthening PLC in Europe?

3 Methodology

This study draws on a structured review of grey literature produced by recent EU-funded initiatives on private land conservation (PLC). The aim was to identify the key determinants influencing landowner engagement across different European contexts. To ensure conceptual consistency, the analysis was guided by the COM-B behavioural framework, which distinguishes between Opportunity, Motivation, and Capability. The documents were processed and coded using an AI-assisted text analysis approach, enabling the systematic extraction, categorisation, and comparison of drivers and barriers reported across projects. The following section outlines the methodological steps and analytical procedures used in this review.

3.1 Data and Analytical context

As input for this analysis, we examine grey literature emerging from recent European initiatives on Private Land Conservation (PLC). These sources include the outputs of several EU-funded projects that, to date, represent the primary collective effort to explore PLC within the European context. Earlier EU projects, such as LIFE ELCN, LIFE Land is Forever, and LIFE ENPLC adopted a strong practice-based focus, piloting PLC initiatives across diverse European regions.

These pilot projects were instrumental in generating experiential insights at multiple levels: learning within pilot sites, learning across regional contexts, and learning between different stakeholder groups including landowners, NGOs involved in nature development, and public authorities. The current Horizon Europe project MOSAIC builds directly on this practice-based foundation, aiming to synthesize and advance existing knowledge to better understand the behavioural, institutional, and policy dimensions of PLC.

The grey literature dataset used in this report comprises 51 documents and videos sourced from the aforementioned LIFE projects and relevant ILCN and ELO publications. These documents and videos are in several languages including English, French, Italian and Catalan. The dataset was created in a step-by-step approach: a first set of documents were made available by the MOSAIC policy leads of the EU policy lab (ELO and Eurosite), next all other available materials were downloaded from the LIFE project websites. Resulting in a database from the following sources:

- LIFE ELCN
- LIFE Land is Forever
- LIFE ENPLC
- IUCN, ILCN and ELO websites

Next the dataset was imported into a Google AI Studio with Gemini 2.5 Pro (Comanici et al., 2025) environment for qualitative synthesis:

While these earlier initiatives produced a wealth of qualitative data and practical lessons, this material had not yet been examined in a systematic or structured analytical framework. The present study therefore builds on these existing outputs to conduct a more comprehensive and comparative analysis of drivers and motivations for PLC across Europe.

This integrative approach allows us to connect the empirical learning from pilot experiences with a theoretical framework grounded in behavioural analysis, thereby contributing to the broader European understanding of how and why private landowners engage in conservation.

3.2 Theoretical Framework for Analysing PLC behaviour

To analyse the drivers and barriers of Private Land Conservation, the COM-B model was employed as the primary analytical framework. This framework provides a robust, theory-driven approach to understanding behaviour, conceptualizing behaviour as a function of *Capability, Opportunity, and Motivation* (Michie, van Stralen, & West, 2011).

This framework was selected for several reasons. Firstly, COM-B has strong empirical and theoretical validation across diverse behavioural contexts, ensuring its robustness and validity in social science research. Secondly, it is highly applicable to the heterogeneous population of private landowners, encompassing different land use activities (agriculture, forestry, hunting), scales, and motivations, rather than being restricted to either forestry or agricultural contexts. Thirdly, the framework offers a comprehensive perspective by capturing not only economic factors but also social, cognitive, and environmental determinants, which are critical for understanding the complex drivers and barriers influencing private land conservation (PLC). Fourthly, COM-B has been shown to facilitate systematic analysis and comparison across regions and contexts, enhancing analytical rigor beyond locally specific studies. Finally, its structure directly supports the translation of findings into policy-relevant recommendations, aligning with the overarching aim of the MOSAIC project to inform actionable strategies for strengthening PLC in Europe.

3.3 Analytical approach

As previously mentioned, a total of 51 text documents and videos were found that have been published on PLC in the context of European practice and policy-oriented projects. Since our resulting qualitative dataset comprised a total several hundred pages of text, we looked into ways of processing these texts thoroughly, rigorously and efficiently at the same time.

3.3.1 Building a PLC-database using AI

With the emergence of ever improving Large Language Models (LLM's) (Dunivin, 2024), we decided to actively use and evaluate AI support for this literature review. By prompting Appendix 0 the LLM as a research peer we were able to set up an environment where the model coded text fragments. This approach had the advantage of coding 1000's pages of text in multiple languages without having a certain bias, fatigue or inconsistency. All traits that could be occurring in human coders. On the other hand, we were less in control. To accommodate for this we tested different models, formulated definitions of the codes with the COM-B model and strictly asked to stay close to the original texts. In short, the final prompt (see Appendix 0) is the result of multiple

iterations whereby the researchers checked and reviewed the draft results to finetune the prompt.

The model we eventually chose for performing deductive coding of the texts was the LLM model Gemini 2.5 Pro. The settings of the model were a Top P of 0.95 and a Temperature 0.6, the latter is to make sure the model keeps close to the original documents and does not start to hallucinate. It is therefore more suited for deterministic work. To make sure all the documents were treated equally every document was imported separately into the context window. It was specifically asked to keep text segments verbatim[1], making sure the model would not 'invent' segments. For scientific accuracy the model was also tested on repeatability of the experiment. With the current settings the model was ran 10 times on the same text to check how it performed on picking the same texts.

To check for congruency between the 10 'readers' a Fleiss Kappa test (Fleiss & Cohen, 1973) was ran on the coding results of the 10 runs. The result of this was a score of 0.63, which means that there is a substantial agreement between the different runs. It is not perfect, but it leaves room for a bit of creativity and would not differ that much from working with 10 human readers.

The deductive coding of the LLM on all the different grey literature resulted in the so-called PLC-database with the filename, location of the text segments, verbatim text segment, allocated code based on the COM-B components of the behavioural change wheel (Michie et al., 2011) indicating it as a driver or barrier. The final column was introduced as an extra help for controlling the model. We explicitly asked to formulate a couple of sentences as a reasoning behind the coding of a text segment. After the model coded the text we could look into these segments and check if we agreed. One could see this step as an investigator triangulation, traditionally done in qualitative research by multiple colleagues (Patton, 1999).

Table 1: Headers of PLC-database

Filename	Page Number	Text Segment	COM-B Component or Policy Category or Extra	Driver or Barrier or Neutral	Notes / Comments

The deductive coding process produced a structured database comprising 702 coded text segments, which, for the purposes of this report, is referred to as the *PLC-database*. Each segment was systematically (AI-based) assigned to one of the three components of the COM-B framework (*Opportunity, Motivation*, or *Capability)* based on its content. The resulting structured dataset provides a transparent and replicable foundation for subsequent interpretation of components.

[1] In a way that uses exactly the same words as were originally used. (VERBATIM | English meaning - Cambridge Dictionary)

3.3.2 Identification and Weighting of Key Determinants

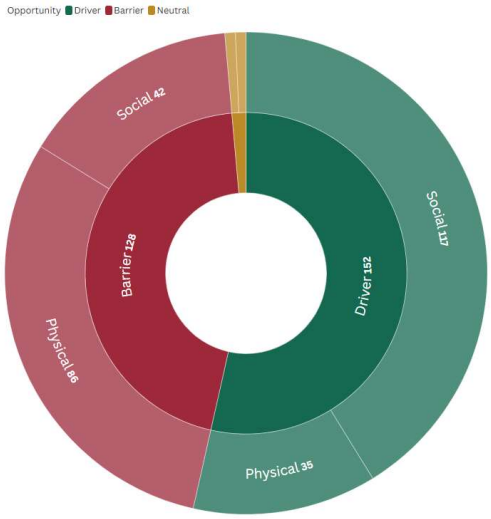
Following the initial AI-coding, the PLC-database was subjected to further human analysis (by the authors of this report) to identify the key determinants within each component. This also involved evaluating both the frequency of occurrence and the intensity of each determinant, allowing for an assessment of their relative significance in influencing private landowners' engagement in PLC. By combining quantitative measures (presence and intensity) with qualitative insights, this approach enabled a robust mapping of the behavioural drivers and barriers across the PLC context. We realize that using frequency as a parameter for importance is not desired. But it can give some idea on relevance or how well a certain type is documented. Because frequency is not

4 Structural external drivers for PLC

4.1 Opportunity

This chapter highlights the structural external factors that shape PLC-related land-use decisions. These structural external drivers refer to conditions beyond the direct control of individual landowners that nonetheless influence their ability to engage in Private Land Conservation (PLC). The COM-B model within the Behaviour Change Wheel (Michie et al., 2011) provides the analytical framework for identifying these external drivers under the *Opportunity* component. In this framework, *Opportunity* refers to external factors that enable or constrain an individual behaviour. It comprises two dimensions:

- **Physical Opportunity:** the material, environmental, and infrastructural conditions—such as financial resources, tools, land-use rules, or time—that shape what is possible. Market and policy factors are theoretically compatible under the COM-B concept of Physical Opportunity, as both shape the material conditions under which land-use decisions are made.
- **Social Opportunity:** the social norms, networks, and cultural cues that influence behaviour.



In this study, *Opportunity* is therefore understood as the external conditions that determine what private landowners *can realistically do*, in contrast to what they want to do (*Motivation*) or what they know how to do (*Capability*).
In Figure 1 a distribution is found on the amount of text segments indicating a determinant categorized as Opportunity. This does not indicate the overall importance of this determinant. Rather does it give a general idea on the amount of segments that have been found on this topic.

Figure 1: For illustration, the distribution of text segments between drivers and barriers in the component Opportunity.

4.1.1 Physical Opportunity Drivers: Economic and Policy Mechanisms

For private landowners, participation in PLC is shaped by the practical feasibility of implementing conservation measures within a viable business framework.

4.1.1.1 Financial and Market structures

The feasibility of engaging in Private Land Conservation (PLC) is highly dependent on financial viability, defined in terms of the external, structural conditions that enable or constrain landowners' actions. Across the PLC grey-literature dataset, multiple coded segments indicate that financial viability constitutes the most prominent Physical Opportunity constraint for engaging in PLC.

Financial viability consistently emerges as the strongest physical barrier related to opportunity for engaging in PLC. Various codes from the PLC dataset highlight how the economic logic of risk and return shapes the broader financial ecosystem surrounding conservation. Conservation is often described as a risky or financially burdensome activity for private landowners, farmers, and land stewards, who frequently operate under low or negative returns. As a result, conservation competes with strategies that provide more immediate or stable income. The PLC dataset repeatedly points to declining profitability in agriculture and forestry, driven by volatile markets, structural indebtedness, rising land prices, non-competitive product chains, and high labour or processing costs, as factors that further amplify this risk exposure.

Several text fragments from the PLC-dataset also indicate that philanthropic and public funding streams are perceived as stagnant or declining, while private capital markets remain underdeveloped, characterised by a shortage of bankable conservation deals, misaligned risk-return expectations (e.g. views on the risks and returns of land conservation diverge amongst landowners, public authorities and other parties).

Evidence from the PLC dataset further shows that, in contexts where market incentives, subsidies, or guaranteed programmes are absent, private land conservation often relies on landowners' own financial resources. For landowners whose land-use activities need to remain economically viable, this can reinforce the perception that engaging in conservation is a high-risk undertaking. While some stewardship may be motivated by intrinsic values or non-commercial objectives (see 0 Motivation), the lack of financial support can limit the practical feasibility of conservation under a market-based land-use model. As a result, landowners who might otherwise be motivated by altruistic considerations are discouraged when conservation entails relinquishing current or potential financial benefits without adequate compensation. Incentive programmes frequently fail to cover the full cost structure of conservation, leaving landowners exposed to residual financing gaps. Often new private markets, e.g. carbon or nature credits, are cited as possible ways to fill these gaps, yet private markets are still premature. Equally private investors, who are on the lookout to provide financial means to conservation efforts, state challenges resulting from an immature market.

"Investors also reported challenges consistent with an immature market, such as a shortage of investment prospects with appropriate risk-return profiles... and a lack of standardized impact metrics." (natureVest & EKO, 2014)

4.1.1.2 Legal and Administrative Frameworks

Legal and administrative systems shape *Physical Opportunity* by defining what forms of conservation are permissible, incentivised, or burdensome. The regulatory environment acts as a dual-edged determinant. While legal frameworks (e.g. policies on land use rights, covenants and easements) provide necessary protection, "overregulation" and complex bureaucracy are frequently cited as physical barriers. Many of the reviewed cases emphasise regulatory overload, rigid bureaucracies, and inflexible or underdeveloped legal instruments. The absence of standardised procedures for private land conservation, insufficient guidance for implementation, and inconsistent enforcement across jurisdictions generate uncertainty and risk for landowners. If legal frameworks do not compensate value losses (e.g., agricultural-to-nature conversions), owners face stark financial disincentives. Also, tax structures (specifically inheritance taxes) can physically force the fragmentation or sale of land, dismantling conservation efforts across generations.

"There is a risk that a high inheritance tax would not be covered by the rental income... resulting in land surface reduction and fragmentation." (Račinska et al., 2015)

In several European countries, public agencies responsible for conservation are perceived as understaffed and general lack of resources. What is more, there is insufficient coordination of land conservation as the policies are siloed and spread across municipal, regional, and national levels. Furthermore, conservation is often implemented through top-down approaches, with little attention to procedural clarity, financial support, or local decision-making contexts. When monitoring responsibilities fall to NGOs, the durability and credibility of conservation instruments can be jeopardised. Unlike public administrations, NGOs are typically not democratically mandated or embedded within stable governmental structures, and their internal organisation and funding may vary over time. As a result, landowners may perceive them as less reliable partners for implementing conservation obligations. This perceived instability can increase uncertainty and reduce confidence in the long-term security of conservation agreements.

4.1.1.3 Transaction and Scale Mechanisms

A second major cluster of physical constraints concerns transaction costs, administrative burdens, and scale inefficiencies. The "cost of entry", is defined in high administrative and technical overheads (soft costs) to access conservation markets (e.g., carbon or biodiversity credits). These costs disproportionately burden small landowners and smaller civil-society organisations. Conservation easements and other durable legal tools routinely incur high administrative costs, lengthy timelines, and complex procedural requirements. In countries with decentralised or inconsistent administrative systems, landowners face prolonged and costly approval processes that many small organisations are ill-equipped to navigate. Without

mechanisms to aggregate these smaller parcels, physical opportunity is restricted to large estates.

Scale further conditions access to opportunity: smallholders struggle to access funding that favours larger estates, to comply with strict documentation requirements, or to bear the burden of recurrent monitoring. Where agricultural subsidy systems impose heavy bureaucratic procedures, and where sanctions are experienced as punitive, land stewards perceive the administrative apparatus not as enabling but as constraining.

The involvement of volunteers, often viewed as a cost-saver, paradoxically generates additional coordination, training, and liability costs that many landowners or NGOs cannot absorb. The required skills and resulting transaction-costs produce a structural bias toward large entities, deepening inequality in access to conservation opportunities.

4.1.2 Social Opportunity Drivers: Network and Norms

Social Opportunity focus on whether landowners and conservation organizations are enabled or hindered by their social environment to take conservation measures. *Social opportunity* captures the cultural context, interpersonal networks, and norms that influence decision-making. In PLC, this is characterized by a tension between deep institutional mistrust and strong peer-to-peer reliance.

4.1.2.1 Trust, as a characteristic of the local network

Trust within the governance and stakeholder system constitute a key component of *Social Opportunity* in private land conservation. Various codes from the PLC dataset highlight that the design, stability, and coordination of institutions and stakeholder networks shape whether conservation actions are feasible and sustainable. Governance systems with frequent rule changes, fragmented responsibilities across municipal, regional, and national levels, or unclear enforcement procedures create structural uncertainty that constrains landowners' ability to participate in conservation programmes.

Similarly, NGOs and intermediary organisations play a structural role in the system: when these organisations are subject to variable funding, short-term mandates, or limited organisational continuity, their capacity to support conservation reliably is reduced. PLC-coded evidence shows that conservation mechanisms administered through unstable or weakly coordinated actors generate structural barriers, even when legal frameworks or incentives exist. Conversely, well-structured, coordinated networks of authorities, NGOs, and local institutions provide clear pathways, procedural guidance, and aligned incentives, enhancing the external conditions under which landowners can engage in conservation.

This framing highlights that *Social Opportunity* is determined not by individual trust or perception, but by the structural configuration, stability, and coordination of actors within the governance and stakeholder system, which collectively shape the feasibility and durability of conservation actions. Hence, trust is to some extent a contextual rather than a human factor.

In PLC, the trust dynamic is further characterized by a tension between deep institutional mistrust and strong peer-to-peer reliance. Consequently, the source of information (the messenger) is often more influential than the information itself.

> *"Trust among the contractual parties of a conservation easement is a key ingredient, as the agreement forms the basis for a lifetime relationship." (European Networks for Private Land Conservation (ENPLC), 2023)*

4.1.2.2 Peer Validation and Social Recognition Structures

Landowners' participation in private land conservation is strongly shaped by external social factors, including recognition by peers, perceived legitimacy, and approval within their networks. Public recognition such as awards, labels, or formal acknowledgement, functions as a social resource that can complement or partially substitute financial incentives.

> *"What's more, it hands out annual prizes - 'Oscars for farmers' - to those farmers whom a jury of peers has judged to excel in conserving nature." (Eurosite, 2023)*

Beyond individual expertise (addressed under *Psychological Capability*), the presence of peer networks, professional communities, and validating organisations provides a social context in which conservation-oriented practices are acknowledged and legitimised. These networks offer opportunities for exchange, benchmarking, and social validation among landowners, thereby embedding private land conservation within shared norms and collective practices. While such recognition structures are not always decisive on their own, they form part of the social environment that can support the continuation of conservation efforts.

> *"And it's not necessarily about financial motivation or incentives. It's about having that recognition and people seeing they are making a difference... they just want this simple recognition. (LIFE ENPLC, 2022)"*

Conversely, negative social narratives surrounding farming, land management, or conservation can constrain *Social Opportunity* by creating environments in which landowners feel judged rather than supported. In networks where stewardship practices are publicly problematised or devalued, landowners may experience social alienation, and conservation-oriented practices lack positive social visibility. Where role models and positive case studies are scarce, conservation success remains socially invisible, limiting diffusion effects within peer networks.

Intergenerational social expectations also shape *Social Opportunity*. In contexts where stewardship is framed as economically precarious or socially unrewarded, younger generations may be discouraged from inheriting or continuing land management responsibilities.

> *"This negative narrative can alienate farmers from nature, making them feel apart from it rather than part of it." (A. Gazenbeek, personal communication, n.d.)*

Finally, some socially embedded drivers operate through normative pressure, such as a sense of moral obligation arising from expectations within social or professional networks. While such pressures may support the uptake of private land conservation, they do not necessarily reflect intrinsic beliefs or values. These mechanisms therefore sit at the interface between *Social*

Opportunity (the presence of norms and expectations) and *Motivation* (the internalisation of those norms), and their long-term effectiveness may depend on whether social expectations align with landowners' own values and capacities.

4.1.2.3 Knowledge and Coordination needs

Effective conservation requires the flow of knowledge, the coordination of networks, and collaborative platforms. Many contexts, however, suffer from fragmented initiatives, limited technical assistance, insufficient guidance, and scarce opportunities for matchmaking between landowners, NGOs, volunteers, and public entities. Local-level disaggregation while offering proximity, often results in strategic incoherence, limited critical mass, and missed synergies.

Where expertise on conservation tools, funding application processes, or monitoring requirements is absent, the capacity to act becomes constrained even when actors are willing *(*See Chapter 5*)*. Volunteer networks, too, require structured coordination, clear rules, and shared training, which are often missing. The absence of durable intermediaries exacerbates these coordination failures. Networks alone cannot fully offset financial or legal barriers, but their absence significantly limits actionability.

> *"This network... seeks to bring together farmers who look after nature on their land. To enable them to swap experience, tips and tricks, between them and with conservation professionals." (A. Gazenbeek, personal communication, n.d.)*

4.1.2.4 Integrated Socio-Economic Drivers

Several determinants identified in the data resist binary classification *(Physical vs Social Opportunity)*. These factors operate at the intersection of *Physical and Social Opportunity*, where structural mechanisms are employed to solve relational problems, or social capital is converted into economic value. Examples from the data include collective arrangements such as landowner networks, cooperatives, or intermediary organisations that facilitate access to funding, markets, or advisory support, while simultaneously relying on trust, shared norms, and peer coordination. In these cases, social relationships enable material opportunities (e.g. reduced transaction costs, pooled investments, or eligibility for schemes), illustrating how social embeddedness can directly shape physical opportunity structures.

4.1.2.5 Market-Based Stewardship Mechanisms

Labels, certification schemes, and branding initiatives function as external coordination mechanisms that link social recognition with material incentives. From an *Opportunity* perspective, these instruments structure access to markets, price premiums, and support schemes, while simultaneously embedding conservation-oriented practices within recognised social and institutional frameworks. As such, they operate at the interface of *Physical Opportunity* (economic viability, reduced transaction costs, eligibility for programmes) and *Social Opportunity* (shared standards, collective visibility, and external validation).

When effectively designed and supported, such mechanisms can increase product value, enhance market access, and provide formal recognition of conservation practices. They may also lower administrative barriers by aligning certification criteria with subsidy, procurement, or award programmes, thereby simplifying participation in conservation-related markets.

However, the effectiveness of these mechanisms depends on the presence of stable institutional backing, coordination, and collective organisation. In contexts where these conditions are weak or absent, labels and certification schemes face limited uptake, low visibility, or competition with other initiatives for public and market attention. In such cases, the marketisation of stewardship remains fragile, and these mechanisms fail to provide a reliable external opportunity structure for private land conservation.

> *"The benefit of participating in such labelling schemes is a better visibility for consumer groups with a demand and a willingness to pay for 'green', regional premium products." (Disselhof, 2015)*

4.1.3 Bringing the external drivers together

Overall, this chapter demonstrates that landowners' engagement in Private Land Conservation (PLC) is strongly shaped by the external conditions that surround and influence their decisions. These conditions encompass both material and social factors that either enable or constrain conservation actions.

Physical drivers (*Physical Opportunity*), including regulatory frameworks, administrative procedures, funding mechanisms, market incentives, and access to technical or organisational support, determine whether PLC is practically achievable. When well-aligned with local realities, these structures create opportunities for action; when misaligned or overly burdensome, they present significant barriers.

Social drivers (*Social Opportunity*) such as cultural norms, peer influence, and prevailing land management traditions, shape how conservation is perceived within communities. They influence whether landowners view PLC as legitimate, appropriate, or valued, and affect the social support and validation available for engaging in conservation.

Taken together, these external drivers make clear that participation in PLC is not solely a matter of individual choice. The broader system must provide the conditions, resources, and social coherence that make conservation both possible and meaningful. Understanding these structural and social factors provides the foundation for examining the internal drivers of behaviour *Capability* and *Motivation* which are addressed in the following chapter.

5 Factors influencing land-use decision making

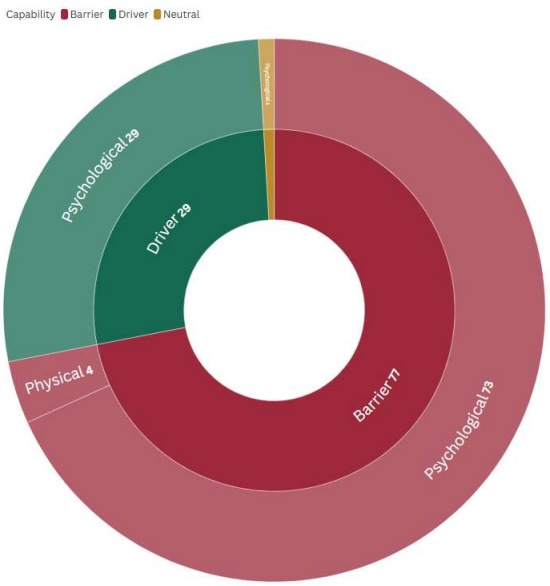
While the previous chapter focused on the structural external conditions that shape landowners' engagement in Private Land Conservation (PLC), this chapter turns more to the internal drivers of behaviour: *Capability* and *Motivation*. These dimensions capture what landowners are capable to do and want to do, complementing the external *Opportunity* factors explored in Chapter 4.

- **Capability** (Michie et al., 2011) refers to the knowledge, skills, and practical competencies that enable landowners to implement conservation actions. This includes understanding relevant ecological principles, navigating administrative procedures, and accessing the technical expertise or management practices necessary to carry out effective PLC.
- **Motivation** (Michie et al., 2011) refers to the internal processes that direct and energize behaviour, including beliefs, values, priorities, and attitudes toward conservation. It encompasses both reflective considerations (*Reflective Motivation*) such as weighing costs and benefits or aligning actions with personal or professional goals, and automatic responses, such as habits, emotional responses, or culturally ingrained tendencies.

By examining *Capability* and Motivation alongside the external *Opportunity* conditions, this chapter provides a comprehensive view of the behavioural determinants that influence landowners' participation in PLC. The following sections present the results of the analysis, highlighting the internal drivers that facilitate or constrain conservation decisions.

For the understanding of the analysis of the text segments, we interpreted Capability as the knowledge or skills: "Do you know and have what it takes?". Motivation is more seen as an internal drive: "Are you willing to do what it takes?

5.1 Capability



To introduce the qualitative analysis of the *Capability* component, we revisit the overview of codes. Most notably, capability in the context of private land conservation (PLC) is predominantly understood by actors as psychological capability, functioning as a driver and a barrier. In contrast, *Physical Capability* is mentioned far less frequently. When mentioned, it is exclusively framed as barrier; limitations in time, labour, or technical capacity to implement conservation measures. Unlike in academic literature on behaviour aspects of land management, *Physical Capability* does not emerge as a salient driver within the PLC context.

Figure 2: For illustration, the distribution of text segments between drivers and barriers in the component Capability.

5.1.1 Psychological Capability

Ipsa scientia potestas est (Knowledge is power), Francis Bacon wrote back in the 16th century. Likewise, this analysis indicates that having the 'right' knowledge is a key enabler for landowners to participate in PLC with more attention being given to the 'lack of knowledge' (barrier) rather than the availability of knowledge (driver).

The 'right' knowledge refers to knowledge in different fields. Private landowners are not necessarily all educated in ecology, biodiversity, climate change, water management, law, governance, … to name just a few of the areas of expertise closely linked to Private Land Conservation. The essential areas of expertise highlighted in the grey literature were Administration & Legal, Ecological, and Business & Financial. The following paragraphs expand on each of these expertise's.

5.1.1.1 Administration and Legal Literacy

The most attention in terms knowledge within the dataset refers not to lack of ecological awareness, but to lack of procedural competence. Different codes in the PLC-dataset repeatedly suggest that landowners may be motivated to conserve, however, they often lack the specific cognitive skills or the confidence needed to navigate the legal and administrative mechanisms aimed at supporting PLC. These mechanisms include easements, stewardship contracts, and relevant tax provisions. The legal and administrative inexperience adds to distrust and therefore scepticism towards policies and government. Meaning that not the conservation work itself, but the paperwork is the barrier.

5.1.1.2 Ecology

Various codes in the PLC-dataset refer to insufficient knowledge on the ecological value. On the one hand, some landowners don't realize how much biodiversity their land holds. They first need an AHA-moment, creating a mind shift. It is this moment of realisation or awareness that makes them ready to act.

Other landowners do realize the biodiversity on their land, and they highlight that they add "unique knowledge" on the land, e.g. a deep knowledge of the lands' history. Therefore, these private landowners see themselves as essential in the conservation of their land, adding specific place-based knowledge to conservation discussions which can be rather technical. Conservation schemes or national policies often require management plans that detail actions and practices which build on guidelines and principles founded in scientific disciplines such as biology and ecology. While these plans are often drafted by NGOs or public authorities, the private landowners struggle to transpose their tacit knowledge into these technical documents.

5.1.1.3 Business and Financial Literacy

Next to an entrepreneurial mindset, there is a certain business and financial literacy needed to speak the right 'language' to attract funding. This field of business and finance uses its own vocabulary and concepts, and is not always easily accessible, e.g. for people with a background in forestry or agriculture. Private landowners with an interest in PLC have to become entrepreneurs on top of their conservation work and their other day-to-day activities. In addition, they must have management skills to run such new type of business, including challenges such as working with field workers and volunteers.

5.1.1.4 Coping strategies

Closely linked to the dominant barrier 'lack of knowledge' within the category capability, the PLC reports put forward several solutions:

(a) Built knowledge and spread awareness. Sometimes landowners would want to start with certain practices, but they simply don't know of their existence, hence the need for knowledge transfer. The spreading of awareness or knowledge is strongly influenced by themes addressed in Social Opportunity and the involved parties. The presence of a network makes knowledge transfer more efficient, effective and realistic, but on the downside knowledge risks to get stuck with the same, small amount of people.
(b) Examples and experts. The lack of real-life cases is a strong barrier to implement certain practices or policy instruments and closely related, the lack of (legal) experts to guide landowners. Hence, the capacity to act on PLC is strongly dependent on the capability to access the right advice.

The data thus places significant weight on the fact that individual capability is rarely sufficient or it is hard to organise on its own. Landowners rely heavily on learning capability from experts, peers and networks which closely relate to the concept of social opportunity (see Chapter 4).

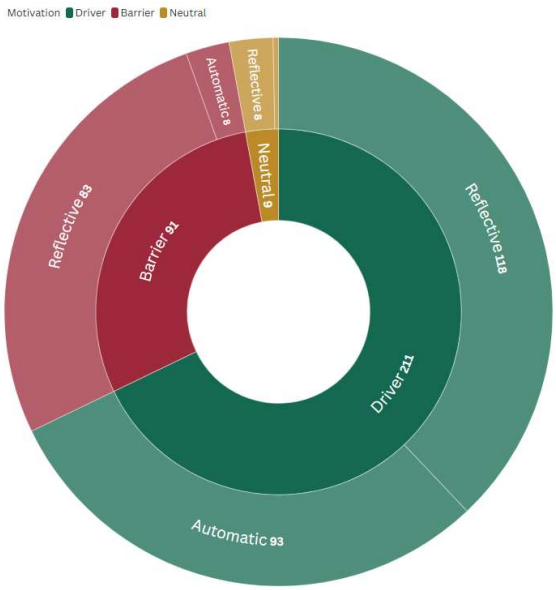
5.1.2 Physical Capability

As indicated above, *Physical Capability* is not mentioned often as a barrier (nor enabler) to start with PLC in the grey literature. To be clear, physical capability is a prerequisite for PLC: labour, time and other resources are a must to act on PLC. The (near) omission of this concept suggests that they are limiting factors of PLC, rather than enablers or barriers. Another possibility is that these factors are so obvious that they are not worth mentioning.

5.2 Motivation

> *"The motivations of landowners to conserve their property can be manifold, ranging from emotional place attachment to personal history, general environmental ethics and values, the feeling of social responsibility, financial considerations or compliance with environmental regulation."*
>
> (Fundación Biodiversidad et al., 2018)

Motivation could be seen both as the beginning and the end for action. Without it, people will never start with PLC. It is therefore a key component in behaviour. The COM-B model addresses motivation on two levels: *Automatic Motivation*, 'the fire from within' or 'the heart', and *Reflective Motivation*, 'I need to think on that' or 'the head'.



Both *Automatic* and *Reflective Motivation* popped up as important factors, backed by around 300 text segments. *Automatic Motivation* almost never identified as a barrier, showcasing the idea that PLC comes from a positive internal driver. People who possess certain traits, such as Agreeableness and Openness are known to show more pro-environmental behaviour (Hirsh, 2010; Kaiser & Wilson, 2004). On the other hand, people might want to start with conservation, but they waiver these ideas when they think them over. This is illustrated by the dataset: near all mentions of barriers are related to *Reflective Motivation*.

Figure 3 For illustration, the distribution of text segments between drivers and barriers in the component Motivation.

5.2.1 Automatic Motivation

5.2.1.1 Identity and legacy

Identity is something that is hard to grasp. It could mean different things to people. In the PLC data there were many references to altruism, i.e. 'doing the right thing', and place-based identity, i.e. 'connection to the land'. Identity and legacy are the main instigators for PLC since private landowners seem to feel a strong internal driver to start conservation. The landowner acts as a guardian for the land and wants to pass this piece of heritage to the next generation in a good, or even better, state. Doing this they can feel a deep emotional satisfaction and pride in being a "good steward" and receiving social recognition from peers or the community. "Love of the land" and "peace of mind" are cited frequently as the actual root cause of action, with finance merely making it possible or even considering it of minor importance.

> *"Not the best profitability, but it is pleasant." (LIFE ENPLC, 2023)*

5.2.1.2 (Dis)trust

As mentioned earlier, *Automatic Motivation* is mostly stated as a positive factor, conceived as an enabler rather than a barrier. The barriers related to automatic motivation are linked to trust, or distrust to be specific. The concept of trust spans the boundaries of the components in the COM-B model, e.g. trust being a characteristic of the local network of social peers (see Section 4.1.2.2) or a characteristic of the relations between land users and public authorities (see Section 4.1.2.1). While there may be rational arguments to (dis)trust someone or something (see section 5.2.2), this section refers to (dis)trust as a gut feel. Generally, there are more feelings of distrust against public institutions or the governmental agencies. What is more, conservation practices or PLC instruments that imply providing public access or offering amenity values are distrusted, linked to a strong sense of loss of autonomy or ownership. For example, some landowners are eager to conserve nature, but they don't want to grant the public access to their estate out of privacy concerns, fear of damage or misuse. From their perspective, there is a mismatch between public access and conservation works.

5.2.2 Reflective Motivation

Reflective Motivation involves the conscious, cognitive processes where landowners evaluate the costs, benefits, and feasibility of conservation. The data indicates that key rationale of landowners related to reflective motivation are a desire for financial viability and the preservation of decision-making autonomy. This section addresses the thoughts that block transposing beliefs into action.

5.2.2.1 Financial Viability

While profit maximisation is rarely the sole driver or even a driver at all, financial viability does often act as a critical baseline condition. The data suggests a hierarchy of needs: only when the land is financially secure, conservation becomes possible. Conversely, structurally loss-making

assets force landowners towards commercial development or sale, regardless of their conservation ethics.

Landowners view land as both a natural asset and a financial instrument. Incentives (tax breaks, subsidies) are often not viewed as rewards, but as necessary mechanisms to bridge the gap between conservation costs and (agricultural) income.

> *"When the rate of return of agricultural land is negative, landowners struggle to maintain an asset that is structurally making a loss. They are tempted to sell or develop their land in order to make a profit that is neither null nor negative." (Fondation pour la recherche sur la , 2021)*

Next to these more classical approaches on land conservation there are new phenomena surging on how to balance the books. The text segments indicated a strong reflective drive to integrate conservation with market mechanisms, such as eco-tourism, green energy points, or premium value-added products (e.g., wool, honey), in order to finance the "cost" of nature conservation. Of course, the pendulum cannot swing too far in the other direction: the PLC frontrunners are looking for a way to cover costs, not to capitalize on nature. Entrepreneurship of an estate or farm thus encompasses more than purely financial or business strategies, yet they is an inherent component of entrepreneurship. This need equally applies for other forms of entrepreneurship, including social entrepreneurship which focuses on the local environment and the community rather than sole financial gain. Even when profit is not the main driver of action, there is still a business that needs to be ran and, as a consequence, financial stability is a prerequisite. This is strongly linked to the business role that landowners need to take on (see Chapter 5.1).

5.2.2.2 Autonomy

The fact that landowners aim to be at the drivers' seat is considered important. When NGOs or environmental organisations want to help, many codes in the dataset refer to the landowners' desire to have the final say, as they are the owners. This determinant is categorized as *Reflective Motivation* because it includes planning and allows for risk management and flexibility.

There is a strong preference for voluntary schemes over regulatory ones. This preference is a mixed determinant, which means there is some aspects of *Automatic Motivation* behind it. Because it also satisfies the psychological need for self-determination and ownership. When a scheme is voluntary, it aligns with the landowner's identity as an independent steward; when it is mandatory, it threatens that identity, triggering resistance.

The sense of autonomy could also spark proactive, self-governing conservation: pre-emptive voluntary decision to prevent the need for harsher interventions down the line. Such defensive conservation link clearly to the sense of autonomy. Through current, voluntary actions, landowners want to avoid a hard change in the future. On the other hand, some landowners see this voluntary and futureproof thinking as a possible trap. They are worried that when the conservation is successful, this could lead to even more regulatory consequences. The most perverse effect of this, landowners explicitly not reporting the presence of certain species. This does not mean that they do not conserve them, but by keeping it quiet they avoid the risk of extra rules or obligations.

5.2.2.3 Ambiguity of Long Term

Long term contracts or agreements, such as easements or some agro-environmental measures are regarded as both a driver and a barrier. Positive arguments by landowners for such long term contracts or agreements is the guarantee that their land will be conserved after they are gone. Through interventions such as conservation easements, for example, landowners ensure that their heirs cannot simply overrule their work, or the work by their ancestors. In addition, such strategies are an efficient way of keeping an estate intact and to ensure its' unity. Preventing the fragmentation of land is particularly hard as private land passes from one generation to the next. What is more, long term conditions are beneficial as their time horizon exceeds the lifespan of a government, a policy framework of even an legislation.

On that downside, this rigidness that is the main barrier to enrol in these long term contracts. The opponents of these long term agreements see them as not flexible enough and they stress that they 'feel locked in'. A dominant determinant is the fear of "permanence" (e.g., permanent easements). Landowners prefer short-term contracts (5-10 years) or result-based schemes that allow them to decide how to manage the land rather than following rigid prescriptions or rules.

5.3 Linkages between determinants

To understand how different components and determinants contribute or limit behavioural change, it is important to untangle the various interrelations. This section evaluates the relative weight or hierarchy of the determinants. In this qualitative research, "weight" is based on the dataset, e.g. the frequency of components that are managed as well as the emphasis on certain topics in the coded text segments, the determinants seem to operate in a hierarchy: some are non-negotiable prerequisites, while others have more of a driving or motivating role.

Both financial viability and autonomy seem to be essential to landowners. When these conditions are not met, the move towards PLC will probably not happen. People are usually aware that they will not get rich of PLC, but some financial reward to cover the expenses seems to be the lower limit.

Together with the financial aspect, landowners also attach great importance on autonomy. As the land is often already within the family for generations, they feel a lot of pride on keeping and maintaining these lands. When the sense of autonomy is lost this acts as a large barrier. It can even overrule financial reward, when it comes with too many strings attached. This is one of the main struggles with contracts like easements, where the feeling of a lock-in or loss of control is felt. These feelings closely relate to both *Automatic* and *Reflective Motivation* and are intensified when there is a lack of confidence in third parties such as NGOs and the government.

On a somewhat lower level of importance there are the determinants linked to *Automatic Motivation*, like pride and legacy. These are necessary to spark the idea and keep the landowners on board. They act as the internal drive. Opposingly, the external drive is considered equally

important and motivating to continue with PLC. Trust in peers and colleagues is valued very high. Especially recognition and expertise that are exchanged in these networks act as a strong driver.

Finally, there are some nice to haves but not really essential determinants for enrolling in PLC. These factors, many related to the component Capability, will mostly influence the scale or longevity rather than enable or inhibit PLC actions. For example, the lack of a network of volunteers, lack of technical knowledge, the big amount of paperwork are discouraging factors but don't influence a landowner's decision about PLC since the main hurdle of starting with PLC is already passed at that stage.

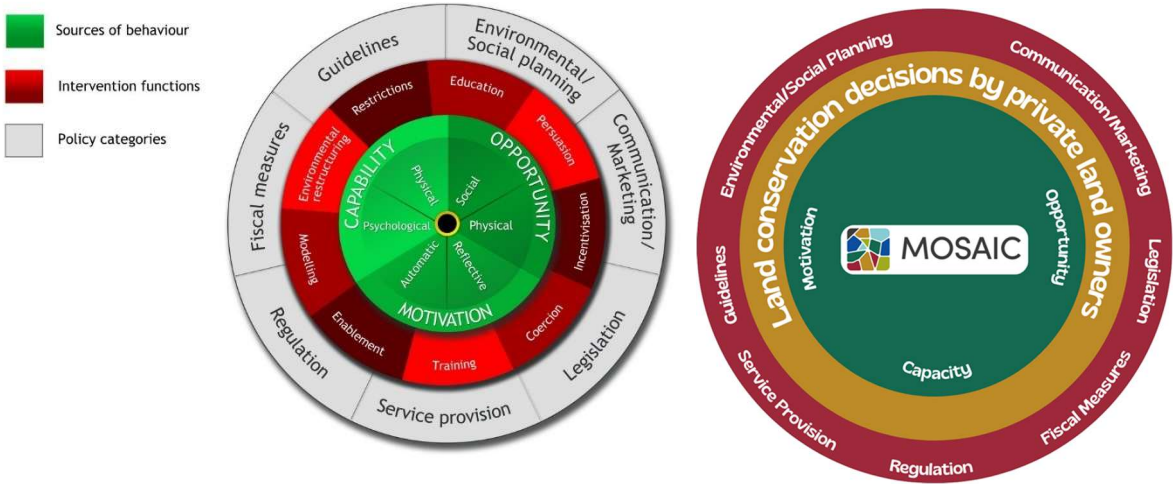


Figure 4: Original Behaviour Change Wheel (left) and adapted version with the elements we are focussing on in this report (right).

Table 2 Summarizing table with the determinants and their function in behaviour.

Determinant Cluster	Function in behaviour
Financial Viability	Gate: "If this is not okay, I cannot start."
Autonomy & Control	Safety Mechanism: "I won't do this if I lose my rights."
Identity & Legacy	Impulse: "I do this because it is who I am (Kaitiaki)."
	Purpose: "I do this for my children/future."
Trust & Networks	Bridge: "I will work with *you* (NGO), but not *them* (Gov)."
Privacy Concerns	Friction: "I want nature, but I don't want strangers."
Market/Labels	Cherry on Top: "It's nice if I can sell 'green' honey too."

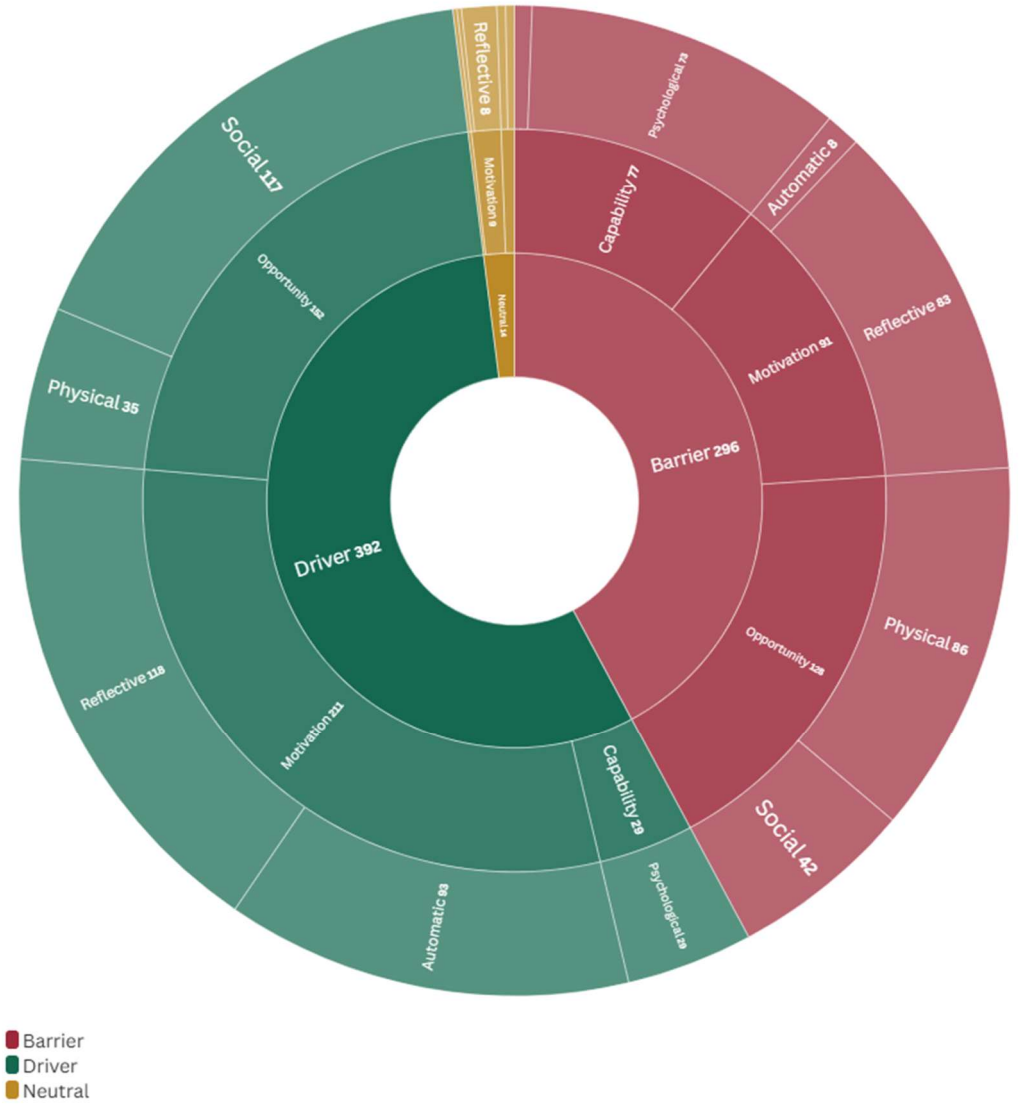


Figure 5: Overview of all analysed text segments and the way they are categorised by the AI-peer.

6 Discussion

6.1 Methodological reflections

6.1.1 Using COM-B for deductive coding

The COM-B model (Capability, Opportunity, Motivation – Behaviour) (Michie et al., 2011) provided a structured and transparent framework for deductive coding in this study. Its use allowed the highly diverse grey-literature dataset to be organised systematically, making it possible to disentangle the different behavioural influences shaping private land conservation. By breaking behaviour into three core components, COM-B offers an accessible way to interpret the interplay between what landowners are able to do, what the context allows them to do, and what they want to do. In this sense, COM-B complements more traditional land-use modelling approaches by producing actionable insights for intervention and policy design.

The simplicity which makes COM-B a practically applicable framework, however, equally sets some limitations. Reducing complex behaviour to three (or six) categories risks oversimplifying nuanced determinants, and its reliance on minimal contextual information constrains the model when addressing rich, context-dependent land-use decisions. More fundamentally, COM-B's focus on *individual*-level behavioural mechanisms does not fully capture structural and systemic drivers, such as market dynamics, policy path dependencies, social norms, and legal frameworks, that operate at institutional or landscape scales. Although these drivers are touched upon in the capability component, they are not addressed in full even though they are critical in shaping long-term ecological outcomes.

For these reasons, COM-B should be viewed as one analytical lens within a broader decision-making framework. In the context of PLC, it offers valuable behavioural insights and adds to the understanding of what policy interventions could be interesting to generate more interest in PLC, yet can be complement with other research methods to feed into policy design such as Agent based modelling and multi-criteria decision analysis (MCDA).

6.1.2 Reflections on AI-method

As noted in Section 2.3.1, the use of an AI research assistant enabled us to handle a substantially larger and more diverse set of texts than would have been feasible manually. The ability to access and process knowledge previously restricted by language barriers was particularly valuable. The AI-assisted approach allowed for the consistent analysis of thousands of pages without fatigue, resulting in the creation of a rigorous dataset of coded text fragments, the PLC-database. This database effectively identified the main drivers and barriers reported in the literature, including sources that might otherwise have been overlooked.

There are, however, important limitations to this approach. One concern is the potential for the model to overlook relevant text segments, which could bias results. To address this, we included a large number of documents and triangulated the coding, checking each other's work and interpretation, ensuring that general trends were reliably captured. Even with robust triangulation, the broad and interpretive nature of the COM-B framework leaves room for ambiguity, which sometimes affected the AI's coding precision. Despite these challenges, AI

proved to be a valuable tool for scaling qualitative analysis, enhancing reproducibility, and revealing patterns across a vast and heterogeneous dataset that would have been difficult to manage using traditional methods.

6.2 Key determinants of voluntary Private Land Conservation

This study provides a systematic, cross-European syntheses of behavioural determinants of Private Land Conservation (PLC) based on grey literature from pioneering PLC initiatives. This focus is significant for two reasons. First, PLC is an emerging policy domain in Europe: many countries are experimenting with voluntary conservation tools, yet structured behavioural evidence has been scarce. Second, the reports, testimonies and project outputs analysed here, although not published in scientific journals, represent the most immediate and practice-grounded body of knowledge on how landowners actually respond to PLC instruments. By systematically analysing this material through the COM-B framework, this study contributes new conceptual clarity to how PLC behaviour is shaped, blocked or enabled across Europe. From this analysis, three overarching conclusions emerge:

- **The Gate is Economic Viability**. Structural economic conditions—particularly risk, return, and transaction costs—form the decisive threshold. Without resolving these external constraints, neither Motivation nor Capability can materialise in behaviour.
- **The Key is Social Trust**. Where physical barriers are addressed, social trust determines whether landowners are willing to step through the gate. Intermediaries, peers and trusted networks are the most influential mediators of participation.
- **Motivation is Latent, not missing**. Rather than lacking environmental concern, many landowners are already motivated by identity, stewardship and legacy. These motivations do not need to be created; they need to be enabled.

These findings underline the value of analysing grey literature: they reveal how PLC behaves “on the ground” not in theory, but in the lived realities of European landowners navigating a still-immature policy field. They echo and refine insights from existing research on land-use behaviour. First, the strong influence of economic conditions confirms a long-standing pattern observed in studies of agricultural and forestry decision-making: when land becomes a structurally loss-making asset, behavioural intentions however positive, are overridden by financial reality. This alignment with earlier work underscores the need to foreground economic feasibility and market design in PLC policy development.

Although the established importance of economic determinants in land-use behaviour is confirmed, this study also highlights dimensions that remain underexplored in PLC research particularly the behavioural weight of trust, identity, and autonomy. This suggests that PLC cannot be effectively understood and promoted through economic tools alone; social legitimacy and relational structures are known to be equally decisive (Fairbrother, 2017). Whereas economic constraints determine whether PLC is possible, social opportunity and intrinsic motivations shape how and with whom landowners are willing to engage. This illustrates the

distinctive behavioural profile of PLC as a voluntary, relationship-dependent form of conservation.

Finally, these results raise important questions for future research. A logical next step is to compare the grey-literature determinants identified here with insights from white academic literature on PLC and land stewardship. An important factor would be to look at the possible bias in the grey literature. Farmers and landowners working in LIFE projects and participating in these interviews could be part of a coalition of the willing. It can therefore give a wrong idea on the motivations or drivers of PLC. For example, work by MOSAIC colleagues Jens Abildtrup and Esther Devillers from INRAE using farm-accountancy and behavioural datasets may provide an empirical counterpoint to the practice-based narratives analysed in this study. A systematic comparison would clarify the extent to which determinants emerging from pioneering PLC projects particularly those related to social trust and identity, are also reflected in formal behavioural research. Such triangulation would strengthen the evidence base for PLC and help distinguish context-specific findings from generalisable behavioural mechanisms.

6.3 Policy implications

Although a formal policy implications analysis was beyond the scope of this study, the findings provide several valuable reflections for private land conservation (PLC). First, PLC remains a high-risk venture for landowners, with uncertain returns and potential loss of rights; policy efforts should aim to de-risk participation to normalize the behavior. Second, barriers are less about knowledge (*Capability*) and more about structural constraints (*Opportunity*), suggesting that interventions should focus on restructuring markets and institutional support rather than education alone. Third, small landowners cannot effectively engage in global conservation markets without intermediaries; professionalizing aggregators such as cooperatives or trusts is critical. Fourth, motivation can be enhanced by combining financial incentives with social recognition: programs that leverage pride and peer influence may drive uptake more effectively than monetary incentives alone. Fifth, mistrust of government-led initiatives can be bypassed by funding and empowering local, bottom-up networks to implement conservation measures. Finally, further research could expand on these insights by applying the *Behaviour Change Wheel*'s outer layer in deductive coding, linking individual behavioural mechanisms to policy and structural incentives. Together, these reflections highlight that effective PLC policy must integrate behavioural, structural, and social levers, combining de-risking, institutional support, and motivation strategies to create lasting impact.

7 Conclusion

This study demonstrates the value of combining a structured behavioural framework and AI-assisted analysis to generate actionable insights for private land conservation (PLC). By systematically coding a diverse and extensive dataset of grey literature, we identified key drivers and barriers shaping landowner decisions, revealing both behavioural and structural influences. While the study does not provide a full policy evaluation, its findings offer practical guidance for de-risking participation, supporting intermediaries, and designing incentive mechanisms that align motivation with opportunity. Importantly, these results can also serve as an input for land-use modelling within MOSAIC, linking behavioural insights to broader landscape and policy scenarios, enhancing the relevance and applicability of PLC interventions.

Appendix

Appendix 1: Prompt for deductive coding in Gemini 2.5 Pro

You will act as a qualitative researcher performing open coding on grey literature about private landowners' decisions on land conservation.

For each uploaded document:

Carefully read the document and identify text segments, quote length — recommend 20–200 words, that relate to landowners' behaviour, drivers or barriers to conservation, and references to policies or interventions.

For each segment assign one or more of: a COM-B component (Capability / Opportunity / Motivation — and subtype where possible), a Policy category (Guidelines, Environmental/Social Planning, Communication/Marketing, Legislation, Service Provision, Regulation, Fiscal Measures), or an Extra code if it doesn't map. Double-code segments when appropriate (e.g., Motivation + Fiscal Measures).

Record: File name (format= DocName_YYYY.pdf), page number, exact quoted text segment, assigned code(s), and optional notes.

Produce a single consolidated spreadsheet (Excel/CSV) with all coded segments. Work document-by-document, but return one consolidated table. Provide a short codebook of all custom "Extra" subcodes used.

Output format (columns): Filename | Page Number | Text Segment | COM-B Component or Policy Category or Extra | Notes / Comments

Requirements: Link every code to exact text; include page number; create subcodes only when required and list them in the codebook; keep quotes verbatim; anonymize owner or location names if present; show examples for each document before completing the whole spreadsheet. Allow multi-codes, but put them in different rows.

Suggested compact codebook (COM-B ↔ examples + Policy categories)

Use this as the assistant's internal mapping. It helps keep coding consistent.

COM-B — definitions + short examples you can use:

- Capability — Psychological: knowledge, awareness, skills.
- Capability — Physical: physical ability, labour capacity.
- Opportunity — Physical: access, time, money, infrastructure.
- Opportunity — Social: cultural norms, peer pressure, social support.
- Motivation — Reflective: plans, beliefs about outcomes, intentions.
- Motivation — Automatic: emotions, habits, identity.

Policy categories (definitions):

- Communication/Marketing — media, outreach
- Regulations — rules/standards (voluntary or required)
- Guidelines — recommended best practice
- Fiscal Measures — subsidies, tax breaks, payments for ecosystem services
- Environmental/Social Planning — design of physical/social environment, zoning, landscape planning;
- Legislation — laws/statutes
- Service Provision — direct services/technical support, extension services

Extra — for concepts outside COM-B/policy (include subcode name)

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