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.

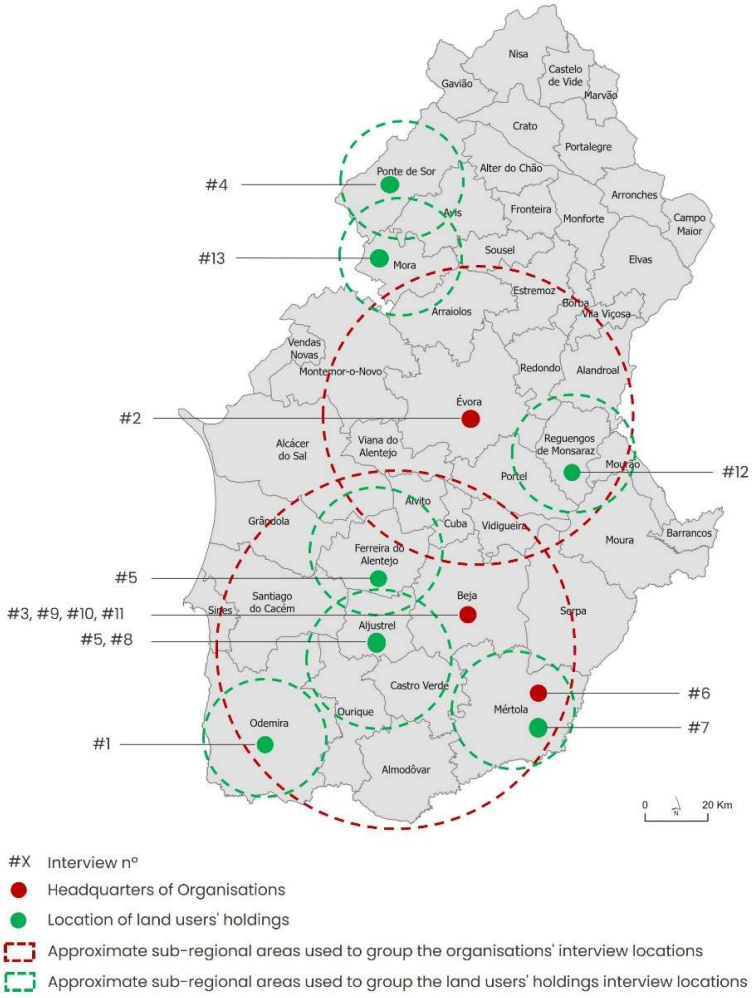

Figure 2: Localisation of the *interview (organisations and land-users) in Alentejo*

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).

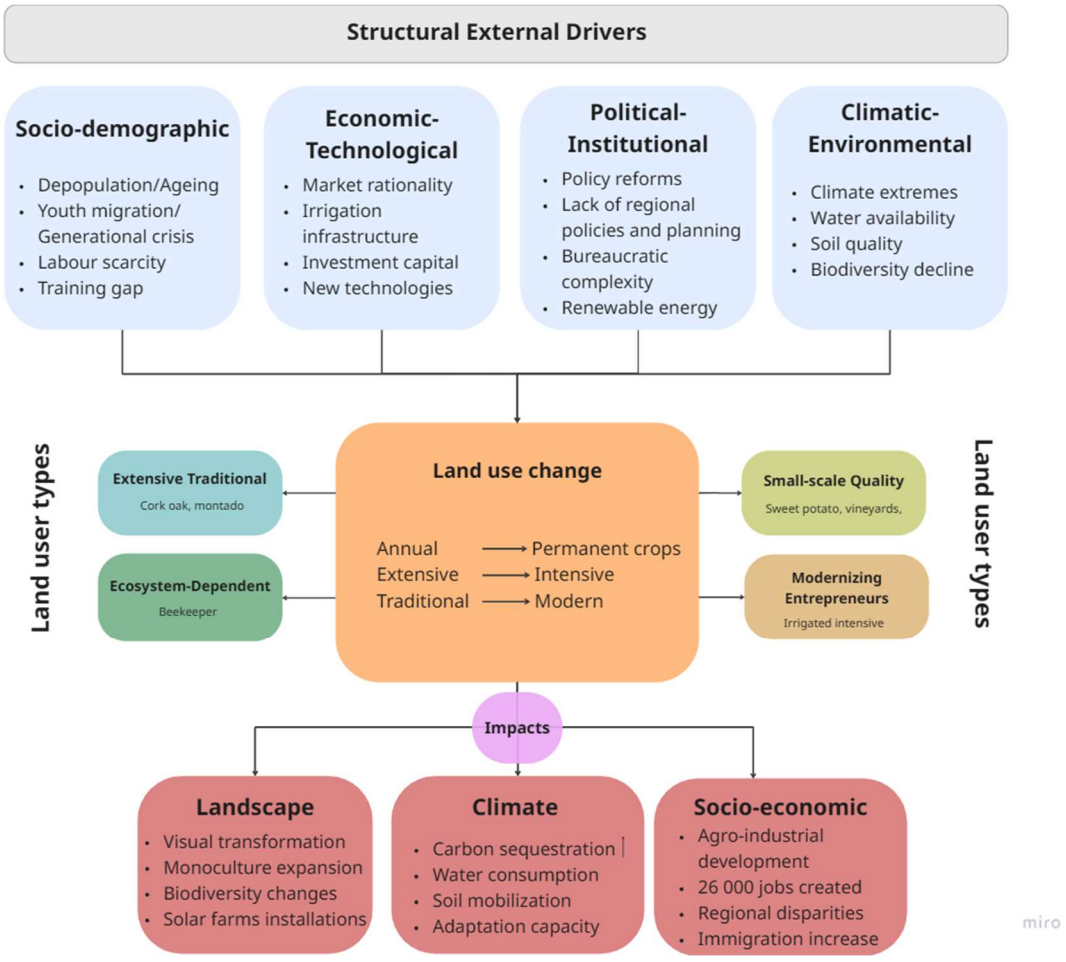

Figure 4: Synthetic visual of structural external drivers, land use change, land user's types and impacts

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.

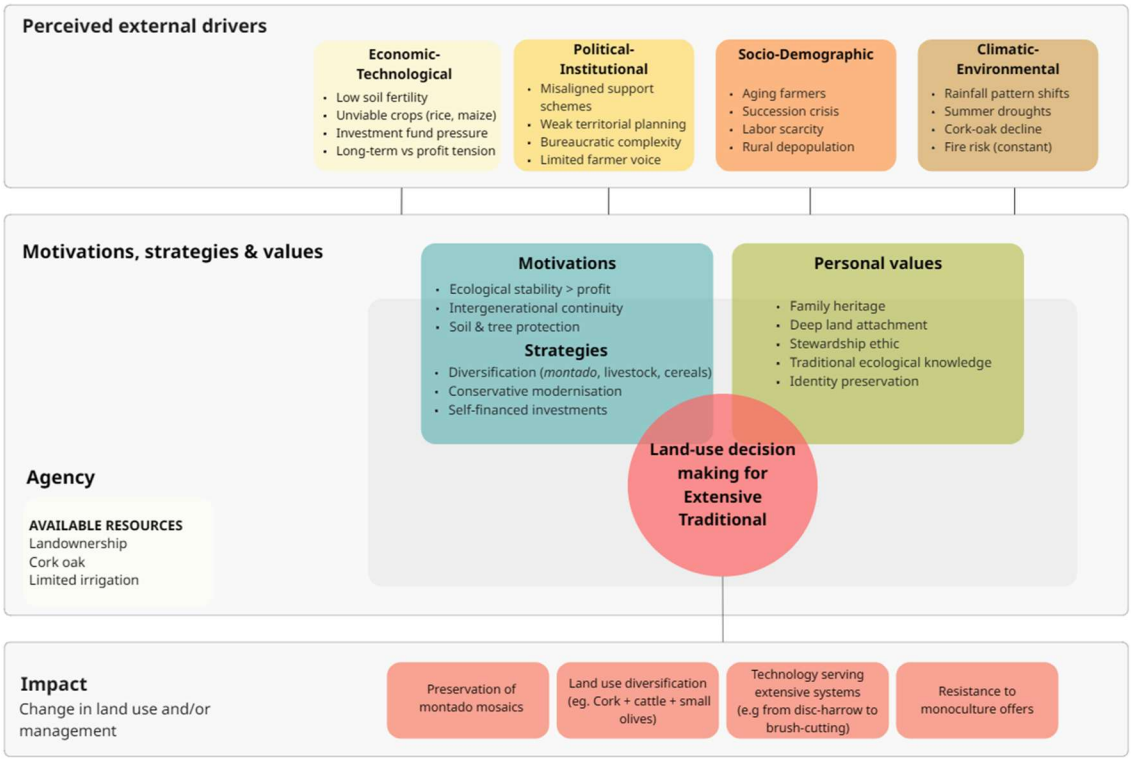

Figure 5: Synthetic visual for the land-use decision-making process for the Extensive Traditional Land User type.

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.

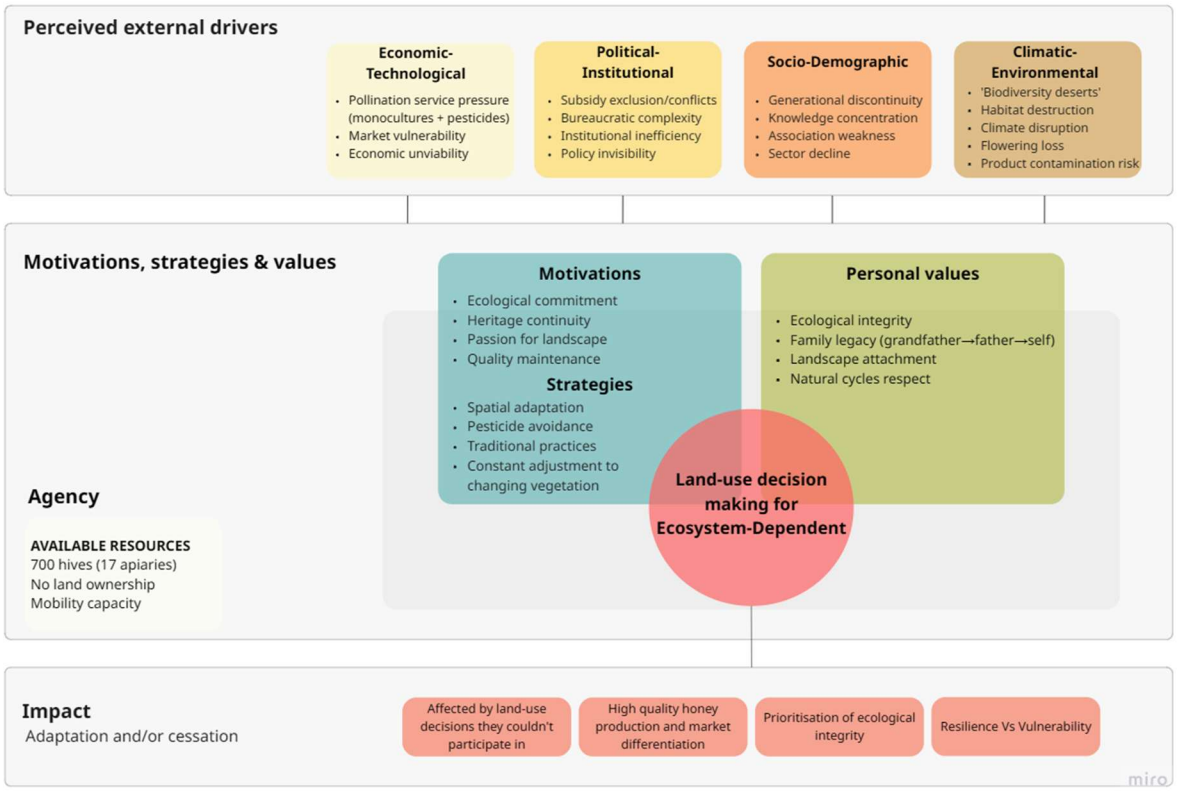

Figure 6: Synthetic visual for the land-use decision-making process for the Ecosystem-dependent Land User type

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.

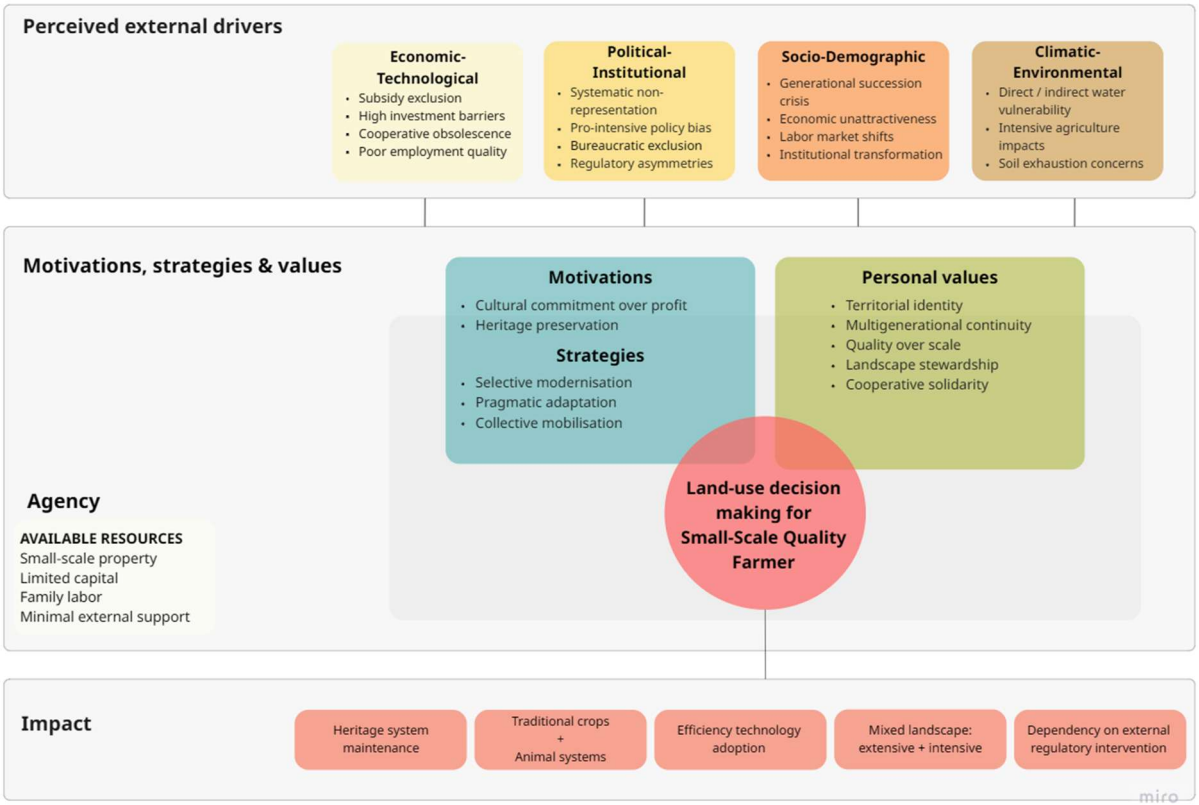

Figure 7:Synthetic visual for the land-use decision-making process for the Small-Scale Quality Farmer Land User type

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 (

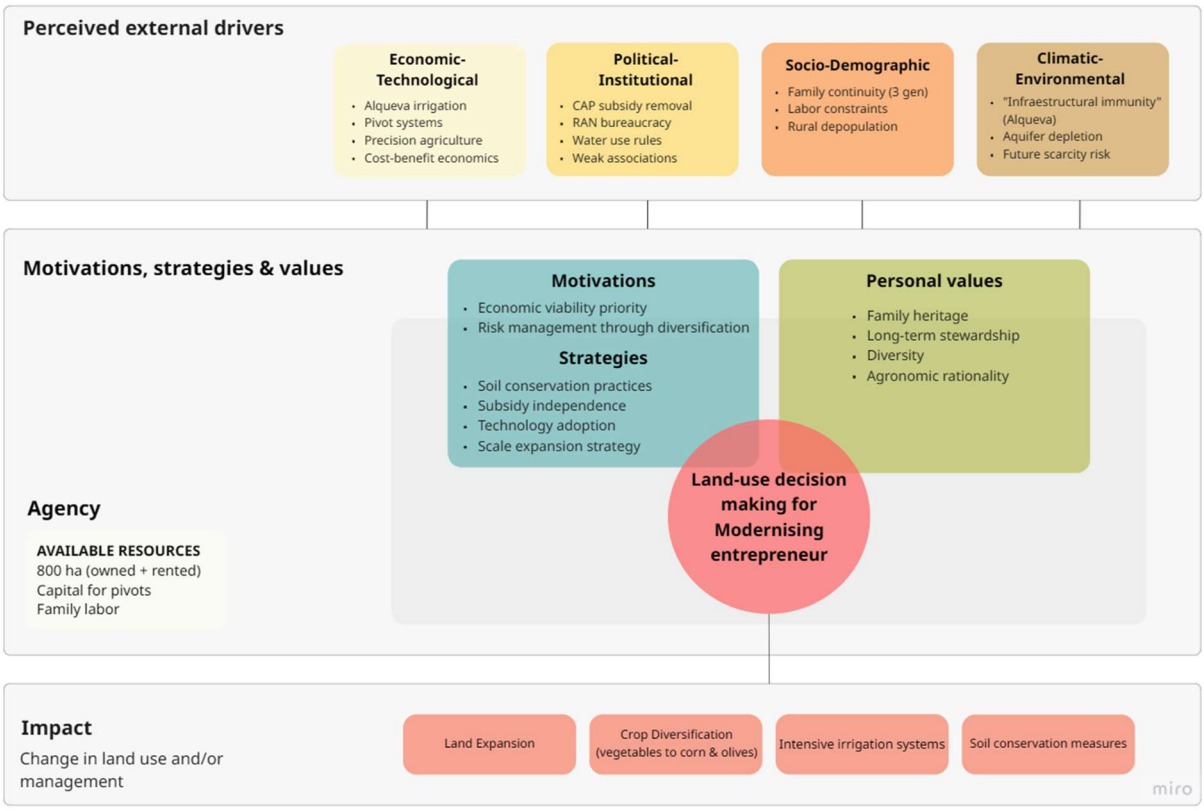

Figure 8).

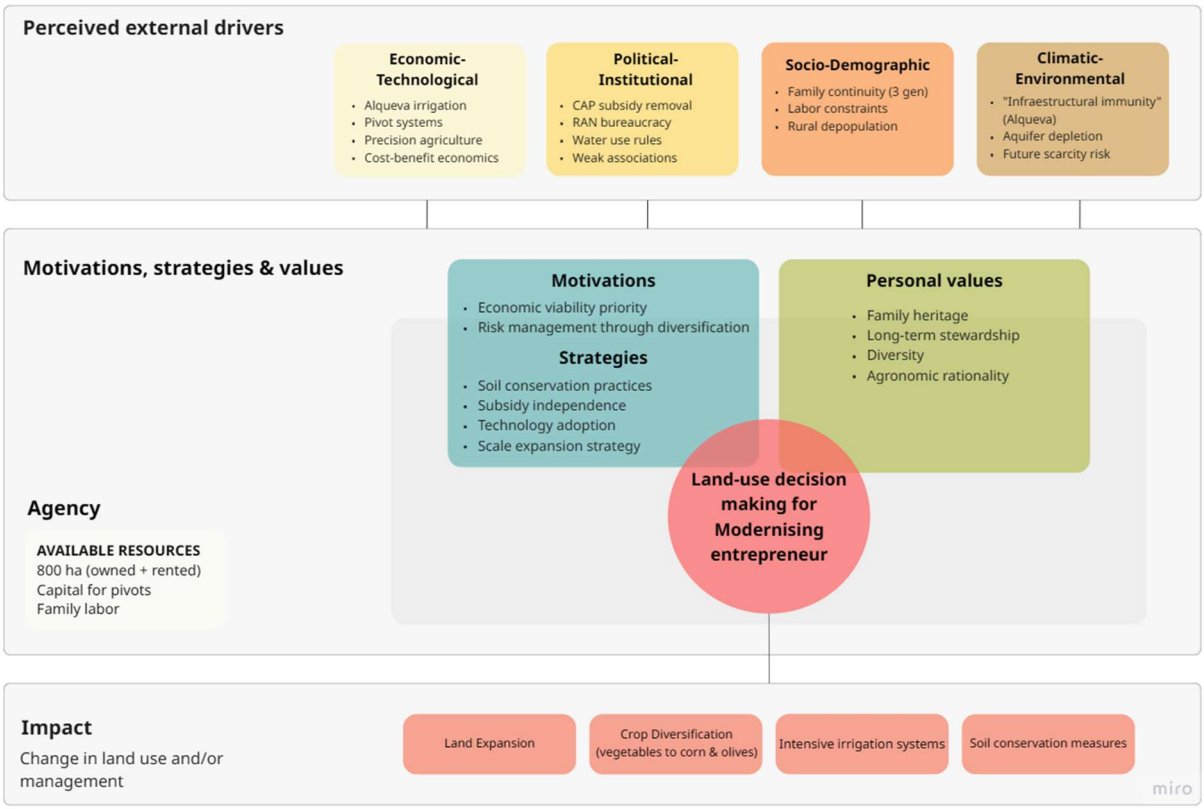

Figure 8: Synthetic visual for the land-use decision-making process for the Modernising Entrepreneur Land User type

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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