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RESEARCH

The characterisation and future sustainability of a rural landscape: using integrated approaches for temporal heritage landscape analysis in Northwest Spain

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Abstract

Context Changing global socioeconomics are endangering agrosilvopastoral landscapes and with them the knowledge of maintaining these historical, sustainable forms of territorial management. Approaches that integrate Local Spatial Knowledge (LSK) with scientific methods are valuable means to understand their landscape heritage, identity, and temporal land use and land cover (LULC).

Objectives Our aim is to utilise an interdisciplinary approach that combines 'bottom-up' ethnographic/participatory studies with 'top-down' Historic Landscape Characterisation (HLC) to characterise and analyse past and present LULC changes and evaluate the future sustainability of a rural cultural landscape case study.

Methods We mapped LULC between the 1900s and the 2010s in a case study in NW Spain. Our approach initially utilised a landscape perception study and participatory mapping of LSK. These ethnographic data were integrated into the HLC temporal maps to characterise and analyse LULC evolution. Using the HLC maps, a statistical analysis of temporal changes of landscape attributes was completed.

Results The perception study revealed a decline in biodiversity and agrosilvopastoralism. Participatory mapping generated new spatial data of historical land cover and land use traditions indicative of multifunctional rural landscapes. HLC maps, utilising empirical sources and participatory data, corroborated ethnographic perceptions of a loss of landscape multifunctionality due to depopulation.

Conclusions This integrative approach underscores a landscape marked by abandonment, increased vegetative growth, nature conservation measures, and wildfires. This study highlights the value of inter and transdisciplinary approaches to analyse and understand temporal landscape change. The research's newly created spatial data can be used as a potential planning tool for sustainable rural development, adaptation to climate change, and heritage conservation.

Keywords Temporal LULC analyses · Participatory mapping · Historic Landscape Characterisation · Landscape abandonment · Interdisciplinary approaches · Agrosilvopastoral landscapes

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Introduction

Global socioeconomic shifts to urbanism and development of industrial and service oriented economies has come at the cost of significant changes to the rural agricultural sector in many nations. Commercial agricultural intensification or landscape abandonment have contributed to the development of widespread monocultures of cultivation or vegetative succession (Plieninger et al. 2006; Otero et al. 2015; Weissgerber et al. 2023; Hearn et al. 2024). With these monocultures comes the loss of once multifunctional, biodiverse human created and often sustainable landscapes. Wu (2013) describes landscape sustainability as "the capacity of a landscape to consistently provide long-term, landscape-specific ecosystem services essential for maintaining and improving human well-being".

With the gradual disappearance of agricultural mosaic landscapes also comes the generationally developed knowledge of maintaining these landscapes. Agrosilvopastoral landscapes are traditional multifunctional rural systems common to the Mediterranean Region (Hearn et al. 2024). Integrating agriculture, forestry, and livestock into smallholdings farms they consist of both tangible and intangible practices and structures related to their historic use and maintenance. As a result, these rural landscapes are considered cultural heritage (Plieninger et al. 2013; Hearn and Prada-Llorente 2024).

While much research and policy justifiably orients to making urban spaces sustainable, vibrant, and liveable, in traditionally agrosilvopastoral landscapes, the biodiversity, sustainability, and cultural heritage related to them are in danger of disappearance. Protecting this heritage is also viewed as contributing to both economic and environmental sustainability (Eliasson et al. 2018). Thus, the concepts of landscape, heritage, and sustainability are intertwined. Mediterranean Europe since the 1950s has witnessed a significant decrease in these rural multifunctional heritage landscapes. Accessing these communities' local spatial knowledge (LSK) of agrosilvopastoral practices is seen as crucial to their preservation as this knowledge can disappear within one generation (Bele et al. 2021). As a result, the disassociation of communities with these agricultural traditions has the potential to contribute to a loss of landscape sustainability (Raymond et al. 2013; Plieninger et al. 2015).

Combining both scientific and LSK from participatory methods is progressively seen as crucial for understanding landscape heritage, evaluating change, and as a tool for future planning (Fagerholm et al. 2013; Fowler 2023). In this vein, incorporating participatory studies with temporal landscape characterisation and analysis has proven a successful means to understand, quantify, and reciprocally share human landscape perceptions (Shrestha and Medley 2016; Saha et al. 2020; Hearn and Álvarez-Mozos 2021; San Martin-Saldias et al. 2022).

Since the 2005 Faro Convention of the Council of Europe, there has been a significant impetus to utilise more inclusive approaches to landscape research with the convention's recommendation of a more democratic approach to understanding heritage and landscape (Fairclough and Londen 2010; Fairclough et al. 2020). Fairclough et al. (2020) have promoted a reciprocal understanding of landscape and heritage whereby experts not only promote general public awareness of landscape and heritage from their perspective but also learn '…to see how landscapes are 'lived', to benefit from the wealth of practical expertise about their landscapes that local people may still hold.'

For this research an approach integrating the democratic ideals espoused by the Faro Convention was implemented with top-down methodologies and tools to analyse the temporal evolution of the landscape. This study will incorporate historic, archival, primary, and secondary sources from the early 20th century implementing archival data, land use maps, and both historical and contemporary aerial photography. Central to all facets of this study, this research will include another very important source: ethnographic data. Public perception and participation data provide community memory of landscape use, history, and changing values. Hence, ethnographic data can provide validity and synergy with more quantitative approaches (Blok and Pedersen 2014; Bjerre-Nielsen and Glavind 2022; Hearn and Carrer 2022). Combined with a quantitative assessment of the landscape through the use of Historic Landscape Characterisation methodology (HLC) (Herring 1998), this participatory data helps to bring the diachronic analysis and understanding of landscape evolution into the present day. Utilising this integrated approach we propose the following research questions:

Fig. 1 Study Area

- What do perception studies and Participatory Geographic Information Systems (PGIS) reveal about temporal LULC of agrosilvopastoral landscapes in NW Spain?
- What is the value of combining 'bottom-up' ethnographic/participatory studies with 'top-down' HLC for understanding the past, present, and future sustainability of cultural landscapes?

Combining HLC with ethnographic/participatory methods from other disciplines has been recommended but has been little implemented or 'explored' (Dabaut and Carrer 2021). This paper goes beyond previous HLC studies in its inclusion of not only community participatory mapping in HLC development, but with its analysis of community perceptions behind the development of the LSK of the heritage landscape study area.

Materials and methods

Study area

This study focuses on the rural village municipality of Pino del Oro in the county of Aliste in the province of Zamora in the autonomous region of Castile and León, Spain. It is located on the Duero River. In 2020 its permanent population was 183 inhabitants.[1] The village is one of many located on the steep Duero River canyon system and its flatland interior banks called *Arribes del Duero* (Fig. 1). The vegetation and climate of the region are Mediterranean with dry hot summers but with continental cold winters being located in the interior of the Iberian Peninsula. The interior flatlands have

[1] Source: Instituto Nacional de Estadística. Población por municipios https://www.ine.es/dyngs/INEbase/es/categoria.htm?c=Estadistica_P&cid=1254734710990.

traditionally allowed for pastoralism supplemented with subsistence cereal crop cultivation (Hearn and Prada-Llorente 2024). Within the river canyon system of the Duero River of villages in this region is a microclimate with warmer winters allowing for Mediterranean type cultivation such as olives or viticulture (Sánchez-Vicente 2010).

Characteristic of villages in this region, Pino del Oro is best typified historically as a multifunctional, subsistence, agrosilvopastoral village. Through time, the people of the village and the greater Arribes del Duero region have developed both tangible and intangible relationships, identity, and understanding of the landscape that manifests itself in the local toponomy, landscape stories and values, land use traditions and management, and vernacular architecture (Prada-Llorente 2011; Rippon 2012; Taylor 2013; Hearn 2021). The agrosilvopastoral landscape organization of Pino del Oro and villages in north-western Spain is organised for the cultivation, field rotation, and milling of cereal crops (wheat, barley, and/or rye), forest management for fuel, building materials, and rough grazing, and finally, ovine, bovine, and caprine transterminant (short distance) pasturing in designated municipal areas at certain times of year (Sánchez-Gómez 1995; Prada-Llorente 2017; Hearn et al. 2024). Having maintained this mosaic of land use traditions for centuries, this agrosilvopastoral land management is considered a form of cultural heritage (Nori et al. 2017).

Pino del Oro's landscape history has a singular designation for its cultural, historic, and natural heritage. Although the village has archival references dating it to the High Medieval Period, then known as Pino (Lera-Maíllo 2000), archaeological excavation has revealed human/environment interaction within the current village boundaries with a hillfort dating to the Protohistoric period followed by Roman settlement into late Antiquity (Sánchez-Palencia et al. 2013, 2018; Romero 2015). From the Medieval to the 19th century, Pino (del Oro was later added in 2002) was controlled by a secular aristocracy that exacted rents in agricultural products from its inhabitants (Moreno-Sebastián 1984; Cañibano 2012). By the early 20th century after the Spanish land confiscations, *desamortizaciones* of the liberal New Regime, much of the village landscape was locally owned by the village residents according to informants. Throughout its history, however, portions of its landscape were maintained as communal lands for both pasturing and/or cultivation.

By the 1960s, residents in Pino del Oro, and throughout rural Spain, seeking greater economic opportunities migrated to larger cities in Spain and abroad resulting in a gradual population decline that continues to the present day (Fig. 2). The emigration of its citizens, as in many parts of rural Spain, has resulted in an abandonment of agrosilvopastoral traditional practices that has allowed the vegetation to grow unchecked (Lasanta-Martínez et al. 2005; Hearn 2021). While some remaining residents still farm and pasture their livestock, they are considerably less in number as well as older. With landscape abandonment and a decreasing population, has also come a gradual loss of the LSK of the formerly sustainable use and management of the agrosilvopastoral landscape (Hearn 2021; Hearn et al. 2024).

Despite the population loss the region has not gone unnoticed by the public authorities. Today the greater region that encompasses the Pino del Oro area extending along the Duero River has been recognised for its natural distinctiveness. The Duero River canyon region was declared a natural park called Arribes del Duero Natural Park in 2002 and in 2015 the entirety of Pino del Oro was incorporated into an even greater conservation area called the Meseta Iberica Biosphere Reserve (Romano et al. 2020).

In Pino del Oro traumatic events within the collective memory have contributed to both changing landscape character and identity. Local landscape events such as floods, wildfires, population loss from emigration, and government decreed land reform have had a great impact on the residents' landscape identity. Together they have resulted in not only an altered landscape character, but also the formation of a new identity composed of landscape memories of the pre-traumatic event, the event itself, and post event (Butler et al. 2018).

Pino del Oro was selected as a case study due to its prior in-depth archaeological study by the Spanish National Research Council (CSIC) (Sastre et al. 2009; Beltrán and Alonso 2010; Sánchez-Palencia and Currás 2010; Sánchez-Palencia et al. 2010; Sánchez-Palencia 2012; Vázquez-Calvo et al. 2016), its significant demographic decline since the 1960s to less than 200 permanent residents (Fig. 2), its location within both the Meseta Iberica Biosphere Reserve and the Arribes del Natural Park, and its tangible and

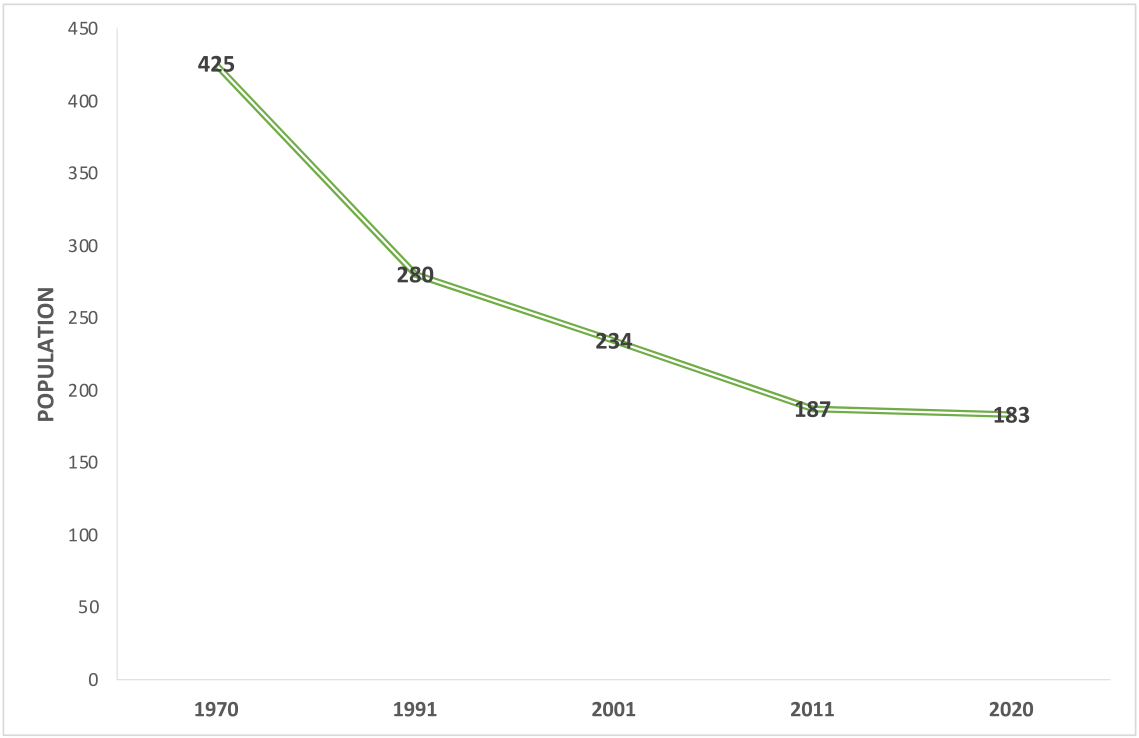


Fig. 2 Population decline of Pino (del Oro) since 1970. Source: ine.es

intangible evidence of multifunctional, agrosilvopastoral, landscape use typical of the region (Sánchez-Gómez 1995; Prada-Llorente 2017).

Study design

To fully understand the temporal landscape changes that have occurred in this representative case study and their drivers, an inter- and transdisciplinary study capable of incorporating local spatial knowledge and empirical spatial datasets was deemed essential.

The method of this study is divided into two approaches: (1) An ethnographic approach comprising two stages and (2) a two stage quantitative approach (Fig. 3).

When conducting heritage research Castillo et al. (2016) emphasises the importance of 'an initial perception study' before beginning participatory activities. Thus, the ethnographic approach was divided into two stages: (1) an initial landscape perception study to learn of the community's identity with their local landscape (Lewicka 2008) followed by (2) a participatory mapping stage.

Local spatial knowledge attained from the participatory activities enriched the quantitative 'top-down' approach consisting of HLC database and GIS map generation. Using HLC a final statistical analysis of temporal land use and land cover change was completed (Fig. 3) (Clark et al. 2004).

Ethnographic approach: the perception study

For the first stage perception study, understanding landscape connection for the community was composed of documenting both individual and collective experiences with the landscape (Knez and Eliasson 2017; Hedblom et al. 2020). Memories, experiences, and localised land use practices—sometimes conflicting—contribute to landscape identity (Saldi et al. 2023). This group identity is closely tied to natural and cultural values from both personal and collective knowledge and memories of a place forming a shared cultural heritage (Eliasson et al. 2018). Trust building and project transparency were also very important in order to complete fieldwork assignments (Hearn 2021; Zafar et al. 2021) (Figs. 3 and 4).

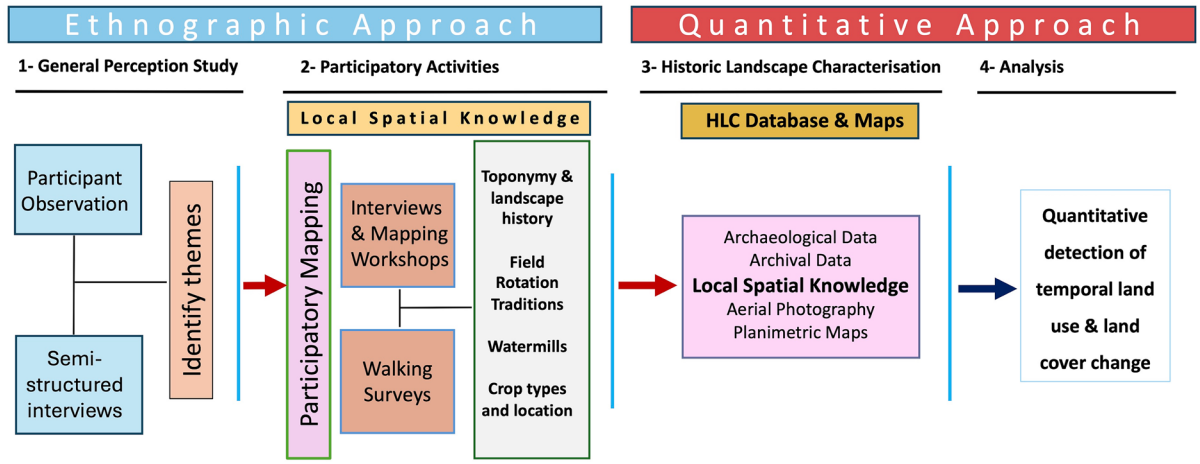


Fig. 3 Study design

Fig. 4 Walking survey with informant in Pino del Oro

Implementation of the perception study

Initial contact with the Pino del Oro community was facilitated through the CSIC landscape archaeology research group that had previously conducted fieldwork in the municipality. Fieldwork was conducted between 2017 and 2019. With the ethnographic approach stages, all participants gave their informed consent to be interviewed. Eleven people were interviewed for both the perception and participatory studies. All interviews were conducted in the village in either the informant's home or in the town hall. Participant observation was an integral part of the ethnographic iterative process (Berthelsen et al. 2017; Turunen et al. 2023). Informal discussions and observations involved approximately 15 people (not from the interview sample) in the village.

During the Perception Study stage fieldnotes and transcripts revealed informants' answers to questions related to landscape memories of use, vegetation, and their identity with and value of the landscape. These written data were then coded for themes under the iterative grounded theory approach that had emerged through text analysis (Bernard 2006; Berthelsen et al. 2017; Chun-Tie et al. 2019).

Ethnographic approach: Participatory Mapping

Participatory mapping, the second stage of the ethnographic approach (Figs. 3 and 4), is a valuable method to reveal many landscape attributes from a community level perspective. Frequently used in applied geography and urban planning, it involves informants performing mapping activities, using applications such as Google Maps or Maptionnaire to map stakeholder subjective data and/or LSK using online surveys (Rantanen and Kahila 2009; Plieninger et al. 2013; Ernoul et al. 2018; Kahila-Tani et al. 2019; Burnett 2023). In archaeology and heritage management, Participatory Mapping is developing as a valuable tool as a more 'bottom-up' grass-roots approach to community engagement in heritage projects to gather place-based LSK (Álvarez-Larrain and McCall 2019).

Implementation of participatory mapping

The Participatory Mapping activities documented residents' LSK of both tangible and intangible characteristics of the landscape. It involved semi-structured, open-ended interviews in either an indoor mapping workshop or a walking survey (Fig. 4). A chain sampling method was used to prevent inconsistencies in the identification and geolocation of landscape features and toponymy. This type of sampling allowed for 'saturation' as participants began to confirm and repeat the same information (Riechers et al. 2020; Yu et al. 2013). Eleven people were interviewed in the village, seven men and four women. Informants were between 40 and 94 years old. All informants had worked and lived in the village in their youth. The youngest, 40s, currently operates the local *casa rural* (typical stone farmhouse converted for rural tourism). Participatory mapping workshops involved the use of large A2 and A3 printed maps that allowed interviewees to mark landscape features onto the maps. Interviews were recorded and transcribed into English.

For walking surveys with informants, a Garmin GPS device and camera were used to photograph and mark specific points deemed important by the participants. Again, interview questions during the walking surveys related to temporal landscape changes which included land use and organisation, land cover, and land ownership changes, especially those that contributed to morphological transformations over time. This knowledge was documented and later mapped using ArcGIS and used to better inform the more 'top down' HLC development and its subsequent quantitative analysis.

Participatory mapping of intangible and tangible landscape attributes

From the rural multifunctional landscape organisation, certain attributes both tangible and intangible have evolved in Pino del Oro and throughout the region that reflect historic, sustainable, agrosilvopastoral management of the landscape (Sánchez-Gómez 1995; Prada-Llorente 2011; Nori et al. 2017; Hearn et al. 2024). From interviews and walking surveys, three historical landscape attributes related to agrosilvopastoral land use were found to be at greatest risk to being lost due to the lack of an extensive record of their existence and/or having never before been mapped. In NW Spain, these mappable attributes have a historical dimension ranging from the Medieval Period to the mid 20th century (García de Cortázar 1999; Glick 2007; Riesco-Chueca 2015; Fernández-Mier and Quirós-Castillo 2015; Fernández-Mier and Alonso-González 2016). They are: (1) the traditional cultivation/pasturing rotation system, (2) the local field name toponomy, and (3) watermill zones. Accessing community LSK of these tangible and intangible attributes provides more background and collective memory regarding temporal land use and landscape character (Fernández-Mier 2006; Rippon 2013; Atik et al. 2022).

Quantitative approach: Historic Landscape Characterisation

The second approach utilised is the GIS based landscape archaeology methodology, HLC (Fig. 3). A very integrative tool for understanding landscape evolution according to varied landscape attributes, HLC utilises prior archaeological research, aerial photography, historic maps, and other written and graphic sources to demonstrate temporal change by characterising the landscape according to classes and further divided into broad types to cover the entire landscape. These landscape patterns are represented as polygons in a GIS and connected to a database rather than point data. With HLC all aspects of a given landscape are considered part of landscape character no matter their time depth be they archaeological or contemporary features (Turner 2006; Crow et al. 2011; Dabaut and Carrer 2021). Key to HLC database design is an understanding of the temporal character of the landscape in question. Thus, the user interface of the database depends on an 'accurate standardisation' that is not 'oversimplified' and flexible enough to reflect an array of diverse attributes (Dabaut and Carrer 2021). HLC's principles are closely tied to the definition of landscape from the ELC of 2000 (Council of Europe 2000) in that landscape is closely tied to collective perception (Clark et al. 2004; Turner 2006).

For this study, some of this collective perception in the form of participatory data from residents of the case study provided additional intangible and tangible temporal landscape information (Hearn and Carrer 2022). Through the use of a database attached to the GIS, the HLC facilitates time layer analyses of land use and change in this study from the early 20th

century to the present. The classes and broad types for this HLC are derived from the seminal regional works of Sánchez-Gómez and Prada-Llorente (Sánchez-Gómez 1991, 1995; Prada-Llorente 2001), and the HLC database organisation developed by Hearn and Carrer (2022).

Implementation of HLC

As mentioned, the design of an HLC project for a landscape requires an understanding, a familiarisation with the historical processes that have contributed to the landscape's evolution (Collins et al. 2014). This HLC's landscape familiarisation was attained from landscape research from archival, secondary, and archaeological sources as well as from the ethnographic interviews and walking surveys conducted in the village.

The intangible and tangible participatory mapping data of the field rotation system and milling zones respectively were integrated into the database's user interface and can be generated as maps depending on the type of database query. Local landscape history as told by informants provided numerous details for the HLC database and allowed for more precise, nuanced, and temporal understanding of the local landscape through the toponomy, the creation and types of enclosures, impact and locations of wildfire burn, the locations and optimum locations for different types of cultivation. HLC class and broad types were developed and adapted for the historic to present character of the Pino del Oro area (Table 1). They are derived from the larger borderland HLC from Hearn and Carrer (2022).

For this study, the HLC database and map preparation general landscape classes and their associative broad types are modified for the following five time periods: Early 20th century, the 1950s, the 1970s, 1990s, and 2010s using the contemporary and archival spatial dataset sources acquired.

These spatial datasets used for the landscape characterisation for each time period were extensive and included historical maps, aerial photography, and vector files especially prepared by the regional government of Castile and León for this research. These temporal data allowed for the creation of polygons

Table 1 HLC class and broad types for Pino del Oro

Class	Broad type
Settlement	
	Nucleated Settlement
Fields	
	Enclosed horticultural plots within village nucleus – *Cortinos*
	Larger enclosed mixed pastoral/ cultivation plots—*Cortinas*
	Rectilinear fields – Unincorporated enclosed plots
	Strip fields – Open fields
	Unenclosed communal pasture
	Communal river canyon pastureland
Rough ground	
	Unenclosed and enclosed woodland – *Monte Alto*
	Unenclosed and enclosed shrubland – *Monte Bajo*
	Denuded ground – wildfire or overgrazing
	Intermittent stream beds used as pasturing corridors – *Valles*
	Unenclosed denuded pasture lands
Communications	
	Roads/Highways
	Bridges
Water source	
	Tributary stream
	Main river
	Reservoir

encompassing the different broad types on the village landscape for each time period. For a complete listing of the data sources used, please consult the supplementary information. Statistical changes in landscape broad types (Table 1) were determined by calculating the percentage of total broad type categories for each time period in MSExcel in relation to the total area of the village landscape. The total area of Pino del Oro is 2986 ha according to the Castile and León government shapefile (https://cartografia.jcyl.es/web/es/idecyl.html). For example, total shrubland in 1990 was 1370.61 hectares. Therefore it consisted of 45.9% of the total landscape (Fig. 8).

Results

The general perception study

The perception study revealed an organised system of agrosilvopastoral landscape use that required 'hard work' to maintain. Informants perceived landscape evolution through the changes brought on by rural abandonment and the subsequent reduction of agrosilvopastoral territorial management. Interviews revealed four significant themes of change: (1) wildlife species loss or invasive species introduction as a result of habitat alteration, (2) former uses of semi-natural vegetation and its now uncontrolled growth, (3) the historic role of pasturing animals (ovine, caprine, and bovine) and their decline, and (4) the decline of cultivation and the creation of smaller, private enclosures over time. Supplementary Information (SI Table 1) demonstrates excerpts from interviews under the coded themes. All comments are translated from Spanish. Scientific names of plant and animal species are provided in cases where informants utilised common names.

Perceptions of wildlife

Informants detected a change in the wildlife typical of diverse habitats. The rise of shrubland and forests on the landscape as seen in the vegetation category was seen as one reason for the loss of some species. The creation of the natural park in 2002 is also seen as a reason for the introduction of new species which the residents in their listing of new species described with disdain. Informants described the loss of species resulting from wildfires and climate change. From the interview transcription:

> *'There used to be birds called pimientos [Erithacus rubecula] and hares. They disappeared because of the wildfires and smoke.'* (Informant early 80s).

Perceptions of vegetation

Residents collectively recalled changes in forest management from their memories and the time of their parents and grandparents from the 1940s to the present. Firewood was attained through the pruning of trees and largely from select areas of the municipal landscape. The arrival of butane stoves in the 1970s reduced the need for firewood. This factor in conjunction with landscape abandonment and consequently less agropastoralism are seen as reasons for the increase in vegetation. From the transcribed interviews:

> *'In the past there was very little firewood because they used it often. Now there's more vegetation. Now there is so much of the land that is not used.* (Informant 70s).

Perception of pasturing

Informants described changes in pasturing trends from the 1950s and 60s to the present. Pasturing consisted of many families pasturing small numbers of sheep, goats, and cattle on designated areas of the landscape and organised at different times of day. Now there are less people living on the landscape with only a few people managing larger herds of sheep and cattle. Related to the wildlife and vegetation perceptions, pasturing was viewed as means to control wildfires. From the interviews:

> *'There are very few people now who live as shepherds. There is one sheep rancher and two cattle ranchers now. In the winter there are only 4 people living here.'* (Informant 65).

Perception of cultivation

The cultivation of the landscape until the 1970s was viewed as more extensive, often with nostalgia and largely unmechanised but with the realisation that

many residents had to leave to find a better life due to changes in national and international socioeconomics. Specific areas of the landscape were designated for the cultivation of specific crops.

> *[circa 1960] 'Nearly everywhere would be ploughed at this time of year until about mid-September. It was planted with rye, potatoes, and carob. This began to change when they opened the doors to Europe and the young people went away.'* (Informant early 80s).

Not all was nostalgic, however. Some informants recalled being hungry in the decades up to the 1970s and having tensions with wealthier residents that had more private lands, and who were opposed to enclosures being divided into smaller holdings according to inheritance.

Undercurrent of wildfires

Wildfire was a theme that crossed through all of the LULC themes. The wildfire of 2017 was a traumatic experience, and the constant threat of future ones weighed heavily on the minds of many residents. It was also a source of solidarity. Fighting the fire was undertaken by both professional firefighters and the villagers themselves.

Residents evaluated both causes and solutions to the wildfires to changes to LULC but also recognised its effects as a symptom of landscape abandonment. From interview transcription:

> *'Before when there was a fire [until the 1970s], it would burn out fast because it would have nowhere else to burn. Now it there are no firewalls to cut the spread.'* (Informant mid 50s).

Controlled burns to generate grass feed, according to informants, used to occur before the significant population decline in the 1960s.

Participatory activities (Participatory Mapping: interviews, workshops, and walking surveys)

Follow-up interviews and walking surveys with residents provided local spatial knowledge of traditional past landscape organisation, collective landscape memories, the aftereffects of the 2017 wildfire, and tangible and intangible changes to agrosilvopastoral use of the landscape today.

Mapping the LSK of the cultivation/pasturing rotation system

Municipal wide crop rotation today was loosely maintained according to informants. In its heyday until the 1970s, rotation occurred yearly alternating the halves of the village lands between fallow land for pasturing and the other half used for cultivation. In enclosures closer to the village center, it was stated that the tradition was not followed, but for those who worked in the open lands, *campo abierto,* maintained by the town hall but allotted to private use, it remained a requirement to follow this tradition. Nevertheless the number of agropastoralists has decreased significantly in the past 50 years. At the time of interviews in 2018 and 2019, informants shared that two people herded cattle and one person herded sheep.

Informants described the geographical dividing line of the rotation system running from the southwest to the northeast of the municipality. The line, beginning in the southwest, is the terminus of the Fuentelarraya stream where it flows into the Duero. Meandering northeast in the river valley it continues eastward along the Pozancos stream. It does not include the horticultural plots and the village centre. Its exit continues on the course of the Pozancos stream in a northeasterly direction where it continues northeasterly until it meets the municipal border.

Cultivation does not occur for a large area of the Fuentelarraya stream that flows northwest of the village centre and an almost continuous strip of land of the municipal banks of the Duero River (Fig. 5). These areas were historically communal pasturing areas, used for wood gathering and most recently, in the case of Pino's canyon pasturing lands, a protected part of the Arribes del Duero Natural Park.

Mapping the LSK of toponomy-field names

Informants used toponymy as a referential tool to describe historic to present day land use and village events memories—sometimes traumatic. These field names were handwritten onto printed maps during the mapping workshops. These ethnographic storied events revealed more local identity and historic landscape character than more top down surveys of visual attributes could provide. Table 2 provides field name toponyms referred to during interviews, descriptions of temporal land use of field name

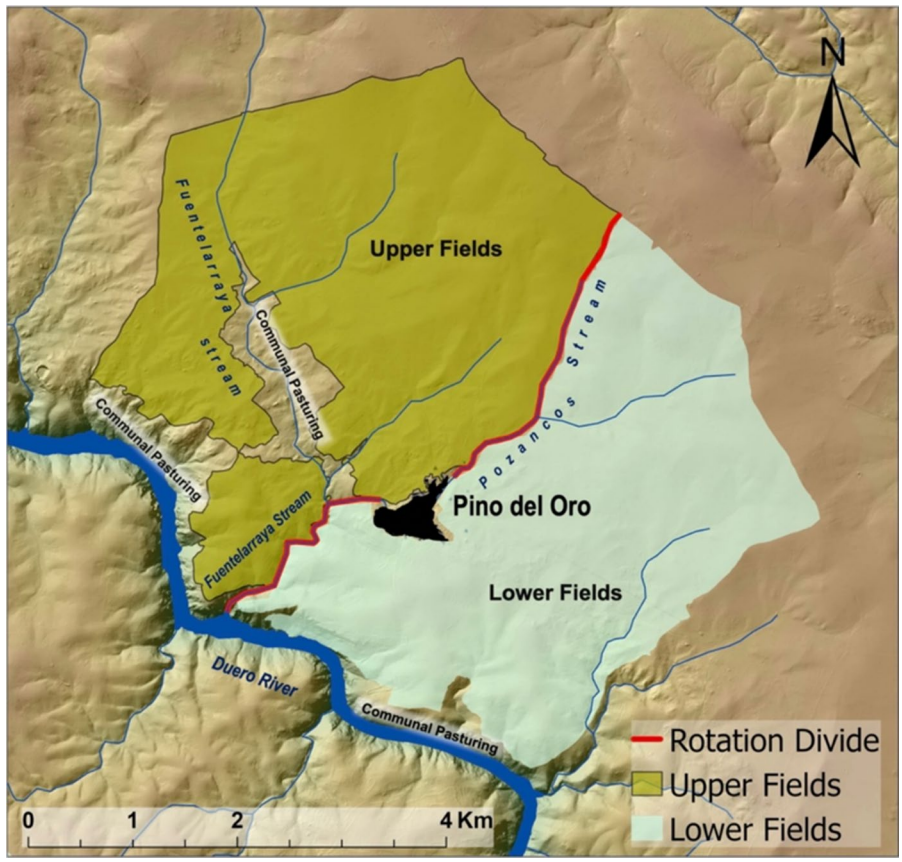


Fig. 5 Field rotation halves of Pino del Oro identified in the participatory mapping of LSK

areas and when available, significant events, legends, and/or memories that occurred in these referential toponyms. The toponyms in Table 2 are not a comprehensive list of all the toponymy in the village. The geolocation of the toponyms discussed in the interviews is in the Supplementary Information (SI Fig. 1). From the interviews and mapping of toponyms with informants, local landscape history detailing traumatic events such as flooding or historic murders were often intertwined with temporal land use of the territory under the toponyms. Additionally important to landscape character, was the past to present ownership of land in which social class in the village was discussed by informants. The perception study provided background on social divisions in the village and the participatory mapping of toponyms down to the level of enclosures provided detailed areas of the landscape where these social tensions occurred as in the case of the San Esteban area (SI Table 1 and text Table 2).

Mapping the LSK of abandoned watermills

In Pino del Oro there were three watermill zones mentioned by informants. Through interviews and a walking survey with a GPS device. Fifteen watermills in three zones in total were mapped. The first zone is the Fuentelarraya stream northwest of the centre with one watermill. The second zone is closest to the village centre is also located on Fuentelarraya stream which flows out of the northwest from into Pino del Oro and eventually merges with the Duero. It has a tributary stream called Pozancos with one watermill which flows from the northeast before merging with Fuentelarraya stream west of the village centre. Ten watermills were located in this zone. The final third zone is the furthest from the village centre and consists of four watermills. In most cases very little remained of the stone watermills. In many villages throughout this NW region, a flash flood that occurred in the summer of 1971 destroyed many watermills. Among the few

Table 2 Toponyms described by informants in Pino del Oro's landscape

Toponym	Land use/history/change	Significant event/legend/memory
Peña Llonga (Valdelameda)	Pasturing	
Valdebesa	Cultivated area – 'Dries faster now because it is not cultivated as before'	
Maluez and south	Rye grows better in soil	1955 destructive flood washed away much topsoil
Flechoso	Vineyards, 'There used to be vineyards in the 1960s and earlier – today shrubland'	
Monago and north	Wheat is more common from here north – better soil conditions	
Los Cuadros	Cultivation, now partially abandoned	All of it was a dehesa (large privately owned land) south to the Duero River
El Carbajo	'Important watering hole for pasturing due to it having a nonabsorbent rock base'	
Prados de la Iglesia	Pasturing	Belonged to church but sold off to private owners
Las Carretas	Stone bridge built to allow cattle to cross when the water was high	
Lago de los Tres Muertos (Lake of the three dead)	Area around Lago de las Tres Muertes was cultivated	Name comes from legend of when Napoleon's troops entered this area. They killed a mother, father, and daughter in 1808. Their bodies were supposedly found in the water
Valformoso	Vineyards	1955 destructive flood washed away much topsoil
Llagomesero	Rye and carob tree groves, pasturing inland and river canyon pasturing close to the Duero	
Pistaño	River canyon pasturing of goats and some sheep	
San Esteban	Microclimate cultivated area with vineyards and potatoes, garlic, figs are cultivated	Difficult area to plough, where the poorest worked the land.' Our grandparents cultivated there.' Much of it is gone now and covered in scrubland.'
Los Turieles	Pasturing/cultivation	Land owned by lesser nobility – 'a count' – later sold to villagers
El Franciscal	River canyon pasturing—communal	

remaining partially intact is the watermill El Piélago in zone 2 (SI Fig. 2).

The furthest watermill from the village in ethnographic memory in the arroyo Fuentelarraya and closest to the Duero was called *El Perdigero*. It is also mentioned in the 18th century Catastro del Marques de Ensenada document. Access to the mills was in a steep and narrow river valley which required a significant of amount of travel time to arrive. A local expression, indicating the distance of the mill from the village center states, 'It's taken you longer than to go to the Perdigero watermill!'.

The mid-18th century *Catastro of Ensenada* (CME) was consulted for historical data. Both a census and cadastre for the territory of the Crown of Castile, it provided historical information on properties, watermills, and land use for numerous villages. The entry for Pino (del Oro) is found in the historic archive in the city of Zamora and online at https://pares.mcu.es/.

The CME for Pino, unlike other entries, does not provide a popular name for each watermill. Instead, only the owners' names are given. Occasionally, the field name where the watermills are located is given. Many of these field names and locales still exist and were confirmed by both informants and the Spanish cadastre. In these situations, the watermills were able to be identified and geolocated (Table 3). The zones and mapped geolocations of the watermills are shown in SI Fig. 2.

Table 3 Watermills geolocated with informants and their mention in the CME

Participatory mapping	CME of 1754	GPS coordinates
Ethnographic account of watermills (by name) from north to the Duero River	*CME mentions of owners and fieldnames that likely match current mill locations*	*WGS 1984 reference system*
Las Trisales		N41° 35.063′ W6° 08.156′
Pintejo (Tio Sanbeira) in el Carretas		N41° 34.855′ W6° 08.069′
Del Cubo		N41° 34.709′ W6° 07.907′
Arroyo de Arriba		N41° 34.681′ W6° 07.934′
Unknown Name ("mill near the puntones del Pasadero")	Likely the watermill of Antonio lbáñez in el **Pasadero**	N41° 34.631′ W6° 07.933′
Tio García		N41° 34.589′ W6° 07.904′
Del Dominguez Castaño		N41° 34.578′ W6° 07.924′
Matacucos (located NE of Tio García)	Watermill of Miguel Castaño in **Matacucos**	N41° 34.620′ W6° 07.790′
Molino de (las cabezas del) Pielago	Watermill of Cathalina Baquero in **El Pielago**	N41° 34.532′ W6° 07.900′
Uncertain (2nd Pielago)		N41° 34.481′ W6° 08.003′
La Vuelta de Namillas		N41° 34.452′ W6° 07.998′
Sortico el Rey		N41° 34.402′ W6° 08.157′
Del Rey Pizarrón		N41° 34.374′ W6° 08.177′
Pizarrón		N41° 34.300′ W6° 08.201′
Perdigero	Watermill of Andres Alonso in el **Perdigero**	N41° 34.136′ W6° 08.400′

Historic Landscape Characterisation

Use of LSK in the HLC

The participatory mapping of intangible and tangible landscape attributes and the ethnographic detail that came with them allowed for a more complete understanding of Pino del Oro's temporal landscape character and provided additional information for the HLC database and temporal map creation (Fig. 3).

Field rotation system

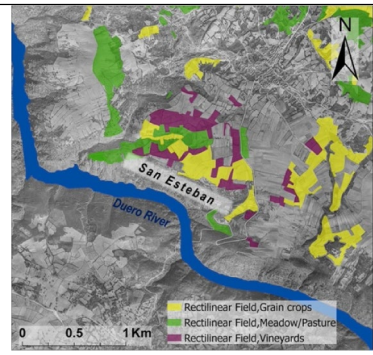
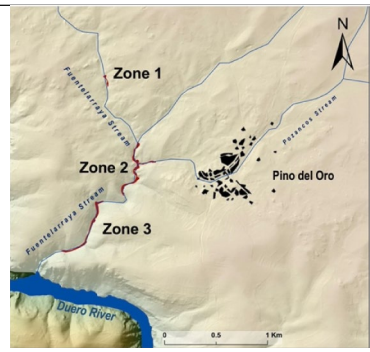
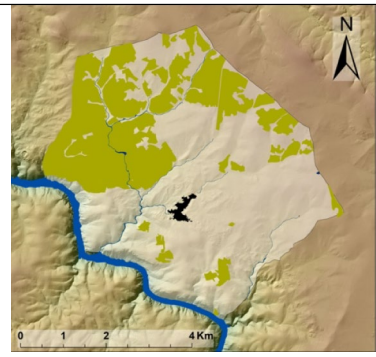
An intangible landscape attribute, the field/pasturing rotation system aided in understanding historic land use management and the landscape character of Pino del Oro (Fig. 5). In the HLC database the northern half of the system polygon was called field rotation system 1 and the southern half field rotation system 2.

Toponymy

Through participatory mapping workshops and walking surveys, residents in Pino del Oro indicated many areas historic land use, often through referential toponyms. Integral to many Mediterranean rural agrosilvopastoral systems often dating back to the Medieval Period are vineyards (Alfonso-Antón 1980). Informants geolocated historic areas of viticulture on the landscape even if they had been abandoned in recent decades. One area that was described in a workshop and walking survey was the area near San Esteban. This was also confirmed with the early 20th planimetric map of Pino (del Oro). Figure 6 shows the HLC map for 1950s Pino del Oro and the distribution of vineyards, grain cultivation, and grazing lands in privately owned rectilinear fields near the San Esteban toponym.

Watermills

The clusters of watermills into work zones in relation to their distance to the village centre is based on Hearn and Carrer (2022). In the HLC these zones are integral to the local landscape history, character, and identity as they represent a significant period of use spanning definitively from the Modern Period to their abandonment in the mid 20th century. The zones are indicated as red polygons in the HLC in Fig. 6.

Participatory Mapping	LSK attribute or broad type confirmation	HLC input
 Vineyard remnants in San Esteban	Toponomy – San Esteban	 HLC of 1950s
 El Piélago, N41° 34.532' W6° 07.900'	Watermill zones	 Watermill zones in red
 Wildfire, 08/2017, west of village centre	Confirmation of 'Denuded Ground' broad type	 Denuded Ground in olive colour
 Burnt area and reservoirs 08/2018	Toponymic characterization & Confirmation of 'Denuded Ground' 'Reservoir' & broad types	 Reservoirs in 2010 HLC

◂**Fig. 6** Examples of LSK input into HLC

Broad type confirmation of land use and land cover changes

Participatory mapping with informants provided further detail for the broad type 'denuded ground' for the HLC. Informants indicated temporal changes on the landscape from formerly cultivated and pastured areas that became more densely vegetated and had been severely burnt from the extensive 2017 wildfire of more than a third of the village territorial landscape. Walking surveys with informants in Pino del Oro del Oro from 2017 to 2019 demonstrated the extent of the burn and the beginnings of grassy and shrubland regrowth (Fig. 6). This 'groundtruthing' provided more precise detail to the shapefile of the 2017 wildfire damage in the municipality.

Two water source broad types in the HLC were added and given both temporal depth and tied closely to local identity related to historical and recent events. Under the broad type of 'reservoir' in the HLC database, informants indicated the creation of a reservoir 10 years before by damming a portion of the Fuentelarraya stream to be used as a water source for firefighting (Fig. 6). The Lake of the Three Dead (Table 2) described from the toponymic analysis was also entered as a reservoir broad type due to its size. The story behind the toponym added more to the local identity behind this landscape broad type as well as the land use of the fields surrounding it (Fig. 6).

Analysis: quantitative detection of temporal land use and landcover change

Temporal quantitative analysis with HLC (Fig. 3) demonstrates a managed agrosilvopastoral landscape from the early to mid-20th century. The village follows a rough concentric pattern of land management typical of and likely inherited from the late medieval period (Glick 2003). It is still visible today and was definitely in full use for much of the 20th century. This concentric pattern of rural land management starts with a village nucleus of small family horticultural plots interspersed between homes up to the immediate outskirts of the nucleus in the local Spanish called *cortinos.* Extending outward concentrically this is followed by larger, irregularly formed stone enclosures called *cortinas*. Cortinas are privately owned and used for cereal cultivation and/or pasturing or corralling of grazing animals, mostly ovine. Beyond the cortinas are open communal strip fields, managed woodlands *monte alto*, and shrublands *monte bajo* used for rough grazing. Privately owned, further afield, but unincorporated into the *cortinas* were extensive rectilinear enclosed fields used for viticulture, cereal agriculture, carob cultivation, and grazing. Communal rough grazing played a significant role in the management of the landscape particularly in the river canyons.

From the early 20th century to the early 1970s, this largely non-mechanised form of landscape management was dominant in Pino del Oro and throughout much of the region (Fig. 7). By the 1960s and continuously to the present, emigration to the cities both domestic and abroad contributed to a decline and an abandonment of this landscape management system leading to a rise in vegetative growth. Corresponding with these national events, informants provided localised information:

> *'In the time of the post-war there was a lot of poverty and many people emigrated to other parts of Europe and they did so with objective of saving enough money to return to buy a tractor to leave behind the use of the cow and donkey.'* (Informant early 60s).

By the 1990s, shrubland increased significantly to 45% in areas that had once been cultivated and/or pastured (canyon pasture, rectilinear fields, cortinas, and strip fields (Fig. 7). Although not as significant, woodlands also increased to 3.5% of the area by this time period. In the Supplementary Information (SI Table 1), informants perceived a definite increase of woodland and shrubland vegetation from their childhood (in the 60s, 70s or earlier) compared to the present.

By the 2010s, continued abandonment coinciding with national park conservation strategies, led to a heightened level of dry scrub vegetation. The 2017 wildfire caused significant damage burning much of this new growth vegetation. A vector file provided by the Territorial Environmental Service agency of Castile and León autonomous region government located in Zamora province demonstrated the extent of this fire (Fig. 7). The HLC broad type of denuded ground rose significantly to 32% at this time and resulted

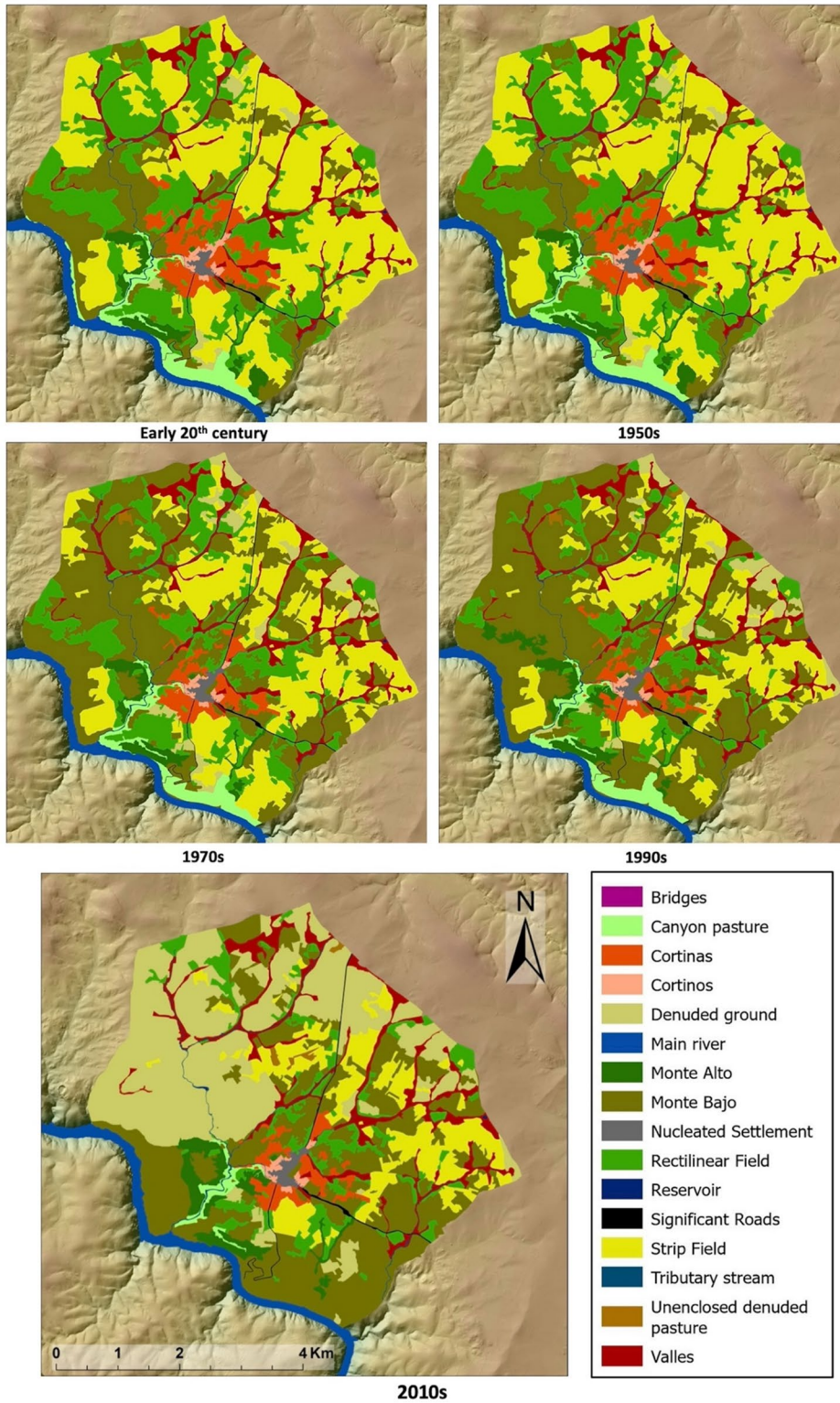


Fig. 7 HLC broad type temporal changes. Denuded ground broad type represents extent of 2017 wildfire

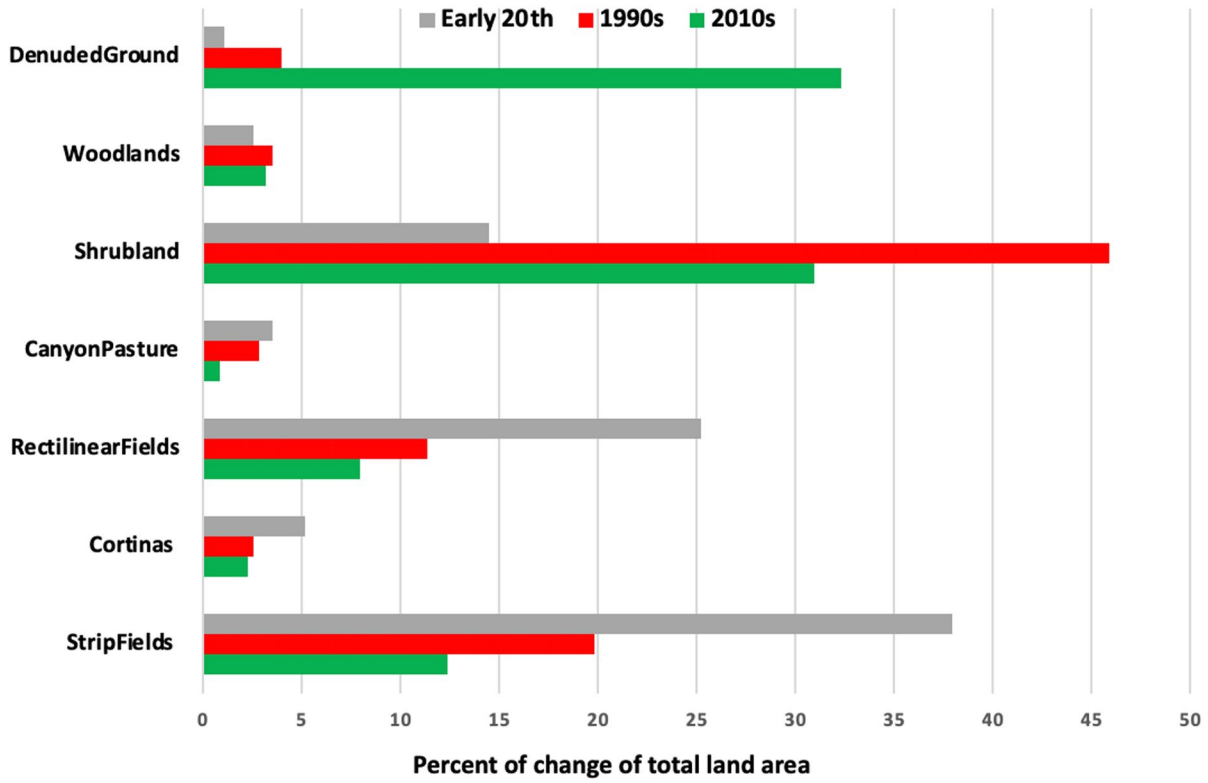


Fig. 8 HLC broad types percent of change from early 20th century to 2010s (Woodlands = Monte Alto, Shrubland = Monte Bajo)

in slight decreases in both woodland and shrubland areas affected (Fig. 8). Despite this, human use of the landscape continued its downward trend with decreases in all pasturing and cultivation attributes (Figs. 7 and 8).

Discussion and implications of this study

Integrated approach and findings

This integrated analysis identifies several themes related to the evolution of the study area landscape. From the ethnographic methods, residents provided their perceptions and demonstrated aspects of the historical use of the landscape and its evolution to the present day. With the participatory mapping of landscape attributes, it has demonstrated the LULC evolution represented by the temporal changes from more intensive agrosilvopastoral use to abandonment on the landscape. Together, the ethnographic perceptions and LSK provided by interviews and walking surveys with informants informed the more map-based HLC analysis through the identification of different types of landscape use, vegetation types, management, and abandonment and its consequences through time. In doing so, the use of participatory methods in this research addresses a strong criticism of the more top-down analyses—that they lack the subtleties and nuances that can only be interpreted from the ground up and would benefit from the inclusion of participatory mapping into the HLC toolbox (Williamson 2007; Dalgish and Leslie 2016; Turner 2018; Dabaut and Carrer 2021).

In the ethnographic interviews in Pino del Oro, knowledge of the landscape history and its evolution were best described by informants old enough to remember the landscape when it was used for agrosilvopastoralism. As these residents recalled the landscape of their youth, they imparted landscape history and used referential toponymic markers to indicate where and when these changes occurred. Knowledge of toponymy with these older villagers was tied to village events, anecdotes, or to a more practical level of

where to plant, prior and contemporary land ownership, where to pasture, where milling occurred, where to acquire firewood and building materials, and where to water and corral livestock. This practical knowledge (tied to toponymy) revealed aspects of Pino del Oro's agrosilvopastoral heritage. This study's toponymic analysis has also emphasised the importance of toponymy as a means to better understand landscape history and organisation and relates to similar research that views toponymy as a valuable tool for landscape characterisation (Fernández-Mier 2006; Rippon 2012; Atik and Swaffield 2017; Atik et al. 2022; Hearn et al. 2024).

Using HLC, the historical processes of landscape change brought on by the socioeconomic and political forces that have contributed to them have been highlighted and explained by both ethnographic testimony and archival information. With HLC, the different types of temporal landscape exploitation and changing landscape values have all been underscored through the method's time layered analysis. In Pino del Oro, the historic role and eventual decline of agrosilvopastoralism can be seen (aided by the participatory approach) down to a hectare level scale through both intangible (toponomy) and tangible (enclosure morphology and LULC) facets. Additional landscape features such as the reservoir created in the 2010s (Fig. 6) could only have been detected and added to the HLC with detail provided from participatory mapping. Top down sources such as the Spanish cadastre, while detecting an abundant accumulation of water, do not identify the area as a manmade reservoir.

The impact of both landscape abandonment and conservation values implemented with the creation of the natural park and biosphere reserve on LULC since 2002 can be visualised in the HLC's 1990s and 2010s time layers. The HLC and participatory approaches tie into the greater body of literature that identifies rural abandonment, especially of agrosilvopastoral traditions, as a major driver for temporal land cover change in the Iberian Peninsula (García-Ruiz et al. 1996; Lasanta-Martínez et al. 2005; Hearn et al. 2024).

Wildfire is an important factor in this dry, inland, Mediterranean climate region. This combined approach has demonstrated the impact of increased vegetation in this region and its consequences. Quantitative empirical studies of diachronic LULC change in the Arribes del Duero international park region and Meseta Iberica Biosphere Reserve have been limited. Marino et al. (2017, 2020) provides an overview of scrubland and arboreal vegetation types and their proliferation of a portion of the Arribes del Duero region. With this increase of growth, he also emphasises that wildfire is a consequential and ever present threat to this changing landscape. As traumatic events, wildfire impacts local identity adding to a sense of loss from all residents. While abandonment, has undoubtedly changed the character of this landscape, the decline of agrosilvopastoralism and the creation of the natural park and biosphere reserve is considered a boon for those tied to recreationist tourism.

Implications for heritage conservation

This interdisciplinary study revealed never before mapped and nearly forgotten historical features of this rural landscape. As rural landscapes continue to be abandoned in Spain and in fact many parts of the Mediterranean Region, there is a loss of heritage, knowledge, and traditions that are tied to the landscape, its past, and often historical sustainable use (Marull et al. 2014; Otero et al. 2015). This loss of heritage is accelerated by the intertwined biodiversity and climate crises that impact and change the landscape (Vidal-González et al. 2024). Landscape abandonment leads to a loss of collective memory and local spatial knowledge (Rippon 2012; Atik et al. 2022; Hearn et al. 2024). These tangible and intangible rural features are markers of a past sustainable use of this and many other agrosilvopastoral local landscapes. In Pino del Oro, fifteen watermills (tangible heritage), in various states of decay were located and mapped for the first time. The field rotation system used to manage agriculture and pastoralism (an intangible tradition) was documented and also mapped for the first time in the village. Toponymic analysis revealed collective identity and local landscape history of management, use, identity, and even traumatic events that have all contributed to a visible landscape morphology that has been temporally mapped. The documentation and mapping of these historical features together with the temporal landscape attributes identified through HLC developed with this study highlight the need to utilise tools to effectively document the landscape history of villages like Pino del Oro that are in danger of disappearing and with them

the unique generational knowledge developed to sustainably manage the landscape.

The final results of this transdisciplinary study were developed in collaboration with the residents of Pino del Oro. The participatory maps of the intangible and tangible landscape attributes, the HLC maps, and GPS coordinate readings were presented in a public forums and given to the town hall and the state agency administering the Arribes del Duero Natural Park. Attendees, including the public authorities, expressed not only gratitude for formalizing their local spatial knowledge in maps, but also expressed the importance of valorising and conserving this landscape heritage knowledge for their future. Landscape abandonment and its effects on the landscape and its people is a concern for Pino del Oro and many rural villages in Mediterranean Europe. This study provided information of what is in danger of being lost and also tools that regional and local planners can use to promote economic development through tourism such as interpretative hiking trails along the watermills zones as well as manage these heritage landscapes to prevent the continued loss of biodiversity in these once sustainable landscapes.

Methodological considerations

Working within and between ethnographic, historical, and contemporary datasets there are conflicting data and challenges that require acknowledgement. Ethnographic data, although instrumental, lends itself to possible inconsistencies and/or variance. Toponymic study faces challenges in accuracy (Tent and Blair 2011; Tent 2015). Spelling conventions, historical meaning, geolocation, and LULC around toponymy were occasionally found inconsistent. Through a comparison of all available related datasets, however, the most repeated information (written and oral) provided the 'common denominator' to be presented.

The 'saturation' method used in ethnographic interviews aided in assessing collective memory, but minority views still hold value to understanding the complexity (and sometimes contradictions) of a community's landscape perception. A case in point was the perspective of the *casa rural* owner who depended on tourism. While many of the community held disdain for the natural park and biosphere reserve and the land use restrictions they enforced, his livelihood depended on tourists coming to experience the overgrowth of forest and shrubland of the protected area. Simultaneously, the owner fully understood the correlation of increased dry vegetation and summer wildfires.

Integrating intangible, ethnographic/participatory, and spatial data with the defined HLC mapping approach required specific adaptations. The crop rotation/transterminant pastoral tradition is an intangible landscape tradition that had never been mapped. Conferring with informants to use identifiable landscape markers such as roads, paths, and streams allowed for a definitive map rendering of this heritage landscape use.

Limitations

Using archival information from the CME of the 1750s to determine the quantity and names of the municipal watermills had several inconsistencies. The CME lists over 22 watermills according to the name of owner at the time. Informants geolocated 15 watermills. Over the centuries since the CME, their names have changed making it challenging to determine exact matches to the watermills described by informants in the present.

Using Participatory Mapping required a different approach when interacting with informants in this case study. A digital approach more commonly found in research conducted in urban areas with greater high-speed internet infrastructure and a more tech-savvy population was not possible. The use of internet mapping technologies for participatory activities with some informants in this rural area of diminishing population would not have been possible due to a lack of reliable internet service and that because some informants, many of advanced age, would have felt overwhelmed if asked to learn and use these unavailable services in the village.

The advanced age of residents in Pino del Oro lends itself to yet another limitation to conducting research in many European Mediterranean Region rural landscape studies—that of diminishing populations. Already historically small settlements, emigration, age related illnesses, and increased mortality limits the pool of available informants capable of providing the Local Spatial Knowledge and retelling of local landscape collective memories and identity. Accessing this diminishing human resource is paramount to better understand the heritage and traditions

of these rural landscapes. The sample size for small, rural, farming villages is not unusual as found in other similar studies (Mohr et al. 2024).

Conclusion

In this study, the results of this integrated approach provide a temporal multi-perspective understanding of human decisions and consequences of using and abandoning the landscape in Pino del Oro in northwest Spain. As a starting point for understanding the landscape, the ethnographic perception and knowledge of landscape change attained from the perception study and participatory mapping and interviews provides further detail to the HLC that cannot be attained solely by a top down analysis of historical maps and aerial photography. Interweaving ethnographic and empirical spatial data sets in a GIS has reconfigured them into a reproducible analysis in the HLC. This newly created spatial model can easily be modified and/or amended through its database. In doing so, this study addresses two gaps in heritage landscape research; the call for more democratic inclusion of bottom-up perception and local spatial knowledge as outlined in the Faro Convention and the specific need for integrating more participatory methods to HLC studies.

The value of this study is two-fold. On a regional level, it provides valuable data demonstrating stakeholders' values, perceptions, and most importantly, knowledge of landscape change that is supported with clear, quantitative results. For heritage landscape research it demonstrates the value of using a combined approach utilising different methodologies to provide a more nuanced and precise understanding of temporal landscape change that can be replicated and adapted to many different contexts.

For the future sustainability of this village and others within the region, the use of approaches that include and value both stakeholders' perspectives and more quantitative methodologies can provide a more detailed characterisation of past to present landscapes. The new spatial datasets created with this approach can aid local policy makers and conservationists in wildfire management with the identification of abandoned, highly vegetated areas and promote rural tourism in the protected park zone area. Most importantly, they can provoke both a revalorisation of this and other heritage landscapes and allow for more effective territorial management that values people's role in the history and future sustainability of these rapidly changing landscapes.

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Author contributions Kyle Hearn: Conceptualization, Methodology, Investigation, Formal analysis, Writing—original draft, Writing—review & editing, Visualization. Nora Fagerholm: Conceptualization, Writing—review & editing, Funding acquisition, Supervision. Both authors read and approved the final manuscript.

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Data availability No datasets were generated or analysed during the current study.

Declarations

Conflict of interest The authors have no relevant financial or non-financial interests to disclose.

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