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Governance, Mobility, and Pastureland Ecology. An Eco-Anthropological Study of Three Pastoral Commons in Northeastern Andalusia

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Abstract
Community-based natural resource governance is increasingly valued by the leading international organizations that promote environmental conservation and sustainable development. At the same time, the ecosystems of the northeastern Andalusian mountains are intrinsically related to the long-standing presence of pastoralism and its different communal forms that have favored a very particular biocultural diversity and sustainable socio-ecological systems locally. Through a transdisciplinary anthropological and ecological study, we aimed to compare how different types of communal governance and pastoral mobilities impact pasturelands in the region. We focused on three contiguous mountain pastoral commons, those of Castril, Santiago de la Espada, and Pontones, which exhibit different forms of communal organization and two main transhumant types of mobility: long-distance and short-distance transhumance. We conducted long-term ethnographic fieldwork with year-round participatory observations of social life, pastoral practices, and governance systems, and performed botanical and soil analyses. As a general result, we found that local pastoralism positively impacts the environment. There were differences between commons and mobility regimes, with a positive impact related mainly to closer forms of cooperation between herders and daily guiding of flocks, along with seasonal long-distance transhumance, especially when the latter is combined with stricter formal community rules. Within the current context highly determined by public subventions, particularly from the EU, primarily directed at pastureland management's administrative and economic aspects, local governance increasingly favors these methods over the conservation of traditional, sustainable uses of pastures. This innovative research marks the first step towards a sounder intertwining of anthropological and ecological approaches towards a more holistic understanding of pastoral commons in general and in the Mediterranean region specifically.

Keywords Mountain pastoral commons · Transhumance · Governance · Social anthropology · Pastoral ecology · Andalusia · Mediterranean

Introduction

About 200 million households around the world continue to practice pastoralism on rangelands, which are usually communally managed and cover about 45% of the Earth's surface (Blench, 2001; ILRI, 2021; Reid et al., 2014; Scoones, 2020). Pastoralist communities, typically characterized by their mobility (Khazanov, 1984), are highly diverse and particularly able to adapt to cultural and socio-environmental changes (Galaty & Johnson, 1990), especially in arid and semi-arid environments (Blench, 2001; Fernández-Giménez & Le Febre, 2006; Galvin, 2009). High ecological and climatic uncertainty, with significant differences between years and within the same year, is characteristic of the mountains of northeastern Andalusia (Spain), where high temperatures and prolonged drought conditions in summer and relatively low temperatures in winter are related to altitude and continentality (Lobo & Rebollar, 2010; Blondel, 2006). These conditions limit plant growth (Mitrakos, 1980), thus pastoralism in the region requires strict levels of organization.

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Specific rules on mobility, herd size, and protection of areas for seasonal use are communally established and also avoid resource depletion (Palomo-Campesino et al., 2018; Anderies & Janssen, 2016; Herrera et al., 2014; Ostrom, 1990; Dominguez, 2010).

Previous research has demonstrated the links between community-based governance and environmental conservation, often in connection to biocultural diversity (Borrini-Feyerabend et al., 2010). Concerning pastoralism, for example, Schermer et al. (2010) illustrate how pastoral commons prevent both erosion through overgrazing and shrub encroachment or forest expansion through underuse, as well as ensure the continuity of grassland ecosystems that have co-evolved with human use over millennia (Roberts et al., 2018). Nonetheless, commons and their important social and environmental values are frequently not publicly recognized and remain legally, politically, socially, and economically underappreciated and unprotected (Manzoni et al., 2023). In the case of Spain, as in most Mediterranean countries, there are no specific national policies and measures addressing common pasturelands. Moreover, at the European level, where commons cover at least 7% of the continent (EUROSTAT, 2013), and grasslands, 17.4% of the EU (EUROSTAT, 2018), there are still no specific measures in the EU Common Agricultural Policy supporting and protecting these very particular socio-ecological systems (Galán et al., 2022; Salguero, 2019).

Mediterranean mountain pastoral commons typically comprise groups of herders operating in different cultural contexts that communally regulate access to pasturelands during the year, particularly in spring, the most sensitive period for plant reproduction, to assure the continuity of the pastoral ecosystem (Dominguez et al., 2010), especially to ensure the continued presence of species beneficial for their herds. This also maximizes fodder production, often allowing the harvest of extra grass in summer for winter use since, in spring, the vegetative parts of the plants are at their maximum growth rate (Bourbouze, 1987). This provides a unique biocultural gathering made of living things tightly related to the cultural frame of pastoralist governance (Dominguez, 2015).

Additionally, community-based management of pastoral systems can ensure maintenance of denser and healthier plant cover and greater species richness than open access or private corporate pasturelands (Auclair & Alifriqui, 2012; Herrera et al., 2014). Ecosystem services provided by extensive grazing systems include seed conservation and dispersal (Grande et al., 2013; Ramos et al., 2006, 2010); water availability (Ramos et al., 2011); and nitrogen, phosphorus (Marshall et al., 2018), as well as carbon sinks against climate change (Silver et al., 2010; Zhuang et al., 2019). From a social perspective, communal governance balances economic differences between its members, facilitates more equitable access to pastures and minimizes social conflicts among herders through the high participation of rights holders (cf. Dominguez et al., 2012). In sum, the conservation of ecosystems based on local ecological knowledge and collective decision-making provides important benefits for both the direct interests of the local communities and the maintenance of biocultural diversity and ecological functions that are of global significance (Berkes, 2004; Borrini-Feyerabend et al., 2014; Brosius et al., 2005; Pretty et al., 2009).

Considering the above and based on previous observations (Madera Pacheco, 2005; Dominguez & Ventura, 2019; Godoy et al., 2021), we infer that institutions of collective governance built and maintained through generations in co-adaptation with local ecosystems, landscapes, and shifting socio-economic conditions provide more effective ecological conservation strategies for the pasturelands they manage. However, studies that empirically test in detail the effects of community-based management on pastoral ecosystems and the impacts of transhumance on communal summer pastures are rare (e.g. Auclair & Alifriqui, 2012; Mwamidi 2018; Moritz et al., 2013). By integrating social and ecological variables, the present study contributes to addressing this key scientific gap. We hypothesized that differences in the types of community governance and in mobility practices (e.g. long-distance transhumance (LDT) vs. short-distance transhumance (SDT) have different ecological impacts on mountain pastures, namely that better ecological pastoral performance could be achieved through (a) more formally structured and socially supported ways of pastoral governance and (b) long-distance transhumance versus a short-distance one. To test this, we identified key local pastoralist practices and collective decision-making processes as well as conducted a soil and botanical assessment of common pasturelands in the northeastern mountains of Andalusia.

Methods

Study Site

The study site consists of three contiguous pastoral commons in the mountains of the Subbetic system in northeastern Andalusia (Spain): Castril, Santiago de la Espada (Santiago, from now on), and Pontones (Fig. 1). The global area of highland communal pastures expands over circa 35,000 ha between 1.400 and 1.900 m. a.s.l., and is located within a main plateau surrounded by peripheral peaks and valleys. The area is under a montane Mediterranean climate regime with strong contrasts: cold and snowy winters, with

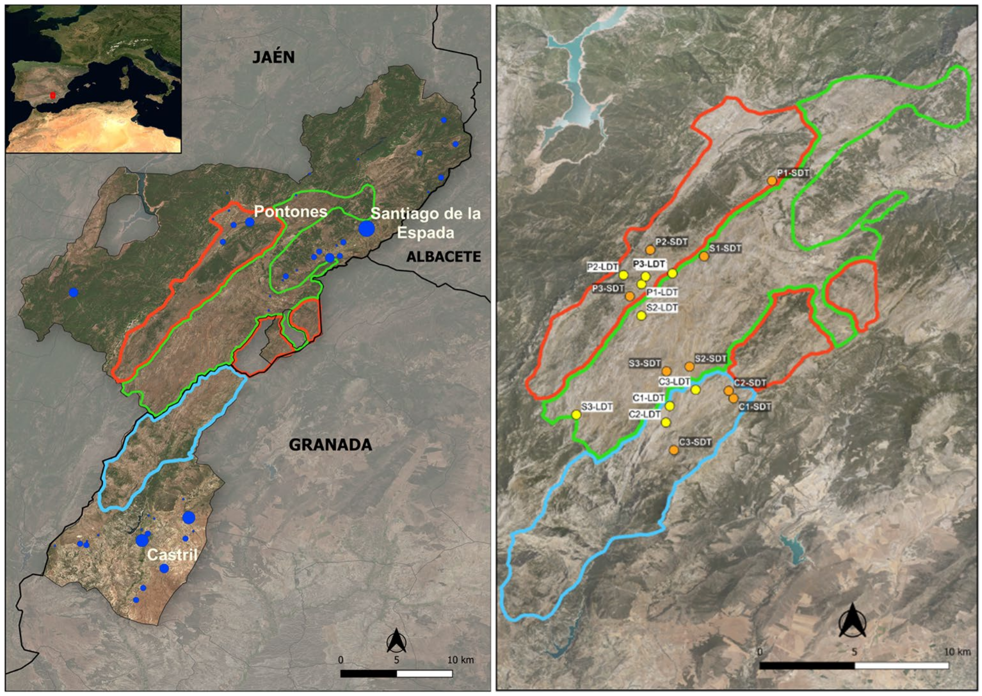

Fig. 1 a (left): Location of the highland pastoral commons of Castril (light blue), Santiago (green) and Pontones (red), and inhabited hamlets and villages (marked with dark blue spheres). The area with gray filter corresponds to other municipalities. Fig. 1b (right): Sampling locations according to each common and transhumance type (LDT in yellow and SDT in orange)

temperatures reaching down to -15ºC; and relatively warm and often very dry summers, with temperatures reaching up to 35ºC. Average rainfall in the plateau is about 630 mm/year, mainly concentrated during spring and autumn, and mostly in the form of snow in winter. Rainfall is very variable, ranging from 300 mm/year in the southernmost parts of Castril's highlands, up to about 1,000 mm/year in the peaks and northern areas of Pontones common (AEMET, 2018). Soil substrates are carbonated, such as limestones, dolomites and marls, with abundant rocky outcrops and surrounding abrupt reliefs (Arroyo y Valle, 2000; Blanca et al., 2011; Fuentes et al., 2015).

These pastures are located in the supra- and oromediterranean belts, above 1,600 m a.s.l., within the biogeographical Baetic province, Subbetic subsector, Cazorlense district. Potential vegetation is mostly represented by two vegetation series: (i) Baetic oromediterranean basophil related to savin *(Juniperus sabina) and (ii)* Baetic supramediterranean basophil dry-subhumid related to holm oak *(Quercus rotundifolia)*. Historically, timber production, livestock grazing and agriculture led to a shift from forests toward shrublands, permanent grasslands and extensive cultivated fields (Araque, 2013). We have focused on dry perennial grassland communities characterized by *Festuca hystrix* such as the phytosociological associations of *Seseli granatensis-Festucetum hystricis*[1] and of *Coronillo minimae-Astragaletum nummulariodes*[2]. In areas with a higher grazing pressure, these can be often intermingled with *Medicago rigidulae-Aegilopetum*[3] (Gómez-Mercado, 2011).

The orography in Castril is more rugged and steep, albeit with areas of smoother inclinations and sedimentation of thick soils where highly productive pastures develop. Castril is mainly exposed southwards, it is dryer and warmer. Even if its highland pasture surface is smaller, it has a wider area of lowlands than Santiago and Pontones. These two are dominated by colder high-plateaus and intra-mountainous plains of high pastoral value but with almost no lowlands available for winter pasturing (Gómez-Mercado, 2011) (see Fig. 2).

Castril stayed under Muslim rule for three centuries more than Santiago and Pontones, granting a much more identifiable heritage related to the arabo-berber period and systems similar to the agdal of Morocco (Dominguez, 2017). In 1491, Castril's highlands were ceded to Hernando de Zafra, secretary of the Catholic Kings, remaining in the hands of the nobility until 1888, when, due to mobilization of local communities, they were given to the neighbors of Castril and are currently formally owned by the municipality (Alfaro, 1998). On the contrary, the

1 Representative species: *Festuca hystrix, Koeleria vallesiana, Arenaria tetraquetra, Poa ligulata, Helianthemum cinereum, Seseli montanum subsp. granatense*, etc.

2 Representative species: *Coronilla minima*, *Astragalus incanus* subsp. *nummularioides*, *Festuca hystrix, Poa ligulata, Seseli granantense, etc.*

3 Dominated by *Medicago orbicularis, M. minima, Trifolium campestre, T.glomeratum, T. scabrum, Coronilla scorpioides, Aegilops geniculata, (A) triuncilais, Bromus hordeaceus, (B) madritensis, Vulpia sp.*

Fig. 2 Highland landscapes of pastoral commons in spring: Castril (upper left), Santiago (upper right), and Pontones (lower left). Pasturelands are mostly covered with snow in winter (lower right)

pastures of Santiago and Pontones were under Christian rule from as early as the 13th century, being ceded to the Orden de Santiago, which contributed to the establishment of the code of *El Común de Segura*, aimed at regulating the common use of natural resources in Sierra de Segura (De la Cruz, 1980). Since the 18th century, these lands became state or private property, destined mainly for timber production (Martínez, 2014). Therefore, a long-lasting cultural border has existed between Santiago-Pontones and Castril, dividing distinct patterns of land tenure: Castril municipality is the owner of over 70% of the highlands, and cedes its use to the Castrilian farmers for just a symbolic amount, while in Santiago and Pontones, the main owners are the state (about 50% of the land) and private individuals (about 40%) to whom the community of herders must pay important amounts every year.

The population is distributed in several scattered towns and hamlets (see Fig. 1a), mainly surrounded by forested areas and private lands used for arable and pastoral farming. In Castril, Fatima is the main settlement of herders. On the other side, Santiago's community of herders gather mainly around Santiago village and La Matea (Fig. 1); in Pontones, the herders live in different hamlets such as Fuente Segura, Pontón Alto and Pontones village. Except for some cases in Castril, all the herders are men, most of them over 50 years old. The role of women is reduced and mostly invisiblized, revolving around taking care of animals on the farm and giving support during periods of seasonal mobility of herds. Santiago and Pontones were two different municipalities since the 19th century, but for administrative and management purposes, the Spanish State joined them in one, even if their respective pastoral commons kept operating separately. The three common highlands are within two Natural Parks (IUCN category V): the Natural Park of Sierra de Castril (which covers the highlands but not the lowlands of Castril) and the Natural Park of Sierra de Cazorla, Segura y Las Villas, within which the entire municipality of Santiago-Pontones is located.

Nearly 90 herders from the three commons manage their flocks collectively in three associations, totaling 60,000 sheep and 5,000 goats. Each of the three community-based associations has its own statutes and board of elected directors (see Table 1).

Grazing in these highland pastures can be described as extensive livestock breeding systems (Ruiz et al., 2017), where we distinguish two main forms of mobility: short-distance transhumance (SDT) and long-distance transhumance (LDT). SDT involves local mobility of flocks between high and low grasslands within the municipality, while LDT is the movement of shepherds and herds to other territories outside of the municipality, implying a walk of three to ten days[4] (Fig. 3). In Santiago and Pontones, over two-thirds of herders practice LDT, while in Castril, only about 10% do it, depending on the year.

The EU Common Agricultural Policy (CAP hereafter) has had a notable impact on the forms of pastoralism and the attitude of herders towards the pastures. CAP's main aim has changed from securing a minimum income to farmers and ranchers to assure the countries' food production autonomy (Clar et al., 2018) to prioritizing environmental aspects, many times allochthonous to local communities

[4] The main destination of LDT is Sierra Morena, a much lower mountain range in northern Andalusia that offers milder winters with good pastoral resources. To arrive there, herders travel between 50 km and 125 km, most of them by foot.

Table 1 Main characteristics of the commons of Castril, Santiago and Pontones[a]

Community	Castril	Santiago	Pontones
Shepherds within study area	*25*	*41*	*22*
Grassland surface area used	*≈ 8.000 ha*	*≈ 15.000 ha*	*≈ 11.000 ha*
Reproductive sheep on pastures during maximum grazing period (June-July)	*12.000*	*32.000*	*14.000*
Sheep/ha during maximum grazing period	*1,5*	*2,1*	*1,3*
Mean number of sheep per flock	*480*	*780*	*636*
LDT Grassland use and seasonal mobility calendar	*3 herders (12%) and 1,900 animals (16%) arrive towards June and leave in November*	*28 herders (68%) and 22,000 animals (69%) arrive towards June and leave in November*	*14 herders (64%) and 11,000 animals (79%) arrive towards June and leave in November*
SDT Grassland use and seasonal mobility calendar	*22 herders (88%) and 10,100 animals (84%) arrive in April/May. Some leave in July, others leave in October or later*	*13 herders (32%) and 10,000 animals (31%) are in the highlands from March/April to November*	*8 herders (36%) and 3,000 animals (21%) are in the highlands from March/April to November*

[a]This information has been collected and produced during fieldwork

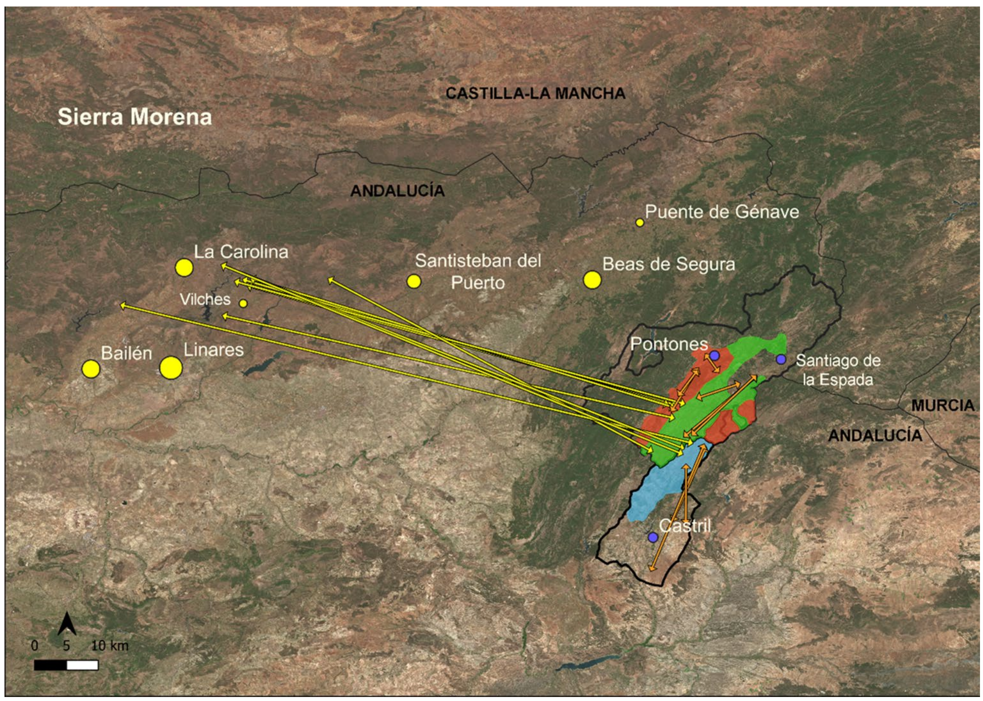

Fig. 3 Representation of pastoralists' movements according to mobility types between summer and winter areas: SDT (orange lines) and LDT (yellow lines). Yellow spheres represent some of the main villages of Sierra Morena, around which long-distance transhumants spend the winters. The arrows represent only the subset of transhumants whose data we have used for this publication, but there are many more. Blue spheres are the villages of Castril, Santiago and Pontones

and with vicious outcomes. Today the subsidies are calculated largely in relation to the surface utilized by each herder (Ruiz et al., 2017) and through a Coefficient of Admissibility of Pastures[5]. Therefore, besides being conceived as a food resource for their animals, pastures are also increasingly seen as a surface implying monetary value associated with subsidies.

[5] This coefficient assigns higher values to flat and humid areas with high vegetation coverage, and generally diminishes the value of the mountainous and the more arid regions of the Mediterranean, to the point of giving very low values or even zero to areas that are grazed for generations. This makes it a source of conflict and also promotes organizational efforts on the part of the herdsmen to contest the method or navigate it.

Data Collection and Analysis

Data collection consisted of two interdependent phases. The ethnographic approach adopted participant observation and visits during herding, accompanied by a series of in-depth interviews with the shepherds ($N = 21$) as well as public agents ($N = 4$). This was aimed at understanding the life of herders within their communities, their relationship with the pastures and animals, their organization of pastureland management, as well as contextual aspects. Fieldwork was made in different campaigns and periods of the year, ranging from 10 months in Castril to 12 months in Santiago-Pontones between 2017 and 2019, and later visits in 2022. All data were gathered through field notebooks and transcribed interviews, subsequently imported, coded and analyzed qualitatively in QSR NVIVO. Most of the herders' grazing areas (*comarcas*) were identified, including potential sampling points to develop the ecological study.

The second part of the study focused on the pastures with the highest pastoral interest: herbaceous perennial grasses characterized by *Festuca hystrix*. We looked at two key factors: i) type of common governance (Castril, Santiago and Pontones) and ii) type of mobility (LDT and SDT). In each common, three LDT and three SDT grazing areas were identified, totalizing 18 sampled grazing areas. Within each of these, we selected three different spots where vegetation samples were taken in June and July of 2018 and of 2019 using 1 × 1m quadrats, as well as soil and manure samples (see table S1 in the methodological annex). We assessed the following vegetation data: structural parameters (i.e. plant cover (%), phytovolume (m^3/ha)), floristic parameters (i.e. plant species richness (number of species), diversity (H', Shannon index)) and plant utilization rate (degree of utilization, from 0 to 5)[6].

For the statistical analysis, Linear (LMMs) and Generalized linear mixed models (GLMMs) were performed depending on the response variable analyzed. The aim of these analyses was to determine whether livestock, management and soil parameters explained the variability of the vegetation parameters. We considered the seasonal (spring, summer, autumn, winter) and annual mean carrying capacities, soil parameters (C, N, P, K, cation exchange capacity, pH), the different community management (Castril, Santiago and Pontones) and type of mobility (SDT or LDT) as explanatory variables. The quadrat was used as a random part of the models. Additionally, Tukey post-hoc tests were performed in order to compare the different treatment combinations and detect significant differences. Several response variables were used: plant cover, photo volume, plant species richness, plant diversity, and plant utilization rate (PUR).

Results

Herds and Herders' Mobility Regimes

There are certain differences on how livestock farming is carried out in Castril, Santiago and Pontones. Common pasturelands are mainly used from May to November, the maximum vegetative period, when animals are mostly fed there (see Fig. 4). Due to the reproductive calendar, pregnant ewes (about 40%) abandon high pastures during August, significantly reducing grass consumption and pastoral pressure (see Fig. 4). Due to the greater availability of crop areas, a considerable number of SDT flocks abandon the mountain pastures early to take advantage of lowland stubbles, that practically do not exist in the municipal area of Santiago-Pontones. Nonetheless, those practicing LDT stay much longer in their grazing areas (until November). In Santiago and Pontones, there are both more LDT and more SDT sheep in the highlands until October-November. At that point, LDT herds leave '*la Sierra*' towards the *fincas* (estates) they rent in the lowlands of Sierra Morena, where they stay for about six months. LDT herders, who will come back to their highland *comarcas* later than the SDT herders, assume that the absence of their herds during this longer period results in a benefit for the growth of their part of the grasslands that theoretically nobody should enter during the

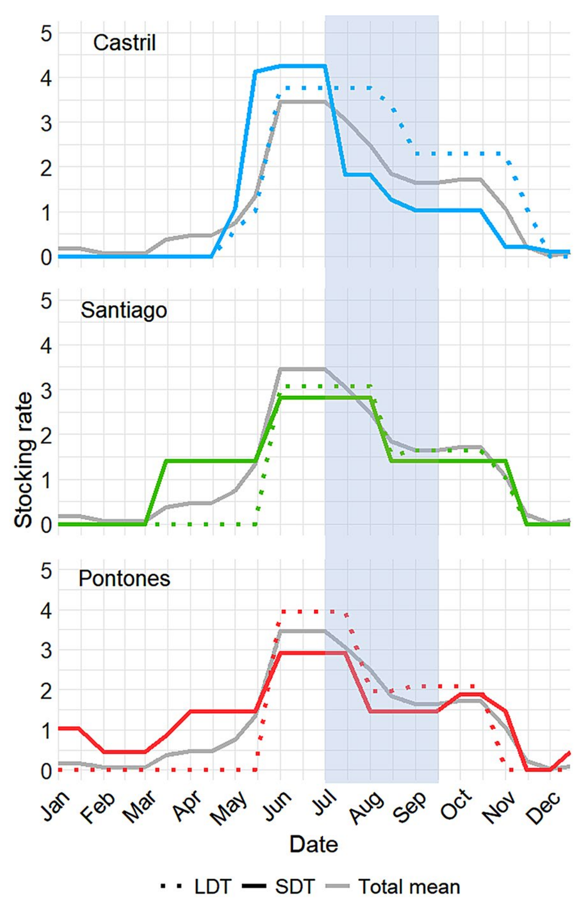

Fig. 4 Biweekly average stocking rate in the common pastures of Castril, Santiago and Pontones, distinguishing between LDT and SDT. Mean stocking rate among all commons and types of mobility is represented in gray. SDT appears as continuous lines and LDT as pointed lines. Vertical color strip marks the period when pregnant ewes leave high pastures

[6] In the results and discussion section, we only include phytovolume, plant species richness and Plant Utilization Rate (PUR) as synthetic variables that best summarize the ecological characteristics and the global effect of grazing, although mean tables and statistical analysis for all the variables are shown as supplementary material (see Supplementary material S2: results for further details on vegetation and soil samples).

highest growth period of the pastures in spring. Therefore, most of them defend a zonation within the common grasslands. As we can see in Fig. 4, Castril's SDT herds spend less time in the highlands, but they are also the ones with the highest stocking rate (number of animals per hectare) of all three commons during the peak of the season.

On the other hand, Santiago and Pontones' SDT animals that did not descend in mid-summer for lambing usually abandon these territories when the snow arrives or when there is not enough pasture. Thus, many of them use the highlands for up to nine months. Some herds in Pontones and Santiago graze from October to March, as long as their zone is clear of snow. These herds have better access from their villages compared to Castril's access to their highlands, where some SDT herders may occasionally stay until late December, as departing and later returning to high grasslands is much more complicated.

Also, due to this same precarious road infrastructure, Castril shepherds spend more time with the herds in the highlands (from 3 to 5 days without leaving the mountain pasturelands), while in Santiago and Pontones, herders rarely sleep in the highlands with their herds, as it was usual two or three decades ago.

Before every winter, herders of Castril, Santiago and Pontones assess expenses related to the payment for the winter farms, where LDT herds stay from November to May, or for fodder, to feed SDT flocks when there is not enough pasture. Herders can shift from LDT to SDT depending on the year, but generally stay quite stable. There is also an identitarian dimension and a certain pride attached to the realization of LDT for several years, even generations. The place where their children attend school within the context of their mobile lives is also a relevant issue. For instance, a shepherd from Pontones was a long-distance transhumant until his sons started school 20 years ago, stabilizing them as short-distance transhumants. But he and his grown-up son are now considering practicing LDT again, thinking about flock's comfort and its greater profitability.

However, changes in wintering areas are relatively more frequent because LDT herders must rent them individually, so LDT entails a higher level of uncertainty. A few herders have maintained their winter zone for decades, but most of them are forced to change it within a decade due to disagreements with landowners who often find others that pay better for their lands (e.g. hunting or olive grove planting investors).

All these changes are part of the main factors that enable closer relationships between communities, blurring possible boundaries between them, since herders that belong to different commons in summer can be neighbors during the winters in Sierra Morena.

Local Management of Pastoralism through Contextual Constraints

Since the mid-20th century, livestock farming has gone in the three commons from an extended family model with small herds (50–100 sheep), where different family members took responsibilities in herd management, to an individualized model centered on middle-aged and older men and bigger herds. Currently, there has been a reduction in the number of herders, so there is a decreasing competence for local material resources combined with an increasing need to articulate the political-administrative dimension of farms. The current average flock size is about 600 breeding ewes, the smallest herds generally comprising about 300 sheep and the largest ones up to 900 or 1000, and even 2.000 ewes.

Notwithstanding these trends, there has been a loss of profitability as the price of 55€ per lamb has not changed for more than three decades despite a twofold increase in the cost of production and living expenses. Lambs are sold below production cost and herders only compensate it via public subsidies. Based on data collected in interviews, we estimate that about half of livestock farmers' income comes from these sources nowadays, especially from the EU CAP. Shepherds of each of the three commons work collectively to manage these subsidies, demonstrating the area and surface that each stockbreeder (theoretically) graze, thus ensuring that each member of the community receives the aid corresponding to the size of his herd and the surface it uses. These new -but key- administrative contexts have led the shepherds to spend progressively more time attending bureaucratic issues and -proportionately- less time with their herds. For instance, discrepancies related to the Coefficient of Admissibility of Pastures have promoted herder's mobilizations, either to get certain grazing areas administratively recognized as such when they were not (as occurred in Pontones in 2019), or as a claim to recover the EU CAP subsidies in case they had been reduced by the administration (as occurred in Castril in 2018).

Main Local Governance Institutions

Herders' associations have played an active role in interacting with public institutions, establishing processes and structures for coordinating them and for decision-making, as well as establishing internal rules to manage livestock and pastureland for sustainability enhancement, and for achieving public subventions (see Table 2). In general, access to grasslands is only permitted to flocks of members of the associations. In the exceptional case when there is an external herder that applies for pastoral use, it must be approved by the assembly. All members of the associations must be born or live in the municipality and their membership must be approved by the majority of members in assembly. Within these governance institutions, most issues are discussed among the herders themselves, without involving other family members. Day-to-day discussions to coordinate different flocks' mobility in the highlands in summer is done among neighbouring herders, who sometimes have kinship ties. At this level, the neighbouring factor is the main one identified, but this continuum of neighbours negotiating pastoral routes in the highlands with one another does not seem to cluster in any particular domestic groups influencing the global governance of the three commons.

Regarding pasturelands access, herders must lease public and private lands to ensure pastures' access, regardless of their purchasing power and flock size. Thus, they actually form a common-pool resource, where *comarcas* are allocated among the herders of each common, which they keep during the year or several years. However, these can be changed in accordance with the internal rules and needs of each common and herder.

Concerning the intensities in the governance of each common, in Pontones, access to pastures is regulated and follows a strict schedule, having more formal rules that are very well known within the group of herders. There are also sanctions imposed in case of noncompliance, which goes from a payment (a fine) to the herders' association to even the interdiction to use common pasturelands. Meanwhile, in the commons of Santiago, these kinds of rules and measures are not so explicit and/or enacted, while in Castril, they can even be non-existent. Thus, formal governance is less structured in Castril, although herders still have a high degree of coordination due to their greater need to cooperate when there is a high pressure over pastures (May-July) in an area with less highland pastoral resources than in the other two commons, along with the fact that they need to pass more time together in the highlands due to the deficient road infrastructure. Beyond a few collective rules, in Castril, there are non-formal agreements among herders; for example, there is an unwritten but clear situational organization regarding dates for grazing each part of the common pastureland that is agreed on every year in the highlands.

The organizational capacity of the herders' communities consolidates them as a valid and publicly recognized interlocutor capable of negotiating relevant aspects of pastoralism with local and regional authorities. Topics may go from access to land and livestock infrastructures to guidelines for the management of Natural Parks. Nowadays, Natural Parks' administrations increasingly recognize the value of extensive livestock management for maintaining the highlands' landscapes, ecosystems and habitats, as well as to enhance the local identity and cultural heritage[7]. In any case, the management of pasturelands is subject to approval by the Natural Parks and ultimately by the regional administration regulations (Junta de Andalucía), leaving the decision capacity of herders well delimited by external actors. The role of the Natural Park in Santiago and Pontones is especially relevant, since they perform a mediation function with the regional administration and secured that 80% of the amount paid for these pastures' leasing gets re-invested in the maintenance and improvement of the livestock infrastructure. For Castril farmers, this intervention does not occur. Therefore, all investments in the highlands must be done directly by Castril's pastoralist community.

The commons' governance body also plays a relevant role in avoiding conflicts among shepherds, in great measure in Pontones and less in Castril (Table 2). The mere existence of sanctions prevents the development of conflicts of different types, such as bringing the flock beyond demarcated areas (*comarcas*), bringing them before the agreed dates, or failing to pay local institution fees.

Table 2 Main differences in institutional arrangements between Castril, Santiago and Pontones

Common	Castril	Santiago	Pontones
Regular pasturelands use	Free mobility within pasturelands, even if *de facto* most shepherds stay in their traditional zones.	Free mobility within pasturelands, even if *de facto* most shepherds stay in their traditional zones.	Each flock must be within their grazing area by May 1st.
Participation in decision-making processes	Most of the shepherds attend ordinary and general assemblies	Most of the shepherds attend ordinary and general assemblies.	All shepherds attend general and ordinary assemblies
Early access	No explicit rules nor fees	No explicit rules nor fees	Shepherds that take their flocks to pasturelands before that date must pay an extra fee per animal.
Sanctions	Economic sanctions for not respecting the rules related to pastureland use, although there was no evidence of application (during fieldwork)	Economic sanctions for not respecting the rules related to pastureland use, although there was no evidence of application (during fieldwork)	Economic sanctions for not respecting the rules related to pastureland use, but also due to non-attendance at assemblies or arrears; land-access revoked in extreme cases.

[7] As shown in the Sect. 2.2.4 (*Paisaje*) and 2.7.2 (*Ganadería*) of the II Sustainable Development Plan of the Cazorla, Segura y Las Villas National Park (Junta de Andalucía, 2022).

Likewise, herders use assemblies to argue and solve these issues when they are unable to do it by themselves first. For instance, in June 2019, two herders from Pontones kept some of their sheep out of their designated zone (ignoring the rule of having to be in their *comarca* by May 1st). After a serious discussion exposing the reasons why it is important to abide by the internal rules, the conflict was solved positively, dismissing the need to bring this issue to an assembly, apply economic sanctions, or make any public actor outside of the community of herders intervene. Similar situations do not have the same resolution in Castril or Santiago, where there is not such a strong *comarca*'s demarcation.

Ecological Characterization of Common Pasturelands

Regarding ecological assessments, Fig. 5 shows at a glance the different variables that were measured in this part of the study to make a global comparison between commons (pooled across mobility types) and between mobility types (pooled across commons). Such an approach allows us to differentiate certain tendencies. Mean values ± standard error for every vegetation, soil and livestock parameter are included in Supplementary material S2: Result tables S3, S4 and S5. No statistical significance around these differences should be inferred in Fig. 5. To tailor this figure, mean values of the variables were scaled from 100 (for the maximum value registered for each variable) to 0 (for the minimum value registered), and proportional intermediate values (only for commons) were plotted. Castril had the highest mean values for all the vegetation parameters, for many of the soil parameters (cation exchange capacity (CEC), P, K, C), and for all livestock parameters, except winter stocking rate. Pontones had the highest values for soil organic matter, N, and winter stocking rate; and had similar values to Castril for soil cation exchange capacity (CEC) and spring stocking rate.

At the same time, when comparing mobility types, SDT scored highest for every soil parameter, also manure, plant utilization rate and spring and winter stocking rate. Nevertheless, LDT scored highest for all the vegetation parameters except plant cover and autumn and summer stocking rates (Fig. 5).

At a more detailed level, we performed statistical analyses related to five ecological parameters (plant cover, species richness, diversity through Shannon Index, phytovolume and plant utilization rate). We selected species richness, phytovolume and PUR as representative of the analyses (Fig. 6, tables S6 and S7), as these parameters showed statistical significance and are the most directly linked to the pastoralist practices and collective pasture management processes observed. Models showed different contributions from soil to the floristic and structural parameters, as well as significant differences among the three commons and between long and short-distance transhumance for some of them (table S7). Figure 6 shows the data for the combination of treatments (commons and types of mobility), where black dots represent mean values, boxplots represent the data distribution through their quartiles, and curves represent the probability density of the data smoothed by a kernel density estimator. Those combinations of treatments having the same letter or letters (a, b, or ab) are considered to be statistically similar, whilst those having different letters (e.g., Pontones concerning commons and especially richness) are statistically different. Phytovolume does not have any letter as all the combinations of treatments were statistically similar.

The variables that better explain the variability of species richness are summer stocking rate, cation exchange capacity (CEC), pH, commons, and mobility type (table S7). In this case, CEC had a positive effect on species richness that was statistically significant. Also, there were significant differences between commons and between mobility types (table S7). Castril had more species than Pontones, pooled across mobility types; and LDT had more species than SDT pooled across commons in a statistically significant manner. When comparing the different combinations of treatments for Castril and Santiago, the post hoc test indicates that mean values were higher for LDT than for SDT, even if these differences were not statistically significant (table S3, Fig. 6a), while for Pontones the differences between LDT and SDT were statistically significant and notably higher for LDT than for SDT (around 30% higher, see table S3 for mean values). It should be reminded here that Pontones is the common with the most structured formal governance rules.

Phytovolume, which in this case could be considered an indirect measure of pasture productivity, resulted in similar values for all the commons and for the different types of mobility (Fig. 6b, table S7), i.e., no statistical differences were detected among treatments. CEC and summer stocking rate were the variables that better explained the phytovolume variability, although these variables were not statistically significant for the model (table S7).

Finally, the parameters that better explained the variability of the plant utilization rate (PUR) are: summer stocking rate, CEC, phosphorus, commons and mobility type. Summer stocking rate had a negative effect on PUR, i.e., the more summer stocking rate, the lower PUR. Also, commons had a significant effect, Castril having a higher PUR than Pontones and Santiago (Fig. 6c; table S7), while there were no significant differences between types of mobility.

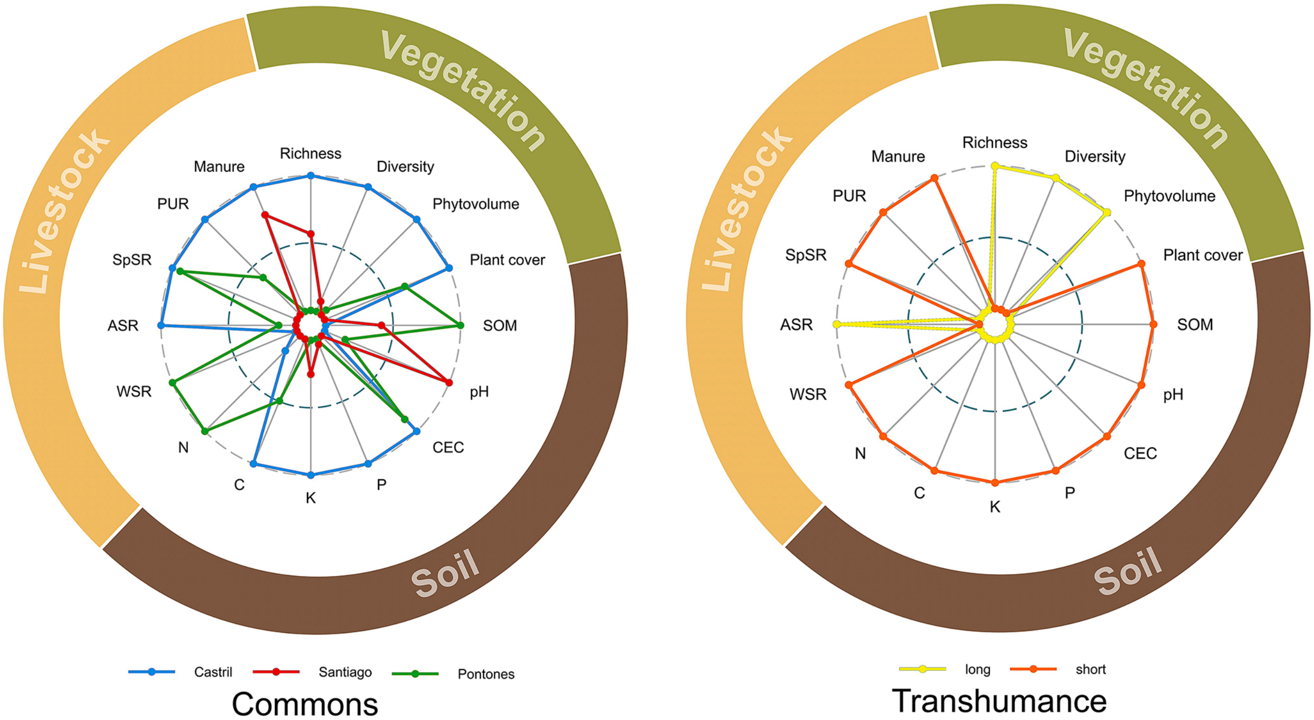

Fig. 5 Radar chart of all soil, vegetation and livestock related variables for the three commons (pooled across transhumance types, left) and for two types of transhumance (LDT and SDT pooled across commons, right). SOM: soil organic matter, CEC: cation exchange capacity, P: phosphorus, K: potassium, N: nitrogen, C: total carbon, SSR: summer stocking rate, ASR: autumn stocking rate, WSR: winter stocking rate, SpSR: spring stocking rate, PUR: plant utilization rate. (Mean values of the variables have been scaled from 100 (for the maximum value registered for each variable) to 0 (for the minimum value registered), and proportional intermediate values (only for Commons) were plotted)

Discussion

The pastoral commons of Castril, Santiago, and Pontones show different forms in terms of formal governance, in situ livestock management, and mobility types. Their institutions and rules are still oriented towards sustainable use and well-distributed access to resources to assure cohesion and avoid conflicts. However, the administration of subsidies and the necessary adaptation to new socio-cultural contexts are becoming increasingly relevant, even over biophysical aspects.

We observed that the three commons have productive pastures that allow herders to feed their livestock while assuring a high number of plant species (see Fig. 6a). Moreover, we found no signs of overgrazing (very low PUR: always less than 2 out of 5), with a high stocking rate only punctually registered in summer (see Fig. 4). This indicates that the management and/or governance of the pastoral ecosystem in the region could be socio-economically and environmentally interesting.

The grassland systems in all three commons have very similar biogeographical and pedoclimatic characteristics, as well as similar -but not identical- cultural and historical traits. Actually, they have been grazed -mostly presumably by sheep- for centuries, and this ancestral plant-herbivore relationship may explain the relatively small differences found between commons and between mobility types, even if some were identified. In fact, we must also be aware that the number of samples taken in this first preliminary research between 2017 and 2019 was still small, and taking a greater number of samples in the future could reveal clearer trends. Furthermore, in such complex and diverse areas as these Mediterranean high-mountain pastures, many different factors interact, buffering and/or hiding the response of vegetation to different management types. For example, some plots sampled might have been cultivated until some decades ago, turning into pastures only once agriculture was abandoned, exerting a particular influence on the ecology of the different pastures. Also, some soil parameters (such as CEC), governance, and grazing management (seasonal stocking rate) influenced the vegetation parameters, as shown by the models (see Table S7).

Focusing on our first hypothesis, Pontones was expected to score the highest performance in conservation terms according to the parameters that were measured in this study. On the contrary, Castril SDT showed better ecological results than all other combinations of commons and

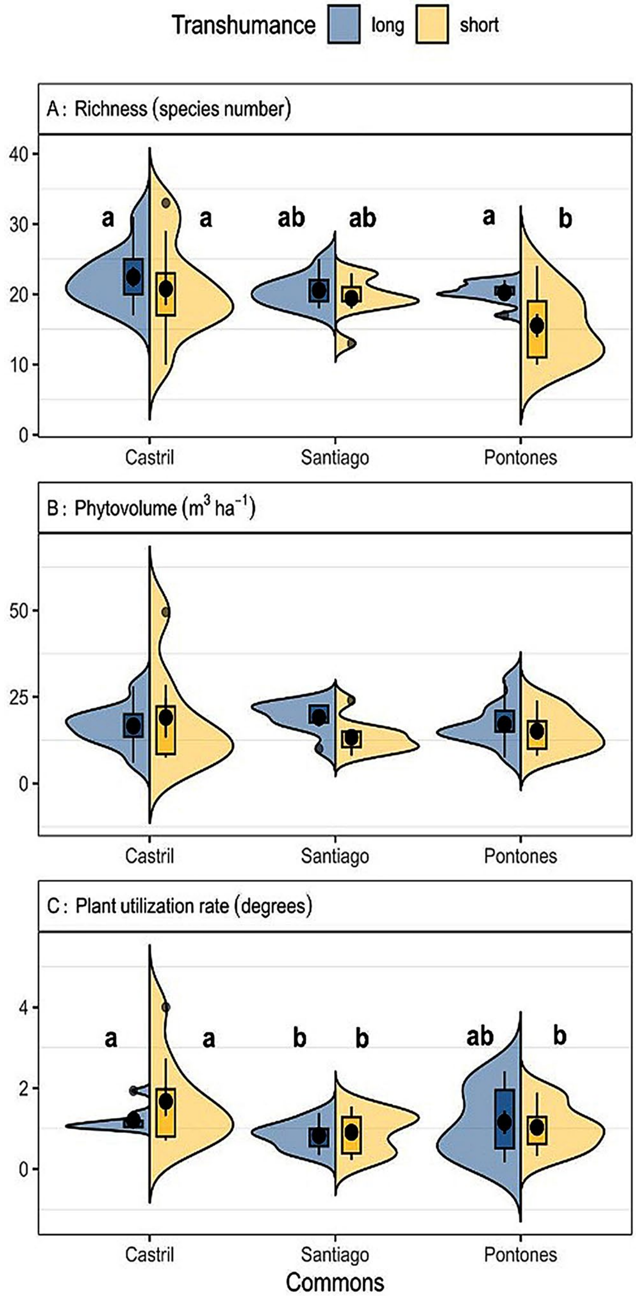

Fig. 6 Violin plots for (a) species richness (number of species/m^2), (b) phytovolume (m^3/ha^1), and (c) plant utilization rate (degree) for three commons (Castril, Santiago and Pontones) and two mobility types: LDT (blue) and SDT (yellow) within each common. Letters (a, b or ab) represent the results of the Tukey post-hoc test, which compares all the different combinations of treatments between them

mobility practices. This could be explained according to the following:

1. Targeted grazing. While in Santiago and Pontones sheep graze relatively freely, in Castril shepherds spend most of the time with their herds, as mentioned previously. This allows them to guide their flocks' movements daily to take full advantage of their herds' feeding capacity, while avoiding overgrazing (which can provoke a decrease in phytovolume and/or plant diversity). Therefore, local targeted grazing may be more effective in Castril than formal governance rules combined with less closely followed flocks as seen in Santiago and Pontones. Daily herd driving is an individual practice embedded in a coordinated collective system of pasture management where herders constantly communicate with one another because they are almost constantly present on the pastures. Given the large presence of livestock farmers and their herds in the narrowest pasturelands (Castril), targeted and implicitly coordinated grazing becomes imperative and possibly the most important tool to ensure the productivity of the pasture despite showing the greatest pastoral pressure from May to July (see Fig. 4).
2. Departure date. The main herding regulations are focused on the date of entry into the pastures to prevent ill effects on the vegetative growth and reproductive cycles of the plants in their critical moment. However, it is also relevant to note the earlier descent of most SDT herds of Castril (which represent nearly 90% of all Castril flock movements) in comparison to Castril-LDT, Pontones, and Santiago (see the shadowed area in Fig. 4). This allows a longer resting time and less overall livestock pressure on the mountain pastures, even if this happens from July onward, outside the key growth and reproductive period of plants. The geomorphology of Castril's territory and the availability of pastures at lower altitudes are key to this movement pattern, as there are enough lowland stubbles after gathering the cereals in June-July. Such cereal lowlands are scant in Santiago and Pontones. Therefore, their herds must remain in the highlands for the whole summer until mid-autumn, when two thirds of them migrate to Sierra Morena for the winter. In this sense, the much greater number of LDT herds in Santiago and Pontones is an effective adaptation to their particular geographical condition. There, a stricter general governance at the beginning of the highland grazing season is more necessary because there are many more LDT herders far from the highlands, but without the close following of the animals on the pastures during the peak of the season in May-July observed in Castril.
3. Higher stocking rate. According to different studies, species richness increases with grazing intensity with a peak at moderate grazing, then decreases again in case of overgrazing (Milchunas & Lauenroth, 1993; Cingolani et al., 2003; de Bello et al., 2006; Sebastià et al., 2008). Coinciding with these findings, the highest number of

species was registered for Castril SDT, which had the highest stocking rate, although only for a short period of time, as pointed above (May-July). Conversely, other authors proposed that heavy grazing during late spring and early summer could reduce seed dispersal and the soil seed bank, which could limit the recovery and persistence of palatable annual and perennial species (O'Connor & Pickett, 1992; Franca et al., 2018). However, this has not been captured for the moment in Castril's summer pastures. Therefore, more research in the area should be undertaken.

Regarding our second hypothesis on the possible virtues of LDT, when plotting all the variables according to the mobility types (Fig. 5), data suggested that SDT had higher content on soil nutrients and higher fertility, probably related to higher manure content due to longer presence of SDT herds on the highlands (Fig. 4). However, most vegetation parameters performed better for LDT. Furthermore, as more species were found in LDT compared to SDT when pooled through all three commons, this may indicate that seeds from different species are also being dispersed from winter pastures to summer pastures. Also, even in the absence of statistical significance, mean values for diversity were higher for LDT than for SDT in all commons (Fig. 6, table S3). Oteros-Rozas et al. (2014) found that transhumance provides a diverse flow of ecosystem services, including connectivity and seed dispersal, which is also of pivotal importance for plants to escape the effects of global climate change. Indeed, the role of LDT on seed dispersal in Mediterranean areas has been supported by different studies, as it prevents habitat fragmentation (Ruiz & Ruiz, 1986; Manzano & Malo, 2006; Manzano et al., 2005). For this reason, transhumant livestock has been suggested as a management tool for restoring species richness and diversity in Mediterranean mountains (Kyriazopoulos et al., 2022).

In this sense, our results support and amplify these statements by relating positive botanical effects of transhumance along upland summer pastures, while cross-checking it with communal governance. Another relevant finding is that when comparing LDT and SDT within each common, Pontones showed the highest botanical performance differences between LDT and SDT, being also the only common where this was identified with a statistical significance. This might be due to the stricter formal governance regarding the zonification of pastoral areas for LDT and SDT herders. These strict regulations for grazing areas and dates of access do not occur in Castril or Santiago, which might be buffering possible ecological differences among transhumance regimes. In fact, in Santiago and Castril, SDT livestock may eventually graze more in LDT areas than in Pontones, and vice versa. Therefore, this point also underlines the close intertwining between formal governance structures and mobility practices. For all these reasons, we consider that our second hypothesis is in great measure validated, as it sheds light over the possible positive ecological influence of Pontones' stricter formal governance system in the LDT areas vs. SDT areas.

Finally, concerning pasture productivity, measured indirectly as phytovolume, no statistical differences were found, probably because the methodology used was not adequate to measure this variable. Other methodologies, such as exclusion parcels, should be considered in the future to measure the real productivity of each plot. Nonetheless, mean values showed higher phytovolume for LDT than for SDT for both Santiago and Pontones, while the opposite was found for Castril, which sticks out as a particular site, calling for further research to better understand the particular case of Castril.

Conclusion

With the relatively scarce data we have available for now, we were unable to confirm an overall direct and positive relationship between more formally structured and explicit communal pastoral governance and better ecological indicators. Nevertheless, a first piece of evidence has emerged supporting our second hypothesis that long-distance transhumance (LDT) produces better ecological results than short-distance transhumance (SDT), especially related to species richness parameters. Moreover, this was most prominent in Pontones, allowing us to conclude that a more formally structured communal governance could simultaneously contribute to a better performance of long-distance transhumance. We can also highlight the value and importance of different forms of in situ cooperation among herders such as in Castril, driven by a much higher physical presence of herders in the summer pastures, which highly influences the everyday management of their flocks and where we can find a grassland particularly rich in species.

Altogether, our findings open eco-anthropological perspectives that point to new directions for research on pastoral commons conservation capacities in other parts of the world. From the ecological perspective, recommendations for future work could include other variables related to pastoral practices and to grazing indicators, such as flock compositions, daily grazing routes, presence of gullies and rills, distance to flock shelters and water points, as well as ways to better homogenize slope and exposition variables to better "isolate" the management effect of herders. Further consideration of plant functional traits in future research may also allow a more mechanistic basis to better understand the responses of plants to different types of livestock grazing and if they translate into changes in ecosystem functioning.

In the social sphere, we can conclude that current concerns and reasons that lead herders to cooperate and continue exercising collective governance over pastures are moving increasingly away from their original objective of sustainability and long-term productivity. In the past, they cared more about the continuity of the grasslands' yield year after year since pastoralism was their only source of income, while now, subventions make up to 50% of farmers' income, substituting partially the importance of the first. For instance, dependence on the EU's CAP or vulnerability in the face of global markets increasingly drives pastoralists' strategies. Likewise, seasonal mobility no longer responds only to the availability of pasture, but also to new economic incentives and sociopolitical constraints. Thus, local herders are now in a process of deep transformation of their governance institutions towards less biophysical sustainability and more short-term profit and administrative interests. To fully comprehend this long-term change, future eco-anthropological analyses should also include variables related to the historical registry, such as the evolution of land uses and tenure that determine many elements of today's land management system, as well as plant ecology (e.g. many past agricultural plots were turned to grasslands). A complete economic analysis at local scale in connection to global economic trends would also be necessary to better understand how these commons are reacting to them[8].

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s10745-024-00495-4.

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Author Contributions F. Godoy-Sepúlveda and P. Sanosa-Cols were the main writers and editors of the manuscript. Also, most of the anthropological research and data is based on their work (including Tables 1 and 2, and Fig. 2).Santiago Parra prepared Fig. 3 and worked on ecological results.Adrià Peña-Enguix prepared Fig. 1 and worked on anthropological results.A. Pérez-Luque prepared Figs. 4 and 5 and worked on ecological methodology and results.M.E. Ramos-Font, A.B. Robles and M. Tognetti worked on the ecological research and also on the methodology and results of the manuscript, preparing also supplementary material.A. González-Robles worked on ecological results.F. Ravera and M. Ventura worked on sociocultural research, participated on the interviews design and supervised fieldwork. P. Dominguez was the general coordinator of the overall research process.All authors reviewed the manuscript and contributed to discussion and conclusions.

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Data Availability In order to provide further data and description of the ecological analysis that we ran for this publication submission, we have provided a full annex with details. However, for any supplementary information at this level, we are open to requests and ready to mobilize the ecological team to provide further answers as needed. At the same time, concerning social data and materials, even if less filtered and complex to obtain directly from the text, the same applies, including mobilization of the anthropological team if needed.

Declarations

Ethical Approval This research adhered to the codes of ethics of the International Society of Ethnobiology and the Society of Economic Botany scientific associations that typically work with indigenous groups and local communities and have developed strict codes of ethics over the years to respect the rights of potentially vulnerable societies. The research was conducted through free, prior and informed consent with shepherds, majors and local Protected Area's managers.

Competing Interests None of the co-authors have any conflict of interest when submitting the following manuscript to Human Ecology.

[8] All these new ecological and anthropological approaches are being developed in the new project "Indigenous and Community Conserved Area for social-ecological Resilience" (ICCA-RE), funded by the Institut Méditerranéen pour la Transition Environnementale of the Aix-Marseille Université, under the leadership of Pablo Dominguez and Didier Genin with the participation of over 15 researchers from the LPED (UMR 156 IRD-AMU, France), GEODE (UMR 5602, France), Écoanthropologie (UMR 7206, France), IMBE (UMR 7263, France), EEZ-CSIC (Spain), and Universitat Autònoma de Barcelona (Spain). This research represents the first stage of ongoing research on socio-ecological systems of transhumant pastoral commons.

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