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Transhumance in Sierra de Segura (Spain): A resilient traditional grazing system

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ABSTRACT

Transhumance is tending to continuously decline globally, despite persisting in certain regions. Due to marked lack of knowledge about this practice and its cultural, economic, and environmental significance, our study aimed to identify the factors that contribute to the persistence of transhumance. We focused on ruminant herds of a transhumant community in the Santiago-Pontones municipality in Sierra de Segura, Spain. We processed official data from ruminant livestock enterprises and incorporated insights gained as observer-participants during seven transhumant displacements from 2016 to 2023. The census included 55042 ruminant heads and 118 herds, and 70 % of animals and 61 % of herds practiced transhumance. These herds wintered in pastures located within a range from 33 to 176 linear kilometers from their respective origins that span 15 municipalities. Significant differences were observed between sedentary and transhumant farm sizes (363 vs. 533 heads, respectively). Transhumance correlated significantly with herd size, number of sheep, percentage of female goats and number of ruminant species in herds. Women owned 19 % of ruminant enterprises, with no differences in herd structure or displacement type compared to those owned by men. Of the transhumant herds, 66 % traveled on foot, with no significant differences in herd structure parameters or distances based on their transport system, except that on-foot transhumant herds commenced their displacements earlier than those using trucks. In conclusion, our study outlines an active transhumant community in southeast Spain, whose resilience is a noteworthy asset that deserves recognition and safeguarding.

1. Introduction

Transhumance is a traditional grazing system of mobile pastoralism that consists of seasonal and cyclic movements of herds to search for fresh pastures and has been common in many world regions for centuries. Although transhumance sharply declined in the last few decades, it persists in some world regions, such as the Argentine (Arrondo et al., 2023), Sub-Saharan Africa (Motta et al., 2018), Mongolia (Altmann et al., 2018) or Europe, as a customary livestock system. Even today in Europe, transhumance contributes to social inclusion by strengthening cultural identity and ties among families, communities and territories, while counteracting the effects of rural depopulation (UNESCO, 2023). Based on environmental values and cultural and social roles of transhumant knowledge and traditions, the UNESCO considers the incorporation of transhumance along migratory routes in Spain and nine more European countries on the Representative List of the Intangible Cultural Heritage of Humanity (ICHH) (UNESCO, 2023). In addition, given its value for safeguarding cultural heritage, transhumance in Spain has been protected since 2017 with the recognition of "Representative Manifestation of Intangible Cultural Heritage" (Real Decreto 385, 2017; Spanish Royal Decree).

As mobile pastoralism, transhumance generates multiple benefits. Of ecosystem services, transhumance contributes to maintain grasslands (Zanon et al., 2022) and biodiversity, and to adapt the ecosystem to climate change, fire prevention, soil regeneration, and reduced water consumption and carbon sequestration (Manzano and Malo, 2006; Manzano and Salguero, 2018). Transhumant routes connect high-value habitats through drove roads that serve as ecological corridors and prevent the isolation and fragmentation of ecosystems (Hevia et al., 2013; Hilty et al., 2020; Azcarate and Hevia, 2023). As a livestock system, its

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low demand for fossil fuels and lesser use of veterinary products generate less waste and healthier products (Easdale et al., 2023). This system is maintained through native breeds raised outdoors, which adds patrimonial value by conserving genetic resources. Transhumance, or mobile pastoralism, not only plays an important role in the fight against rural depopulation, but also favors the development of a resilient rural economy in a cultural landscape environment with a very high tourism potential (Easdale et al., 2023; Ghirardello et al., 2022; Plieninger et al., 2014). Nevertheless, all these benefits are maintained when the overgrazing threshold is not reached and the natural equilibrium of the ecosystem is conserved, like these traditional livestock systems usually do (Manzano and Casas, 2010). Despite the role that transhumance has played in deforestation in certain high mountain areas, it is acknowledged that this traditional practice has contributed to shape cultural landscape shaping and to benefit ecosystem conservation ((López-Sáez et al., 2016)). In addition to contributions of transhumance to food sovereignty, and the fight against rural depopulation and the aforementioned ecosystem services, we must add those associated with cultural elements related to intangible heritage, such as the maintenance of transhumant populations' cultural identity, reinforcement between families and communities that keeps elements of social practices alive, such as festivals or even clothing, and the existence of historical settlements along transhumance routes (Easdale et al., 2023). As pastoralists have adapted to uncertain and changing environmental conditions using strategies based on flexibility, mobility, diversity and reserves (Fernandez-Gimenez and Le Febre, 2006), their bioculture can be important as a "retro-innovation" tool to face climate change-related challenges and to promote mitigation and adaptation to it by responding to social changes and promoting resilient livelihoods (Manzano and Salguero, 2018)().

Of the regions in the northern Mediterranean Basin, the Iberian Peninsula has been where transhumance has developed the most thanks to its predominant Mediterranean-type climate, which favors the complementary role of mountains and plains by allowing an alternation between northern mountain pastures for the summer and open savanna-like woodlands in the south ("dehesas") for winter. Based on Merino sheep and protected by royal privileges since the 13th century, transhumance in Spain has generated an unprecedented economic and cultural model by shaping the landscape and generating complex and interesting ecosystems (MAAM, 2013, Ruiz and Ruiz, 1986). The maximum development of transhumant livestock was in 1765 with 3.7 million transhumant sheep, but then a slow decline began. At the beginning of the 20th century, 1.5 million sheep were still moved along livestock routes, but the industrial boom of the 1960s marked the decline of this traditional activity and most transhumants adapted to railway or truck as a way to travel and the use of drove roads diminished (Ruiz and Ruiz, 1986; Manzano and Casas, 2010). Unlike other countries like France however, where all transhumant movements longer than 10 km are done by truck (Malzac et al., 2024), in Spain on-foot transhumance is still counted as 10 % of the transhumant movements between Spanish regions (MAAM, 2013). This decreasing trend is in accordance with the progressive decline in sheep farming in Spain, with a drop of 40 % in total adult sheep numbers in one decade (23.8 million in 2002 vs. 14.4 million in 2022) (MAPA, 2023a). The reduction in sheep farming is a generalized-trend global effect in Europe, and it has a stronger impact on traditional farms. This progressive abandonment of traditional livestock farming in high mountain areas has had negative effects on both cultural heritage and biodiversity, and European authorities are paying attention to these effects (Mac Donald et al., 2000)).

Despite the continuous decreasing transhumance trend in Spain, there is still a large group of transhumant shepherds from Sierra de Segura (Andalusia) who seasonally travel to the Sierra Morena pastures for wintering (Fig. 1), mostly by walking along drove roads. This winter transhumance has remained relatively and paradoxically ignored (Rubio de Lucas et al., 1995)(Rubio de Lucas et al., 1995) instead acknowledging its importance, and despite it connecting the most extensive protected area in Spain and the second largest in Europe (Cazorla, Segura and las Villas National Park) with the biggest Mediterranean forest in the world (Sierra Morena). This distinctive transhumance from east to west, conversely to the traditional north-south movement of most Spanish transhumance, is the basis for maintaining an economic, cultural and heritage sector that constitutes the largest contingent of shepherds to maintain traditional transhumance in Spain today (Contreras et al., 2021; Godoy-Sepúlveda et al., 2024; Gómez, 2021).

One major shortcoming of transhumance knowledge is that national statistics do not discriminate between different livestock production systems and, therefore, we cannot accurately determine the population of transhumant people and animals (Manzano and Salguero, 2018). Furthermore, much information related to transhumance is published in formats that are not easily accessible (García-Ruiz et al., 2020a). Finally, the significant role of women in pastoralism has not been emphasized in the scientific literature despite them possessing and developing essential competencies for these livestock systems to survive (Tugjamba et al., 2023).

Based on officially recorded information, and on the direct experiences accompanying transhumant sheep transhuman farmers, our main objective is to document this resilient transhumance by comparing its difference to sedentary herds and evaluating the importance of different factors; i.e., herd size animal census, farmers population, herds location, and transhumant activity, mostly on foot, to determine that this activity that takes place between Sierra de Segura and Sierra Morena in Andalusia (Spain). Hence we should gain a deeper understanding of the key factors that influence this activity and comprehend the reasons why transhumant practices persist, which is crucial information for a more comprehensive prediction of its future. In addition, this knowledge could help to obtain institutional support measures at local, regional, state or European levels, and to increase its chances of survival.

Fig. 1. Transhumant Segureño sheep herds: a) leaving Sierra de Segura on their autumn transhumance movement, Los Campos de Hernán Perea, Santiago-Pontones, Jaén (Spain), November 2021; b) wintering in the dehesas of Sierra Morena, Baños de la Encina, Jaén (Spain), March 2018. Author Ángel Gómez-Martín.

2. Material and methods

2.1. Study area

These winter transhumant livestock migrate from summer pastures in Sierra de Segura (June to November) (Fig. 1a) to winter pastures in the dehesas of Sierra Morena (December to May) (Fig. 1b) as part of a strategy to optimize pasture use. Sierra de Segura forms part of the Prebetic system in the SE Iberian Peninsula with marked climatic seasonality and extreme conditions in winter, and many endemic species, including native breeds of livestock, such as Segureña sheep. In addition to these longer transhumant displacements, the altitudinal gradient and orographic characteristics of the region determine the existence of shorter seasonal livestock movements (transterminance) there. More specifically, these areas form part of the Sierras de Cazorla, Segura and the Las Villas Natural Park, and cover more than half the park's total area. This Natural Park covers 2140 km^2, which makes it the largest protected area in the Iberian Peninsula. Los Campos de Hernán Perea is particularly noteworthy, which is a communal plateau covering around 150 km^2 located in Sierra de Segura with altitudes ranging between 1600 and 1700 m. It is characterized by the communal use of pastures and is one of the most characteristic grazing areas in this region. The soils in Sierra de Segura are calcareous in origin, evidence scarce development and generally lack horizon development. The dominant soils are Calcaric Regosols and Leptosols (IUSS, 2015), typically located on fragmented bedrock. Vegetation belongs to the supramediterranean Betican basophylous series of the holm oak forest. Woodland consists mainly of *Pinus nigra* subsp. *Salzmanii*. The shrub stratum is predominantly characterized by *Quercus ilex, Berberis hispanica, Crataegus monogyna, Rosa canina, Juniperus oxycedrus, Daphne gnidium, Cytisus reverchonii, Echinospartum boisierii* and *Thymus zygis* (Valle et al. 2004; Benavente, 2008; Gómez-Mercado, 2011). The climate is Mediterranean with annual rainfall between 300 mm and 1600 mm, and an average temperature of 12–16 ºC (Aguilera-Alcalá et al. 2022).

Sierra Morena covers more than 18,000 km^2 and part of the Huelva, Seville, Córdoba and Jaén provinces. It has six Natural Parks and a Biosphere Reserve, of which the last one is officially a Site of Community Importance (Rodriguez et al., 2010). It is characterized by its siliceous nature, mainly slate, quartzite and Palaeozoic escarpments. Sierra Morena has occasional limestone islets of Cretaceous origin. The predominant natural vegetation in Sierra Morena is classified as Mediterranean sclerophyllous forest (Valle et al., 2004). The interaction between the environment and traditional land uses is evident. Dehesas are mainly holm oak (*Quercus ilex*) and constitute large landscapes adapted to extensive pig, cattle and small ruminants farming in the development of dehesa forests. The cork oak (*Quercus suber*) dehesas highlight the impact of industrialized cork production in the region. Scrubland is composed mainly of arbutus (*Arbutus unedo*), terebinth (*Pistacia terebinthus*), mastic (*Pistacia lentiscus*), sarsaparilla (*Smilax aspera*) and kermes oak (*Quercus coccifera*) (Valle et al., 2004)(). The Sierra Morena climate is strongly influenced by a prolonged dry period, with high temperatures and irregular interannual rainfall. Winter precipitation peaks are juxtaposed with almost total summer drought to form the characteristic climatic profile of this region (Rodriguez et al., 2010).

2.2. Data analysis

We merged two databases containing official information about ruminant farms: one from the Zonal Agrarian Office (OCA) of Beas de Segura (Sierra Segura, Jaén) and the second from the Spanish Ministry of Agriculture Fisheries and Food (MAPA). Given the personal nature of some data, they were processed by maintaining anonymity and guaranteeing personal data protection. The OCA data were generated after the 2021–22 transhumance season by incorporating the data from the Santiago-Pontones municipality. They included the official record of livestock farm codes (REGA) of home farms and type of species, sex, age strata and number of animals associated with each stock owner of ruminants. For transhumant stock owners, they also contained the departure date and the autumn transhumance displacement type (on foot or by truck), as well as the REGA code of the destination farm. The REGA is an alphanumeric code that identifies each farm, its location (municipality, province and administrative region) and farm type. The information contained in each REGA can be accessed by means of a search engine for REGA codes (MAPA, 2023b). The data in the MAPA database contain population information about the enterprise, their REGA codes and their geographical coordinates.

We first aimed to understand the farming parameters that could influence our response variable "transhumance". For this reason, we independently tested the effect of farming parameters (owner's gender) and herd parameters (size, number of main species, female percentage by species) that may be adapted to transhumance mobility. Due to the binomial nature of the response variable, we implemented one-predictor generalized linear models (GLMs; family = binomial; link = logit), which do not assume normality of the dependent variable, but assume linearity between the predictor variables and the logit of utcome. For all the models, we used the ''glm' function from the ''lme4'' package (Bates et al., 2014). Then we fitted one-predictor GLMs (family = binomial; link = logit) that could explain the other response variable "means of transport" (on foot or by truck). In this case, we evaluated the same dependent variables, but we also considered transhumance distances between summer and winter locations. We extracted transhumant enterprises from the joint database, and we measured transhumance distances with the R terra package (Hijmans et al., 2022). Finally, we also applied a Wilcoxon nonparametric test to evaluate any significant differences between sedentary and transhumant enterprises and between transhumant herds traveling on foot or by truck. We performed the data analysis in the R environment (R Core Team, 2023).

2.3. Observational experiences with on-foot transhumant Segureño shepherds

Some of the contributions that we provide stem from our knowledge of the transhumant sector, which we acquired from our participation as observer-participants in some activities jointly organized by two Spanish universities that involved both livestock and human aspects (Contreras et al., 2021). Thus since 2016, students and teachers from the veterinary faculties of Murcia and the CEU-CH of Valencia have directly witnessed transhumance conditions to facilitate their understanding of this livestock sector. We specifically accompanied transhumant Segureño shepherds during their displacements ("vereda") in spring (2016 and 2018) and autumn (2018, 2019, 2021, 2022 and 2023). In all, we participated in seven "veredas", including 41 full days when accompanying 10 different Segureño sheep owners and some of their relatives. During these periods, we moved on foot along drove roads, endured the same environmental conditions as transhumant farmers (heat at the end of spring, and cold, snowfall or rain in late autumn), and shared with them all tasks, such as organizing camp, putting up tents or preparing meals, and observing and recording the particularities of routines along the way.

3. Results

The joint database contained information of 118 REGA codes from ruminant farms, with a census of 55042 heads. Table 1 and Fig. 2 indicate the number of farms, heads per farm, the p-value and their percentages depending on herd type: transhumant or sedentary. Of them all, 61 % practiced transhumance (n = 72) and 70 % of all the animals practiced transhumance (38338 ruminant heads). Over half the farms were mixed sheep and goat farms (56 %) and one third were exclusively sheep farms (34 %). A minority of farms had only cattle (5 %) or only

Table 1
Farms censuses according to the main species of sedentary and transhumant herds in Santiago-Pontones (Jaén, Andalusia, Spain) for 2021–2022: number of farms (F), mean of heads per herd (M) and significance of the mean comparison between groups (p value).

	Sedentary		*Transhumant*		
Species	***F***	***M***	***F***	***M***	***p-value***
Ovine and Caprine	*33*	*384.45*	*33*	*667.73*	*<0.001*
Ovine	*8*	*317.63*	*32*	*475.13*	*0.005*
Bovine	*1*	*77*	*5*	*185*	*<0.001*
Caprine	*3*	*305*	*2*	*88*	*ns.*
Ovine, Caprine and Bovine	*1*	*484*	-	-	-
Total ruminants	***46***	***363.13***	***72***	***532.5***	***<0.001***
Equine (1)	-	-	*15*	*4.2*	-

(1) Only records from transhumant herds were available.

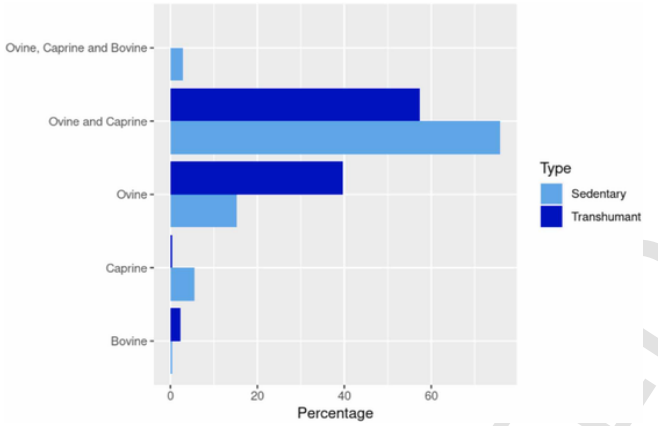

Fig. 2. Percentage (0–100 %) of livestock heads by herd type in sedentary and transhumant herds.

goats (4 %), and one had all three ruminant species. In relation to animal censuses, mixed sheep and goat farms also stood out by providing the largest number of heads (63 % of the census). On the overall count of equines that participated in transhumance during the campaign, records included 67 animals from 47 farms, all of which belonged to herds that traveled on foot. When comparing the sedentary farm and transhumant livestock farm sizes, the analysis of variance showed significant differences in the size of the transhumant ovine and caprine farms compared to the sedentary ones for both mixed sheep and goat farms, and for exclusively ovine farms.

Regardless of farm type, four herd structure parameters were significantly related to transhumance: herd size, number of sheep, percentage of female goats and number of ruminant species in herds (Fig. 3). Herd size considers the total number of ruminants, including sheep, goats and cows, and it was directly related to the transhumance probability ($Z = 3.379$; p-value < 0.001; Fig. 3a). Therefore, the enterprise with a bigger size tended to be transhumant in the study area. The analysis of variance showed statistically significant differences in the census of sedentary and transhumant herds, and the mean number of ruminants was bigger for transhumant farms (363 vs. 533 Table 1). The mean number of ruminants was also significantly bigger on transhumant farms when particularly considering ovine herds, ovine with caprine herds or bovine herds. On the contrary, transhumant herds showed a negative relation with the number of different species making up the flock ($Z = -3.053$; p-value $= 0.002$; Fig. 3.b; Table S1) and the percentage of female goats ($Z = -4.947$; p-value < 0.001; Fig. 3.c; Table S1). Hence sedentary enterprises had a bigger number of species and a higher percentage of female goats. Regarding stock owners' gender (Table 2), 22 herds (19 %) were owned by women, many of whom (64 %) were owners of transhumant enterprises. The statistical analysis revealed no association for either owners' gender and the farming system type (transhumant or sedentary) or displacement type on transhumant farms or herd size.

Regarding transhumant farmers' displacement type, most (66 %) traveled on foot and the rest used trucks (Table 3). Neither the herd structure parameters nor distances showed a significant difference between the herds that traveled on foot and those by truck. Transhumant movements initiated between November 11 and December 30. Those that went on foot started earlier, with a median start date of November 25, compared to December 10 for those using trucks (Fig. 4).

The geographical distribution of the studied farms (sedentary or transhumant) is located in two mountain systems in the southern Iberian Peninsula. Fig. 5 shows the study area and the destinations of the winter transhumant herds. Regarding the geographic location of the involved REGAs, as the database provided by the Spanish Ministry lacked the coordinates of five locations (winter or summer), only the geographical information of 113 records was processed (Table 3). The mean linear distance between the summer and winter locations was 79.19 km, which varied from 33.08 to 176.15 km, and no differences were found in distances according to displacement type. Of the 74 transhumant farms, 95 % wintered in the Jaén province (distributed across

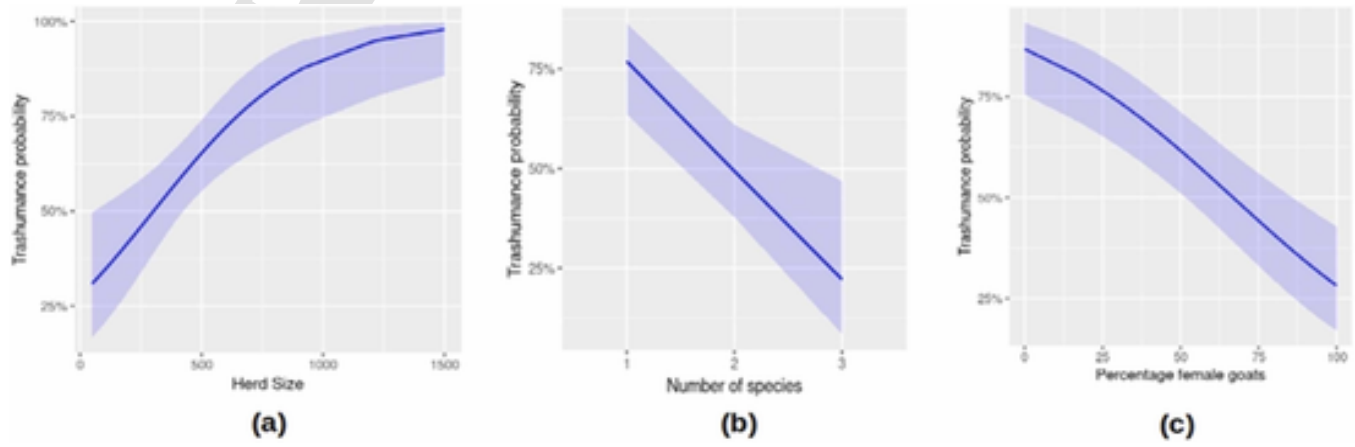

Fig. 3. Predicted likelihood (from GLM models) of herd transhumance according to its structure. (a) Herd size includes: total number or ruminants (sheep, goat or cow); (b) number of main herd species (1–3 species); (c) percentage of female goats in relation to total number of goats (0–100 %).

Table 2
Owner´s gender stratified for sedentary or transhumant farms and type of movements from Santiago-Pontones (Jaén, Andalusia, Spain) during the 2021–22 transhumance campaign.

Owner´s Gender	*Ovine*	*Caprine*	*Bovine*	*Sedentary*	*Transhumant*	*Transhumant*	
	(Mean of heads/herd)			*(Number of herds)*			
						On foot	*By truck*
Men	*448.48*	*23*	*167*	*38*	*58*	*38*	*20*
Women	*363.59*	*17.17*	*-*	*8*	*14*	*9*	*5*
Total	*-*	*-*	*-*	*46*	*72*	*47*	*25*
p-value	*ns*	*ns*	*-*	*ns*	*ns*	*ns*	*ns*

15 municipalities in this province). Of them, three municipalities hosted the largest number of herds: Santisteban del Puerto and Vilches (12 each) and Navas de San Juan (with 11). Of the four remaining farms, three wintered in Montoro (Córdoba), and one in a municipality outside Andalusia: Almodóvar del Campo (Ciudad Real, Castilla-La Mancha).

From the results obtained as participants/observers, we observed that the primary challenge for these transhumant farmers is being separated from their family home for more than 6 months a year (from late November to early June), followed by the high cost of leasing pastures in the wintering area (Sierra Morena) and the uncertainty associated with the temporary nature of these leases. In addition, some farmers claimed that certain winter dwellings are in poor condition.

Health surveillance programs introduce another element of uncertainty, and recent transhumance campaigns appear to have been significantly impacted by global warming and its associated prolonged droughts and heat waves in recent years in Spain. The ovine pox outbreaks that occurred in 2022 and 2023 delayed the return in summer 2023 of the flock that wintered in Castilla-La Mancha (Fig. 5b). Adverse weather conditions, such as snow or rain at the end of autumn or excess heat in late spring on the return journey, and lack of shelters so that shepherds can spend the night near their animals, increase the hardship of making the trip. In addition, the 2023 spring drought led to an unexpected shortage of pastures and water along the route, which rendered the displacement of herds *via* drove roads unfeasible, especially for journeys lasting longer than 5 days. Consequently, many transhumant farmers who traditionally travel on foot opted for truck transport late in the spring of 2023. We encountered challenges traveling on drove roads because some were closed by landowners, partially fenced or obstructed by crops, mostly olive trees. There were also instances when water intended for drove roads had been diverted for agricultural irrigation purposes. Finally, the presence of main roads for traffic on some drove roads necessitates traffic closures that must be previously coordinated with authorities (Civil Guard), which poses another challenge (Fig. 6b). On the contrary, we also noted improvements since 2016 in the infrastructures related to drinking troughs or corrals, especially in 2022 and 2023.

Segureño sheep are exclusively bred for meat production and the flocks in the study are certified for ecological production. Milk production is not an objective and their wool has no commercial value because of its lower quality compared to merino wool. In fact the wool from Segureño sheep shearing is considered a "waste product" and must be removed from farms, which incurs further costs for farmers. The milk produced by the goats that accompany sheep flocks, which are used as nursemaids for lambs, is not commercially used, but is domestically consumed, mainly for making cheese and desserts. Lambs are typically sold at an average age of 45 days and a minimum weight of 17 kg, usually to feedlots to complete their development until 25 kg. Manure is left in grazing fields because only the summer lambing group, approximately one-third of the flock, is housed in August and September, and the produced manure is taken by the person who cleans the barn in exchange for their cleaning services. Thus farmers do not earn any income from it, but its removal incurs no expense. There are no issues with wolf (*Canis lupus signatus*) predation in the study areas, and predation by foxes (*Vulpes vulpes)* during the lambing season is very common. Occasionally in the Sierra Morena region, there are cases of lamb predation by lynxes (*Lynx pardinus*). Farmers use mastiff dogs to protect their animals from these predators, and in the scarce areas where lynx attacks are sporadic, they use electric corrals to safeguard young lambs. From our experience, the social relationships of on-foot transhumant herders with other inhabitants in the region are very satisfactory. The other inhabitants are generally accustomed to see flocks pass by twice a year. They often admire this spectacle, and sometimes they offer transhumants food and drink, mainly local products. Occasionally, they provide fenced areas for herders' animals to spend the night and, therefore, benefit from the clearing of grass or shrubs on their land and from organic manure, while herders find it easier to manage their flock, or even for shepherds to find shelter.

Part of the experience gained by students and teachers as participant observers in transhumance between 2016 and 2018 was used to produce a documentary to highlight the most characteristic aspects of this transhumance type (Gómez-Martin et al., 2019).

4. Discussion

Our results indicated the presence of a significant group of farmers who continue practicing transhumance, mostly on foot, in SE Spain despite the decline in both extensive farms in general and in transhumance in particular (Manzano and Casas, 2010). Furthermore, this considerable population of transhumant farmers is concentrated in only one municipality, Santiago-Pontones, in the Sierra de Segura region (Fig. 5). This municipality has always been a reference given the importance of extensive ovine livestock farming and has been defined as the quintessential transhumant area in the ensemble of the Prebetic mountain system. So in 1991, 138 transhumant enterprises were recorded for the ensemble of the Sierras de Alcaraz, Cazorla and Segura, of which 74 (54 %) belonged to the Santiago-Pontones municipality with a census of 27710 sheep, 3020 goats and 200 heads of cattle (Rubio et al., 1995). When comparing our 2021 data (Table 1) to those from 1991, we ob-

Table 3
Means of transport (on foot or by truck) of transhumant herds during the 2021–22 campaign: number of farms (F), mean number of heads ± standard deviation (M), distance (km) ± standard deviation (D) and significance of the mean comparison between groups (p value).

	Transhumant									
	On foot		*By truck*			*On foot*		*By truck*		
	F	*M*	*F*	*M*	p-value	*F*	*D*	*F*	*D*	p-value
Ovine and Caprine	*21*	*639.52 ± 280*	*12*	*717.08 ± 260*	*ns*	*19*	*78.02 ± 22*	*12*	*68.27 ± 2*	*ns*
Ovine	*21*	*484.24 ± 128*	*11*	*457.73 ± 193*	*ns*	*19*	*69.96 ± 16*	*10*	*98.89 ± 48*	*ns*
Bovine	*4*	*198.25 ± 108*	*1*	*132*	*ns*	*4*	*98.63 ± 7*	*1*	*97.37*	*ns*
Caprine	*1*	*96.00 ± 0.00*	*1*	*80*	*-*	*1*	*55*	*1*	*138.97*	*-*
Total ruminants	***47***	***521.02 ± 249***	***25***	***554.08 ± 284***	***ns***	***43***	***75.84 ± 2***	***24***	***85.19 ± 38***	***ns***

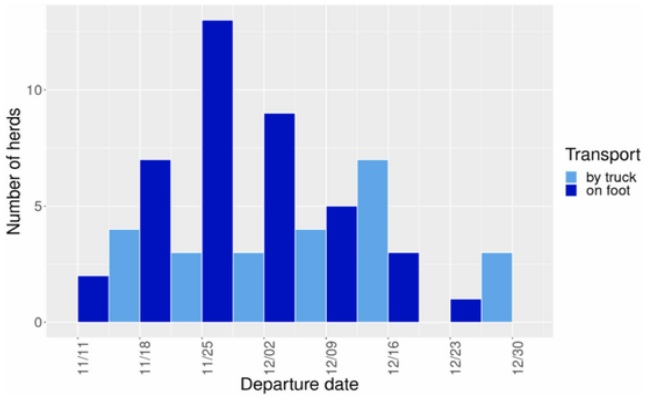

Fig. 4. Departure dates (month/day) and means of transport (on foot or by truck) for transhumant herds toward winter pastures in November and December.

served that the number of transhumant livestock farms has remained constant (72 vs. 74), and respectively represent 61 % of farms and 70 % of the actual census of the transhumant livestock population in the area. The census of transhumant ruminants has increased by 7408 more heads in the last three decades. The maintenance of transhumance in this area contrasts with the general decrease of this practice in Spain and other countries where data are available. For example, in Greece the number of transhumance farms has gone from 30 % to 7 % in 50 years (Galanopoulos et al., 2011). In Spain, there is another example of transhumance that resists and is not disappearing because a small group of transhumant farmers in the valleys of the Western Pyrenees (N Spain) has begun a transhumance recovery process of transhumant activity (Fernandez-Gimenez and Ritten, 2020).

Apart from this transhumant livestock community, sedentary ruminant livestock represents 30 % of the total census of the municipality (16704 heads in the sedentary regime). This sedentary livestock depends on extensive pasturelands that allow livestock to move from one grazing area to another on the municipal boundary, with seasonal displacements from village areas (valleys) for winter grazing to higher areas (Los Campos de Hernán Perea). As these transterminant movements do not require the corresponding origin and health reports, they are not reflected in official databases. These data confirm the predictions of Rubio et al., (1995) about favorable livestock development in the area and represent an opposite trend to the progressively declining ovine livestock census in Spain.

As demonstrated for the transhumant farmers of the Spanish Pyrenees and Greece (Fernandez-Gimenez and Ritten, 2020), the fact that transhumant herds are larger than sedentary ones can be explained by transhumant herds having lower feeding costs in winter than sedentary ones. Furthermore, transhumant herd productivity per ewe is lower because they depend on the resources in the environment, and not having to pay for any extra feed is quite normal. These circumstances not only allow herd size to increase, but it is a productive necessity that compensates for lower reproductive production. In our study, this difference in size was statistically significant for all the ruminant species, except for a few herds exclusively consisting of goats (Table 1). This increase in the size of transhumant herds compared to sedentary ones has also been observed in Greece (Papanastasis, 2009 as cited in Galanopoulos et al., 2011).

In relation to the size of the transhumant herds that travel on foot or by truck, the analysis of variance did not reveal any significant differences between both strata, which indicates that means of transport is independent of herd size (Table 3). We can consider that these herds are similar, but the choice between on-foot or truck transport sometimes varies for different reasons, including the climate conditions at both the wintering and origin locations, proximity to lambing, family or per-

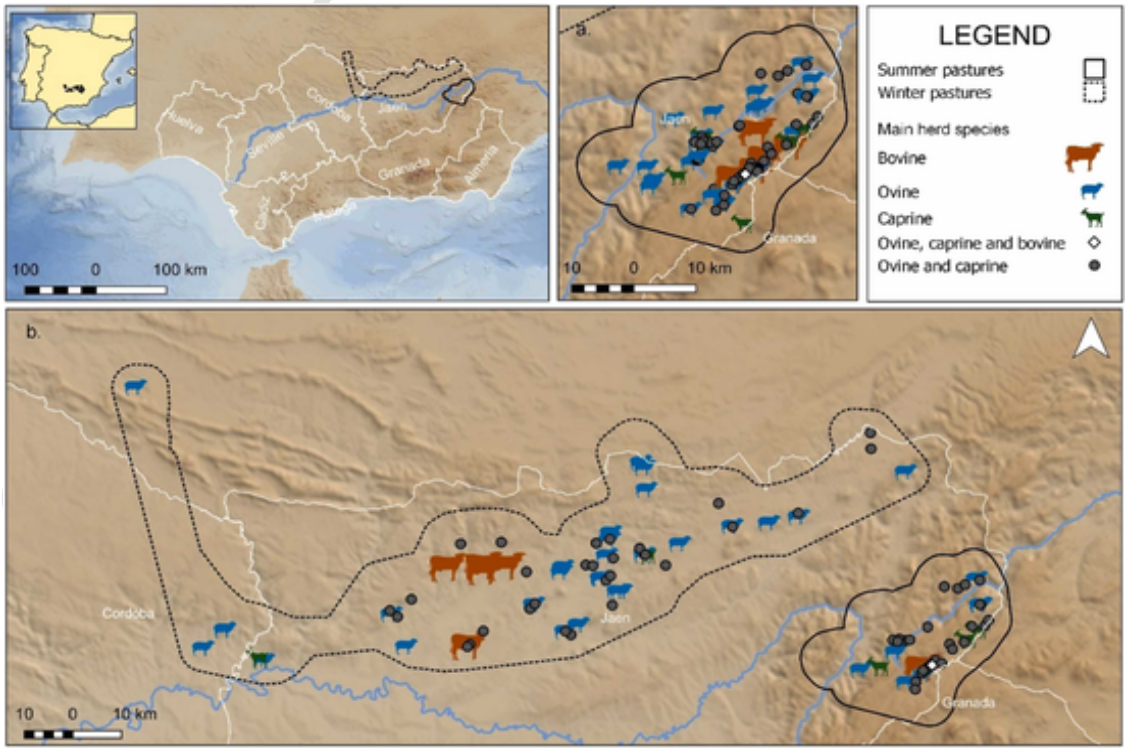

Fig. 5. Ruminant enterprises from Santiago-Pontones (Jaén, Spain) differentiated in terms of species present (bovine, ovine and or caprine): (a) location of transhumant and non transhumant in summer (June-November); (b) location of transhumant and non transhumant in winter (December-May).

Fig. 6. Segureña sheep herds on transhumance along traffic roads that have been built over drove roads: a) male goats leading the herd; these bucks lead steers are obtained by crossing native goat breeds in danger of extinction. Their large size and appearance facilitate flock leadership and constitute both a tradition and a source of pride for shepherds. May 2020, Navas de San Juan, Jaén (Spain). Author Katy Gómez Catalina; b) traffic congestion because of transhumant movement in Santisteban del Puerto, Jaén (Spain). November 2021. According to Spanish law, herd movement on drove roads has priority over road traffic. Author Antonio Contreras.

sonal matters, or animal health alerts. We verified that it is relatively common for some herders who typically move on foot to occasionally opt for truck transport due to health issues. Conversely, those who routinely use trucks as a means of transport regularly continue this practice, despite its higher economic cost, because it is much more convenient. This situation might result in loss of knowledge about the skills required to face transhumance challenges on foot, which are closely tied to both intangible heritage and the maintenance of the ecosystem services of drove roads (Hevia et al., 2013, Hilty et al., 2020). The environmental benefit of moving livestock along drove roads is such that in those areas where extensive grazing or transhumance has disappeared, livestock reintroduction has been proposed to maintain their ecological role (Azcarate and Hevia, 2023). This study focuses on winter transhumance, which is carried out mostly on foot. However, transhumance in trucks continues in the 21st century and, thanks to it, seasonal use of grasslands is allowed in not only Spain, but also in other Europeans countries, especially in the south of France (Malzac et al., 2024).

A strong correlation is evident between the study area and its native sheep breed, namely the Segureña sheep, which establishes it as the principal species within ruminant flocks. Ovine herds also include a few goats for practical herd management reasons. Female goats provide support for additional lamb nursing and castrated bucks are used by shepherds as leading steers. These animals are essential for leading flocks, especially on complicated routes like river fords, or when crossing towns or roads, in excess snow or on unknown routes where sheep refuse to walk. These bucks are usually large-sized, which facilitates their visualization, and are normally obtained by mixing two autochthonous Spanish goat breeds in danger of extinction, namely the white Andalusian goat and the black mountain goat; (Real Decreto, 2023; Spanish Royal Decree 527 of 2023). This allows these herds to be distinguished, which is why farmers usually feel very proud of their spectacular males and it is a patrimonial element of these transhumant enterprises (Fig. 6a). Although the use of leading steers is essential for transhumance, it is not exclusive to them, and sedentary farmers also employ them for guided grazing.

Mixed sheep and goat herds have a higher percentage of goats to sustain goat productivity over time. According to our results, the herds with a higher percentage of female goats showed a lower transhumance probability (Fig. 3c). Moreover, goats gaining access to the food resources inaccessible to sheep in winter may explain why the transhumance probability lowers on the farms that combine caprine and ovine production. Food resources optimization throughout seasons may also explain why the transhumance probability lowers as the number of herd species increases. In line with this, the food resources for sedentary herds may be optimized through diversification. On the contrary, transhumant herds follow seasonal green grasslands to optimize natural food resources. They tend to be specialized in ovine production and to be more profitable because transhumance is directly related to herd size and number of sheep. This reinforces the marked transhumant vocation in the area, albeit rooted in Segureño sheep production. Nonetheless, herds of other ruminant species diversify farm incomes while showing different patterns of adaptation to local resources.

Regarding gender, 19 % of the official REGA codes belong to women, most of whom (64 %) are of transhumant enterprises (Table 2). Although many women do not own farms, we should not overlook the fact that these women often perform support tasks when the entire family's help is required, such as during lambing or disease outbreaks, especially when diarrhea affects lambs. In addition, women often perform essential logistical tasks during travel and wintering, such as driving support vehicles, and preparing and maintaining wintering residences. All this is done along with domestic chores, caring for children and other family relatives, at their place of origin for educational (children) or health (older people) reasons. Sometimes the wives of these transhumant farmers facilitate family cohesion by traveling with their children to the wintering place at weekends, and breaking the isolation that has always punished transhumant shepherds in winter. Sometimes when children finish schooling and if they must no longer take care of grandparents, women spend winters with their husbands in the Sierra Morena pastures. Although women are not the official stock owners of most herds, they play a crucial role in performing livestock activities and provide key support to maintain transhumance. The masculinization of livestock farming is one factors that has been correlated with the disappearance of family farms that breed and process traditional agricultural products (Camarero and Sampedro, 2008). As noted in Spain, the enterprises where the farmer is an unmarried man typically end up disappearing (MAAM, 2013). Furthermore, some women involved in transhumant livestock are not recognized as stock owners or shepherds either administratively (because they are not registered as owners in the REGA system) or socially (because they are not generally visible). This lack of recognition prevents them from being financially paid for their work or gaining social acknowledgment. However, feminization of livestock farming is increasing. It is essential to highlight the care-giving role that women have historically played and continue to do so, which has allowed transhumance to persist, even though this work has often been invisible. Given the importance of the role of women in pastoralism and their responsibility for maintaining the skills needed to allow this livestock system to survive (Tugjamba et al., 2023), it is not only important to bring their work to light, but to also recognize it and emphasize the need for this labor to be economically paid. A study into female pastoralism in Spain revealed the need to enhance support for women to establish and maintain economic autonomy because they contribute to family enterprises or to establish their own businesses (Fernandez-Gimenez et al., 2021).

This studied specific east-west transhumance covers a shorter distance than the traditional displacements that occurred in the heyday of the Mesta, Spain, which moved herds from north to south on large

drove roads, of which very few examples still remain (Plaza et al., 2023). The linear distances between destination and wintering areas in our study range from 33.08 to 176.15 km. However, on the ground these distances are longer due to the topography of the terrain and the communication network used in each case (either drove roads or traffic roads). Our experience as observer-participants enabled us to confirm that on-foot displacements vary between 5 and 10 days, and cover distances from 110 to 220 km along drove roads, respectively. A more detailed description of distances and itineraries will be obtained as we process the data from the GPS collars installed in on-foot transhumant herds, which are integral to future studies.

The fact that herds do not move outside their Spanish Autonomous Community simplifies bureaucratic management, especially concerning animal health regulations. Thus almost all the herds studied during the 2021 transhumance campaign remained in the same Spanish Autonomous Community (Andalusia), with only one herd wintered in another one (Castilla-la Mancha). The challenges of on-foot travel are minimized with journeys spanning a few days, which are not comparable to the characteristic month-long trip of traditional Spanish transhumance. In addition, many of these flocks sell lambs that are included in the Protected Geographical Identification (PGI) "Cordero Segureño". Such protection (quality seal) guarantees that the origin of this food could have protected them in the past from fluctuations in the price of lambs. This cooperative system has been able to innovate in recent years by developing a system of direct online sales to consumers and transporting meat nationwide within 24 hours. That is why this quality seal made them positively face the challenges linked with the COVID-19 restrictions established in Spain because it had beneficial effects on sales and price stability during that crisis. Consumer confidence shown in these value-added products has also been suggested to be related to the role that this type of quality seal plays (Vidaurreta et al., 2020).

One distinction between transhumance on foot and by truck lies in the starting dates of displacements. Herds engaging in on-foot transhumance commence their journeys earlier than those on trucks. This pattern is apparently associated with environmental conditions, which become more challenging for on-foot displacements as winter approaches, and is also linked with the proximity of winter lambing, typically between late December and January. This period discourages moving ewes close to lambing for several days, especially when traveling involves daily distances of 20–25 km.

The challenges faced by these transhumant farmers, as described in the results, are similar to those that affect other transhumant communities (Fernandez-Gimenez, 2019), and the most critical challenge is the condition that drove roads are in. In any case, the conditions under which drove roads are currently used by transhumant farmers are much better than those in the rest of Spain, where transhumance is abandoned. Since the law to protect these came into force in 1995 (Ley 3/1995, 1995), it has been calculated that more than 30 % of livestock herds have been lost (Hilty et al., 2020).

Regarding restrictions due to animal health concerns, although ovine and caprine brucellosis is no longer a concern because Spain has been officially declared devoid of it (OJEU, 2021)(), diseases like bluetongue, ovine and caprine pox, or epizootic hemorrhagic disease, pose a threat to transhumant movement and may restrict certain livestock movements. The ovine pox outbreaks of 2022 and 2023 (MAPA, 2023c) not only affected the transhumance that wintered in Castilla la Mancha, mentioned in the Results section, but also influenced transhumance in regions near Sierra de Segura, such as that of transhumant farmers in the Sierra de Castril (Granada). Thus in autumn 2022, the fear of ovine pox outbreaks in the Granada province would have affected the farms from Sierra de Segura and prevented livestock movements for health reasons, which would have led some transhumant farmers to choose transport by truck instead of on foot. Similarly, the drought situation in Spain in recent years has meant increased truck transport, as we previously mentioned in relation to the spring 2023 transhumance. Paradoxically that year, the herds traveling by truck received financial aid from the public administration to compensate for drought effects, but those traveling on foot did not and were affected by pasture and water scarcity along the way.

5. Conclusions

Our study reveals a notable community of transhumant farmers who primarily raise Segureña sheep, and who continue to practice traditional transhumance in Jaén (Andalusia, south Spain). This contrasts with the declining transhumance trend observed across much of Europe. Originating in Sierra de Segura and migrating to the Sierra Morena pastures, these farmers travel mostly on foot, with displacements lasting up to 10 days along drove roads.

Transhumant herds are generally larger and composed mostly of only sheep, or sheep and goats, but include a lower percentage of female goats than those of sedentary farmers who remain in the region all year round. The transhumant herds that move on foot or by truck do not differ in size or in terms of distance to wintering pastures. So, we can consider them a homogeneous group. Likewise, the sex of farm owners does not determine herd size or herd structure, its sedentary or transhumant status, or displacement type.

The most significant challenges faced by transhumant farmers during these on-foot journeys include deterioration of drove roads, harsh environmental conditions, threats of movement restrictions imposed by zoosanitary regulations, and lack of water on the return journey at the end of spring during drought periods.

The limited information available in scientific journals about the populations, characteristics and challenges of transhumant communities is a significant constraint that diminishes support for this ecologically valuable activity. Therefore, it is essential to quantify and analyze the demographic characteristics of transhumant groups, such as that examined in our study, and to make this information accessible to both the scientific community and the broader public. It is also essential for society and institutions to acknowledge the considerable personal effort and sacrifices made by these herders. Support in the form of infrastructure improvements and other aid are necessary to sustain this ancestral practice. Finally, these pastoralists should be valued for the contributions they make to the cultural and environmental preservation of this livestock practice, and the quality of their products should be acknowledged.

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CRediT authorship contribution statement

Teresa Maestre: Writing – review & editing, Writing – original draft. **Jomar Magalhaes Barbosa:** Writing – review & editing, Validation, Supervision, Resources, Project administration, Funding acquisition. **Marina Rincon-Madroñero:** Writing – review & editing, Visualization. **Antonio Contreras de Vera:** Writing – review & edit-

ing, Writing – original draft, Visualization, Validation, Supervision, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Mario Velamazán:** Writing – review & editing, Visualization, Investigation, Formal analysis, Data curation, Conceptualization. **Ángel Gómez-Martín:** Writing – review & editing, Conceptualization.

Declaration of Competing Interest

In relation to the database used, it contained personally identifiable information related to the geographical location of farms and the REGA code that identifies each livestock farm, which includes population data. Therefore, this sensitive information has been masked to comply with the current personal data protection law.

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Abbreviations

MAPA: Spanish Ministry of Agriculture Fisheries and Food (Ministerio de Agricultura Pesca y Alimentación)

OCA: Zonal agrarian office (Oficina Comarcal Agraria)

REGA: Official record of livestock farms (Registro general de explotaciones ganaderas)

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.smallrumres.2024.107343.

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