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How is decision-making about grazing management influenced by reliance on rangelands at farm level? Insights from small ruminant farms in French Mediterranean areas

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Shrubby and wooded rangelands are highly heterogeneous environments that require adaptive grazing management. In the Mediterranean basin, their use is increasingly challenged by climate change, land abandonment, and the erosion of intergenerational knowledge. This study examined how small-ruminant farmers structure their decision-making about rangeland use, depending on their reliance on them to feed the flock. We conducted 18 semi-structured interviews in Ardèche and Hérault (France), covering diverse farm types and levels of reliance on pastoral resources. Discourse analysis identified four objects shaping decision-making for all farmers: landscape units, vegetation, pastoral resources, and animal behaviour. The farms were categorized in three groups (P-, P, P+) on the basis of the integration of rangelands into the feeding system, ranging from input-dependent feeding systems aimed at the stability of intake and animal performance, to systems relying heavily on rangelands and aimed at self-sufficiency, accepting variations in animal performance. The three types of farms were associated with contrasted decision-making systems, ranging from simplified and reactive approaches based on a limited set of measurable indicators (e.g., resource availability, animal performance), to more integrative and anticipatory strategies combining multiple indicators such as vegetation dynamics, resource diversity and animal behaviour. This study provides a structured way to analyse how farmers mobilise knowledge and indicators in their decision-making, and helps identify how additional information may complement farmers' decision-making in a context-specific manner.

KEYWORDS

adaptive management, decision-making, livestock farming systems, local ecological knowledge, Mediterranean rangelands

Introduction

Rangelands cover more than half of the Earth's land surface and support the livelihoods of millions of people worldwide, particularly in arid, semi-arid, and mountainous regions (Calvo and Maria, 2024). They play a critical role not only in food production but also in biodiversity conservation and climate regulation. Shrubby and wooded rangelands are

widespread in the Mediterranean basin (Rodríguez-Rigueiro et al., 2021), are characterised by strong spatial heterogeneity and marked seasonal variability. In the Mediterranean area, rangelands are increasingly considered as a key forage resource to address climate variability, particularly due to the presence of woody plants whose foliage remains available during the hot and dry summer and can provide a valuable feed resource when herbaceous vegetation becomes scarce (Papachristou and Papanastasis, 1994; Papanastasis et al., 2008; Porqueddu et al., 2016; Jouven et al., 2024). However, very few studies address the question of how to manage grazing in such diverse and variable environments, and the standardized decision support tools available for grasslands rarely apply (Sayre, 2022).

Pastoral decision-making has long been studied through the lens of local ecological knowledge (LEK), understood as a cumulative body of knowledge, practices and social norms developed through interactions with the environment and continuously updated through experience and observation (Fernandez-Gimenez, 2000). LEK is central to herders' ability to decide when and where to graze, how to move flocks, and how to deal with variability. Such decisions are grounded in farmers' perceptions of rangelands and in the interpretation of multiple cues derived from the pastoral ecosystem. Gobindram et al. (2018) showed that the extent of LEK held by Moroccan shepherds and its integration into grazing management decisions were greater when rangelands were valued as a valuable forage resource thus grazed with little or no associated supplementation, and for shepherds with a longer experience in a given grazing environment. The basis of decision-making may thus differ depending on the relative importance of pastoral resources within the feeding system, but also on the perception and experience of the pastoral ecosystem by the manager (farmer, shepherd).

The Livestock Farming Systems (LFS) framework proposed by French researchers analyzes the decision-making processes underlying the management of herd, land units and their interactions (Dedieu et al., 2008; Gibon et al., 1999). Within this framework, as Gibon (2005) underlines, grassland and rangeland management should be considered as a multi-level process where farmers balance productive, environmental, and landscape objectives. Petit et al. (2019) show that farmers assign different functions to grasslands depending on their production strategies and perceptions. Similarly, Smith et al. (2023) emphasize that rangeland management is based on adaptive decision-making processes: farmers adjust their grazing practices according to environmental conditions, management objectives and feedback from the flock or the vegetation. Thus, differences between farmers' practices might reflect contrasting priorities or different ranking of objectives.

Building on this body of work, and focusing on Mediterranean small-ruminant pastoral systems, we hypothesise that the degree of reliance on rangelands to feed the flock is associated with different decision-making processes, including how farmers perceive, interpret and manage these resources. To explore this, our study combines Livestock Farming Systems (LFS) and Local Ecological Knowledge (LEK) approaches to: (i) identify different types of farms according to their use of rangelands and production objectives; and (ii) analyse how farmers perceive rangelands and mobilise indicators and knowledge in their grazing decision-making processes. Rather

than only documenting the knowledge mobilised by farmers, this study examines how such knowledge is structured, interpreted and translated into decision-making and management practices. This perspective contributes to a more structured understanding of how grazing decisions are made in heterogeneous environments and helps identify where different types of knowledge, including scientific information, may complement farmers' own decision-making.

Materials and methods

Study areas

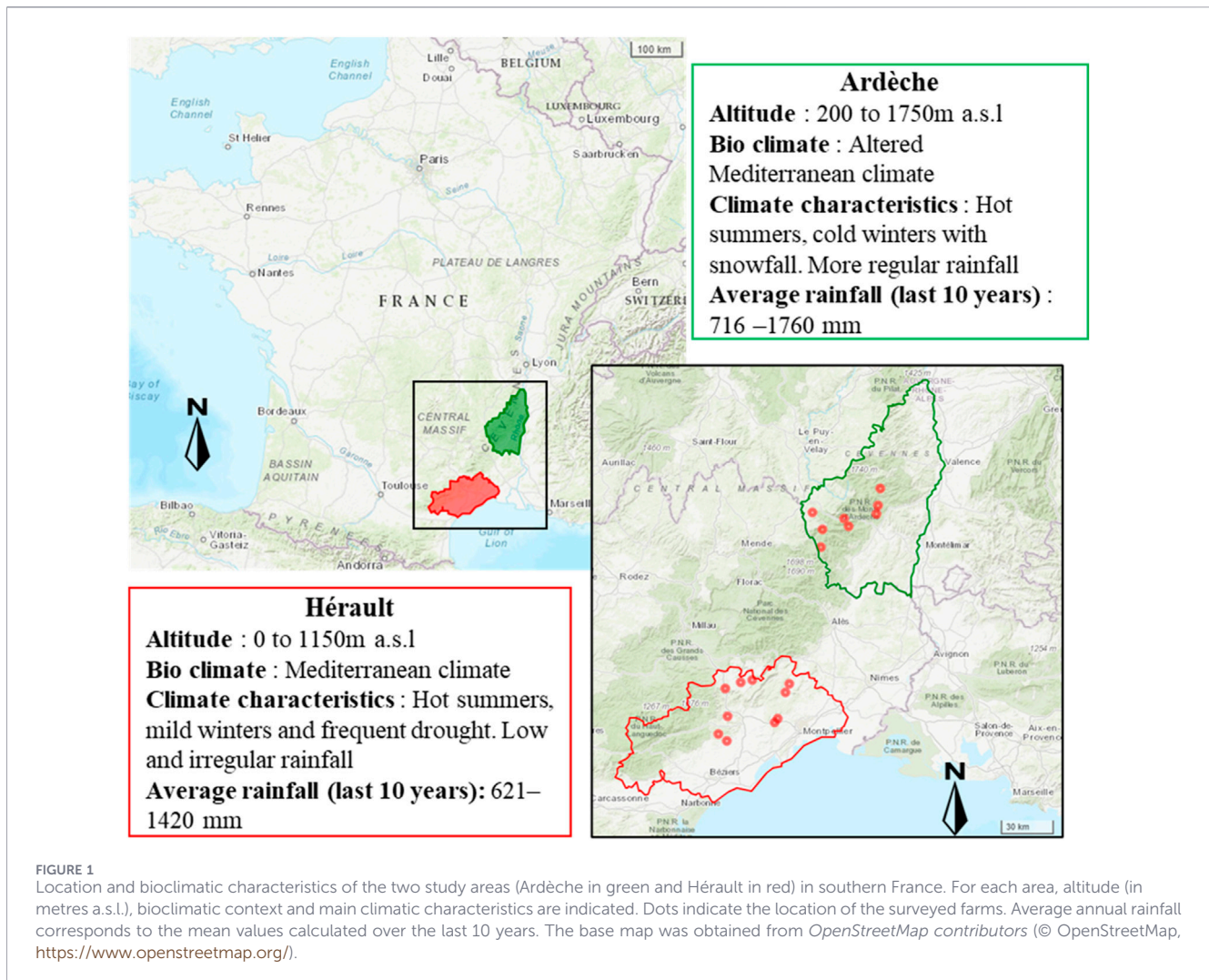
This study was conducted in the French Mediterranean region, in two departments with long-standing pastoral traditions: *Hérault* and *Ardèche* (Figure 1).

Hérault has a typical Mediterranean climate, with highly variable annual precipitation, concentrated in early spring and autumn. The landscape is characterised by shallow limestone soils and a mosaic of *garrigue* shrublands, woodlands, grasslands, and cultivated areas. Natural vegetation includes Mediterranean shrubs (e.g., *Quercus ilex*, *Quercus coccifera*, *Cistus* sp., *Juniperus* sp.), and herbaceous species such as *Aphyllanthes monspeliensis* and *Brachypodium retusum*. According to the 2020 agricultural census, the department supports 42,355 sheep and 4,515 goats, corresponding to 8.5 small ruminants per square kilometre (SR/km²).

Ardèche features an altered Mediterranean climate, with pronounced variation along an altitudinal gradient ranging from 200 to 1700 m a.s.l.: higher elevations receive up to 1800 mm rainfall per year, vs. 700 mm in the lowlands. Soils are mainly of granitic origin in the uplands, but volcanic and calcareous substrates are also present, creating a heterogeneous mosaic of pastoral habitats, including broom-dominated shrublands, deciduous forests, chestnut groves, wetlands, and upland grasslands. Common woody plant species and trees include *Sorbus aria*, *Sorbus aucuparia*, *Cytisus scoparius*, *Genista scorpius*, and the herbaceous layer is dominated by *Festuca* spp. The department supports 79,185 sheep and 32,952 goats, equivalent to 18.4 SR/km².

Selection of farms and interview methodology

Local agricultural services provided us with a list of pastoral farms selected to capture a gradient of feeding systems in terms of reliance on rangelands and grazing management strategies. The farmers interviewed were selected according to four criteria: (i) significant use of semi-natural and wooded pastures (at least a few months per year, for part of the flock); (ii) livestock composed mainly of sheep or goats; (iii) interest in rangelands as a forage resource; and (iv) willingness to engage in a detailed discussion about rangeland utilization. The last two criteria were not measurable farm attributes, so they were evaluated based on the expertise of advisory services. The sample was not intended to be statistically representative of all pastoral systems in the study areas, but rather to capture a diversity of farming systems and decision-making processes across contrasting levels of reliance on rangelands



and modes of grazing management. The farms included in the study were predominantly small-scale systems, with flock sizes generally below 500 animals, which reflects the structural characteristics of small-ruminant farming in the study regions. These systems are typically managed directly by farmers, who are closely involved in day-to-day grazing management.

Eighteen pastoral farmers were interviewed. Most interviews (N = 16) were conducted in spring 2024, with two additional interviews in October 2024. Interviews lasted between 2 and 5 h and were held on-farm. All interviews systematically included a visit of the grazing areas used by the farmers. This enables to refer to concrete situations and specific locations, and supported a more contextualised and grounded understanding of their decision-making processes.

A small subset of interviews (2 out of 18) was conducted by MSc students under the close supervision of the authors. All interviewees followed the same interview guide (Supplementary Material 1), and the interviews were recorded to ensure consistency and quality. All transcripts were analysed by the authors. The semi-structured format encouraged participants to describe their decision-making process in their own words, using practical references to objects, locations, or specific situations (Kauffman, 1996).

Each interview began with a brief overview of the farm's structure and was then organised around five core topics: (1) farm characteristics, (2) role of rangelands in the livestock feeding system, (3) characterisation of pastoral resources, (4) decision-making processes related to grazing management, and (5) acquisition of local knowledge. Each topic was introduced by an open-ended lead question (identical across interviews), followed by optional supplementary questions to deepen and clarify responses (Table 1). The full interview guide is provided in Supplementary Material S1. The objective was to elicit farmers' knowledge and to analyse how this knowledge is translated into decision-making processes and management practices.

Data analysis and clustering

The interviews were recorded and transcribed. Transcripts were then coded thematically using Taguette, an open-source qualitative analysis tool (Rampin and Rampin, 2021). Farmers' narratives were organized into a matrix of themes and respondents, allowing systematic comparison of convergences and divergences across farms. The analysis unfolded in two stages.

TABLE 1 Structure of the interview guide, including sections, guiding questions, and objectives.

Section	Main guiding question	Objective
1. Role of rangelands in the feeding system	<i>What role do rangelands play in feeding the flock, and how does their use fit into your strategy?</i>	Understand how farmers integrate rangelands into flock nutrition and production planning
2. Perception of rangeland diversity and functionality	<i>How do you assess the quality and functionality of different grazing areas throughout the year, and how does this influence their use in your management strategy?</i>	Explore farmers' environmental representations and spatial/temporal knowledge of grazing areas
3. Indicators used for grazing management	<i>What factors influence your use of grazing areas over the seasons and over the years?</i>	Identify decision drivers (e.g., weather, vegetation, livestock condition) shaping short- and long-term use
4. Acquisition of local knowledge	<i>How did you acquire your knowledge of grazing resources and their value for animal feed?</i>	Document the origins of farmers' knowledge: Experiential learning, transmission, formal training etc.

TABLE 2 Qualitative and quantitative variables used for the farm typology, with methods of calculation and observed modalities. SR: Small Ruminants.

Variable	Type	Method of calculation/Description	Modalities observed
Utilised agricultural area (UAA) and rangelands	Quantitative	Declared by the farmer	From ~50 ha to >300 ha
Annual use of rangelands (months)	Quantitative	Number of months with predominant rangeland use	Under 7 months, 8–10 months, more than 10 months
Level of supplementation	Qualitative	Categorised from interview data	High (year-round, hay + concentrate); moderate (~3 months, low concentrate); low (<3 months, hay only)
Flock size (head)	Quantitative	Declared by the farmer	Small (<100), medium (~200), large (>200)
Breeds/species	Qualitative	Declared by the farmer	Productive dairy goats, mixed breeds, hardy local sheep/goats
Types of grazing areas	Qualitative	Descriptions declared by farmers	Paddocks, shepherding, free-ranging
Stocking rate (SR/ha)	Quantitative	Flock size (head of small ruminants) ÷ available grazing area	High (>2), moderate (~1), low (<1)
Pastoralism rate (%)	Quantitative	Pastoral intake ÷ total intake × 100	Opportunistic (<50%), adaptive (~70%), strategic (>85%)
Flock management	Qualitative	Declared by farmers	Shepherd, mixed, paddocks

First, we constructed a typology of farms. Based on a set of variables (Table 2), we grouped the farms according to the degree and manner in which rangelands were integrated into the feeding system. The classification was based on farm characteristics (e.g., utilised agricultural area, share of rangelands, flock composition, breeds) and management practices (e.g., stocking rate, duration of rangeland use, pastoralism rate, flock management, forage production, supplementation). It was constructed through iterative cross-farm comparisons, based on the visual clustering method of Bertin (1983), which is widely applied in qualitative research.

Second, we analysed farmers' decision-making processes and underlying perception of the rangeland ecosystem within each type of farm. This second step focused on how farmers interpret their environment and make their decisions about grazing management on rangelands. In this study, "objects" refer to the elements of the pastoral system that farmers actively monitor in their daily practice, and that serve as reference points to interpret their environment and guide their decision-making (e.g., flock condition, resource availability, vegetation characteristics). Farmers' discourse was

analysed to identify: (i) the objects monitored, (ii) the indicators used to describe each object, and (iii) the strategies implemented to manage the complexity and variability of the pastoral ecosystem. This approach allowed us to explicitly link the objects monitored by farmers, the indicators they use to describe them, and the resulting decision-making processes.

Results

Characteristics of the farms investigated

The 18 farms in this study displayed a wide range of structural characteristics and grazing management practices, consistent with our objective of capturing diversity in pastoral systems. The details for each farm are provided in Supplementary Material S2. In the following sections, farm codes are used to link quotes to specific farms and groups. Farm codes start with "A" for *Ardèche*, and with "H" for *Hérault*.

TABLE 3 Characteristics of the three groups of farms (P-, P, P+) identified based on their strategies of pastoral resource use. Farm codes enable to trace the individual farm characteristics in **Supplementary Material S1**.

Characteristics of the strategies	P-opportunistic	P Adaptive	P+ Strategic
Farm codes (see Supplementary Material S1)	A4, A5, A8, H3	A1, A2, A3, H1, H2, H4, H5, H6, H8, H9, H10	A6, A7, H7
UAA (ha)	148.5 ± 81.5	374.5 ± 246	146.7 ± 55
Rangelands/UAA (%)	70 ± 15	86.8 ± 8.5	100 ± 0
Small ruminant flock size (head)	212 ± 46	236 ± 186	93 ± 53
Annual stocking rate on rangelands (SR/ha)	2.2 ± 1.2	0.9 ± 0.7	0.7 ± 0.7
Annual use of rangelands (months)	6.6 ± 0.5	10.0 ± 0.7	11.8 ± 0.5
Pastoralism rate (%)	41.7 ± 6.6	72.5 ± 4.5	87.2 ± 2.8
Forage production	Yes	Mostly not	No
Breeds	Dairy goats (1 flock of sheep) – productive breeds	Meat sheep (1 flock of goats) – local/hardy and productive breeds	Meat sheep/dairy goats –local/hardy breeds
Flock management	Paddocks and/or guided free-ranging	Paddocks and shepherding	Shepherding
Supplementation level	Moderate to high	Low to moderate	Very low

All farms included shrubby or wooded rangelands in their grazing area. Their relative importance varied from around 50% of the utilised agricultural area in the most input-dependent farms to nearly 100% in the most extensive ones. Flock sizes varied from fewer than 50 goats to over 400 sheep, and stocking rates changed accordingly. Grazing management practices varied across farms. Shepherding was practised on most farms (12/18), either year-round or only in the grazing season, while four farms relied mainly on fixed or mobile paddocks. Patterns of mobility ranged from daily grazing circuits to seasonal transhumance across altitudinal gradients. Production objectives also differed across farms. Eight farms were specialised in dairy products (mainly goats), while ten focused on meat production with hardy local sheep breeds. Dairy farms generally displayed higher levels of intensification of the feeding system (more conserved forage and concentrate), whereas extensive meat farms relied more on local rangelands. This diversity in farm structure and management provided a robust basis for the typology presented below.

Three types of farms

The typology revealed three types of farms (Table 3): P- (opportunistic rangeland users), P (adaptive users), and P+ (strategic users). These types differ not only in their level of reliance on rangelands, but also in how farmers interpret and manage resource variability.

P+ farms (N = 3) were characterised by a high pastoralism rate (~90%), year-round rangeland use, very low supplementation, and 100% of their utilised agricultural area (UAA) consisted of rangelands. They relied on shepherded grazing, raised flocks composed of hardy local breeds (e.g., *Caussearde des Garrigues* sheep, *Rove* goats) and accepted changes in animal performance, which had a limited economic impact due to low feeding costs. As

one farmer [H7] noted: “I’m not looking for prolificacy. If the resources are there, great. If not, we don’t push it. They [the goats] self-regulate their intake.” P+ farmers displayed risk tolerance and valued self-sufficiency most.

P farms (N = 11) were characterised by moderate pastoralism rates (~70%), intermediate rangeland use (~10 months), mixed grazing strategies (paddocks and shepherding), and intermediate supplementation levels. The share of rangelands in the UAA averaged around 85%. P farmers relied on rangelands for most of the year, but practiced targeted supplementation (e.g., hay, alfalfa) during critical phases such as lactation. Some also (8/11) practiced seasonal transhumance to avoid summer shortages. This strategy accommodated both hardy meat sheep and more productive dairy goat systems. As one interviewee [H1] explained: “Most of the time, I use grazing resources as much as possible—especially before critical periods like lambing. When forage is lacking, I compensate with supplementary feed.” P farmers favoured grazing but adjusted the feeding system to secure their [moderate] production objectives against climatic uncertainty.

P- farms (N = 4) had a low pastoralism rate (<45%, often <40%), shorter rangeland use (~6.5 months), moderate-to-high supplementation, and less reliance on long-range mobility. P- farmers typically developed paddocks or free-ranging systems, used more productive breeds and practiced on-farm production of conserved forage. Rangelands were grazed by animals with low nutritional requirements such as dry females. As one farmer [A4] put it: “I prefer to ensure a stable ingestion to prevent production drops, even if we could make better use of rangelands.” P- farmers followed input-dependent production models, prioritising animal performance and a tighter control of feed intake. These three groups of farms illustrate different strategies of rangeland use, which are associated with distinct decision-making processes analysed in the following sections.

Perceptions of rangelands

Farmers expressed contrasting perceptions and objectives regarding the role of shrubby and wooded rangelands in their systems. These perceptions, which were unequally distributed among groups, ranged from highly positive valuations to more negative or constrained views.

First, all P+ and P farmers viewed rangelands as a pillar of the feeding system. They valued them for their low-cost contribution to forage self-sufficiency and to the resilience against climatic and economic uncertainties. As one farmer [A1] explained: *“When grass is lacking, we can rely on woody plants. Animals eat the leaves, the fruits, and even if production or body condition declines a little, you can still maintain them.”* Another farmer noted: *“It’s really a matter of perspective. Once you understand that shrubs are a pastoral resource, you no longer want to remove, burn or shred them. You keep them—they provide shade and help maintain some grass during the summer.”* The botanical and spatial heterogeneity of rangelands was perceived as a source of flexibility, enabling nutritional balance, stimulating intake and reducing parasite load. Another farmer [H7] noted: *“It is the diversity of what they eat that matters. The more diversity you have, the better you make use of the resource.”* A third farmer [H4] added: *“These systems operate on a self-sufficient and cost-effective model, where external inputs are minimised.”* For some farmers [A6, A7, H1, H4, H7], rangelands also contributed to the typicity and quality of animal products. These positive perceptions are associated with a greater reliance on rangelands and a more flexible approach to managing resource variability. As one farmer [H7] explained: *“With climate variability, you’re never sure what resources you’ll have the following year, so you shouldn’t overuse them. And when there’s not enough, you have to go further to find it.”*

In contrast, P– farmers considered rangelands as too variable and uncertain, requiring time-consuming constant observation and anticipatory adjustments. They highlighted the low or heterogeneous forage value of these areas, and the risks due to the presence of toxic plants. As a result, they deemed rangelands suitable only for animals with low nutritional requirements. As one dairy goat farmer [A4] explained: *“I prefer to ensure a stable ration to avoid production drops. On rangelands I don’t think I can meet the needs of lactating females—at best they can be used for maintenance animals, but there is always the question of forage value, it’s too variable.”* Another farmer [A5] stressed: *“I think animals spend too much energy on rangelands—moving around, searching, dealing with climatic stresses. You cannot expect too much from rangelands, they are too uncertain.”* P– farmers tended to respond to this uncertainty by increasing supplementation. As one farmer [A4] explained: *“The more uncertain it is, the more I prefer to rely on supplementation to secure production.”* Encroachment and difficult access further reinforced the perception of rangelands as unfavourable environments and, in some cases, as a burden within the farming system – areas that need to be grazed in order to avoid encroachment.

Finally, a number of farmers (12/18) attributed to rangelands a strong ecological and patrimonial value, beyond immediate feeding objectives. This perspective was not expressed by P– farmers and by two P farmers. For them, maintaining pastoral practices was important not only for flock feeding, but also for biodiversity conservation, landscape maintenance, and the preservation of local heritage. As one farmer [A1] stressed: *“It is important to*

keep these lands open, not only for the animals, but for the landscape and heritage—this is also our role.” These farmers associated rangeland use not only with forage provision, but also with ecological and cultural services.

These contrasting perceptions of rangelands shape how farmers interpret resource variability and directly influence their decision-making processes regarding grazing management.

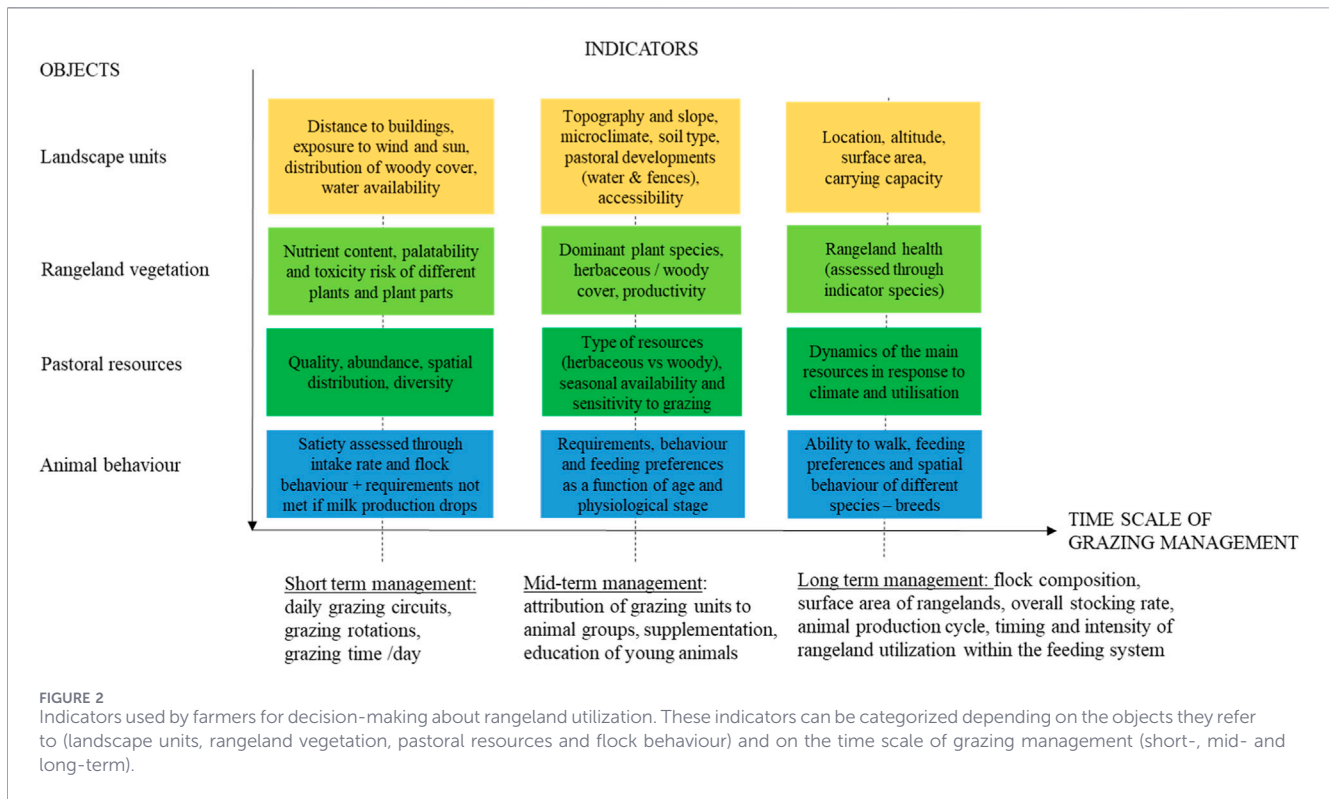
Objects and indicators structuring decision-making

Our analysis of the decision-making process revealed that farmers mobilise four objects: landscape units, rangeland vegetation, pastoral resources and flock behaviour. For each of these objects, farmers referred to a set of indicators, which differed in relation to the time scale of grazing management (Figure 2). For instance, regarding the object “pastoral resources”, the daily grazing circuit could be managed on the basis of the spatial distribution of resource diversity, quality and abundance; the attribution of grazing units to animal groups for a period of time could be decided on the basis of the proportion of woody species and the seasonal availability of the pastoral resource; the setting of the whole feeding system could depend on the dynamics of the main forage resources in response to climatic conditions, past utilisation and their interactions.

The indicators used to describe each object and their use for decision making also differed between farm types. Illustrative examples of these differences, including verbatim quotes, are provided in Table 4.

Farmers differentiated landscape units on the basis of slope, altitude, microclimate, and accessibility; shade and water availability were considered as well, especially in summer. P+ farmers provided detailed and anticipatory descriptions of these features, adjusting grazing plans in advance according to expected changes in animal comfort and energy expenditure. P– farmers, in contrast, relied more on immediate, visual indicators—choosing units based on convenience or easily measurable signs (e.g., herbage height), with little integration of spatial or seasonal dynamics. P farmers occupied an intermediate position, with their strategies often shaped by the herd management mode: when animals were kept in fenced areas near the farm—especially around lambing—they made simple, short-term choices like P– farmers; when animals were herded, they relied on more anticipatory planning, though less refined than that of P+ farmers.

Generally, farmers described rangeland vegetation on the basis of its structure and composition, naming dominant plant species. They assessed vegetation dynamics in response to climate and grazing pressure, identifying key species (including woody plants) and indicators of rangeland health, such as plant cover diversity, regrowth potential, drought resistance, and presence of resilient species. Phenology and regrowth potential informed the ideal timing and intensity of use. P+ farmers showed fine-tuned knowledge of species composition, regrowth cycles, and palatability for livestock. P farmers used indicator species such as *Brachypodium retusum* (a low palatable grass) to decide on grazing rotations. In this study, rangeland “vegetation” refers to the biophysical characteristics of plant communities (e.g., structure and species composition), whereas “pastoral resources” refer to the fraction of vegetation



that is accessible, selected, and consumed by animals, reflecting its functional role in feeding.

Pastoral resources were assessed with several criteria: nutrient content, palatability, toxicity risk, and forage diversity. P+ farmers stood out for their ability to accurately identify what constitutes a valuable resource for a given type of animal at a specific time of year, and to combine different plant species in ways that promote intake and nutritional balance. P farmers aimed to match high-quality grazing areas with key physiological stages of the animals. In contrast, P- farmers adopted a reactive strategy based on single indicators such as perceived forage quality, grass height, and immediate forage availability.

Animal behaviour provided real-time feedback on the quality and palatability of the forage. Farmers observed intake rate, movement patterns, and flock cohesion. Differences between animal species and breeds guided landscape use. Post-ingestive responses (e.g., rumen fill, milk production, body condition) were key to adjusting grazing strategies. P+ farmers showed a sophisticated interpretation of animal behaviour linking motivation, movement, and group cohesion. P farmers recognised the grazing preferences of different breeds—such as a tendency to favour certain plants or avoid steep terrain—and adjusted grazing timing and location accordingly. P- farmers used animal performance (milk yield, body condition) as delayed feedback, often reacting after issues had emerged.

Interpretive strategies: how farmers read and respond to rangeland complexity

The four aforementioned objects played complementary roles in decision-making, for all farms. The key differences between farms

lay in how information about these objects was combined and interpreted. Table 4 illustrate a gradient of interpretive strategies, from reactive and fragmented to integrated and anticipatory approaches to grazing management. P- farmers tended to rely on simple, isolated cues (e.g., herbage height, milk yield), while P+ farmers integrated multiple indicators across dimensions to construct anticipatory strategies. P farmers occupied an intermediate position, shifting between simplified and integrated decision-making processes depending on the production cycle, resource availability, and labour constraints. Accordingly, Table 4 highlights distinct ways of engaging with uncertainty, autonomy and ecological variability through the integration of information across objects. This gradient—from fragmented to integrated interpretation—shows that attention should not only be devoted to *which* indicators are used, but also to *how* they are assembled into structured decision-making processes.

Discussion

Knowledge and decision systems in pastoral farms

The objects observed and monitored by the farmers interviewed in our study — landscape units, rangeland vegetation, pastoral resources and animal behaviour — are consistent with observations from pastoral systems worldwide (Mongolia: Fernandez-Gimenez, 2000; Ethiopia: Oba and Kotile, 2001; Spain: Oteros-Rozas et al., 2013), and reflect the type of local ecological knowledge (LEK) long associated with adaptive rangeland management (Berkes et al., 2000). In particular,

TABLE 4 Objects and indicators used to describe the pastoral ecosystem, with their interpretation and integration into decision-making about rangelands, for the various types of farms (P-, P, P+). Farm codes enable to trace the individual farm characteristics in **Supplementary Material S1**.

Objects	Indicators and interpretation	Illustrative quote [farm code]
Landscape units	P-: Use of nearby, accessible zones with basic structural criteria	<i>"They never go too far. If it rains or if something goes wrong, I can bring them back in right away"</i> [A5]
	P: Selection based on key landscape units (slope, shade, water points) and grazing logistics	<i>"We often prioritise areas that thaw quickly. We also take into account the slope and microclimate of a location"</i> [A1]
	P+: In depth understanding of the landscape and its spatio-temporal dynamics	<i>"On hot summer days, I take them to shaded areas earlier. In winter, we avoid exposed ridges where the wind makes it too cold to stay long."</i> [H7]
Rangeland vegetation	P-: Evaluation of biomass height before/after grazing as basic indicator	<i>"In the paddocks, the indicator is quite simple: it's the grass height. It tells you when to enter and when to leave — once there isn't enough left."</i> [A4]
	P: Knowledge of species regrowth and timing for optimal use	<i>"There are vegetation types that you can graze once in early spring, and they will grow back well for autumn, while others won't. You have to know which ones so that you graze them at the right time."</i> [H4]
	P+: Fine-tuned knowledge of species palatability and seasonal value	<i>"A good rangeland is when you have diversity; it is good for the animals and it maintains the ecological balance"</i> [A7]
Pastoral resources	P-: Focus on basic nutritional content (fibre, nitrogen)	<i>"I make sure there's enough fibre and nitrogen in the diet."</i> [A8]
	P: Targeted use of high-quality pastures in line with physiological stages	<i>"I put them on rich areas before reproduction to induce a sort of flushing. After lambing and at the beginning of lactation, I try to prioritise high-quality grass"</i> [H1]
	P+: Strategic combination of diverse resources to ensure balanced diet	<i>"With experience, you know where they'll stick around and where they'll just pass through. It depends on the season and how often they've been there. Novelty stimulates them, and the circuit must be well-designed to balance what they eat."</i> [H7]
Animal behaviour	P-: Indirect indicators (milk yield, body condition) used reactively	<i>"When you see a drop, you adjust quickly, and then you see if you need to change paddocks"</i> [H3]
	P: Use of animal preferences and breed aptitudes for grazing choices	<i>"If the ewes don't graze brachypodium retusum at the right time, they won't eat it later—it becomes unpalatable."</i> [H6]
	P+: A detailed interpretation of motivation, ingestion rate and group dynamics	<i>"Our first indicator is the animal. We understand what constitutes a resource by observing the herd's behaviour. The shape of the group and its internal dynamics serve as key signals."</i> [A6]

knowledge related to vegetation and pastoral resources typically includes the ability to identify plant species, understand their spatial distribution and seasonal dynamics, and assess their palatability for different types of livestock and at different times of the year. Such knowledge illustrates how pastoralists do not only observe vegetation as a static entity, but interpret it through its functional role in animal feeding.

Another common aspect is the use of animal behaviour cues in order to assess the amount and quality of the pastoral resources available, especially by farmers who practice shepherding. As Molnár (2017) summarised, "[pastoralists] see the grass through the mouths of [their] animals." Monitoring and interpreting animal behaviour is an efficient way of dealing with the diversity and complexity of rangeland vegetation, which rarely lends itself to standardized quantitative assessments of forage availability, such as sward height or biomass measurements. Animal-based cues were part of all the pastoral decision systems we documented, although the indicators used differed between farm groups and types of decisions. These ranged from simple measures, such as body condition or animal weight, to more fine-gained, long-term observations of animal's dietary choices. In some cases, this

enabled farmers to anticipate flock's responses on rangelands and influence their movements and exploration of the environment.

The cross-analysis of studies carried out in different countries reveals that the choice of indicators and their utilisation for decision-making differs between and within groups of pastoralists. For instance, Pakistani and East African pastoralists integrate behavioural cues as well as information on seasonal forage availability, quality and climate variability to guide their mobility and grazing decisions (Jamil et al., 2022; Oba and Kotile, 2001). Likewise, Mediterranean, West African and Maasai pastoralists combine topography, vegetation phenology and animal responses—treating animals as ecological indicators of palatability and dietary needs—to manage grazing under labour and risk constraints (Mapinduzi et al., 2003; Meuret and Provenza, 2015; Oteros-Rozas et al., 2013; Tamou et al., 2018). In our study we identified three distinct decision-making systems among French pastoral farmers, based on different combinations of indicators and responding to different priority objectives (self-sufficiency, low-cost production, or production performance). Our results contribute to documenting this diversity by showing how indicators are combined and interpreted within structured decision-making processes, in line

with recent efforts to better characterise pastoral decision systems (Reyes-García et al., 2020; Wilmer et al., 2018). Rather than providing a descriptive inventory of local ecological knowledge, our analysis focuses on how farmers mobilise, combine and interpret different types of information to support their decisions. This highlights that the key issue is not only which knowledge is available, but how it is operationalised within decision-making processes. By making explicit these links between indicators, interpretation and action, this approach offers a way to analyse decision-making processes and helps identify where local ecological knowledge and scientific information may complement and support the development of context-specific advisory approaches.

The adaptive nature of pastoral decision systems

Our results highlight a strong adaptive component of pastoral decision systems, within each group of farmers. In fact, the indicators used to support decision differed depending on the time scale of grazing management decisions: daily, mid-term (seasonal) or long-term (multi-year). Reed and Dougill (2002) argue that the use of plural indicators is itself a strategy to engage with uncertainty. Between groups of farmers, we documented a gradient of adaptation—from short-term reactive adjustments in the least pastoral systems, to targeted anticipatory decisions, to proactive integrative strategies in the systems relying most on rangeland. Beyond this gradient, pastoral decision-making is a dynamic process in which farmers perceive signals from the pastoral ecosystem, interpret them through experience and knowledge, act, observe outcomes, and adjust practices accordingly.

Our study also identified shifts in decision systems, especially for farmers aiming at low-cost animal production with moderate use of rangelands: certain periods of the year and animal groups would be managed following a “performance first” logic, while others would be managed following a “low-input” logic. Thus, farmers—particularly those in the intermediate group—may shift between different decision-making logics depending on resource conditions, market pressures or flock needs. This complexity echoes recent work emphasizing that farming practices cannot be reduced to a single rationality, but rather reflect diverse logics, priorities and relationships to risk and resource variability (Blasi et al., 2023). Darnhofer (2010) analysed resilience in farming systems, and suggested that adaptability results not from fixed inherently resilient strategies but rather from the ability to shift between decision logics as contexts evolve. Pastoral farmers’ decision systems thus align with the principles of adaptive management and resilience thinking (Berkes et al., 2003; Folke et al., 2010). These results illustrate how adaptation is not only expressed through practices, but also through the ways farmers interpret and combine information in their decision-making processes.

What shapes pastoral decision-making and the underlying knowledge?

The comparison of the three decision systems highlights how farmers engage with the complexity and variability of rangeland environments. In particular, we identified that the farmers who

relied most on rangelands had a low aversion to risk and a high confidence in the ability of rangelands to adequately feed their flock; conversely, farmers who used rangelands only a few months per year, for dry females, aimed at animal production stability and considered rangeland vegetation as an unreliable source of low-quality forage. In another geographical and production context, Michaud et al. (2020) showed that some French dairy farmers distrusted grasslands, while others relied on them to strengthen autonomy.

The accessibility of information about the pastoral ecosystem appears to play an important role in the refinement of rangeland management and in the perception of pastoral resources as well. In our study, the farmers that held the most accurate and diverse knowledge and displayed the most sophisticated decision system were also those who practiced shepherding. Although the practice of shepherding does not guarantee a high level of pastoral knowledge (see: Gobindram et al. (2018) for Moroccan shepherds), it implies a constant presence alongside the herd, on the rangeland. Thus, it gives the opportunity to observe the pastoral ecosystem across days, seasons and years. Since pastoral knowledge builds largely on repeated observations and trial and error tests by the farmers themselves (Sharifian et al., 2023), shepherding represents an asset for a good understanding of the pastoral ecosystem and the development of refined management strategies. Conversely, farmers who spend less time on the rangeland and/or with their grazing herd (either because they do not have the time, or they are not interested) will struggle to put together a decent amount of information about the pastoral ecosystem, which might become a “blind spot” in the feeding system. Such limited knowledge supports a lack of confidence in rangelands. Although our study did not specifically address the origins of farmers’ knowledge, the interviews suggest that learning processes are embedded in life trajectories, combining experience, observation and social transmission complemented by technical advice, as reported by Fernandez-Gimenez et al. (2021).

Implications and limitations for understanding pastoral decision-making

Whereas previous studies have treated LEK mainly as a corpus of observations and heuristics (Abule et al., 2005; Dabasso et al., 2012; Fernandez-Gimenez, 2000; Oba, 2012), we interpret it here as a dynamic process in which indicators are interpreted and combined to guide action (Jouven et al., 2024). This perspective provides a useful lens to analyse pastoral decision-making and to better understand how knowledge is mobilised in practice. By moving beyond a descriptive approach, our study shows how farmers mobilise knowledge through indicators within their decision-making processes. It helps identify how and where scientific knowledge may complement farmers’ own decision-making in a context-specific manner, and highlights potential points of articulation between local ecological knowledge and scientific information.

The uneven distribution of farms across the three groups, with a majority of P farms, reflects both the diversity of systems encountered in the field and the nature of this intermediate group. Indeed, P farms combine characteristics of the two more contrasting strategies (P+ and P–), and may rely on different decision-making logics depending on the time of year,

production stage, or resource availability. Although this group could have been further subdivided, the focus was on capturing contrasted decision-making processes, particularly by highlighting the more distinct strategies represented by the extreme groups.

In addition, the sample reflects key structural characteristics of the study regions, which are predominantly composed of small-scale small ruminant systems. Flock sizes are generally small (< 500 heads), and large-scale pastoral systems are not represented. This focus is also consistent with the research objective, as it allowed us to analyse decision-making processes of farmers directly involved in day-to-day grazing management. In larger or more complex systems, grazing management may be partially delegated (e.g., to hired shepherds), making it more difficult to access individual decision-making processes. The study also focuses on systems relying on shrubby and wooded rangelands, which are characteristic of the study areas and involve specific ecological dynamics and management constraints. This provides a relevant context to explore decision-making under heterogeneous and variable conditions. The results may also provide insights into simpler situations, although their transferability to other types of pastoral context remains to be discussed.

These results suggest that advisory approaches in pastoral systems cannot rely on standardised recommendations, but need to be tailored to the diversity of farmers' decision-making systems. As shown by the contrasted strategies identified in this study, farmers differ in the indicators they mobilise, their interpretation of resource variability, and their relationship to rangeland variability. Supporting adaptation to climatic variability therefore involves not only providing technical solutions, but also strengthening farmers' capacity to interpret and combine indicators within their own context. In this perspective, the articulation between scientific and local ecological knowledge should be context-specific and aligned with existing decision-making logics.

Conclusion

This study shows that the degree of reliance on rangelands is associated with distinct ways of perceiving, interpreting, and managing pastoral resources. The three farm types identified were not only characterised by different levels of rangeland use, but also by contrasted decision-making systems. These systems formed a gradient, ranging from control-oriented and reactive approaches based on a limited set of measurable indicators, to more integrative and anticipatory strategies combining information on landscape units, vegetation, pastoral resources, and animal behaviour.

We also show that these decision systems are not fixed: farmers—particularly in intermediate systems—may shift between decision logics depending on production objectives, resource availability or contextual constraints. Finally, more integrative decision systems were generally associated with farmers who practiced shepherding, suggesting that continuous, direct observation of the pastoral ecosystem plays a key role in the development of refined decision-making processes.

This study highlights how farmers actively observe, mobilise and combine knowledge in grazing management decisions and practices.

This contributes to a better understanding of how knowledge is used in practice, and how scientific and local knowledge can be articulated to support context-specific grazing management strategies.

These findings could have important implications for the design of advisory tools and policies aimed at supporting pastoral systems, particularly in the context of increasing environmental variability. Future research could further investigate how these decision-making processes evolve under climate change, and how local and scientific knowledge can be articulated to support grazing management in different pastoral contexts.

Data availability statement

The original contributions presented in the study are included in the article/[Supplementary Material](#), further inquiries can be directed to the corresponding author.

Ethics statement

Ethical approval was not required for the study involving humans in accordance with the local legislation and institutional requirements. Written informed consent to participate in this study was not required from the participants or the participants' legal guardians/next of kin in accordance with the national legislation and the institutional requirements. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

ED and MJ jointly conceived and designed the study. ED conducted the interviews and performed the initial analysis of the raw data. ED and MJ jointly interpreted the results and co-wrote the manuscript. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declared that generative AI was used in the creation of this manuscript. During the preparation of this work, the authors used a generative artificial intelligence tool (ChatGPT, OpenAI, GPT-4) exclusively for minor language editing and very limited rephrasing. All scientific content, analyses, and

interpretations were produced by the authors without the use of generative AI.

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Supplementary material

The Supplementary Material for this article can be found online at: <https://www.frontierspartnerships.org/articles/10.3389/past.2026.16171/full#supplementary-material>

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