Traditional ecological knowledge in Sierra de Andía (Navarre, Spain), and its applicability for nature conservation

Conocimiento ecológico tradicional en la Sierra de Andía (Navarra, España) y su aplicabilidad para la conservación de la naturaleza

Luis Gorriz[1] & Manuel Pardo-de-Santayana[1,2*]

1. Departamento de Biología (Botánica), Universidad Autónoma de Madrid, Madrid, Spain.
2. Centro de Investigación en Biodiversidad y Cambio Global (CIBC-UAM), Universidad Autónoma de Madrid, Madrid, Spain.

*manuel.pardo@uam.es

Citar este artículo
GORRIZ, L. & M. PARDO-DE-SANTAYANA. 2021. Traditional ecological knowledge in Sierra de Andía (Navarre, Spain), and its applicability for nature conservation. *Bol. Soc. Argent. Bot.* 56: 93-111.

DOI: https://doi.org/10.31055/1851.2372.v56.n1.32299

Summary

Background and aims: In the current context of global biodiversity loss, consensus is growing about the importance of incorporating Traditional Ecological Knowledge in nature conservation. However, efforts with this concern have mainly focused on indigenous cultures. In this scenario we chose Sierra de Andía, a Spanish Red Natura Site with ancient grazelands where pastoral management shifts could be leading into a conservation issue. In this context, this study aims to contribute to the valorisation and applicability of traditional ecological knowledge from an industrialized country, by using it to identify problematics and propose management solutions for the site.

M&M: In order to discover traditional knowledge that could be beneficial for conservation management of Sierra de Andía, we interviewed informants about *Chamaemelum nobile* (a popular medicinal plant closely dependant on grazing pastures) and conducted a pilot vegetation survey about the species.

Results: Informants showed deep knowledge about the plant and provided ecological indicators to locate best populations and understand its recent evolution. While there are multiple coincidences between traditional and scientific knowledge, new information only mentioned by interviewees also arose. For instance, rain scarcity at the end of the summer was considered as a probable threat for *C. nobile* blooming.

Conclusions: This study suggests that local ecological knowledge is accurate, contrastable, and can be applied for a more sustainable management of grazing pastures of Sierra de Andía.

Key words

Chamaemelum nobile, sustainable comanagement, traditional ecological knowledge.

Resumen

Introducción y objetivos: En un contexto de crisis de biodiversidad global, existe un consenso científico y político creciente acerca de la importancia de incorporar el Conocimiento Ecológico Tradicional para la conservación de la naturaleza. Sin embargo, dichos esfuerzos se han centrado en culturas indígenas. En este escenario elegimos la Sierra de Andía, un espacio de la Red Natura en España caracterizado por sus antiguos pastos ganaderos, cuyos cambios de gestión recientes podrían conllevar problemáticas para su conservación. En este escenario, el estudio busca contribuir a la valorización y la aplicabilidad del conocimiento ecológico tradicional de un país industrializado, utilizándolo para localizar problemáticas y proponer soluciones de manejo en un área concreta.

M&M: Con el fin de descubrir el conocimiento tradicional que pudiera ser beneficioso para el manejo y conservación de la Sierra de Andía, se realizaron entrevistas acerca de *Chamaemelum nobile* (una popular planta medicinal ligada a estos pastos ganaderos) y se llevó a cabo un estudio de campo sobre la especie.

Resultados: Los informantes mostraron un profundo conocimiento sobre la planta, y proveyeron indicadores ecológicos con los que localizar las poblaciones más abundantes y comprender su evolución reciente. A la vez que encontramos numerosas coincidencias entre el conocimiento ecológico tradicional y el científico, también surgió información exclusiva de los informantes.

Conclusiones: Este estudio sugiere que el conocimiento ecológico tradicional aportado es preciso, contrastable, y puede ser utilizado para un manejo sostenible de los pastos en la Sierra de Andía.

Palabras clave

Chamaemelum nobile, conocimiento ecológico tradicional, cogestión sostenible.

Recibido: 28 Feb 2021
Aceptado: 22 Mar 2021
Publicado impreso: 31 Mar 2021
Editora: Norma Hilgert

ISSN versión impresa 0373-580X
ISSN versión on-line 1851-2372

Introduction

During the last decades, human impact on the planet has quickly increased, leading to a quick disappearing of species that is being considered the sixth big extinction event of the earth (Pimm & Raven, 2000; Thomas *et al.*, 2004; IPBES, 2018). Due to this biodiversity crisis, conservation efforts and sustainable management are becoming increasingly urgent, especially in those hotspots where living organisms are particularly threatened and diverse (Reid, 1998; Myers *et al.*, 2000). In this context, a growing consensus exists about the relevance of including traditional ecological knowledge (TEK) as a source of information for nature management and decision making (United Nations, 1992; Gadgil *et al.*, 1993; Drew & Henne, 2006; Shackeroff & Campbell, 2007; Guadilla-Sáez *et al.*, 2019).

The term "TEK", has been traditionally defined as "a cumulative body of knowledge, practice and belief, evolving from adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment" (Berkes *et al.*, 2000). However, more recent definitions regard TEK not only as an accumulation of knowledge, but as a dynamic body that both allows adaptation and cocreates new realities on socio-ecological systems (Gómez-Baggethun & Reyes-García, 2013). Several studies have shown that TEK can give useful and complementary information to scientists, as well as acting as a way of engaging communities in conservation efforts, improving co-governance and reinforcing resilience of socio-ecological systems (Drew, 2005; Houde, 2007; Ruiz-Mallén & Corbera, 2013; Hernández-Morcillo *et al.*, 2014; Ludwig & Macnaghten, 2020). This collaborative decision making and complementary knowledge approach (Scientific + TEK), has been performed in several studies around the world (Newmaster *et al.*, 2011; Gadamus *et al.,* 2015; Tomasini & Theilade, 2019). In the case of plants, Tomasini & Theilade (2019) performed a study in Prespa National Park (Albania), where locals granted useful local ecological indicators for a better management of the site. These and other studies demonstrate the utility of collecting TEK in conservation projects, as an essential tool for a better management and protection of natural areas, as it can be a cheap, broad, long time and inclusive method (Moller *et al.*, 2004). Unfortunately, TEK use in conservation has mainly been focused on indigenous communities of developing countries such as in Latin America, leading to a lack of studies in rural areas of more industrialized countries, where some locals still preserve this wisdom (Hernández-Morcillo *et al.*, 2014; Aswani *et al.*, 2018). This phenomena happens in Spain, where despite the tradition in ethnobotanical research (Bonet, 1994; Morales *et al.*, 2011), only few studies have tried to empirically link TEK with nature conservation (Reyes-García, 2009; Benítez *et al.,* 2010), leading to a requirement of studies that provide evidence of the relevance of ethnobotanical knowledge for a more sustainable nature management. In this context we find Sierra de Andía, a Spanish Red Natura site characterized by its ancient grazelands which, regarding nearby local people, are suffering quick management shifts that could pose a conservation issue. With this regard, there is a need to assess these problematics and propose management solutions for the area based on locals TEK, and therefore giving evidence about its value in nature conservation plans. To do so, it could be especially convenient to use well known wild species by informants, as some could act as ecological indicators of their habitats. Despite the deep erosion of TEK (Ramirez, 2007), there are still some species such as Roman chamomile [*Chamaemelum nobile* (L.) All. *Anthemis nobilis* L.] which locals still gather and know (Pardo-de-Santayana & Morales, 2010; Blanco-Salas *et al.*, 2018).

Chamaemelum nobile is ordinarily called *manzanilla amarga*, *manzanilla fina* or *manzanilla de monte* in Spain (Pardo-de-Santayana & Morales, 2010). It is an herbaceous plant with a perennial rhizome and alternate tri-pinnatisect leaves, that generally creeps on the ground depending on cattle pressure over the pasture. By the end of the summer (from late July to September), *C. nobile* produces solitary erect stalks with flower heads composed of outer white ray-florets and yellow inner florets, which remind to daisy inflorescences (Al-Snafi, 2016) (Fig. 1). *Chamaemelum nobile* mainly grows in western Europe (Spain, Portugal, UK, France and Ireland) and Northern Africa (Morocco and Algeria), inhabiting seasonally wet grasslands, where the presence of cattle inhibits competition from other plant species (Blanco-Salas *et. al.*, 2018; Botanical Society of Britain and Ireland, 2021). Roman chamomile is widely used in its distribution

Fig. 1. *Chamaemelum nobile*.

areas, being even grown and sold commercially in many countries (e.g, Germany, France, Egypt or Argentina). It is usually consumed as an herbal tea for dyspepsia, nausea or menstrual disorders, and its infusion is used to clean wounds, infected eyes or against earache (EMA, 2011). Moreover, the plant has been proved to be a promising herbal drug due to its safety and effectiveness over several body processes (Al-Snafi, 2016), which explains its current and past popularity (Blanco-Salas *et. al.*, 2018).

In Spain, especially in northern regions such as Navarre, many people enjoy its characteristic bitter flavour, which they claim to prefer over the chamomiles available in supermarkets, bars and restaurants (*Matricaria chamomilla* L.), so wild gathering of the plant is still preserved (Pardo-de-Santayana & Morales, 2010). Unfortunately, deep changes in agropastoral systems in several countries of Europe have led to less intensive grazing, pasture loss, and according to local people to a decline in *C. nobile* populations. This phenomena has been mentioned in Spain (Barandiarán *et al.*, 1990), and is particular remarkable in other European territories such as UK, where grazeland abandonment has markedly diminished *C. nobile* abundance (Botanical Society of Britain and Ireland, 2021).

Given its popularity among locals in northern Spain, and its tight link with grazing pastures, we selected *C. nobile* as a source of TEK in order to promote effective and inclusive sustainable management measures in Sierra de Andía, a Red Natura mountain tableland with extent grazelands located in Northern Spain (Navarre) (MITECO, 2015), where quick socio-economical changes and management shifts could be leading to a conservation issue.

To achieve this goal, here we present the following specific objectives:

1. Compiling traditional ecological knowledge about *C. nobile* (ecology, habitat, population shifts, threats, sustainable gathering techniques, etc.).
2. Comparing TEK conclusions with field vegetation observations and bibliography.
3. Merging both TEK and scientific knowledge and developing proposals for a better management of *C. nobile* and its habitat, and therefore highlighting TEK's utility.

We hypothesize that there is coincidence between both types of wisdom since both are based on experimental knowledge and deep observation. Besides, as TEK is based on locally social and environmental conditions, we also hypothesize that it is essential for designing long term successful management, since scientific knowledge may be based in generalizations that are not adapted for specific sites.

Materials and methods

Description of the site

The present study was performed in Sierra de Andía, a mountain tableland located in the centre-west of Navarre (northern Spain) (Fig. 2), where local people have traditionally gathered *C. nobile*. We interviewed inhabitants from the nearby municipality of Valle de Ollo, at 504 masl and located 22 km west from the capital of the region (Pamplona). Traditionally, the main activity of the site has been shepherding, complemented with dry land crops growing, such as barley, wheat, and oats. In 1984, something more than half of the population (54%), was dedicated to stockbreeding (Gran Enciclopedia de Navarra, 1990). However, nowadays jobs in the secondary and tertiary sectors (production, tourism) predominate. According to Instituto de Estadística de Navarra (2021), predominant jobs are from service sector (108), followed by industry (30), agriculture (16) and construction (10).

Population in Valle de Ollo is scattered in nine small villages. It has quickly declined in the last 150 years, going from 1186 inhabitants in 1857 to a minimum of 316 in the year 1991, due to deep social changes and countryside abandonment. After that, neo-rural population has arrived, incrementing the population to 421 inhabitants by 2019 (Instituto de Estadística de Navarra, 1991; Instituto Nacional de Estadística, 2020).

This area is in the transition of the Mediterranean and Eurosiberian biogeographic zones, with precipitations of about 1100 mm/year, and mean temperatures of 11º C. *Quercus rotundifolia* Lam. forests grow in the sunny and driest lowlands, whereas *Quercus pubescens* Willd. dominate deeper and humid locations. As we go up (700 ~ 1100 m), beech forests of *Fagus sylvatica* L. appear, and they are finally replaced by the high grazing pastures of Sierra de Andía on the top of the tableland (Gran Enciclopedia de Navarra, 1990; WFO, 2021). In these grasslands, over 12 different pastures types have been identified, five of them cited as "community interest habitats" (Berasategui *et al*.,

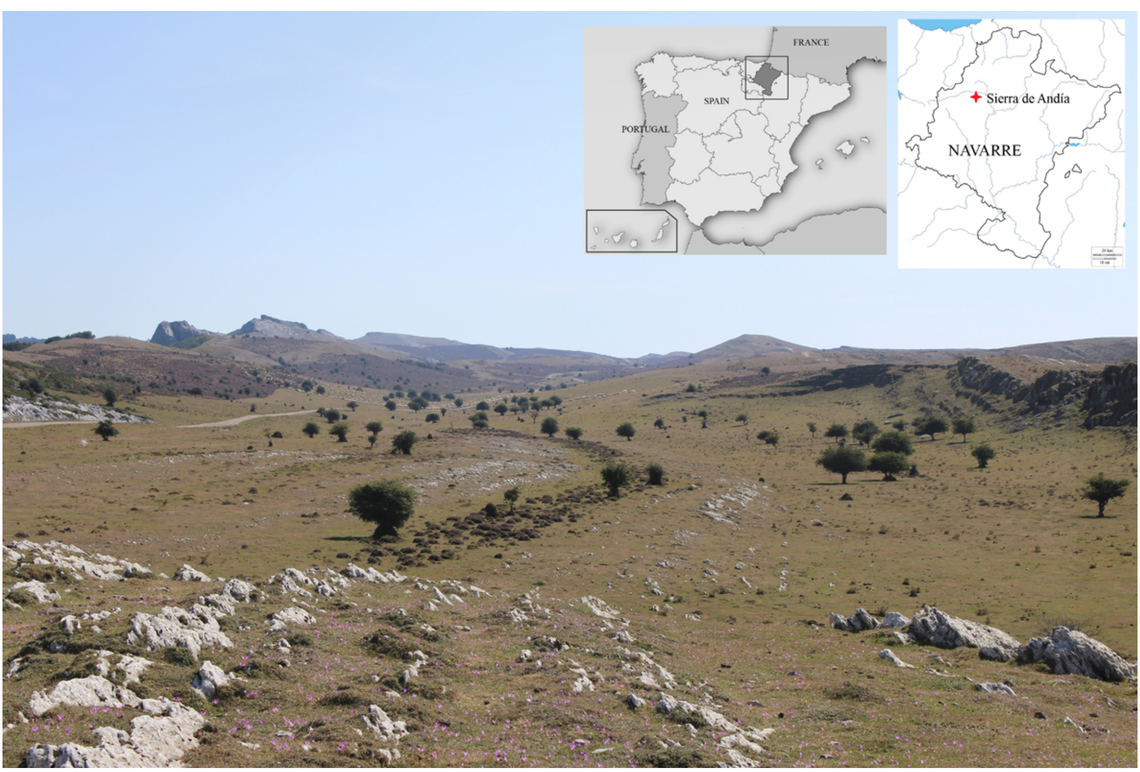

Fig. 2. Sierra de Andía; location and appearance.

2011; MITECO, 2015). Within these pastures, we can find sandstone-substrate sites where abundant seasonal precipitation washes the nutrients from the soil, leading to certain acidification. It is here were the therophitic-acidophilous community of *Helianthemion guttati* Braun Blanq. 1940 develops (Pérez-Prieto & Font, 2005), and where *C. nobile*, is often found (López-Fernández, 1970). According to the Spanish habitat directives, the plant is also associated with diverse *Nardus* spp. grasslands over siliceous substrate (Code: 6230) (MITECO, 2020). All of these pastures and adjoining forests, which had been utilised by transhumant and local shepherds since centuries ago (Fig. 3A) (Garayo-Urruela *et al*., 1996), also preserve a great importance due to its biodiversity, containing species of interest such as the grey partridge (*Perdix perdix* L., 1758), the bearded vulture (*Gypaetus barbatus* L., 1758), and the alpine newt (*Ichtyosaura alpestris* Lau., 1768), which inhabits grazing ponds created by shepherds (Gobierno de Navarra, 2010) (Fig. 3B). All these natural and cultural values, as well as other ecosystem services have put Sierra de Andía and the adjoining Sierra de Urbasa in the focus of conservation plans, leading to the creation of Sierra de Urbasa y Andía Natural Park in 1997 with the resulting management plans (Boletín Oficial de Navarra, 1996, 2001; Boletín Oficial del Estado, 1997).

Data collection

In order to reach our goals, we merged data from three different sources: (1) semi-structured ethnobotanical interviews about *C. nobile,* were we collected TEK in the villages and during field trips with informants; (2) a pilot vegetation sampling survey of the plant in the grazelands of Sierra de Andía; and (3) a complementary bibliographic review. The later was used both to complement the field study, and to gather information about current management practices in Sierra de Andía, so as to compare it with the appreciations of the informants and make a final management proposal for *C. nobile* and its habitat.

a) TEK (semi-structured interviews)

Traditional ecological knowledge about *C. nobile* was collected from July to August 2019, by interviewing locals that were recommended by inhabitants in the area as they were people with deep experiential knowledge about the plant. After contacting the first key informants, we used the "Snowball Method" (Handcock & Gile, 2011) in order to recruit the rest of the interviewees. We only selected inhabitants that still gathered the plant yearly or have collected it frequently during their lives, and therefore preserved TEK. In order to define sample size, we used the law of diminishing returns; i.e., once new information was not appearing and it was confirmed by several interviews, we stopped adding new participants (Martin, 2004). Moreover, we noted that new contacts recommended by last informants had already been interviewed.

We performed a total of 10 consented interviews, with a mean age of 80 years, from locals that had lived tightly linked to surrounding natural resources. Besides interviews next to informants' homes, four field trips to collection sites with participants were conducted (Martin, 2004). Most participants (80%) had herded

Fig. 3. Sierra de Andía. **A**: Ancient shepherd's cabins. **B**: Artificial grazing ponds, where *Ichthyosaura alpestris* inhabits.

cattle in their youth and infancy across Sierra de Andía, and preserved deep understanding of grazelands. The reason why no women were interviewed during this study is that, even though they knew the applications and uses of the plant, there were men who recollected and spent more time in the habitat of *C. nobile* while herding the cattle, and therefore had developed deeper ecological knowledge.

Firstly, we asked the interviewees broad questions about Sierra de Andía pastures, so as to encourage them to share those topics that they considered of interest. This helped us to have into account local's perspective and better design or create some of the questions of the subsequent interview. After this, informants were asked about the local names of *C. nobile*, its morphological characteristics, how it was recognised, its blooming period, recollection technique, preparation and use, gathering sites and their abundance, population trends, threats for the plant and finally, we encouraged them to propose management measures for *C. nobile* and its habitat. In addition to this, we paid special attention to all ecological indicators used by informants during the interviews, as they were the basis to perform the following vegetation survey.

b) Scientific measurements (vegetation survey)

In order to compare local ecological indicators of informants, and to assess if they were contrastable and complimentary with scientific measurements, we performed a preliminary field vegetation study in one of the most common recollection sites during the flowering season of the plant (August-September 2020). First, we visited the recollection spots mentioned during the interviews, making observations about the abundance and location of the plant. Following informant's advice, we also measured weight (g) and height (cm from floor to the base of the receptacle) from two groups of 50 inflorescences; one from inside a pond's fence (non-accessible to cattle), and other from outside (accessible to cattle). We also observed and recorded visible threats and other ecological details of *C. nobile* as we visited the sites.

After coming by main recollection spots in Sierra de Andía, we chose a popular harvesting site (60% mentioned it) with elevated soil humidity and sunken terrain, which had a high abundance of inflorescences. In this area we placed three different plots, each of them representative of a combination of traditional indicators used by informants (orography, grass colour, bush presence and erosion) (Table 1; Table 2). Each plot was 7 x 20 m, as these measures were the ones that best fitted with terrain and local indicators. To demarcate them, we used four stakes joined by cords (Fig. 4A). In each plot, traditional indicators predicted a negative or positive impact over *C. nobile* abundance. To assess traditional indicators accuracy, we measured *C. nobile* coverture inside each plot. Other variables such as the number of blooms per area, the number of individuals and the number of cut flowers were also quantified. Once the plot was delimited, we measured the variables inside by performing eleven equidistant transects, each 10 cm wide (Fig. 4B). The number of transects per plot was chosen using the "Promedio corrido" method, a representative number for measuring coverage (Mostacedo & Fredericksen, 2000).

Fig. 4. Vegetation survey with plots. **A:** plot's dimensions, adjusted to terrain indicators. **B:** Sampling coverture with equidistant transects.

Table 1. Ecological indicators used by informants, in order to predict flowering abundance of *C. nobile*.

Indicator		Predicted impacts on flowering
Rain	Several days of abundant rains during the second half of august	Abundant blooming, 4 to 10 days after rainfall.
	Little rain during the second half of august	Scarce blooming
Festivities	Days between *Virgen de Agosto* (15/8) and *Virgen de Septiembre* (15/9)	Potential blooming
	Other dates	Rare blooming
Terrain topography	Depressed zones of terrain (*Hoyadas*) and flat areas	Enhances flowering abundance
	Sloping terrain	Perjudicial for flowering abundance
Grass colour	Dark green	Enhances flowering abundance
	Light green, or not green	Perjudicial for flowering abundance
Soil erosion	Low	Enhances flowering abundance
	High	Perjudicial for flowering abundance
Soil depth	Deep soils, rich in organic matter	Enhances flowering abundance
	Short rocky soils	Perjudicial for flowering abundance
Bush growth	Bush absence	Enhances flowering abundance
	Bush presence	Perjudicial for flowering abundance
Nearby ponds	Yes	Enhances flowering abundance
	No (Far away)	Perjudicial for flowering abundance

Table 2. Indicators present in each plot of the vegetation survey.

			Plot		
			1	2	3
Indicator	Enhances flowering	Terrain topography: Flat	x		x
		Grass colour: Dark green	x		x
		Bush growth: Absence	x		x
		Soil erosion: Low	x	x	
	Perjudicial to flowering	Terrein topography: Slope		x	
		Grass colour: Light green, or yellowish		x	
		Bush growth: Presence		x	
		Soil erosion: High			x

In order to complement the field study, we reviewed literature about *C. nobile* and its habitat, looking to find differences or similitudes between informant's knowledge and scientific results. Main key words used in this search were "*Chamaemelum nobile*", "*Anthemis nobilis*" and "Ecology", and main browser applied was Google Scholar.

c) Knowledge resemblance and integrated proposals

After compiling informants TEK and performing the vegetation survey, we reviewed pre-existing literature regarding *C. nobile* ecology, threats, and management (pasture management) (Boletín Oficial de Navarra, 1996, 2001; Boletín Oficial del Estado, 1997; Sección de Gestión Forestal, 2009, 2011, 2017).

Main key words used were: *Chamaemelum nobile & Ecology / Pasture ecology / Management pastures shepherding*. With this, we performed a comparison between traditional wisdom (from informants) and scientific knowledge (from literature and the field survey), allowing us to assess knowledge resemblance between both.

After the aforementioned, last part of the study aimed to reach some final conclusions for a better sustainable management of *C. nobile* and its pastoral ecosystem, by merging all scientific and traditional knowledge. Final management proposals can be checked at the end of discussion.

Results

TEK; semi-structured interviews

Local names: Informants referred to *C. nobile* with two different names: *manzanilla fina* (delicate chamomile) and *manzanilla de los altos* (mountain chamomile). It is interesting to note that the term *fina* was used as an appreciative epithet, meaning that the plant was better and stronger in chemical compounds than *Anthemis arvensis* L., a morphologically similar and well-known medicinal plant in the area which informants called with the pejorative epithet *manzanilla basta* (coarse chamomile).

Gathering, preparation and applications: Informants explained that, to gather the plant, it is only necessary to take the inflorescences without damaging the vegetative part, therefore facilitating following year blooming. To prepare the plant, inflorescences are dehydrated during several days on paper or absorbent surface, in a close and dry place. Once dried, it is possible to store them in a hermetic pot during long periods of time until they are used. To do so, infusion was the only preparation method mentioned (100%), while some people added a splash of anise liqueur for improving its flavour (30%). Once prepared, it has a variety of applications; it is used as analgesic for stomach and head pain (100%), favours body relaxation (40%), helps releasing stomachal air in calves when they overgraze (20%) and reduces local inflammation in wounds when applied as poultice (10%). Informants highlighted that only a few inflorescences per glass are needed. They explained that, when compared to *A. arvensis, C. nobile* contains higher concentration of active compounds in the inflorescences, so a lower amount is needed to prepare the infusion.

Flowering: To delimit the blooming period of the plant, informants made use of festivities (80%); “it flowers between August Virgin (15th) and September Virgin (15th)”. Moreover, some of them (30%) mentioned that the plant’s abundance is tightly linked to precipitation during this period. They specified that “if it doesn´t rain enough during those days, the plant will not flower until the next year”. If it rains enough, though, “it flowers all over”. In the year of the present study, interviewees predicted a low flowering due to the scarce rains at the end of the summer.

Population location and abundance: Informants agreed that most abundant *C. nobile* populations were located in the grazing pastures of Sierra de Andía, concretely in the proximity of the artificial ponds made by shepherds, where terrain is depressed and moisture levels are higher.

Traditional ecological indicators: During interviews, informants alluded to different local indicators about the ecology of the plant to locate and predict its flowering and abundance. Most popular indicators were rain (100%) and field topography (50%) (Table 1).

Population changes and threats: Even though interviewees were aware of a variety of short-period threats for *C. nobile*, there was not a clear consensus about how the whole plant populations in Sierra de Andía had evolved in the long-term period of 50 years. Some informants said that populations might have decreased due to quick changes in cattle management (40%), whereas others mentioned that they hadn’t perceived any appreciable changes (30%). One of them even claimed that “nowadays the plant is more abundant because recollection has decreased”. The rest of informants didn’t know what to answer to this question (20%). However, a considerable number of them assured that, independently to *C. nobile’s* trends, quick management changes in the pastures of Sierra de Andía and Valle de Ollo had happened in the last decades (40%). Moreover, informants were aware about a variety of threats that could negatively impact the plant. These were usually mentioned regarding specific sites, such as two recollection spots inside Valle de Ollo were *C. nobile* was next to disappear (30%). Six main threats mentioned were: rain scarcity, grazing abandonment, soil erosion, cattle increase, over-recollection and pasture overgrazing (Fig. 5).

a) *Rain scarcity*: Most informants (70%), mentioned precipitation shortage during flowering period as one of the main factors affecting flowering abundance yearly. Even though they couldn't confirm any long-term effect over the plant's populations, they were sure it was the main driving factor affecting annual blooming of the plant. Some other quotes related to rainfall patterns of the area in the long term were "Pastures didn't dry that much some decades ago, and they used to remain greenish even at the end of the summer", or "nowadays, climate changes quicker and more abruptly".
b) *Grazing abandonment*: Other threat that was cited several times by informants was shrub and grass overgrowth due to cattle cease and pasture abandonment (40%). In fact, a specific area was cited by one of the informants were pasture (and therefore *C. nobile*) had almost disappeared due to loss of ovine shepherding.
c) *Soil degradation*: Some of the interviewees mentioned that excessive trampling over the soil can disrupt the terrain leading to decline of *C. nobile* (30%). Moreover, they highlighted that wet soils are particularly vulnerable to this process (30%), especially in the proximity of cattle ponds, depressed terrains and during rainy months of the year.
d) *Bigger cattle increase*: Some informants said that cattle type in Sierra de Andía had been altered in the last decades; from big herds of minor cattle (mainly sheep), towards predominance of bigger cattle (horses and cows). They explained that both horses and cows, which are heavier, generate a higher impact over the field by trampling and mowing. Additionally, they highlighted that there has been a progressive loss in the caring of cattle, which could induce changes in the pasture ecosystem (40%).
e) *Over-recollection*: Even though interviewees agreed that gathering pressure has declined over the last decades, two of them (20%) mentioned that overexploitation may occur in those sites that are particularly popular.
f) *Temporal over-grazing*: According to some, (20%), grazing period length in Sierra de Andía pastures has increased over the last decades. Traditionally, shepherds would take their cattle back to the villages by 25th of July. However, nowadays cattle spends much more time in the high pastures due

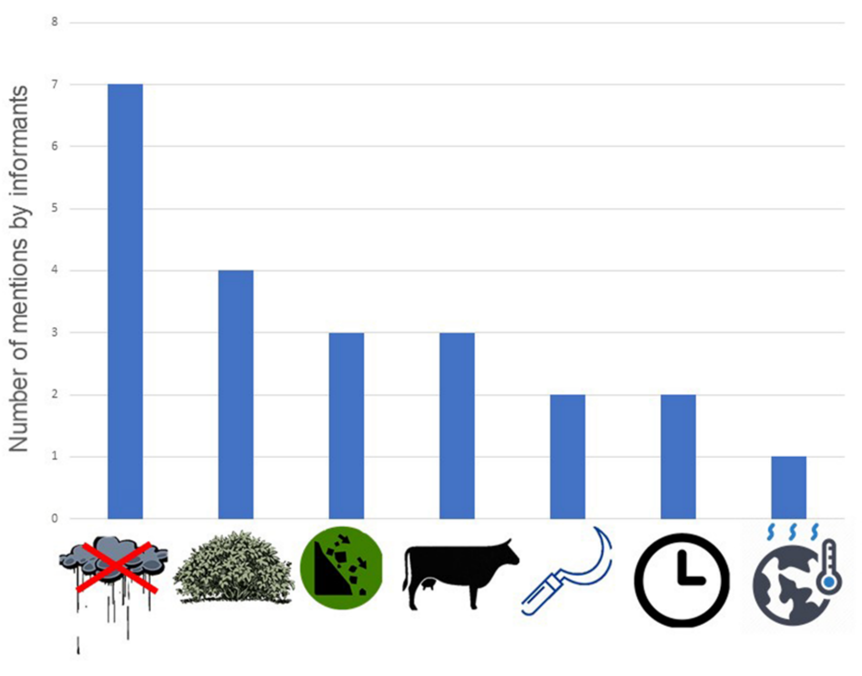

Fig. 5. Threats for *C. nobile*, according to informants.

to socio-economical changes and better climatic conditions.

Management proposals: When asked about possible management actions that could benefit *C. nobile* and the pasture ecosystem, unexpectedly, interviewees didn't mention harvesting control as an important measurement to avoid overexploitation, as they considered other factors like precipitations to have much stronger effect in population abundance. Finally, they pointed out several proposals related to cattle management:

a) *Favouring sheep and goat livestock*: Interviewees repeated several times the significance of limiting beef cattle and equines and promoting sheep and goats, and therefore maintaining traditional livestock proportions (50%). Bigger cattle was described as highly erosive and more difficult to control, something that favours pasture abandonment and overexploitation of desirable locations.
b) *Avoid grazing abandonment and shrub growth*: Informants mentioned the importance of maintaining the pasture thanks to cattle presence (20%). In addition to this, they pointed out the relevance of shepherds, who favour cattle movement and avoid free livestock concentration among most appealing sites.
c) *Limiting grazing duration*: Informants mentioned that removing cattle from the high pastures of Sierra de Andía before the end of the summer could have benefits for the plant and its habitat, as it enhances grazeland regeneration with late-summer rainfall (20%).
d) *Avoiding cattle over wet soils*: Informants proposed two ways of protecting wet soils from cattle trampling; on the one hand by fencing artificial ponds, so cattle could not reach their shores and disrupt the soil (20%). On the other hand, by removing cattle from valuable soils during the rainy months of autumn and spring (20%).

Scientific measurements: vegetation survey

After visiting popular recollection sites along Sierra de Andía during the flowering period of *C. nobile*, we appreciated a low inflorescence abundance of the plant, comparing to previous descriptions of informants about abundant years. According to interviewees, favourable years are distinguished by conspicuous blooming of the plant all over propitious locations. Flowering abundance during these years was described as "it blooms all around" or "everything becomes white with flowers". Although being a qualitative comparison, observations during this study at main recollections spots through flowering period, showed that blooming abundance was much lower than compared to "abundant years". This was confirmed by informants by previous predictions; "it might not bloom a lot this year, because it has not rain enough", as well as direct appreciations by two of them in the field. Only in sunken areas or in the proximity of cattle ponds we could observe higher inflorescence abundance.

After making these general observations, height and weight of two groups of 60 inflorescences were measured, one from inside and other from outside a pond's fence. Average height was five times higher inside than outside (Inside; 8.16 cm, outside; 1.54 cm), and average weight was 1.4 times greater (Inside;

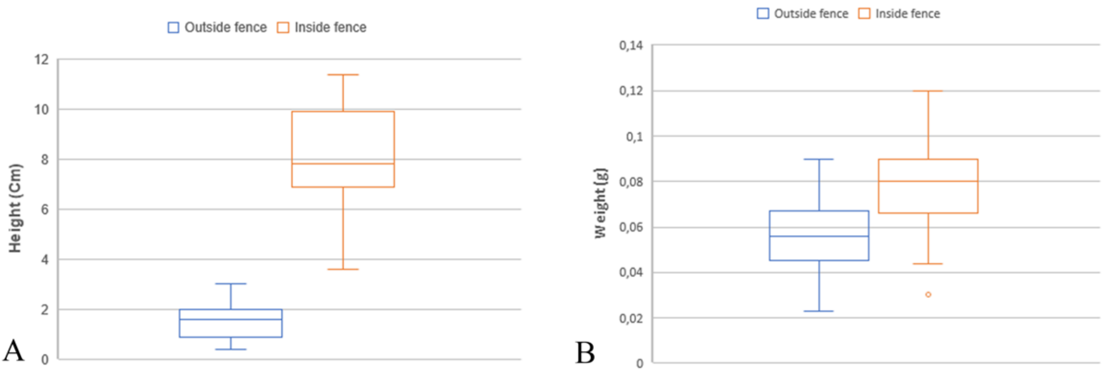

Fig. 6. *C. nobile* weight and height comparison from inside and outside a pond's fence.

Table 3. Knowledge resemblance with two different approaches; traditional (TEK), and scientific. Abreviations = ~: broad coincidence; ✓: coincidence; x: disagreement; −: no information.

Knowledge	Approach		
	TEK	SCIENTIFIC	
		FIELD STUDY	ARTICLE REVIEW
Ecology	Flowering from 15th august to 15th september		~ (Pardo de Santayana & Morales, 2010; Al-Snafi, 2016)
	Blooming is tightly linked to summer-end rainfall	–	–
	Habitat: grazing pastures	✓	✓ (López-Fernández, 1970; Blanco-Salas *et al.*, 2018)
	Habitat: proximity of artificial ponds and humid soils	✓	✓ (Blanco-Salas *et al.*, 2018)
	Habitat: Depressed zones of terrain	✓	✓ (Blanco-Salas *et al.*, 2018)
	Habitat: linked to “dark green pasture”	✓	–
	Habitat: Deep soils, rich in organic matter	–	–
	Better growth with lower grazing pressure (fences)	✓	✓ (Stroh, 2015)
	Linked to winter wet soils	–	✓ (López-Fernández, 1970; Stroh, 2015)
	-	-	Grows in slightly acidic soils (Lopez-Fernández, 1970)
	-	-	Grows within a therophitic community (López-Fernández, 1970)
Threats	Trampling in wet soils	✓	~ (Marlow & Pogacnick, 1985)
	Grazing abandonment (shrub growth)	✓	✓ (Stroh, 2015; Blanco-Salas *et al.*, 2018)
	Rain scarcity (at the end of the summer)	–	–
	Senior cattle increase	–	–
	Excesive grazing and trampling pressure	✓	✓ (Stroh, 2015)
	Over-recollection	–	✓ (Pardo de Santayana *et al.*, 2018)
	Excesive length of grazing period	–	~ (Aguirre - Pérez de Eulate, 2011)
	Negatively affected by artificial fertilizers	–	✓ (Stroh, 2015)
	Temperature changes	–	–
	–	–	Artificial drainage of the soil (Stroh, 2015; Blanco-Salas *et al.*, 2018)
	–	–	Use of broad-spectrum pesticides (Stroh, 2015)
	–	–	Habitat poughing (Stroh, 2015)
Management proposals	Avoiding grazing abandonment	✓	✓ (Stroh, 2015; Blanco-Salas *et al.*, 2018)
	Favouring minor cattle		~ (Molnár *et al.*, 2020)
	Limiting grazing period duration		~ Aguirre - Pérez de Eulate, 2011)
	Avoiding cattle over wet soils		✓ (Stroh, 2015)

0.078 g, outside; 0.056 g) (Fig. 6). T student test for two samples showed significance difference between them ($\alpha/2$ = 0,005, lib. value= 98), both for weight and height. Moreover, informants were aware about these differences as they suggested recollection inside pond's fences, due to bigger growth of *C. nobile* thanks to lower cattle pressure.

By quantifying coverage by transects, we could appreciate that plot 1, which had the most favourable traditional indicators, had the highest *C. nobile* coverage (34.58%), whereas plots 2 and 3, which had one or more negative indicators, showed much lower values (2.24% and 4% respectively).

Knowledge resemblance and integrated management proposals

After comparing both informants' management proposals with field survey and the literature (Table 3), we found multiple coincidence between them. Many ecological facts about the plant, such as its link with seasonally wet soils, its dependence on grazing pastures and its susceptibility to excessive trampling appeared both in the interviews and the literature. Other topics however, were only found in scientific sources or only mentioned by locals. Integrated management proposals that resulted from common ideas found both in literature and informants' knowledge were supported with observations made on the field. These final management suggestions are shown later in the Discussion in the section *Proposals for sustainable management.*

Discussion

Knowledge Co-production

Traditional ecological knowledge is often qualitative and has a very different way of understanding things when compared to science, especially in those non-industrialized countries where indigenous and citizens cosmologies remain remarkably different. This aspect has made it difficult to harmonize both TEK and science together in order to achieve better research and nature management plans (Drew & Henne, 2006). However, this pilot study suggests that for this particular case, TEK could be of big relevance when obtaining information about a species of interest and its habitat, as well as suggesting interesting management measures.

Contrasting both traditional knowledge and scientific information (field survey and literature review) (Table 3), shows how multiple coincidence arises between them. In addition to this, both ways of knowledge seem to complement each other in certain topics, even if approaching the same ecosystem in a very different manner. For instance, specific and accurate data requires particular methodologies only available from a scientific approach. However, broader topics like long term changes in the ecosystem, local observations, and an integrated vision of the area is often easier to obtain from those who inhabit the territory. This aspect has already been mentioned by several authors and is one of the arguments that supports the use of traditional knowledge for a better management of natural resources (Baker & Community Mutitjulu, 1992).

Apart from these broad arguments, merging both traditional and scientific knowledge has provided, for this pilot study, with the following advantages:

Orientation and specification: On the one hand informants' indications allowed us to quickly focus on the most relevant information and therefore orientating our research. This pilot study suggests that thanks to well experienced informants, it is possible to nimbly find most relevant topics when addressing a local conservation plan, without performing a long and exhausting previous research. Once main topics are identified, scientific methods could be undertaken in order to obtain more accurate conclusions. For this pilot study, this aspect has been noticed when studying the threats of the plant. As it is shown in Table 3, a bunch of threats for *C. nobile* is regarded in the literature. However, informants only mentioned some of them during the interviews, which enabled us to get rid of trivial information. Subsequent field survey suggests that other literature threats not mentioned by locals, like broad spectrum pesticides, artificial draining and habitat ploughing, are actually not relevant for this specific area. Moreover, informants were able to give specific information about broader topics cited in the literature, allowing us to adapt scientific recommendations to the specificities of the area. Cattle trampling over wet soils, for example, is a well-known matter in the scientific literature (Marlow & Pogacnik, 1985) that has been mostly related to riverbank destruction. In this study, however, informants mentioned it by referring it to cattle presence over wet soils during the rainy months of the year.

New ideas: On the other hand, and probably most important, informants have acted as a source of new knowledge that was not found in the literature. This is the case of rain scarcity at the end of the summer, as a probable threat for *C. nobile* blooming on the site. Climate change predictions in Spain (Vargas-Amelin & Pindado, 2014) as well as its effect on top-mountainous systems (Pauli & Gottfried, 1996), suggest that this problematic could be relevant for the plant in the future.

TEK for conservation. Location, abundance and threats.

In the previous paragraph, we discussed how traditional knowledge can help to orientate scientific research and discover new topics when performing a conservation study. But is there specific information given by locals that could be directly applied in conservation plans? After performing this pilot study, we suggest three topics of interest that could be useful with this regard: population's location, ecological indicators and threats.

Firstly, as happened in previous studies (Tomasini & Theilade, 2019) informants made possible to quickly locate the main populations of *C. nobile*, coincident with traditional recollection sites. Secondly, informants were able to give a range of ecological indicators (Table 1), which could be a good basis for researchers to better understand plant's ecology and make optimal management decisions. In fact, plot study during vegetation survey, suggests that some traditional ecological indicators are correlated with plant's abundance, something also mentioned by Tomasini & Theilade (2019). Finally, a list of threats for *C. nobile* was obtained after the interviews. Some of them like pasture abandonment and excessive trampling coincide with scientific literature and the field survey (Table 3), and others like rain scarcity at the end of the summer, were unexpected (Fig. 5). In any case, compiling a list of potential threats for any species or habitat from informants can be of great use for conservation managers.

Overall picture and proposals for sustainable management

By merging threats and management suggestions of locals with scientific literature, we present an overall view of the site for a better management of *C. nobile* and its habitat.

On the one hand, change in livestock proportions and management in Sierra de Andía has been one of the most repeated issues by informants (60%). According to them, sheep has been the traditional predominant cattle type of the site. However, over the last decades, a progressive change has been occurring towards a higher proportion of bigger non-shepherded cattle (cows and mares). In concordance with locals, bibliography showed us that there has been an appreciable shift in livestock proportions in the last decades (Garayo-Urruela *et al.*, 1996; Sección de Gestión Forestal, 2009, 2011, 2017) (Fig. 7). This could have implications in pasture dynamics, like overgrazing and over-trampling

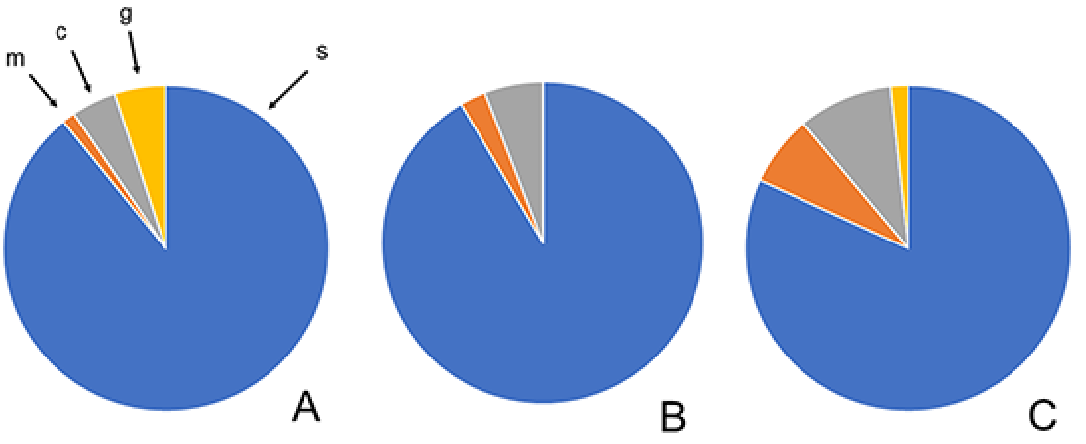

Fig. 7. Cattle proportions shifts in Sierra de Andía. **A:** Traditional proportions (Given by Informants). **B:** Proportions in 1996 (Garayo Urruela *et al*., 1996). **C:** Proportions in 2019 (Sección de Gestión Forestal, 2019). "s": sheep; "g": goats; "m": mares; "c": cows.

in most-desirable areas, as well as abandonment of others. Actually, according to Molnár *et al.* (2020), shepherding might be an essential element in order to manage cattle movement and avoid pasture abandonment over certain areas. Finally, informants suggested that overgrazing and over trampling leads to a more prostrate phenotype of *C. nobile*, so it is advisable to collect the plant “inside pond’s fences, where absence of cattle let it grow bigger”. Following informant’s experience, we studied this phenomenon measuring flowers from both in and out of a pond’s fence, finding a more prostrate phenotype and lighter inflorescence production outside the fence (Fig. 6). This suggests that not only vegetative parts of the plant, but sexual reproduction efficiency could be affected in the long term by all these impacts. Interestingly, this hypothesis has been found as well in the literature (Botanical Society of Britain and Ireland, 2021).

On the other hand, informants suggested that compared to traditional grazing times, change towards longer grazing periods is occurring in Sierra de Andía. Comparing traditional grazing periods with current data suggests that there has been a change in that regard (Garayo-Urruela *et al*., 1996; Sección de Gestión Forestal, 2009, 2011, 2017) (Fig. 8). This could have an effect over pasture regeneration in certain areas, as interviewees mentioned late summer rainfall as a key factor for grazeland renewing, something also highlighted in the literature (Aguirre-Pérez de Eulate, 2011). Moreover, end summer rainfall can lead to an increase on soil fragility due to higher humidity (Marlow & Pogacnik, 1985). This phenomenon had already been mentioned by informants, using as an example soil destruction near artificial ponds, or when cattle remains in reduced areas during rainfall season at the end of the summer. With respect to all this, we found that Navarrean government promoted the fencing of some of these ponds due to the presence of *Ichthyosaura alpestris* (GAN-NIK & Gobierno de Navarra, 2018), therefore limiting shore-land destruction. However, no measurements regarding cattle management during wet months of the year were found, which is an increasingly important topic as herds nowadays remain longer time in the pastures of Sierra de Andía.

Proposals for sustainable management

Merging TEK and scientific knowledge allowed us to reach a better understanding of the site and its threats. By knowing this, here we suggest some actions that could benefit general pasture management and conservation of *C. nobile* in Sierra de Andía:

1) Recognising and promoting sheep shepherds as key elements of the ecosystem: Sheep shepherds still maintain and give cultural and ecological

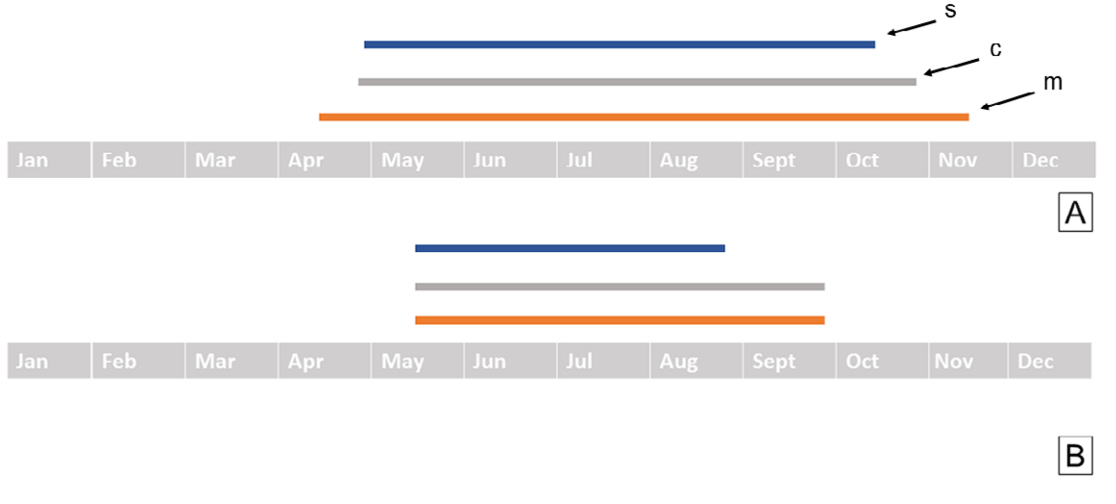

Fig. 8. Grazing period duration. **A:** Dates in 2019 (Sección de Gestión Forestal, 2019). **B:** Traditional dates (given by informants). “s”: sheep; “m”: mares; “g”: cows.

services that should be recognised, as they maintain a tight human-nature relationship and keep up pasture ecosystems, avoiding their abandonment and loss. Contrary to free-bigger cattle, shepherded sheep allow for a more efficient and homogenous use of grazelands, eluding abandonment of non-desirable areas and over-exploitation of most appealing ones (Molnár *et al*., 2020). This measure would allow to maintain traditional predomination of minor cattle and prevent progressive abandonment of bigger cattle in Sierra de Andía. Moreover, if future changes like wolf recovering in the site happen (RTVE, 2021), shepherds could again become essential to ensure cattle protection.

2) Limiting livestock in Sierra de Andía since rainfall begins (September-October): This measurement might allow for a better recovery of pastures at the end of the summer, as well as avoiding wet-soil disruption by trampling in specific areas. If cattle removal is not feasible, we suggest to locate them in most dry areas (soil humidity less than 10%), so trample destruction is reduced (Marlow & Pogacnik, 1985).
3) Fencing artificial ponds: By protecting artificial ponds from cattle entrance and stablishing buffer areas, humid shores disruption could be prevented. This would benefit key fauna species like *Ichtiosauria alpestris,* and other amphibians, as well as allowing *C. nobile* and other plant species to recover, and reducing disease spreading from wild animals to livestock.
4) Promoting sustainable recollection of *C. nobile*: We suggest that a good management of natural resources such as *C. nobile*, also implies sustainable exploitation for human use. By doing this, new stakeholders can arise to better understand and protect the area. Moreover, promoting different uses of Sierra de Andía, (alternative to pastoral and recreational), might increase benefits from the site.

Limitations of the study

It is essential to remark that the following project should be only understood as a pilot study, without statistical significance, but as a possible orientation for future research and decision making. The small number of informants can be partly explained due to the low population of Valle de Ollo, time availability (each informant was visited more than once), and the advanced age of those who still maintain traditional ecological knowledge of *C. nobile* and its habitat. Even though the sample could be partially representative of Valle de Ollo's population, wider research would be needed to cover all possible interviewees.

Finally, it is important to note that this conservation approach might not work when locals don't have a direct relationship with the natural resource of study. *Chamaemelum nobile* is a well-known plant among informants, about which they have developed strong ecological knowledge and therefore promising contributions to any hypothetical management plan. Besides, this is an argument to maintain traditional harvesting practices as a possible pool for ecological information.

Further research

Firstly, after performing plot vegetation survey, we realized that future studies could try to better contrast traditional indicators by disposing enough plots for all their possible combinations (4x4=16 plots). Secondly, we suggest future research regarding the effects of minor and bigger cattle over pasture dynamics, as it would help to improve management decisions in Sierra de Andía. Thirdly, we encourage any study regarding climate change consequences on the site, looking to improve resilience of the area in the long term. Finally, we believe that new solutions and ideas enhancing sustainable nature harvesting and traditional knowledge transmission, would greatly help TEK survival, a precious wisdom for nature conservation.

Conclusions

This study suggests that locals still maintain a rich and varied TEK about *C. nobile* and its habitat. However, high mean age of the sample indicates that TEK is at risk, as little generational substitution exists. Secondly, multiple coincidence between TEK and scientific wisdom suggests that they could be merged in order to achieve better and more precise management decisions in Sierra de Andía, supporting the general idea of TEK use in nature sustainable management for industrialized countries. The study also suggests that current trends in Sierra de Andía towards higher proportions of bigger non-shepherded cattle, could lead into important changes on ecosystem dynamics, favouring over-exploitation of certain areas and abandonment of others. Finally, in order to increase pasture resilience and *C. nobile* conservation, traditional customs such as sheep shepherding, limiting grazing period, fencing artificial ponds and promoting sustainable recollection of *C. nobile*, are suggested.

Authors contributions

LG and MP conceived and designed the study. LG Collected the data and performed the analysis. MP contributed with data and analysis tools. LG Wrote the paper with the guidance and mentorship of MP.

Acknowledgments

I would like to give thanks to all my informants, who have embraced me without knowing me. Thankyou as well to Silvia Akerreta, Ricardo Andueza and the staff from Navarrean government. And finally, to my dear father. Because without him this study wouldn't be half of what it is.

References

AGUIRRE - PEREZ DE EULATE, M. S. 2011. *Situación del sector ovino extensivo en las Sierras de Urbasa y Andía en 2006: Análisis y propuestas de mejora*. Trabajo Final de Carrera. Universidad Pública de Navarra, Escuela Técnica Superior de Ingenieros Agrónomos, Spain.

AL-SNAFI, A. E. 2016. Medical importance of *Anthemis nobilis* (*Chamaemelum nobile*) - a review. *Asian J. Pharm. Sci. Technology* 6: 89-95.

ASWANI, S., A. LEMAHIEU & W. H. H. SAUER. 2018. Global trends of local ecological knowledge and future implications. *Plos One* 4: Article e0195440 (Online). https://doi.org/10.1371/journal.pone.0195440

BAKER, L. M. & COMMUNITY MUTITJULU. 1992. Comparing two views of the landscape: aboriginal traditional ecological knowledge and modern scientific knowledge. *Rangel. J.* 14: 174-189. https://doi.org/10.1071/RJ9920174

BARANDIARÁN, M., J. MANTEROLA & A. MANTEROLA, 1990. *Atlas etnográfico de Vasconia. La alimentación doméstica en Vasconia.* Eusko Jaurlaritza, Bilbao.

BENÍTEZ, G., J. MOLERO & M. R GONZÁLEZ-TEJERO. 2010. Floristic and ecological diversity of ethnobotanical resources used in Western Granada (Spain) and their conservation. *Acta Bot. Gall.* 157: 769–86. https://doi.org/10.1080/12538078.2010.10516246

BERASATEGUI, A., K. VAN DORT & O. SCHWENDTNER. 2011. Valor de conservación de la flora y la vegetación de las Sierras de Urbasa-Andía (Navarra). In: SERRA, L. (ed.), *Jornadas Estatales de estudio y divulgación de la flora de los Parques Nacionales y Naturales,* pp. 177-198. CAM, Alcoi.

BERKES, F., J. COLDING & C. FOLKE. 2000. Rediscovery of Traditional Ecological Knowledge as adaptive management. *Ecol. Applications*. 10: 1251–62. https://doi.org/10.2307/2641280

BLANCO-SALAS, J., T. RUIZ-TÉLLEZ & F. M. VÁZQUEZ. 2018. Chamaemelum nobile (L.) All. In: PARDO DE SANTAYANA, M., R. MORALES, J. TARDÍO & M. MOLINA (eds.), *Inventario Español de los Conocimientos Tradicionales Relativos a la Biodiversidad, Fase 2 (1)*. pp. 202-207. Ministerio de Agricultura y Pesca, Alimentación y Medio Ambiente, Madrid.

BOLETÍN OFICIAL DE NAVARRA. 1996. *Decreto Foral 267/1996, de 1 de Julio, Por el que se aprueba definitivamente el Plan de Ordenación de los Recursos Naturales de Urbasa y Andía* [online]. Available at: https://bon.navarra.es/es/anuncio/-/texto/1996/97/0. [Accessed 20 October 2021].

BOLETÍN OFICIAL DE NAVARRA. 2001. *Decreto Foral 340/2001, de 4 de Diciembre, por el que se aprueba El Plan Rector de Uso y Gestión de Urbasa y Andía* [online]. Available at: https://bon.navarra.es/es/anuncio/-/texto/2002/15/0. [Accessed 4 November 2020].

BOLETÍN OFICIAL DEL ESTADO. 1997. *Ley Foral 3/1997, de 27 de Febrero, del Parque Natural de Urbasa y Andía* [online]. Available at: https://boe.es/buscar/doc.php?id=BOE-A-1997-10810. [Accessed 3 November 2020].

BONET, M. À. 1994. Etnobotànica de La Vall Del Tenes (Vallès Oriental). *Lauro: Rev. Museo Granollers*. 7: 20.

BOTANICAL SOCIETY OF BRITAIN AND IRELAND. 2021. Chamaemelum nobile. *Online Atlas of the British and Irish Flora* [online]. Available at: https://www.brc.ac.uk/plantatlas/plant/chamaemelum-nobile [Accessed: 11 February 2021].

DREW, J. A. 2005. Use of Traditional Ecological Knowledge in marine conservation. *Conserv. Biol.* 19: 1286-1293. https://doi.org/10.1111/j.1523-1739.2005.00158.x

DREW, J. A. & A. P. HENNE. 2006. Conservation Biology and Traditional Ecological Knowledge: Integrating academic disciplines for better conservation practice. *Ecol. Soc.* 11: 34. https://doi.org/10.7916/D8HT301J

EMA. 2011. *Assessment report on* Chamaemelum nobile *(L.) All., Flos*. European Medicines Agency, Westferry Circus, Canary Wharf, London, United Kingdom.

GADAMUS, L., J. RAYMOND-YAKOUBIAN, R. ASHENFELTER, A. AHMASUK, V. METCALF & G. NOONGWOOK. 2015. Building an indigenous evidence-base for tribally-led habitat conservation policies. *Mar. Policy* 62: 116-124. https://doi.org/10.1016/j.marpol.2015.09.008

GADGIL, M., F. BERKES & C. FOLKE. 1993. Indigenous Knowledge for Biodiversity Conservation. *Ambio* 22: 151-56. https://www.jstor.org/stable/4314060

GAN-NIK & GOBIERNO DE NAVARRA. 2018. *Proyecto de inversiones en el Parque Natural de Urbasa y Andía (2018).* Project report. Available at: file:///C:/Users/usuario/Downloads/Lote%20n%C2%BA4.-Proyecto_compl_mejora_pistas_urbasa.pdf.

GARAYO-URRUELA, J. M., F. L. CALVO & M. J. M. MERELO. 1996. Andía, Urbasa, Encía. El pastoreo en La Sierra. In: *Cuadernos de la trashumancia* 24. Ministerio de Agricultura, Pesca y Alimentación, Madrid.

GOBIERNO DE NAVARRA. 2010. *Parque Natural Urbasa - Andía Parke Naturala* [online]. Available at: http://www.parquedeurbasa.es/informacion/el-parque.html [Accessed 10 January 2021].

GÓMEZ-BAGGETHUN, E. & V. REYES-GARCÍA. 2013. Reinterpreting change in traditional ecological knowledge. *Hum. Ecol.* 41: 643-647. https://doi.org/ 10.1007/s10745-013-9577-9.

GRAN ENCICLOPEDIA DE NAVARRA. 1990. *Ollo* [online]. Available at: http://www.enciclopedianavarra.com/?page_id=15633 [Accessed 1 October 2020].

GUADILLA-SÁEZ, S., M. PARDO-DE-SANTAYANA & V. REYES-GARCÍA. 2019. The role of traditional management practices in shaping a diverse habitat mosaic in a mountain region of Northern Spain. *Land Use Policy* 89: 104235. https://doi.org/10.1016/j.landusepol.2019.104235

HANDCOCK, M. & K. J GILE. 2011. Comment: on the concept of snowball sampling. *Sociol. Method.* 41: 367-371.

HERNÁNDEZ-MORCILLO, M., J. HOBERG, E. OTEROS-ROZAS, T. PLIENINGER, E. GÓMEZ-BAGGETHUN & V. REYES-GARCÍA. 2014. Traditional Ecological Knowledge in Europe: status quo and insights for the environmental policy agenda. *Environ. Sci. Policy Sustain Dev.* 56: 3-17. https://doi.org/10.1080/00139157.2014.861673

HOUDE, N. 2007. The six faces of traditional ecological knowledge: challenges and opportunities for Canadian co-management arrangements. *Ecol Soc.* 12: 34. http://www.ecologyandsociety.org/vol12/iss2/art34/

INSTITUTO DE ESTADÍSTICA DE NAVARRA. 1991. *Evolución de la población de hecho, según municipios y por sexo, según municipios. Años 1857 a 1991* [online]. Available at: https://administracionelectronica.navarra.es/GN.InstitutoEstadistica.Web/informacionestadistica.aspx?R=1&E=1.

INSTITUTO DE ESTADÍSTICA DE NAVARRA. 2021. *Información municipal - Mercado de trabajo - Afiliación según municipio de residencia* [online]. Available at: https://administracionelectronica.navarra.es/GN.InstitutoEstadistica.Web/InformacionEstadistica.aspx?R=4 [Accessed 15 March 2021].

INSTITUTO NACIONAL DE ESTADÍSTICA. 2020. *Población del Padrón continuo por Unidad Poblacional a 1 de enero* [online]. Available at: https://www.ine.es/nomen2/index.do?accion=busquedaAvanzada&entidad_amb=no&codProv=31&codMuni=194&codEC=0&codES=0&codNUC=0&denominacion_op=like&denominacion_txt=&L=0.

IPBES. 2018. The IPBES regional assessment report on biodiversity and ecosystem services for Europe and Central Asia. In: ROUNSEVELL, M., M. FISCHER, A. TORRE-MARIN RANDO & A. MADER (eds.). *Regional / subregional assessments on biodiversity and ecosystem services.* Secretariat of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, Bonn, Germany. https://doi.org/10.5281/zenodo.3237428

LÓPEZ-FERNÁNDEZ, M. L. 1970. *Aportación al estudio de la flora y del paisaje vegetal de las Sierras de Urbasa, Andía, Santiago de Lóquiz y El Perdón (Navarra)*. Tesis Doctoral. Universidad de Navarra, España.

LUDWIG, D. & P. MACNAGHTEN. 2020. Traditional Ecological Knowledge in innovation governance: a framework for responsible and just innovation. *J. Responsible Innov.* 7: 26-44. https://doi.org/10.1080/23299460.2019.1676686

MARLOW, C. & T. M. POGACNIK. 1985. Time of grazing and cattle induced damage to streambrakes. In: JOHNSON, R. R., C.D. ZIEBELL, D.R. PATTON, P.F. FFOLLIOT, R.H. HAMRE (coords). *Riparian Ecosystems and Their Uses. Reconciling Conflict Uses. First North American Riparian Conference,* pp. 279-284 USDA Forest Service, Tucson, Arizona.

MARTIN, G.J. 2004. *Ethnobotany, a Methods Manual. People and Plants Conservation Series*. Earthscan, London, UK.

MITECO. 2015. Red Natura Dataforms - N2K ES2200021 [Online]. Available at: https://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=ES2200021 [Accessed 24 November 2020].

MITECO. 2020. *Eidos. Ministerio para la Transición Ecológica y el Reto Demográfico, Madrid, Spain.* Available at: https://www.miteco.gob.es/es/biodiversidad/servicios/banco-datos-naturaleza/Eidos.aspx.

MOLLER, H., P. F. BERKES, P. O'BRIAN, L. & M. KISLALIOGLU. 2004. Combining science and Traditional Ecological Knowledge: Monitoring populations for co-management. *Ecol. Soc.* 9: 2. http://www.ecologyandsociety.org/vol9/iss3/art2/

MOLNÁR, Z., A. KELEMEN, R. KUN, J. MÁTÉ, L. SÁFIÁN, F. PROVENZA & S. DÍAZ. 2020. Knowledge co-production with traditional herders on cattle grazing behaviour for better management of species-rich grasslands. *J. Appl. Ecol.* 57: 1677–1687. https://doi.org/10.1111/1365-2664.13664

MORALES, R., J. TARDÍO, L. ACEITUNO, M. MOLINA & M. PARDO-DE-SANTAYANA. 2011. Biodiversidad y Etnobotánica en España. *Mem. Real Soc. Esp. Hist. Nat*. 9: 157-207.

MOSTACEDO, B. & T. S. FREDERICKSEN. 2000. *Manual de métodos básicos de muestreo y análisis en ecología vegetal. BOLFOR*. Santa Cruz, Bolivia.

MYERS, N., R. A. MITTERMELER, C. R. G. MITTERMELER, G. A. B. DA FONSECA & J. KENT. 2000. Biodiversity hotspots for conservation priorities. *Nature* 403: 853–858. http://dx.doi.org/10.1038/35002501

NEWMASTER, A. F., K. J. BERG, S. RAGUPATHY, M. PALANISAMY, K. SAMBANDAN & S. G. NEWMASTER. 2011. Local knowledge and conservation of seagrasses in the Tamil Nadu State of India. *J. Ethnobiol. Ethnomed.* 7: 1–17. http://dx.doi.org/10.1186/1746-4269-7-37

PARDO-DE-SANTAYANA, M. & R. MORALES. 2010. Chamomiles in Spain. The dynamics of plant nomenclature. In: PARDO-DE-SANTAYANA, M., A. PIERONI & R. PURI (eds.). *Ethnobotany in the New Europe: People, Health and Wild Plant Resources*, pp. 283-307. Berghahn Press, New York, Oxford, UK.

PAULI, H. & M. GOTTFRIED. 1996. Effects of climate change on mountain ecosystems--upward shifting of alpine plants. *World Resour. Rev.* 8:382-390.

PÉREZ - PRIETO, D. & X. FONT. 2005. Revisión sintaxonómica a nivel de subalianza del Orden *Helianthemetalia Guttati* en la Península Ibérica e Islas Baleares. *Acta Bot. Mal.* 30: 139–156. https://doi.org/10.24310/abm.v30i0.7188

PIMM, S. L. & P. RAVEN. 2000. Extinction by Numbers. *Nature* 403: 843–845. https://doi.org/10.1038/35002708

RAMIREZ, C. R. 2007. Ethnobotany and the loss of Traditional Knowledge in the 21st Century. *Ethnobot. Res. Appl.* 5: 245–247. https://doi.org/10.17348/era.5.0.245-247

REID, W. V. 1998. Biodiversity Hotspots. *Trends Ecol. Evol.* 13: 275-280. https://doi.org/10.1016/S0169-5347(98)01363-9

REYES-GARCIA, V. 2009. Conocimiento Ecológico Tradicional para la conservación: dinámicas y conflictos. *Pap.* 107: 39–55.

RTVE. 2021. La caza del lobo quedará prohibida en toda España [Online]. Available at: https://www.rtve.es/noticias/20210204/caza-lobo-queda-prohibida-toda-espana/2072955.shtml [Accessed 20 February 2021].

RUIZ-MALLÉN, I. & E. CORBERA. 2013. Community-based conservation and Traditional Ecological Knowledge: Implications for social-ecological resilience. *Ecol. Soc.* 18:12. http://dx.doi.org/10.5751/ES-05867-180412

SECCIÓN DE GESTIÓN FORESTAL. 2009. *Monte Sierra de Urbasa, Nº 6 del Catálogo de Montes de Utilidad Pública de Navarra. Propiedad del Patrimonio Forestal de Navarra* [online]. Available at: http://www.parquedeurbasa.es/imgx/pdf_urbasa/Resumenes/Resumen_publico_Monte_Urbasa_a%C3%B1o_2009.pdf- [Accessed 20 November 2020].

SECCIÓN DE GESTIÓN FORESTAL. 2011. *Monte Sierra de Urbasa, Nº 6 del Catálogo de Montes de Utilidad Pública de Navarra. Propiedad del Patrimonio Forestal de Navarra* [online]. Available at: http://www.parquedeurbasa.es/imgx/pdf_urbasa/Resumenes/Resumen_P%C3%BAblico_Urbasa_FSC_2011_planos.pdf [Accessed 3 November 2020].

SECCIÓN DE GESTIÓN FORESTAL. 2017. *Monte Sierra de Urbasa, Nº 6 del Catálogo de Montes de Utilidad Pública de Navarra. Propiedad Del Patrimonio Forestal de Navarra* [online]. Available at: http://www.parquedeurbasa.es/imgx/pdf_urbasa/certificacion/Urbasa_FSC_2017.pdf [Accesed 3 December 2020].

SHACKEROFF, J. M & L. M. CAMPBELL. 2007. Traditional Ecological Knowledge in conservation research : problems and prospects for their constructive engagement. *Conserv. Soc.* 5: 343-360.

STROH, P. A. 2015. *Chamaemelum nobile* (L.) All. *Chamomile. Species Account. Botanical Society of Britain and Ireland* [Online]. Available at: https://bsbi.org/species-accounts. [Acessed 12 December 2020].

THOMAS, J. A., M. G. TELFER, D. B. ROY, C. D. PRESTON, J. J. D. GREENWOOD, J. ASHER, R. FOX, R. T. CLARKE & J. H. LAWTON. 2004. Comparative losses of British butterflies, birds, and plants and the global extinction crisis. *Science* 303: 1879-1881. https://doi.org/10.1126/science.1095046

TOMASINI, S. & I. THEILADE. 2019. Local Ecological Knowledge indicators for wild plant management: autonomous local monitoring in Prespa, Albania. *Ecol. Ind.* 101: 1064-1076. https://doi.org/10.1016/j.ecolind.2019.01.076

UNITED NATIONS, 1992. Recognizing and strengthening the role of indigenous people and their communities. In: UNITED NATIONS (ed.), *Report of United Nations conference on Environment and Development,* pp 385- 388. Río de Janeiro, Brazil.

VARGAS-AMELIN, E. & P. PINDADO. 2014. The challenge of Climate Change in Spain: water resources, agriculture and land. *J. Hydrol.* 518: 243–249. https://doi.org/10.1016/j.jhydrol.2013.11.035

WFO. 2021. *World Flora Online*. Global Partnership for plant conservation, India [online]. Available at: http://worldfloraonline.org [Accessed 20 October 2021].