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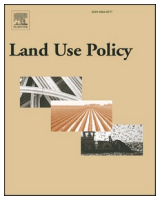

Unveiling soil stewardship: plural values in the management of the Montado agro-silvo-pastoral system in Portugal

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ABSTRACT

Farmers' and landowners' decisions affecting soil management reflect not only economic motivations related to productivity, but also deeper principles and values associated with soil health. However, such values are often implicit and not explicitly acknowledged in decision-making processes. In complex agro-silvo-pastoral systems like the Montado in Southern Iberia, where multiple productive and climatic pressures intersect, soil often remains hidden in farmers' strategic priorities. This study investigates the values and motivations behind soil regeneration efforts in the Montado, a multifunctional system capable of delivering a wide range of ecosystem services but increasingly threatened by degradation and decline. Drawing on interviews with farmers and landowners, we developed a value-driven understanding of soil health through the analytical dimensions of care, knowledge, and agency. While Montado farmers show strong commitment to soil health and have sought out education and innovative practices, they often lack long-term planning capacity, technical support, and feel poorly supported by current policy instruments. This results in fragmented and short-term soil management strategies. At the same time, key stewardship values including place attachment, self-determination and responsibility, emerge as powerful motivators for regenerative practices. Yet these values alone are not sufficient to translate into effective agency when the agricultural knowledge and innovation system (AKIS) remains weak and uncoordinated. The case of Montado underscores the need for governance frameworks that recognize both instrumental and non-instrumental values, integrating them into policy and advisory systems. Doing so could better align support structures with farmers' lived realities, enabling more coherent and scalable soil regeneration efforts.

1. Introduction

While contribution of soils to overall planetary and human health, as well as to primary productivity, is increasingly recognized and advocated for, soils' conditions are threatened by several processes – including loss of organic matter and biodiversity, salinization, pollution and reduction of multifunctionality (Kopittke et al., 2024). In agricultural soil, primary production is at risk under current agricultural systems that fail to promote soils' biodiversity and health (Romero et al., 2024). Agricultural landscapes, which amount to 38 % of the European Union's (EU) territory, are currently at a crossroads, as over 60 % of European soils are classified as unhealthy (European Commission, 2021). Soil health as defined by the recent EU Strategy is the capacity to provide a list of Ecosystem Services (ES), from primary production to climate regulation. However, as soils are predominantly privately owned, they lack a property rights definition that safeguards their public goods function (Bartkowski et al., 2018). Consequently, soil degradation often results from management practices shaped by public policy schemes and governance structures (Juerges and Hansjürgens, 2018).

As Lehmann et al. (2020) argue, policy instruments that effectively address soil health must operate at a regional or territorial scale, capable of accounting for ES that go beyond field-level productivity and have public good characteristics, such as habitat provision, carbon sequestration, and cultural heritage conservation. On the other hand, soils' characteristics are highly localized and variable, and farmers need access to rather specific information in order to take management decisions (Falcão et al., 2024). Therefore, expecting farmers to simultaneously maintain productivity and income while also delivering

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on public-good-oriented soil governance may be unrealistic (Martin and Lawson, 2022) and public policy has so far struggled to fill this gap. In the EU for instance, until now the issue of soil protection has been poorly addressed through both regulatory and incentive instruments, resulting in insufficient action across member states (Turpin et al., 2017). Currently, the Common Agricultural Policy (CAP) remains the primary economic mechanism supporting farmers in integrating primary production with environmental protection. Yet, both voluntary agro-environmental measures and cross-compliance actions rarely focus on soil management and protection (Ronchi et al., 2019; Augier at al., 2020). Additionally, advisory services are limited by project-based funding and a lack of specialized expertise on soil health management. As a result, the support farmers receive from Agricultural Knowledge and Innovation Systems (AKIS) remains insufficient at the EU level (Ingram et al., 2022; Klerkx, 2020). Even under the promising framework of the European Green Deal, which includes a non-binding Strategy for Soil Health introduced in 2020 and anticipates a European Soil Resilience and Monitoring Law, adequate action to restore EU soils still appears to be a distant goal (Heuser, 2022; Montanarella and Panagos, 2021).

1.1. Stewardship: a value-driven approach to understand soil health

Focusing on agricultural soils, farmers and landowners are the primary users of this resource and their management decisions reflect both monetary benefits that can be derived from soil productivity, but also motivations and values guiding and driving their action. Challenging the ES concept of nature's "service" to people, the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) has proposed a framework to include non-instrumental values in land system governance (Díaz et al., 2015). Intrinsic values imply that nature has an inherent worth besides the human use, while relational values include principles and virtues associated with relationships humans establish with nature (Chan et al., 2016). For instance, it was found that farmers preferences for certain management practices reflect a plurality of values including stewardship, place attachment, pride and family heritage (Allen et al., 2018; Vizuete et al., 2025). Nevertheless, the dynamics of interaction between farmers and their soils within a landscape have been simplified to more universally appliable models of agriculture.

In recent decades, conventional farming based on the paradigm of soil fertility has viewed soil primarily as a substrate suitable for production, provided that balanced physical and chemical conditions are met through ploughing and fertilizers inputs, neglecting the fact that soils are living ecosystems (Lehmann et al., 2020).

A value-driven understanding of soil health offers insights into the barriers and drivers towards adoption of practices, that can be informative for building sustainable soil governance at territorial level. Literature agrees that more research is needed to understand farmers' allocation of value towards soil health and its relationship with management decisions (Friedrichsen et al., 2021; Juerges and Hansjürgens, 2018). It is not only the intention, but the decision and the implementation capacity that can result in successful soil stewardship (Martin and Lawson, 2022). Peçanha Enqvist et al. (2018) understand stewardship action as a "boundary object" enacted through three dimensions: care, knowledge and agency, which intersect through three subdimensions: ethic, motivation, and outcome (Fig. 1). This concept can be used as a way to frame complex environmental issues and to identify barriers to purposeful action.

This paper contributes to the ongoing debate on motivating farmers to prioritize soil in their business models by highlighting the diverse values embedded in soil management within the agro-silvo-pastoral system of Montado, southern Portugal. It also explores how soil stewardship is understood and what are the barriers to its enactment.

1.2. Montado as a complex and multifunctional landscape

The Montado is an agro-silvo-pastoral system covering approximately one million hectares in the Alentejo region of southern Portugal, closely related to the Dehesa system, which spans three million hectares in Spain. This landscape integrates extensive livestock production with open tree cover, primarily evergreen cork oak (*Quercus suber*) and holm oak (*Quercus rotundifolia*), along with semi-natural shrub vegetation and improved grasslands. Recognized as a multifunctional landscape, the Montado delivers not only private goods—such as cork, livestock, and crops—despite the scarce natural conditions of a dry Mediterranean climate and shallow soils, but also provides broader societal benefits. These include serving as a rich habitat for biodiversity, contributing to carbon sequestration, enhancing water infiltration, and preventing

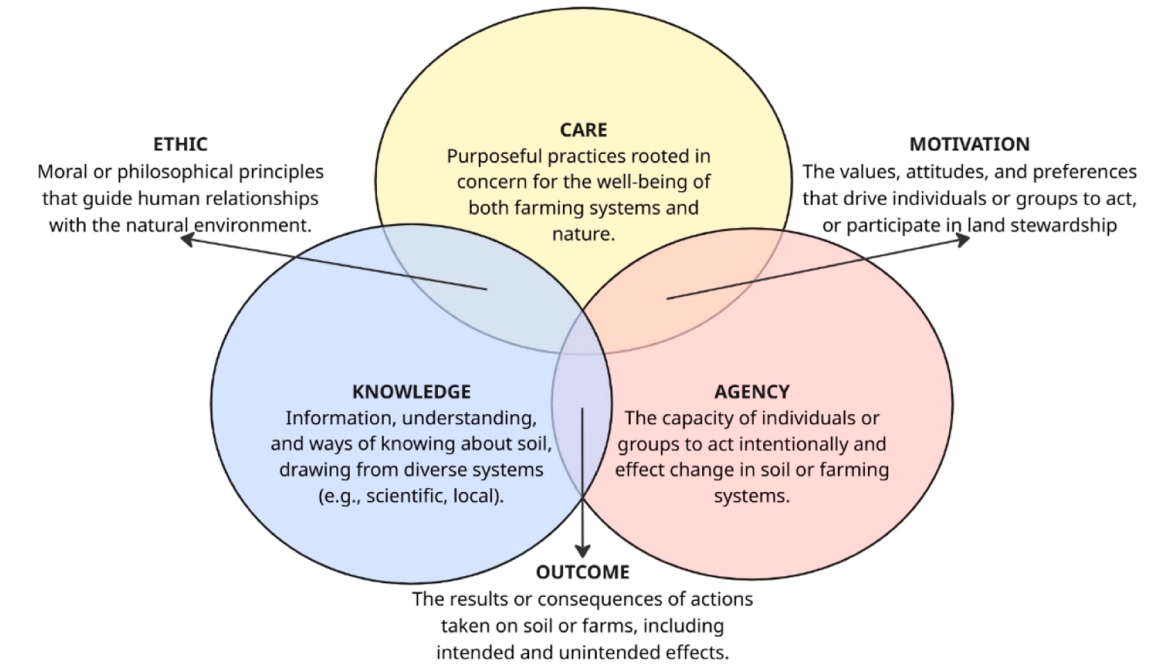

Fig. 1. Stewardship dimensions, adapted from (Peçanha Enqvist et al. 2018).

floods and soil erosion (Azeda et al., 2021; Guiomarães et al., 2018).

Over recent decades, research on the Montado has highlighted the complexity of managing and conserving such multifunctional systems. Climate change, along with various degradation processes—particularly soil erosion—poses a serious threat to Mediterranean soils, more so than in other European regions. These challenges underscore the critical role of farm management practices in either contributing to or mitigating soil degradation (Guerra and Pinto-Correia, 2016; Pinto-Correia et al., 2019). While the value of the Montado as both a productive and ecologically significant landscape is acknowledged by farmers and value chain actors (Sørensen et al., 2023), the system is under pressure. A decline in oak tree density, intensification of livestock farming, and fragmented or misaligned policy incentives have contributed to the deterioration of the Montado, exposing contradictions in land management choices (Azeda et al., 2021). The disconnect between farmers' land management decisions and broader environmental conservation goals remains a major governance gap. In an effort to address this, pilot policy schemes have emerged that aim to enhance the system's resilience. These initiatives include result-based payments for ES, embedded within agri-environmental measures under Portugal's CAP (Guimarães et al., 2023).

Despite the shared recognition of the Montado's decline, few studies have examined farmers' perspectives in depth (Guimarães et al., 2024b), and even fewer have focused specifically on the role and meaning of soil health for these land managers. Land within the Montado is often inherited and represents a key asset for landowners (Pinto-Correia and Azeda, 2017). Yet, the motivations for investing in soil regeneration, as well as the barriers to taking purposeful action, remain poorly understood. A deeper exploration of these factors – particularly how far soil stewardship is enacted – can illuminate how farmers connect with their land and guide more effective, value-driven policy and governance interventions.

2. Research methodology

2.1. Methodological approach and data collection

This study followed a qualitative research design based on a case study approach, to explore the extent to which soil management practices are influenced by stewardship values within the Montado agro-silvo-pastoral system of southern Portugal. This approach facilitates an in-depth understanding of the complex interplay between farmers' values and their land management decisions, situated within the broader context of the region (Yin, 2018). A case study approach allows to collect contextual information and aligns with our understanding of soil health as the ongoing ability of a soil to sustain its functions, embedded within socio-ecological systems and dynamic landscapes (Janzen et al., 2021).

Data collection was conducted between December 2024 and March 2025, involving semi-structured interviews with 11 key stakeholders engaged in soil regeneration practices within the Montado Living Lab (Fig. 1). In 2024, the collaboration between academia, farmers, sector organizations and private companies interested in committing in more structured and long-term experiments, has been formalized in a Living Lab, today certified by ENOLL – European Network of Living Labs. While not all farmers define themselves as regenerative, their commitment to the Montado regeneration through soil health resonates with the definition of regenerative agriculture as "an outcomes- and principles-based approach to agriculture that prioritizes soil health restoration and enhancement (…) implementing practice systems adapted to local contexts" (EU CAP Network Focus Group, 2024)

Respondents were distributed in all five sub-districts of Alentejo. Two respondents were set in the southernmost part of the region (close to the municipalities of Serpa and Mertola) where harder environmental conditions consist in hotter temperatures and shorter rainfall. Here regeneration rates of Montado are estimated < 10 % unlike the 20 – 30 % of the regeneration capacity of the farms closed to the Serra do Monfurado.

Participants were purposefully selected from among farmers, landowners, agronomists, and technicians, ensuring the inclusion of the stakeholders that primarily take decisions on soil health and management. This qualitative approach allows for deeper, context-rich insights that would be difficult to capture through large-scale, statistically representative surveys but limits the generalizability of findings to the broader farming population.

Interviews were conducted in Portuguese or English, depending on participant preference, and were either in-person or online to accommodate geographical constraints.

The interview guide was developed with a set of 13 open-ended questions, to capture a range of values associated with soil management. The questions were adapted to the topic of soil management and based on the framework of Peçanha Enqvist et al. (2018) to understand what farmers know about their soils, how do they act and why do they engage (or not) in certain practices. The interview guide comprised three thematic sections: (1) perceptions of soil threats and motivations for action, (2) current management practices and challenges, and (3) long-term visions for soil health and landscape stewardship. Each section included open-ended questions designed to elicit detailed narratives and reflections on personal and collective values related to land stewardship (Fig. 2).

2.2. Data analysis of interviews

The 11 semi-structured interviews conducted for this study ranged in duration from 27 to 87 min. All interviews were transcribed using the free online tool TurboScribe (TurboScribe, 2025) and subsequently analysed with MAXQDA Analytics Pro (VERBI Software, 2024) The data analysis followed a thematic analysis approach, employing deductive coding (Gizzi and Rädiker, 2021), grounded in the knowledge–agency–care framework (Peçanha Enqvist et al.,2018). This framework was selected as a foundational basis for the coding structure, given the detailed definition and empirical evidence provided by the authors. The coding structure was further adapted by integrating insights from literature on soil stewardship and non-instrumental values. Table 1 presents an overview of the themes used in the analysis, along with definitions, applied codes, and associated keywords.

3. Results

All of the interviewees are partners in the Montado Living Lab, therefore on beforehand interested in linking to research and willing to allow experiments on their land. This set of farmers was found to be most relevant for the analysis, given their commitment to soil regeneration, although we acknowledge that they are not formally representative of the mainstream Montado farmer in the region. Nevertheless, they represent the most common type of land manager of Montado: middle aged, male, land owners with high education, managing as single managers an inherited family farm (Guimarães et al., 2018; Pinto Correia et al., 2022). The positive predisposition of participants towards soil regeneration can be seen as both a potential source of bias and a strength, as it foregrounds the perspectives of early adopters and innovators, offering valuable insights for understanding pathways toward wider adoption, while also highlighting the need for caution in transferring findings beyond this context.

Most of the respondent responsible for soil management decisions were male landowners, with age distribution varying across the group, though the majority were in their mid-life (Table 2). The farms were generally large in size, with a few exceptions, and reflect the historical structure of landholdings in the Montado landscape.

Primary motivations reported by farmers for pursuing soil health were predominantly instrumental, centered on focusing on economic benefits such as improved farm profitability, reduced input costs, more

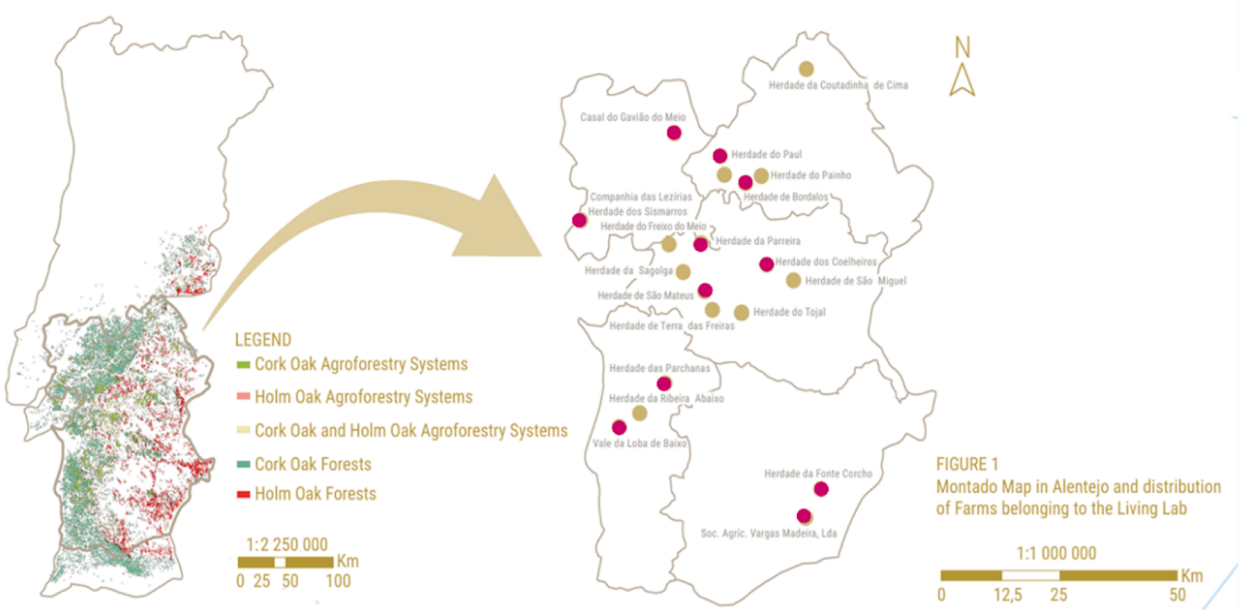

Fig. 2. Farms belonging to the Living Lab, in red the ones involved in the interviews (source: the authors).

resilient trees, and better animal health. However, this interviews also revealed a strong presence of non-instrumental values. Several respondents emphasized that investing in soil was not only essential for sustaining the ecosystem that supports their livelihoods but also for ensuring the long-term health of the land and the future of the territory. In the coming sections results will be presented accordingly to the most frequently coded values within the three dimensions of the framework; Table 3 below provides some exemplary quotes from the interviews.

3.1. *Agency – on the possibility to act*

Soil regeneration was described by respondents primarily as a *practice*, rather than a *value*, and is therefore closely tied to the concept of agency. We found that agency was strongly linked to a sense of *self-determination*, reflected in farmers' decisions to adopt new soil management practices. This is reflected in the relatively recent shift toward regenerative soil management, which, according to interviewees, only became an explicit management goal with the current or previous generation of landowners. The set of practices identified as regenerative was relatively consistent across respondents and included: no soil mobilization, cutting scrub with disk harrows, maintaining permanent soil cover through grassland seeding, and implementing crop rotation. Less consensus emerged around the role of animal husbandry. Some respondents considered it essential to the very definition of Montado and key to active soil regeneration (e.g., through the input of organic matter via manure), and were pursuing holistic pasture management. Others viewed livestock, particularly in relation to oak tree regeneration, as detrimental – two respondents had even removed animals from their systems.

While overall positive outcomes from shifting towards regenerative practices were reported – not only for soil but for the broader Montado ecosystem (M7, M6) – uncertainties regarding management outcomes, the long timescales required for regeneration, and the unpredictable effects of climate change were cited as factors limiting broader investment in practice change.

Regarding *incentives* and *support* for agency, most respondents acknowledged that while their production is heavily subsidized under the direct payments of the CAP – particularly for livestock, organic farming, and integrated production – they saw very few explicit measures targeting soil health (M10). For instance, respondents pointed to a lack of support for the *technological* innovations required for regenerative farming. Specific machinery, such as direct drill seeders and shrub-cutting disk harrows, are essential for basic operations, yet high costs, lack of specialized labour, and limited availability of contractors constrain implementation. Some interviewees involved in the *Montado por Resultados* pilot for result-based payments expressed moderate satisfaction with the support system and were encouraged by improvements in environmental outcomes. However, they also identified areas needing improvement, such as the evaluation of grassland diversity (M9).

When asked about their medium-term plans for soil regeneration (5–10 years), most respondents struggled to provide specific answers. Eight out of eleven referred instead to "maintaining the system": protecting and planting new oak trees, keeping the soil covered to retain moisture, and increasing organic matter. Isolated, often plot-level innovations were mentioned. Three landowners reported diversifying tree species by including stone pine and strawberry tree; others described sowing more biodiverse grasslands, planting shrubs and trees to enhance farm biodiversity, or consistently applying compost. Only a few explicitly discussed balancing the effects of livestock on soils, either by reducing cattle numbers in favour of sheep or by giving soils sufficient rest through rotational grazing.

3.2. *Knowledge – situated, diverse and evolving*

Knowledge was the second most frequently coded value. Looking more closely at its role, we found that most interviewees considered themselves to possess a high level of theoretical knowledge about soils. This understanding was grounded in formal education – eight out of eleven respondents held a degree in agricultural or environmental sciences – and supplemented by ongoing training on soil-related topics. High awareness of soil-related threats was evident, with soil erosion and organic matter depletion named as the most serious risks, and oak tree mortality as their most visible consequence.

Empirical knowledge surfaced even more prominently. This was acquired in two main ways: first, through growing up on the land and learning from local ecological knowledge passed down through generations; and second, through direct observation of the outcomes of on-farm practices such as liming or soil mobilization. All respondents reported engagement with university-led projects and collaborations with researchers. One agronomist and soil specialist, widely recognized in the region, was repeatedly identified as a key actor in the transition toward

Table 1
Themes (based on Peçanha Enqvist et al., 2018) and codes developed for data analysis.

Theme	Cross-theme	CODES used by the authors	References	Key words
KNOWLEDGE		soil functions	Neaman et al. (2024); Chi et al. (2025)	water/ nutrients regulation, biodiversity
		soil threats		erosion, compaction, loss of SOM
		soil specific knowledge		source of, theoretical, empirical
		networks		research, other
	OUTCOME	positive	Tobin (2023); Pape (2023)	soil functions, tree regeneration
		negative		soil degradation, disease, phytophthora
		uncertain		"nobody knows" of results, causes
AGENCY		soil management	Friedrichsen et al. (2021); etal.,2018	techniques, approach, planning
		self-determination		change of practices, experiments, ownership
		incentives		CAP, subsidies, projects
		other support		to action, to regeneration, needs
		technology		machinery, availability
	MOTIVATION	economical	Chapman et al. (2019); Sørensen et al. (2023)	individual livelihood, support, incentives
		environmental		concern, conservation, natural capital
		social		community, mindset, innovation, isolation
CARE		responsibility	West et al. (2018); Jax et al. (2018)	(im) possibilities to care, future
		awareness		cognitive, emotional family
		sense of place		inheritance, local history
	ETHIC	agricultural approaches	Stronge et al. (2023); Roesch-McNally et al. (2018)	organic, regenerative, conservation, conventional
		ecosystem management		resilience, socio-ecological system

regenerative soil management. Nevertheless, respondents noted resistance among the broader agricultural workforce to change practices, as well as a lack of peer farmers with whom to exchange knowledge (M4, M9). Uncertainty about the effects of certain practices and a perceived lack of reliable knowledge also emerged. For example, respondents held differing views on the connection between Phytophthora-related oak mortality, soil degradation, and climate change. Disagreements also arose over specific practices: some used glyphosate for weed control to avoid soil mobilization, others implemented keyline design to reduce soil erosion, highlighting the contested understanding and evolving nature of regenerative methods. This scattered body of knowledge also related to the sources of ongoing training, where the private sector plays a significant role. Nine out of eleven respondents cited international online courses, on topics such as holistic management and regenerative agriculture, as pivotal to their learning. In contrast, public extension services and sectoral organizations were rarely mentioned as knowledge sources. When these institutions were referenced, their support was mainly bureaucratic or focused on specific production sectors (e.g., livestock, cork, cereals), rather than on soil management. As a result, landowners tend not to rely on local public institutions for soil-related advice, instead sourcing knowledge independently or through international private education and consultancy.

Conversely, participation in farmer networks was seen as highly beneficial. The transdisciplinary initiative *Tertúlias do Montado*, launched in 2019 by the University of Évora and still ongoing, was frequently mentioned. Respondents highlighted its role in exchanging knowledge and practices between farmers and the scientific community. Moreover, it is seen as fostering a sense of belonging to a wider network concerned with soil health and in alleviating the isolation often felt within the mainstream local farming community.

3.3. Care – a practice rooted in space and time

Respondents demonstrated a strong acquaintance of soil conditions on their farms, shaped by inherent challenges such as sandy, nutrient-poor soils, increasingly hot and dry climates, and the historical legacy of land degradation. The latter was particularly associated with the Campanha do Trigo (Wheat Campaign, 1929–1938), a state-imposed push for intensive cereal cultivation during the Estado Novo dictatorship in Portugal. What respondents also reported, is the passing over of the properties throughout generations that is strongly linked to the caretaking of Montado.

In this context, care for soil emerges at the intersection of *responsibility* for family heritage, a deep *sense of place* attached to the Montado landscape, and a growing *awareness* and recognition of environmental degradation. Even if not on the first line, environmental concerns against desertification were cited as further motivations for taking action towards soil protection (M2, M9, M5). Thus, respondents viewed the ethical principles underpinning regenerative agriculture and holistic pasture management as a meaningful approach to achieving soil recovery. A sense of care was further reflected by the emotional responses to questions about changes of soil health over time. Despite uncertain outcomes of certain change of practices, ten out of eleven respondents expressed the belief that soil conditions had improved compared to those experienced by the previous generation, revealing a shared sense of satisfaction and commitment. With the exception of two cases, respondents were already planning the passing over of the property to the next generation. However, future hopes were tempered by structural limitations. Long-term planning for the next 5–10 years was often constrained by limited agency, particularly due to the restrictive nature of CAP payment schemes and the dependency on funding through approved investment projects. This reveals a gap between the intention to care and the actual possibility to do so.

4. Discussion

In this case study, farmers primarily relate to soils through the complex Montado production system. For them, healthier soils are reflected in healthier trees and animals. Their expressed interest lies in taking care of the soil by applying regenerative soil management, thereby contributing to landscape maintenance. This understanding of care aligns with what Peçanha Enqvist et al. (2018) describe as a

Table 2
Respondents' socio-demographic details.

interview code	sex	stakeholder type	age group (years)	education level	Farm size (ha)	Years of mgmt
M1	F	owner, manager	> 60	PhD	555	21
M2	M	future owner	20–40	bachelor in tourism	800	20
M3	M	future owner	20–40	master in viticulture	700	24
M4	M	technician, manager	40–60	master in viticulture	768	6
M5	F	owner, manager	40–60	*not available*	200	8
M6	M	co-owner, manager	40–60	secondary education	700	20
M7	M	owner, manager	40–60	master in environmental sciences	590	25
M8	M	owner, passing over	> 60	secondary education	80	13
M9	M	co-owner, manager	40–60	master in agronomy	218	17
M10	M	owner, manager	40–60	bachelor in agronomy	800	14
M11	F	co-owner, manager	> 60	secondary education	520	33

Table 3
Key coded themes and quotes from the interviews, in brackets number of interviews mentioning them and reference to the respondent.

code (n)	Examplary quotes (respondent)
soil management (11)	We stopped mobilizing the soil. And the most interesting thing that happened was the increase of sanity in the trees. (…) we still have normal needs, but not the same disease pressure that we had before. (M7)
self-determination (11)	My father never tilled the soil and never used pesticides. 20 years ago he was a pioneer in thinking about what I can do to improve the soil and the animals condition. So he changed a lot compared to his previous generation. (M6)
livelihood (10)	The benefit is for all. It's for the trees, it's for the animals. And I only have healthy animals and I only put the costs down if I have a living soil. So, the most important thing is to give the rest time that the soil needs. Otherwise, I have to till the soil, I have to put synthetic fertilizers, I have to spend money in seeds. And it's a cycle that you don't have at hand. (M6)
Uncertain outcomes (8)	Sometimes I ask my uncle if he thinks that the soil is getting better with this. And he said he's not sure. We do what we can. (…) Our life period doesn't work with soil and trees that live so long. (M2)
social motivation (9)	It is important that the people who are in the field try to understand a minimum the logic. There are people who are very hard-headed, they tell me "I don't want to do that, it's all dirty, full of weeds". And little by little they move on. (M4)
Knowledge networks (9)	What I really like about the meetings is that they allow us to exchange experiences and do a bit of rural extension, because I'm also aware that one or two farmers who do this in isolation don't achieve great results, they're oases in the middle of the desert. And farmers work a lot by imitating what works well, don't they? (M8)
ethic (10)	And you also need something else, you need to like it. You have to feel the land, you have to feel the trees, the cork oak forest, because if you don't like it, there's no point in coming here. This is a work of resilience, because you can't see it. (M5)
sense of place (11)	For me Montado is this diversity, this multiplicity of being able to have various types of extensive pastures, in this space, which is an interesting agricultural space to have animals, if it was a place without trees, the animals are not so comfortable. (M7) When we make a decision, it's a decision because we read the landscape. I have the different species because it's what the landscape needs. It's not a thing that I want to do, it's the thing that the land needs and balance. (M6)
awareness (11)	But this issue of soil is quickly destroyed. It takes decades to build and then, in two or three years, whoever comes next can destroy it. (M10)
responsibility (11)	For me it was to try… how do I put it… to save the cork oak forest and try not to turn that mountain range into a desert. (M9) Regeneration of cork oaks and holm oaks is low. There is some, but this is an area that we haven't really taken much care of. One of the things we're doing is dividing up the area so to have less pressure from the cattle on the cork oak forest. (M10)

dimension of stewardship that reflects a sense of attachment and responsibility. The farmers interviewed have actively sought education and training, thereby acquiring knowledge about soil functions and deepening their understanding of regenerative practices. However, they still experience a certain degree of uncertainty around possible outcomes, and recognize that transitioning to regenerative agriculture is an ongoing and iterative practice that requires time, experimentation, and adjustment, therefore necessitating continuous technical support.

Our findings show a contradiction between farmers' willingness to base soil regeneration practices on robust scientific knowledge and the limitations posed by a weak AKIS. Similar to other case studies, advice on sustainable soil management is based on fragmented knowledge (Jaworski et al., 2024). As previously found by Ingram et al. (2022), technical support neither from regional agricultural offices nor from producer organization is focusing on soil health management. Consequently, farmers rely on these institutions primarily for the administrative support required to access CAP subsidies and comply with regulations. This likely contributes to the aforementioned uncertainty regarding the information and guidance received, creating confusion and hindering farmers' ability to transform their farming business (Klerkx, 2020). Moreover, the high reliance on online courses indicates that the shift towards regenerative agriculture is also being shaped by the growing "knowledge market" of private education and extension institutions (Ingram et al., 2022). While this can result in the adoption of innovative farming practices, soil-specific challenges and the socio-economic features of the local context may be overlooked, limiting the effectiveness of restoration efforts (Janzen et al., 2021).

Overall, agency over soil regeneration in the context of Montado appears primarily as an individual farmer action, with limited capacity to produce broader-scale impacts. Respondents in this case study perceive themselves as rather isolated pioneering innovators, typically associating soil regeneration with a small number of practices applied to limited portions of their farmland. This limited collective engagement may stem from structural barriers such as lack of institutional facilitation or cultural norms favoring individualism (West et al., 2018). As a result, more collective or systemic action, essential for effective soil stewardship at landscape scale is lacking.

Knowledge and practice exchanges between and beyond farmers and scientists highlight the role of networking and contribute to the social learning fostered by living labs (Taskin et al., 2025). However, there is limited evidence of a broader, improved rural community-based agency, as reported elsewhere in literature (Friedrichsen et al., 2021; Jaworski et al., 2024).

Indeed, the results underscore the perceived importance of building supportive knowledge networks, but raise questions about continuous and long-term involvement and collective agency. On one hand, the *Tertúlias do Montado* constitute a long-lasting effort of community understanding of the challenges faced in the Montado system, and are well attended, yet participation remains voluntary and spontaneous (Guimarães et al., 2024a). On the other hand, the Montado Living Lab is a formalized network that requires greater engagement from all parts. It

demands a commitment to experimentation, knowledge co-creation and autonomous governance. Currently, 40 individuals have signed the partnership agreement as active participants. Despite these efforts, the longevity and scalability of these initiatives remain constrained by structural challenges, particularly dependence on external funding and limited stakeholder engagement and planning capacity (Taskin et al., 2025).

To address these constraints, respondents appear very cautious and heavily reliant on the availability of funding in their planning processes, currently depending largely on project-based funding to implement changes in soil management. Although the mentioned practices each contribute in their way to improved soil conditions, farmers – even those highly educated and aware – demonstrate limited planning capacity and entrepreneurship, which stems from a fragmented AKIS. The ability to plan is crucial in bridging soil management, closely tied to agency, with the responsibility that care entails when is rooted practice (Jax et al., 2018). It also supports the long timescales and commitment required to achieve soil regeneration (Lehmann et al., 2020)

The lack of effective support and advisory services emerges as a significant barrier to assuming full responsibility for soil stewardship, posing practical challenges to farmers' value systems (Klerkx, 2020; van Noordwijk et al., 2023). A hidden conflict emerges between farmers' strong willingness to adopt regenerative practices and their high dependence on CAP schemes, combined with a general aversion to risk. As demonstrated before (Pinto-Correia et al., 2019), this risk aversion is reinforced by the weak and fragmented advisory system available to support these farmers, and the focus of existing advisors on specific components of the system – livestock or annual crops – thus manifesting constraints in considering the whole silvo-pastoral system and its future perspectives. This conflict emerges from our findings, when set against each other. Neaman et al. (2024) found that effective soil stewardship arises from the overlap between care, as a form of responsibility for the land, and the application of knowledge to landscape management. In contrast to this model, our findings show that while knowledge and care are high among the farmers studies, the corresponding agency remains limited.

Previous research has shown (Pinto-Correia et al., 2019; Pinto-Correia and Azeda, 2017; Azeda et al., 2021) how policy measures can create tensions between farmer's values and behavior in Montado management, and may even contradict the system's resilience requirements. Our results reinforce this finding, even though the farmers in our study are part of a motivated group, actively seeking to enhance Montado resilience and acquire the knowledge needed to do so. The case of Montado, being complex, diversified in production and embedded in a multifunctional landscape, highlights persistent gaps in the AKIS, which remains fragmented and unprepared to pursue soil health goals (Ingram et al., 2022). We hypothesize that a clear and consistent system of knowledge co-construction and dissemination, integrating both public and private actors and explicitly focused on soil regeneration, could significantly enhance farmers' capacity and confidence to adopt the regenerative agricultural practices they seek to apply.

5. Main conclusions and future research

This study highlights how engaged Montado farmers perceive and approach soil health through the lenses of stewardship. By applying the care-knowledge-agency framework, we reveal that soil regeneration is not merely a technical issue but deeply embedded in personal, cultural, and ecological relationships. This resonates with the concept of relational values (Chan et al., 2016), showing how farmers' environmental actions are shaped by connections to land, heritage, and community, not just economic incentives (Pratson et al., 2023). Our findings underscore that farmers' agency remains structurally limited by fragmented support systems, weak long-term planning capacity, and institutional barriers.

Although economic factors remain central, particularly given farmers' dependence on agriculture and CAP subsidies for their livelihoods, our results show that these do not preclude strong ethical and ecological commitments. Regenerative agriculture, in this context, emerges not only as a strategy for productivity or resilience, but as a purposeful and values-driven choice and calls for the need to recognize the plural, overlapping motivations that drive land management choice (Himes and Muraca, 2018; Chapman et al., 2019; van Noordwijk et al., 2023).

However, farmers' ability to implement regenerative practices is constrained by insufficient technical support, lack of coordinated advisory services, and a limited capacity for long-term planning. Agency over the long term is overall needed in the management of the Montado system, where the forest is a central component: if no tillage, shrub cutting and livestock management are important change of practices, ongoing improvements in creating fruitful conditions for tree regeneration are urgently needed to halt the ongoing decline of Montado (Godinho et al., 2016).

These challenges are particularly striking given the relatively high levels of knowledge, awareness and motivation among our respondents. If even early adopters face such barriers, more conventional or constrained actors may be even less able to transition toward regenerative practices. The findings call for policy shifts that prioritize systemic support: funding institutional innovation, training advisors in soil regeneration, and developing trust-based, locally embedded knowledge systems (AKIS). Regenerative agriculture remains marginal in the region, and scaling it up should be a priority for future research particularly among conventional farmers. Overcoming the widespread skepticism toward regenerative practices, as identified in this and other case studies (Jaworski et al., 2024), is essential. A well-functioning, trusted AKIS could provide regionally adapted technical assistance, support farmers in navigating local soil threats, and accompany them through management transitions. Furthermore, in line with the goals of the European Soil Resilience and Monitoring Law, soil monitoring systems based on site-specific data could help farmers assess the medium- and long-term effectiveness of their practices, while also contributing to open-access national soil datasets.

Although we structured our results through the distinct lenses of care, knowledge, and agency, the values expressed by land managers often revealed significant overlap and fluidity between these dimensions. This supports recent theoretical work suggesting that instrumental and relational values are not mutually exclusive, but rather interwoven and mutually reinforcing (Vizuete et al., 2025). Our findings add to this body of literature by showing that economic motivations, such as improving livelihoods or reducing input costs, can coexist with deeper commitments to landscape stewardship, cultural identity, and intergenerational responsibility (Byfuglien et al., 2024). In this light, regenerative agriculture is not only pursued for its productivity benefits but also as an ethical and autonomous choice rooted in personal and place-based values.

In terms of soil governance, this value pluralism challenges conventional paradigms that reduce soils to chemical substrates optimized for yield. A relational understanding instead recognizes soils as living ecosystems embedded in social, ecological, and cultural landscapes (Janzen et al., 2021). Placing values at the centre of soil governance offers a more holistic approach to understanding farmer behaviour and designing inclusive, effective interventions. It suggests that building sustainable, climate-resilient agricultural landscapes is as much a cultural and social process as a technical one. Acknowledging this complexity can help align future CAP policies with the lived realities, values, and aspirations of land managers, making the pursuit of soil health a more tangible and achievable endeavour.

During the preparation of this work the author(s) used TurboScibe AI to transcribe the interviews in orginal language and ChatGPT – 4.0 in order to check grammar and language improvements. After using this tools, the authors reviewed and edited the content as needed and takes full responsibility for the content of the publication.

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CRediT authorship contribution statement

Greta Winkler: Writing – review & editing, Writing – original draft, Methodology, Conceptualization. **Teresa Pinto-Correia:** Writing – review & editing, Validation, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data availability

The data that has been used is confidential.

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