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The social-ecological landscape of herding on the high mountain commons of Larrau in the western Pyrenees (France)

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Introduction: Much has been written about herding, pastoralism and the ethos of the commons that persists in Soule and the valley republics of the western Pyrenees. However, more has been written about the idealized norms of the practice than the social dynamics of alliance formation on which cooperation in herding on the high mountain commons in Soule has depended for centuries. We use empirical evidence from the parish-commune of Larrau to analyze the emergence, social alliance, and landscape placement of Cayolar, a syndicate of herders associated with a named inholding within the high mountain commons, to inform our understanding of the process of settling down in the western Pyrenees.

Methods: We abstract the institutional features of herding in the Soule Valley then proceed with a (1) Bayesian analysis of calibrated radiocarbon dates from herding sites across the commons, (2) a Bayesian social network analysis of herders and other alliance-relevant information, and (3) a landscape analysis of the placement of Cayolar inholdings.

Results: A syndicate of herders organized as a Cayolar succeed by following mutually agreed upon rules, making credible commitments to each other, and monitoring members' conformance to the rules. The organizational performance of a Cayolar depends on the articulation of herders to the members of the Soule community of interest through nested levels of institutional decision-making. Archaeological, historical and ethnographic results provide direct evidence for use of Cayolar structures and inholdings by c. 1000 CE and the institutional and organizational aspects of decision-making by c. 1100 CE.

Discussion: The Cayolar is an enduring place-based organization with an average use-span of c. 850 years. Members have a regulatory interest in enforcing the collaboration of others in collective herding and little incentive to defect since unlike Hardin's herders, Cayolar members share a past and expect to share a future as members of the Soule community of interest. Íñigo Arista established the Basque kingdom of Navarra in 824 CE, and his donations contributed to the founding of the Benedictine monastery of Leyre that established a pastoral enterprise at Betzula within the Soule Valley. Other monastic orders soon turned their attention to the western Pyrenees responding to attempts by the Catholic Church to counter civil unrest in southern France. The real turning point for collective herding on the high mountain commons was the introduction of primordial fueros on the Iberian side of the Pyrenees. These direct royal agreements with freemen encouraged resettlement and repopulation of the western Pyrenees and provided the means for local communities of interest to coalesce and develop institutions to organize the collective effort of individuals for the benefit of a group.

KEYWORDS

Bayesian analysis, collective action, radiocarbon dating, social network analysis, vertical transhumance

1 Introduction

Theoretical understanding of the transition from mobile to sedentary lifeways is colored by reliance on a categorical paradigm that is often at odds with empirical evidence pointing to the interplay of individual agency and networks of social affiliation (Feinman and Neitzel, 2023). People are simultaneously social and selfish and, despite decision-making abilities, limited in their ability to process information (Kahneman, 2011; Cronk and Leech, 2013; Thaler, 2015; Feinman and Neitzel, 2023). However, for communities to endure in the face of social and environmental challenges, people must often find new ways to cooperate by forming institutional arrangements. Our contribution on communal herding in the western Pyrenees Mountains and its Medieval antecedents, documents the social and environmental contexts surrounding the emergence and longevity of a cooperative herding institution called a Cayolar that enabled the intensive seasonal exploitation of high mountain pastures. Scholarly understandings of mountain herders, in particular, have been imprisoned by the belief that "…above 1,000 m, there is no history" (Falque-Vert, 1997, p. 9). While archaeology typically depends on material proxies of collective action (Gragson et al., 2020; Feinman and Neitzel, 2023; Quirós Castillo et al., 2023), in this paper, we relate archaeological evidence of land use and settlement to ethnographic and historical evidence of the less tangible institutional and organizational aspects of how Basque herders overcome conflicts of interests and issues of coordination.

It has been suggested that the creation of upland pastures in the western Pyrenees was an abrupt transition resulting from rapid, intentional landscape conversion in alignment with conventional archaeological periods (Rius et al., 2009; Galop et al., 2013). Such satisfyingly simple explanations are often based on a single archive, the opinion of a single agent, or the population inferred from an SPD of calibrated radiocarbon dates (Coughlan, 2015; Gragson and Thompson, 2022). Our results-to-date in the western Pyrenees and that of others in comparable mid-elevation mountain settings suggest the agropastoral niche emerged across Europe through a slow, non-linear, cumulative and persistent press linked to social processes that are still under debate (Arnold and Greenfield, 2006; Gragson et al., 2020; Quirós Castillo et al., 2023). Netting's (1972, 1976, 1981) seminal work in the community of Törbel documented cooperative mountain agropastoralism as a static and bounded end point in the effort to find a sustainable balance between community and environment. There are clear similarities and important differences between Basque agropastoralism in the western Pyrenees and that described by Netting in the Swiss Alps. The comparative value of these two cases (and others on mountain agropastoralism) is how they inform our understanding of individual agency, the surprising solutions communities of interest can arrive at to overcome social dilemmas, and how these improve our ability to explain phase shifts such as settling down.

Olson (1965) initiated the first period of collective action inquiry by challenging the assumption that individuals would voluntarily form alliances to the benefit of a group. His contribution was framed by market theory and considered how a perfectly rational individual with perfect information (i.e., *Homo economicus*) would make a decision about collaborating with others using objective costs and benefits. This challenged many to offer empirical examples of selfish individuals incurring personal costs to coordinate with others for the benefit of a group (McCay and Acheson, 1987; Feeny et al., 1990; McCabe, 1990; Smith and Wishnie, 2000) and marked the start of the second period of collective action research spearheaded by Ostrom (1990). She recognized that rationality was contingent rather than absolute and showed in case-after-case how individuals combined costs and benefits with shared norms and opportunities in a subjective calculus to reach a decision about whether or not to collaborate with others. This served to shift attention away from the internal calculus to the situational variables conditioning an individual's decision-making. These variables included attributes of the resource system, the resource units, and the resource appropriators including the social facilitators of collective action such as the willingness of individuals to accept personal costs to punish a free rider (Van Zomeren and Iyer, 2009; Cronk and Leech, 2013; Jagers et al., 2020; Thomas et al., 2020).

Ostrom (1990) frequently used Netting's example of Törbel to illustrate what she referred to as the design principles of collective action. It is nevertheless important to recognize that Netting (1972, 1976, 1981) framed his study in light of contemporary issues in ecological anthropology. This included identifying cybernetic regulatory mechanisms to socially enforce conservation and equitably share the benefits of communal effort. Netting added historical and demographic dimensions to the inquiry as these were largely ignored in ecological anthropology investigations at the time. The value of Netting's contribution is without question yet there are conceptual, methodological, and analytical means available now to investigate the processes of change and collective action across time (Thompson et al., 2018; Feinman and Neitzel, 2020; Quirós Castillo et al., 2023) that were not available when Netting pioneered the study of how the people of Törbel balanced on an alp.

We begin our study of Basque communal herding by abstracting from diverse sources how the Cayolar as both an organization and a structure is embedded geographically and socially in several decision-making levels within the Soule Valley. Using original data we collected in the parish-commune of Larrau we: (1) Evaluate the use of Cayolar structures through a Bayesian analysis of calibrated radiocarbon dates from herding sites across the commons constrained by cadastral and other historical records. (2) Examine the social alliance of herders in Cayolar organizations through a Bayesian social network analysis of herders and other alliance-relevant information extracted from cadastral and voter records. (3) Examine the placement of Cayolar inholdings in the landscape using field-collected GPS data, cadastral records and a digital elevation model. In our concluding discussion, we combine the institutional, historical, archaeological and landscape evidence to understand how it conditions the agency and alliance of herders on the high-mountain commons and then drawing from several sources identify the antecedents for governing the commons in the western Pyrenees.

1.1 Setting and context

This study of Basque herding is based in the Soule Valley (Xiberoa, in Souletin Basque hereafter SB) on the north-facing western Pyrenees Mountains (Figure 1). It is the smallest of the three Basque Provinces in France with a territory of 785 km^2

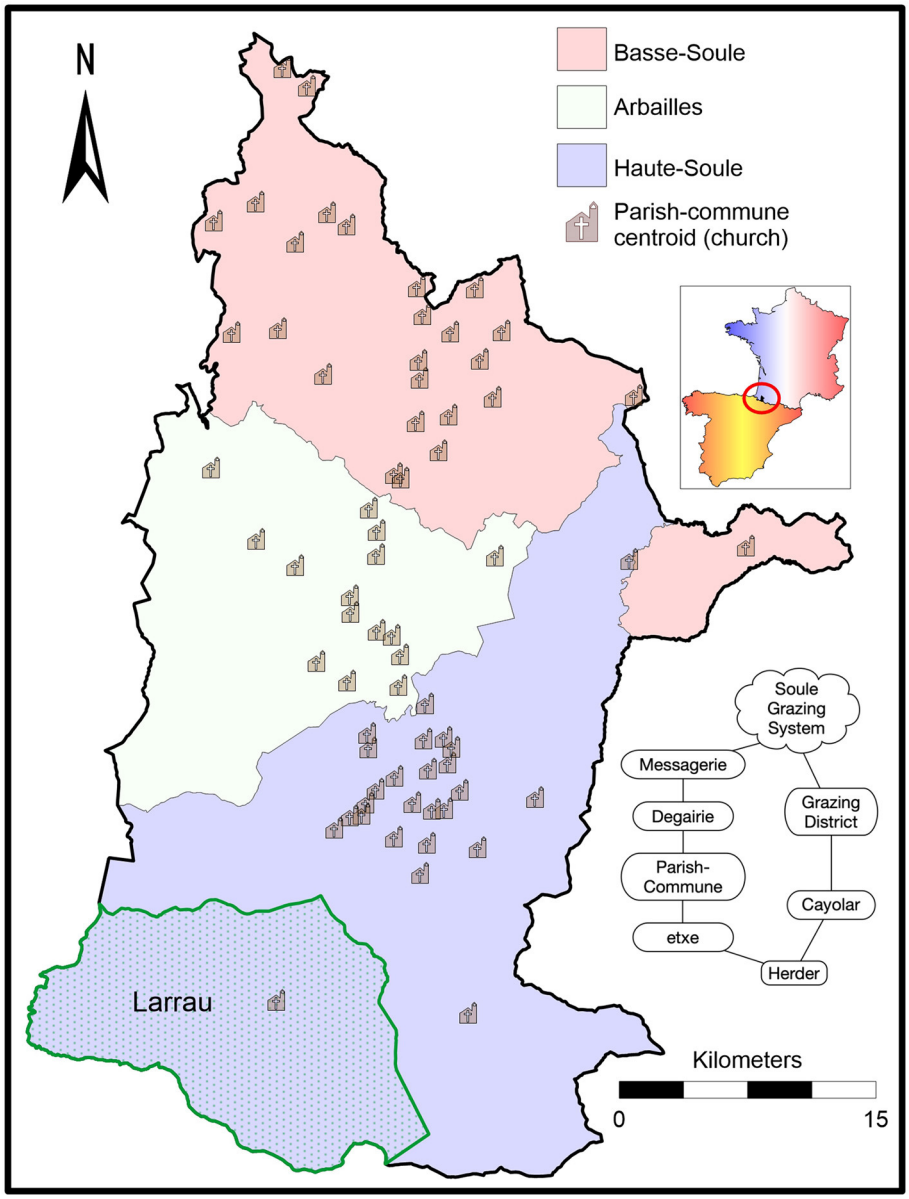


FIGURE 1
Soule Valley with location of parish-communes and the lower, middle and upper provinces into which the valley is divided, and the conceptual relation (insert panel) between named geographic elements associated with the Soule grazing system.

centered on the axis of the Saison River where we have conducted place-based investigations for several years on the onset and progression of pastoralism above 800 masl. The western Pyrenees Mountains form the hinge between the Ebro River Valley to the south and the Aquitanian Plain to the north. They are central not only to the agropastoral domestication of European landscapes but the rise and fall of renowned lords and kings in their battles for control over people and territory. Our investigations in the Soule Valley include stratigraphically sampling slope wash deposits (i.e., colluvium from zero-order watersheds) back to the Late Pleistocene ca. 20,000 BCE to recover multiproxy evidence for landscape fire (Leigh et al., 2015, 2016). We have also carried out ethnographic and historic research on the use of pastoral fire to manage common grazing lands as well as the processes of land use change and household abandonment (Coughlan, 2013; Coughlan and Gragson, 2016; Coughlan et al., 2022).

The use of high-mountain pastures in the Soule Valley can be summarized as a summer event recurring from time-out-of-memory that involves hundreds of Basque herders from dozens of villages across the valley converging with thousands of sheep on to the commons in the parish-commune of Larrau. The sheep consume grass which they transform into milk that the herders transform into cheese. Much has been written about herding and pastoralism in the western Pyrenees beginning with the well-known accounts by Lefebvre (1928, 1933) and Cavaillès (1931a,b). Ott (1993) conducted research on the parish-commune of Saint Engrâce bordering the parish-commune of Larrau, both located within the Soule Valley. None of these works substantively address

the process of herders forming alliances to the potential benefit of the 30,000 inhabitants in the Soule Valley living in 68 towns in the early 19th century. Törbel, by comparison, is a single closed-corporate community with a maximum population of about 700 in 1950 CE.

The Coutume de Soule first published in 1521 CE (Grosclaude, 1993) and older documents divide the Soule Valley into community lands and common lands. Community lands are enclosed within the defined boundaries of a parish-commune centered on a church. Common lands generally lie above 800 masl and consist of open rangeland and forest areas only available to residents of parish-communes within the Soule Valley (Noussy Saint-Saëns, 1955).

The parish-commune of Larrau contains 62% (9,257 ha) of the high common rangelands in Soule, and elevations that range from 300 to 2,000 masl. Flatter lands in the lower elevations (300–800 masl) contain the hamlet of Larrau centered on the parish church with houses, businesses and administrative buildings clustered around it. Privately held agricultural parcels are concentrated in the flatter areas peripheral to the hamlet. Steeper lands between 800 and 1,300 masl contain communal woodlands and heathlands as well as fragmented private inholdings (*borda*, SB). Named households (*etxe*, SB) owning the borda use them to harvest hay for feeding and bracken for bedding livestock in the winter (Palu, 1992; Gragson et al., 2020). Lands above 1,300 masl are the alpine and subalpine common grasslands and heaths used by herders from throughout the Soule Valley. Only residents of Soule have access to the communal summer pastures and only those who are members of a Cayolar have a right to graze sheep in the grazing districts.

Before turning to details of herding on the commons in Soule, we provide succinct definitions of relevant terms based on key collective action sources (Olson, 1965; North, 1990; Ostrom, 1990; van Zomeren et al., 2008; Van Zomeren and Iyer, 2009; Cronk and Leech, 2013; Jagers et al., 2020; Thomas et al., 2020). Collective action means action taken by two or more individuals to improve the status, power, or influence of a group, while a collective action dilemma (or collective action problem or social dilemma) refers to factors limiting collective action. Limitations to collective action are most commonly the result of individuals free-riding on the efforts of others or a failure to coordinate the action of individuals. For the former limitation, individuals cannot be excluded from the benefits that others provide so they are unmotivated to contribute to the effort themselves. In contexts involving common-pool resources such as open grasslands used for grazing, resource units removed from the common-pool reduce the quantity available for others yet the characteristics of the resource pool (e.g., size, etc.) limit the possibility of excluding potential beneficiaries. The failure to coordinate results from the uneven distribution of information and knowledge across individuals resulting in conflicts of interest between them as they attempt to find the solution to a social dilemma.

Individuals resolve collective action problems by either (a) supplying a new set of institutions, i.e., constraints that shape social interaction often expressed in the form of rules, (b) making credible commitments to those they cooperate with and/or (c) mutual monitoring to ensure everyone "follows the rules." These solutions require shared, common knowledge that translate to individual collaborators knowing the rules, knowing their collaborators know the rules and knowing their collaborators know they know the rules. Such rules are classified as operational, collective, and constitutional:

- Operational choice rules: these are the day-to-day decisions made by appropriators about when, where, and how to withdraw resource units, who should monitor the actions of others and how, and what information must be exchanged along with the rewards or sanctions allocated to actions and outcomes.
- Collective choice rules: these are rules used by appropriators, officials or external authorities in making policies about how a common poor resource should be managed.
- Constitutional choice rules: these rules determine who is eligible to participate in operational activities and which rules will be used to craft collective choice rules that in turn affect operational rules.

1.2 Institutional features of herding

A Cayolar is a syndicate of herders associated with a named inholding that serves as a gateway to the common lands surrounding it [Cayolar is a Gascogne word used in French equivalent to Olha in Souletin Basque and rendered as Kaiolar in Standard Basque (Ott, 1993; Barandiaran and Manterola, 2000)]. The inholding itself minimally contains a stone-walled and wood-roofed shelter (either a hut or a barn) used by the herders, a corral to hold the sheep and is generally near water (Figure 2). The most frequently referenced description of a Cayolar is from the 1521 Coutume de Soule (Grosclaude, 1993) with additional details derived from other sources (Lefebvre, 1933; Noussy Saint-Saëns, 1955; Ott, 1993; Etchegoyhen, 2012). Cayolar members participate in the syndicate by contributing a share (*txotx*, SB) equal to a finite, partible number between 45 and 60 head of milch ewes. The txotx is in fact the "purchase price" of a proportional title to the inholding. It is thus a credible commitment to the other members of the organization that the herder will follow the norms of the syndicate. The fundamental norm being that the herder assures the other members that they will contribute a flock of sheep equal in size to their txotx.

To achieve success in operating a Cayolar herders must: (a) supply a set of rules they agree to follow, (b) make credible commitments to each other, and (c) mutually monitor members' conformance to the rules (Ostrom, 1990). The appropriators must trust each other to succeed. As all are inhabitants of the Soule Valley, their shared history and expected future together substantially reduces each individual's future discount rate to collaborate in the present. Cayolar organizational performance is assured by the articulation between individual herders and the population of the Soule Valley through a set of nested spatial-institutional levels.

1.2.1 Operational choice level

A Cayolar organization consists of individual herders combining their share of sheep into a single flock. Individuals bear the personal costs and reap the collective benefits from

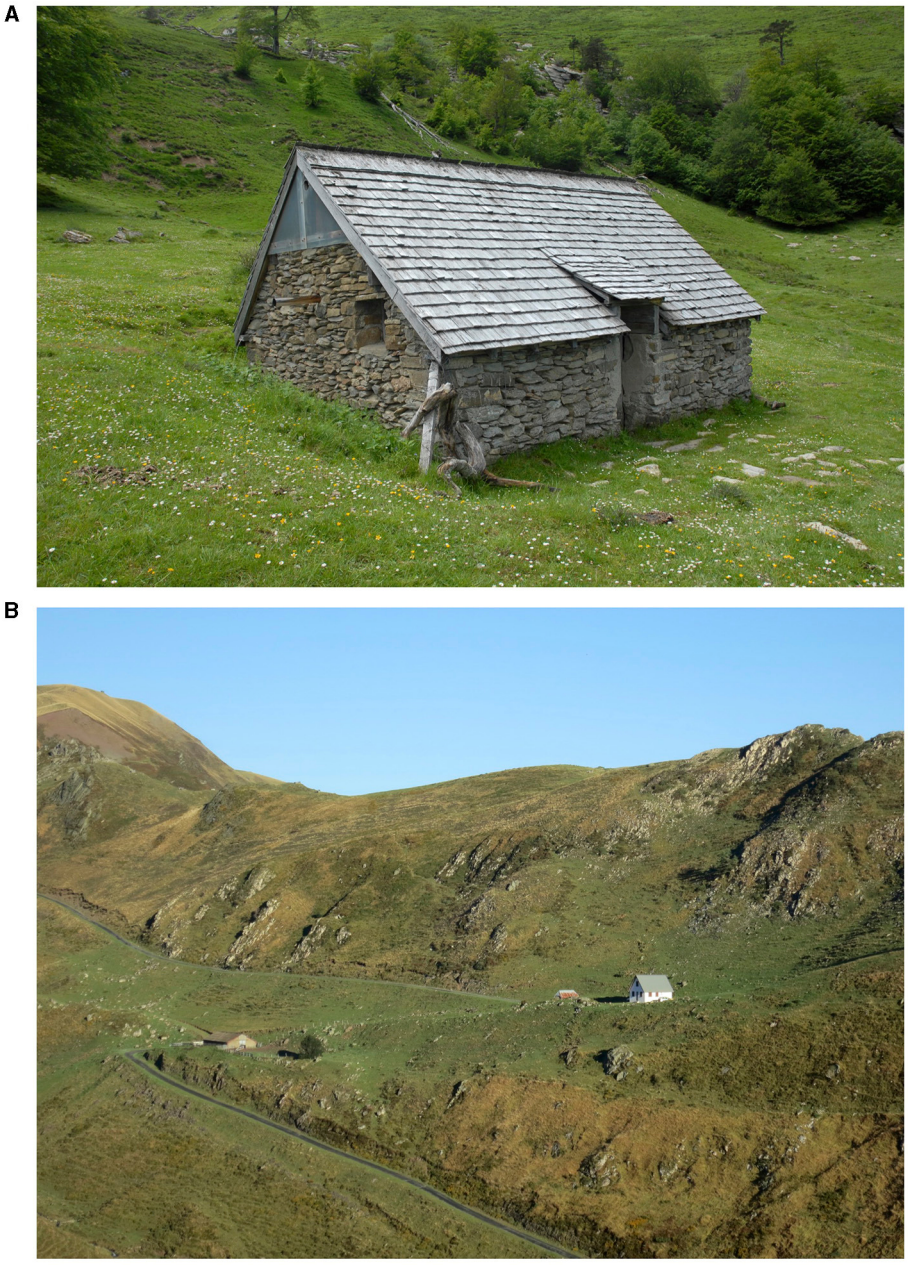


FIGURE 2
Cayolar shepherd huts: **(A)** Historic shepherd hut with stream course in the background, **(B)** Contemporary shepherd hut with storage shed visible to its immediate left and its associated holding pen/milking shed downslope to the left.

cooperating to manage the sheep flock, make cheese and carry out the other tasks that assure success of the syndicate. The Cayolar is a durable organization typically involving two or more herders acting openly as a legal person in that they own assets and produce goods for consumption or sale (Coase, 1937; Hodgson, 2001). Day-to-day decisions by the members of the Cayolar are made in light of a series of operational rules that minimize the problems of self-interest with guile and coordination.

The rules include meeting about March 25 (Catholic Feast of the Annunciation) to make decisions about infrastructure maintenance on the inholding, the dates the herders will move the sheep up and back from the Cayolar inholding, the work rotation of herders during the cheese-production season and the number of cheese rounds they will produce (Noussy Saint-Saëns, 1955; Goyheneche, 1973; Ott, 1993; Etchegoyhen, 2012). The members meet a second time around 22 July (Catholic Day of Saint Madeline) at the end of the cheese-production season to divide up the expenses and profits. The sheep are shorn then moved to higher common rangelands. The sheep are finally brought down from the commons in mid- to late-October and divided into the original share-flocks (Goyheneche, 1973; Richer, 1998).

1.2.2 Collective choice level

Named etxe (SB) stem family households were the fundamental unit of production and decision-making in Soule and an enduring solution to subsistence, marriages, births, deaths, and the aging process of individuals (Coughlan and Gragson, 2016). The etxe is a spatially fixed, real-property stock consisting of a house, barns, tools, etc. conceptually distinguished by Souletin Basque from the family using the stock to produce a flow of resource units. The distinction is evident in that etxe can "die" while the family lives on and symmetrically an etxe can "live" on even after the family bloodline ends (Arrizabalaga, 1997). The normative stem family consists of two couples respectively from the parental and the inheritor generation, their spouses and their unmarried siblings and offspring living under one roof. The two couples at the root of the family are collectively referred to as masters of the house (*maîtres de maison*, French hereafter FR), and when necessary distinguished as old master (*maître vieux*, FR) and young master (*maître jeune*, FR) (Lafourcade, 2003).

Basque stem family inheritance rules are primogeniture and impartibility of the estate (Arrizabalaga, 2005): the eldest male *or* female child inherits the entire estate and the right to form a family. Törbel households were simple or single-family production units adhering to the western Alpine tradition of partible inheritance (Netting, 1981). In Soule, the younger siblings of the maître jeune inheriting the estate stayed on as celibate members beholden to the decisions of the inheritor (Grosclaude, 1993; Arrizabalaga, 1997). The maîtres de maison thus operationalized the rhythms of the family life cycle comprised of different generations and their associated capacities for work and consumption. The herder aligned with other herders in a Cayolar organization represented the interests of a named etxe as expressed by the maîtres de maison, and the txotx the herder used as a stake to participate in the organization was drawn from the stock of the etxe.

1.2.3 Constitutional choice level

All native inhabitants of Soule were free and without servitude obligations, while the Valley was defined as a "pays de franc-alleu naturel et d'origine" (FR) (Grosclaude, 1993; Lafourcade, 2010a,b). In approximate translation, the land was free from other titles, most importantly royal titles, undeveloped, and ancestral to those currently inhabiting it; the inhabitants themselves formed a community of interest (*pays*, FR) with allodial title to all lands within the geographic limits of the Soule Valley summarized in the adage, "nul seigneur sans titer" or no lord/master without a title (Lefebvre, 1928; Dalla-Rosa, 1984; Poumarede, 1984; Lafourcade, 2006). A "native inhabitant" of Soule was defined in the Coutume as one holding land (*heritage*, FR) which placed them under the law (*ressortissant*, FR) comprised of choice rules at different levels including those operational and collective rules mentioned above.

Constitutionally, parish-communes held the right to assemble and manage their own affairs including the establishment of rules to manage and protect forests, vacant lands, livestock and legal matters within the boundaries of the parish-commune. The interests of parish-commune inhabitants were represented by the maîtres de maisons (either the old or the young, but not both) who met each Sunday to discuss and take decisions on matters concerning the parish-commune. Among these were ensuring compliance with the rule contained in the Coutume stating that the number of livestock a member of the community of interest could graze on the commons was limited to the number an etxe was able to winter-feed with hay and straw derived from its private lands within the boundaries of the Soule Valley. Parish-communes were typically divided into neighborhoods (*quartier*, FR) (Coughlan and Gragson, 2016). The maîtres de maison delegated execution of small decisions to a secular clergyman (*maire abbé*, FR) and two elected representatives from each quartier while taking direct responsibility for those matters likely to incur a second-order collective dilemma. For example, the maîtres de maisons designated tax assessors (*cotisateurs*, FR) in each quartier to determine the fiscal tax burden of each etxe, yet appointed a tax collector (*fermance vezalier*, FR) from among themselves to collect the tax.

Parish-communes were organized into seven districts (*degairie* or *vic*, FR) that in turn were organized into three provinces (*messagerie*, FR). Once per year on May 1, the maîtres de maisons from all parish-communes within a degairie would cast lots to elect a degan. All maîtres de maison from one parish-commune within the degairie (the parish-commune rotated annually) stood to be elected and was expected to serve or else pay a fine equal to one beef per day until the position was filled. The degan coordinated the parish-commune tax collectors and received the tax from them, managed the district affairs of interest to the inhabitants and liaised with provincial officers overseeing construction and maintenance of roads and bridges along with public safety and security. The Silviet operated at the inclusive level of the entire Valley and consisted of a general assembly of all maîtres de maisons from every parish-commune. As a group they were responsible for managing the communal lands, had authority to extend 4-year concessions to individuals for clearing land and harvesting wood on the commons, authority to levy corvée for public works, and enter into contracts (*faceries*, FR) with adjoining valleys on the south-facing Pyrenees for use of communal pastures.

We turn next to an evaluation of the use of Cayolar structures, membership and alliance in Cayolar organizations and placement of Cayolar inholdings in the parish-commune of Larrau.

2 Data

Our evidence consists of radiocarbon dates from the features and areas associated with named Cayolar structures, membership records for all named Cayolar operating on common lands of Soule within the boundaries of the parish-commune of Larrau c. 1830 CE, and spatial attributes of the placement of Cayolar inholdings in the commons.

2.1 Cayolar structures

We conducted an archaeological pedestrian survey of ~4,710 hectares of pastures above 800 m asl during which we located

FIGURE 3
Anchors of pastoral activity in Soule recorded archaeologically: **(A)** shepherd hut, **(B)** watering trough, **(C)** livestock enclosure, **(D)** tertres.

42 sites and associated surface features used in seasonal herding activities excluding Cayolar huts still actively used in herding (Champagne et al., 2014). Surface features included small mounds called tertre, livestock enclosures or corrals and stone foundations of shepherd huts (Figure 3). Tertre are ~2 m in diameter at the base and 1 m high; corrals have variable dimensions and consist of bermed earth, bedrock, or stacked stone structures with an opening at one end. Shepherd hut foundations are morphologically consistent with extant though not modern shepherd huts and are roughly rectangular alignments of rocks measuring ~6 (range: 4.5–8 m) by 4 m (range: 3–5.6 m).

We used a 10 cm bucket auger to sample the soil profile at 10 cm intervals within and adjacent to huts, corrals and tertres at each site and screened each sample at 0.45 and 0.2 mm to recover cultural material and macro-charcoal for dating. Forty-eight radiocarbon samples were recovered from seven, widely distributed sites and submitted for dating to the Center for Applied Isotope Studies (UGA). Multiple 14C samples were obtained from each site but no sample provided more than one date. Samples were processed following a standard protocol with 14C/13C ratios measured with a 0.5 MeV accelerator mass spectrometer and 13C/12C ratios measured separately on a stable isotope ratio mass spectrometer. Table 1 lists the details on the archaeologically recovered samples.

2.2 Cayolar membership

We discovered in examining cadastral documents in the archives of the Department of Pyrénées-Atlantiques (Pau, France) a supplement to the 1830 Napoleonic Cadaster titled "co-owners of indivisible otherwise 'collective' property." The supplement is not dated, but cross-referencing the named Cayolar members with other records indicate the supplement dates between 1830 and 1832 CE. Soule faced a series of legal and fiscal challenges between the fall of the Napoleonic Empire in 1814 CE and the creation of the Commision Syndicale du Pays de Soule in 1838 CE and it seems the supplement was compiled to support claims by or against the parish-commune of Larrau.

The supplement contains comprehensive information on 68 named Cayolar operating on the commons in the parish-commune of Larrau and 231 Cayolar members from 35 parish-communes within the Soule Valley. Nine Cayolar are identified as the property of a parish-commune leased or rented to an *ad hoc* group of herders from one parish-commune. Twenty-three Cayolar are owned by a single individual who is sometimes indicated as renting out the property and in others is recorded as a nobleman or a public official who most likely also rented out the property. While a Cayolar refers to an organized group of herders, in this article we use the term owner/herder since 32 entries in the supplement indicate an owner for the inholding but not the individuals using the inholding.

TABLE 1 Uncalibrated AMS dates in radiocarbon years before 1950 CE (years BP) using the 14C half-life of 5,568 years and one standard deviation reflecting both statistical and experimental errors.

UGAMS#	SiteNo	SiteName	SampDepth	Mat	δ13C,‰	Years BP	±	pMC	±2
19014	42	Anchologuia	40–50	Wood	−26.2	270	25	96.67	0.28
19015	42	Anchologuia	30–40	Wood	−25.8	350	20	95.72	0.26
19016	42	Anchologuia	20–30	Wood	−25.8	870	20	89.72	0.25
19017	42	Anchologuia	20–30	Wood	−25.9	970	20	88.57	0.25
21150	42	Anchologuia	11	Char	−26.2	180	20	97.73	0.27
21151	42	Anchologuia	33	Char	−24.9	420	20	94.95	0.26
21155	42	Anchologuia	38	Char	−24.2	870	20	89.70	0.25
21156	42	Anchologuia	7	Char	−20.4	590	20	92.86	0.27
65645	42	Anchologuia	10–20	Char	−22.4	330	20	95.96	0.26
65646	42	Anchologuia	20–30	Char	−23.7	750	20	91.07	0.26
23473	41	Burustola Upper	10–20	Char	−27.7	250	35	96.87	0.44
23474	41	Burustola Upper	40–50	Char	−26.3	250	25	96.93	0.28
23475	41	Burustola Upper	10–20	Char	−26.9	140	20	98.21	0.28
65642	41	Burustola Upper	10–20	Char	−26.9	180	20	97.78	0.26
65643	41	Burustola Upper	20–30	Char	−25.2	570	20	93.16	0.26
65644	41	Burustola Upper	30–40	Char	−23.6	150	20	98.12	0.26
21153	3	Ibarandoua (locus 3)	33	Char	−25.8	330	20	95.95	0.27
65631	3	Ibarandoua (locus 3)	10–20	Char	−26.4	260	20	96.81	0.26
65632	3	Ibarandoua (locus 3)	20–30	Char	−25.5	660	20	92.09	0.25
65633	3	Ibarandoua (locus 3)	30–40	Char	−26.8	1,630	20	81.67	0.22
19018	27	Ibarandoua (locus 4)	30–40	Wood	−24.9	310	20	96.21	0.27
19019	27	Ibarandoua (locus 4)	20–30	Wood	−24.3	300	20	96.37	0.27
19020	27	Ibarandoua (locus 4)	30–40	Wood	−26.8	340	20	95.82	0.27
19021	27	Ibarandoua (locus 4)	50–60	Wood	−27.2	700	25	91.68	0.26
21152	27	Ibarandoua (locus 4)	23–34	Char	−27.0	160	20	97.96	0.27
65638	27	Ibarandoua (locus 4)	10–20	Char	−23.3	300	20	96.34	0.26
65639	27	Ibarandoua (locus 4)	20–30	Char	−25.2	720	20	91.42	0.25
65640	27	Ibarandoua (locus 4)	40–50	Char	−25.2	230	20	97.11	0.26
65641	27	Ibarandoua (locus 4)	60–65	Char	−26.5	310	20	96.15	0.26
23477	37	Ihitsaga	10–20	Char	−27.0	60	20	99.19	0.28
23479	37	Ihitsaga	30–35	Char	−25.4	220	20	97.26	0.27
65652	37	Ihitsaga	20–30	Char	−26.1	200	20	97.51	0.27
23470	71	Malta	10–20	Char	−26.3	90	20	98.86	0.28
23471	71	Malta	40–50	Char	−27.2	150	20	98.20	0.28
65650	71	Malta	10–20	Char	−26.9	180	20	97.78	0.26
65651	71	Malta	20–30	Char	−25.8	110	20	98.61	0.26
23472	55	Pista Gagnekoa	10–20	Char	−24.4	230	25	97.16	0.28
23478	55	Pista Gagnekoa	40–50	Char	−26.3	110	20	98.65	0.28
65647	55	Pista Gagnekoa	20–30	Char	−11.1	570	20	93.15	0.26
65648	55	Pista Gagnekoa	30–40	char	−25.8	130	20	98.40	0.26
65649	55	Pista Gagnekoa	50–60	char	−23.1	110	20	98.66	0.26

(Continued)

TABLE 1 (Continued)

UGAMS#	SiteNo	SiteName	SampDepth	Mat	δ13C,‰	Years BP	±	pMC	±2
19022	5	Ugnhurritze	90–100	Wood	−25.8	720	30	91.42	0.37
19023	5	Ugnhurritze	60–70	Wood	−25.9	410	20	95.00	0.26
23476	5	Ugnhurritze	20–30	Char	−26.3	150	25	98.16	0.30
65634	5	Ugnhurritze	110–120	Char	−25.9	840	20	90.10	0.25
65635	5	Ugnhurritze	110–120	Char	−26.9	970	25	88.61	0.27
65636	5	Ugnhurritze	80–90	Char	−23.4	810	20	90.43	0.25
65637	5	Ugnhurritze	90–100	Char	28.1	120	20	98.48	0.26

SampDepth in cm.

2.3 Cayolar inholdings

We obtained coordinates for waterways, parish-commune boundaries and village church centroids from the BD Carto (IGN) thematic map series then verified and modified the information to match the information from the 1830 Napoleonic Cadaster. We obtained parish-commune name variants and membership in districts and provinces from Orpustan (2010) Nouvelle Toponomie Basque and the Basque Onomastics Database (Euskaltzaindia, 2022). We georeferenced the locations of Cayolar inholdings and the footprint of shepherd huts either during the pedestrian survey or from the digitized maps from the 1830 Napoleonic Cadaster. We combined all placement information into an ArcGIS analytical geodatabase.

3 Analysis

We present below the relevant details of our methods and results from the analysis of dated radiocarbon samples from Cayolar structures, the social network analysis of Cayolar membership records, and the placement of Cayolar inholdings in the common grazing lands.

3.1 Structure chronology

We investigated two different chronological models using OxCal version 4.4.4 and the IntCal20 calibration curve (Bronk Ramsey, 2009; Reimer et al., 2020). We conditioned the models to constrain date ranges (Hamilton and Krus, 2018) using our knowledge of the landscape and stratigraphic context of samples. We set the site abandonment date (i.e., *terminus ante quem*, TPQ) either to 1829 CE for sites that had been abandoned at an unknown date prior to the 1830 CE cadaster otherwise we used the site's known, post-1829 CE abandonment date. We consider a model to be significant when the A_{model} and $A_{overall}$ values >60, and the convergence value (C) >95% (Bronk Ramsey, 1995; Manning and Birch, 2022), and report dates in calendar years CE rounded to the nearest 5 years.

In Figure 4 we provide a summary of the dates using kernel-density estimation (KDE) with default parameters (Bronk Ramsey, 2017) that shows they span 705 and 915 years ($p = 95.4\%$) with a distinctly bimodal distribution with peaks at c. 1300 CE and c. 1700 CE ($A_{model} = 90.9$, $A_{overall} = 92.2$, and $C > 97.2$). We excluded one sample (65633) that dates between 405 and 540 CE ($p = 95\%$, $C = 97.5$) as it derives from the deepest sampled stratigraphic position at the site and may represent landscape burning rather than site use. In Figure 5 we present the results of our simple bounded-phase chronological model (Bronk Ramsey, 2009), which again excludes sample 65633 and sets the end-of-phase to 1958 CE when the last site in this set was abandoned. Dates in this model ($A_{model} = 88.6$, $A_{overall} = 88.3$, and $C > 99.2$) are assumed to derive from a continuous activity phase that began between 1035 and 1150 CE ($p = 95\%$, $C > 99.2$). The use-phase lasted between 805 and 920 years with a median duration of 850 years. The distribution is again bimodal with a break between the peaks at c. 1450 CE. The KDE and simple bounded-phase model results are very similar giving us confidence in the overall duration and the general shape of the distribution.

Figure 6 contains the results of our bounded overlapping phase model that assumes the occupational phases of individual sites are independent and possibly overlapping. This allows us to estimate the start date and end date of use for each site. We constrained site use in this model to begin between 840 and 850 CE (contains the 842 CE founding date of Leyre Monastery discussed below) and the last possible date each site was abandoned. This robust model ($A_{model} = 89.2$ and $A_{overall} = 90.5$, and $C > 95.9$) provides greater chronological control on each site yet still aligns with the results of the KDE and simple bounded-phase model.

3.2 Social networks

We previously used UCINET (Borgatti et al., 2002) to analyze the three interdependent sub-networks of the Soule herding network (Gragson et al., 2021) and characterize its structural features: (a) any herder selected at random can reach any other herder in the network irrespective of village of residence or Cayolar membership: (b) any herder selected at random is connected to more than half the total number of herders participating in the herding network; and, (c) there is no "central authority" determining where individual herders reside, who they form alliances with, or the sheep share they contribute. In summary, each sub-network as well as the overall network form a densely knit, tightly bound valley-wide structure, yet the sub-networks and the overall network are socially emergent rather than autocratically directed.

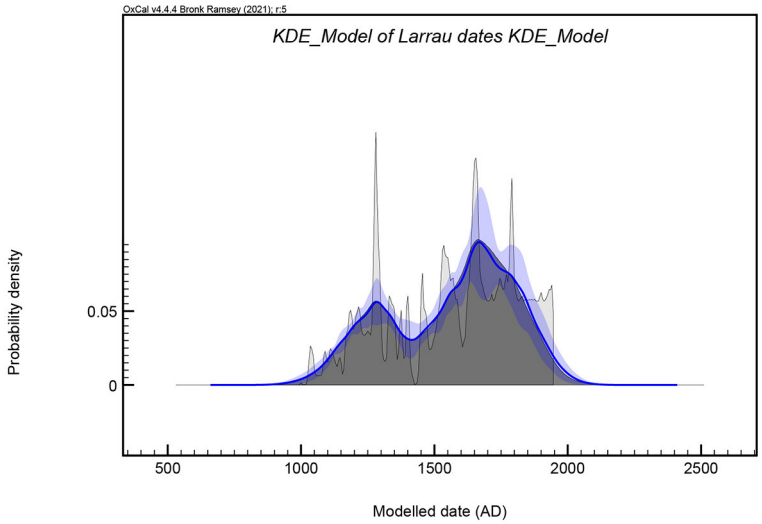


FIGURE 4
Kernel-density estimate summarizing 47 dates from seven high elevation pastoral sites. Red crosses (left) show median uncalibrated 14C ages and black crosses (below) the median modeled calibrated dates. Gray crosses (below) represent median calibrated dates before KDE modeling. The relevant section of the IntCal20 calibration curve is shown for reference.

Here we use Exponential Random Graph Modeling (ERGM) to analyze the joint probability of edges connecting an owner/herder to a named Cayolar. The data are organized as a bipartite, 2-mode network. Unlike two, one-mode projections of the same data, the bipartite network accounts for ties forming between the individuals in the network who come from multiple parish-communes and are in partnership in more than one Cayolar. We analyze the network using ERGM 4.5.0 (Krivitsky et al., 2003–2022, 2023; Goodreau, 2007) dependent on R (>4.1) (R Core Team, 2013) and running in RStudio (RStudio Team, 2015). ERGM is a bottom-up, actor-based analysis framework sensitive to the non-independence of two nodes linked by an edge (Kenny et al., 2006) which treats the social network as a dependent variable of one or more independent conditions. The estimated coefficients are log-odds ratios of establishing a network tie conditional on the rest of the network (Goodreau, 2007). ERGM offers a stronger basis for interpreting how social networks form than the descriptive measures available in UCINET (Wasserman and Pattison, 1996; Robins et al., 2001; Goodreau et al., 2009; Snijders et al., 2010; Wang et al., 2013).

The bipartite network consists of 231 owner/herder nodes and 68 Cayolar nodes joined by 270 edges (Figure 7) that we condition by the (a) parish-commune ($n = 34$), (b) degairie ($n = 7$), and (c) messagerie ($n = 3$) an owner/herder is associated with. Fifty-five percent of all parish-communes, and 100% of all degairie and messagerie in Soule are represented in the network. We tested the fundamental question that needs to be asked about any association of two or more individuals: do the groups observed differ from the groups that might result by chance alone. We performed the test by treating the observed network as a single observation from the distribution of all possible networks with the same number of nodes (Robins et al., 2007), then fit the dataset to the Erdös-Rényi random graph model in which each edge appears independently and with equal probability. Figure 8 is a representative graph from the model run that shows numerous unaffiliated owner/herders even though in the actual network every individual is affiliated with at least one Cayolar. The edges coefficient (−4.03) indicates the Erdös-Rényi model is a poor fit to the empirical network, which is further demonstrated by the inverse logit of θ with $p = 0.02$ of a tie forming between any two individuals through their common membership in a Cayolar.

The simple reason for the poor fit is that ties in the empirical network beyond that of two individuals through a single Cayolar (i.e., two-star) are dyad-dependent (Figure 9) whereas ties in the Erdös-Rényi model are equiprobable. Once two individuals are allied in the empirical network, the probability of a third joining them (i.e., three-star) is a dependent probability of the first two. The widely reported number of herders needed to organize a Cayolar is seven (i.e., seven-star) yet the empirical network ranges from one-star (single individual) through 13-star (13 members) with a strong clustering of observed cases between four and eight-star and a simulated median value c. four. The parsimonious model we identified for the observed distribution of joint probability ties is that more individuals from the same parish-commune organize into a Cayolar than expected by chance alone. This result rests on the statistically significant and positive b1nodematch estimate of 0.607, equivalent to $p = 0.65$ of a tie forming between any two individuals from the same parish-commune. This result amounts to a test of the social principle of homophily (i.e., sociality, ethnicity) in which individuals form alliances with other individuals with similar attributes.

3.3 Inholding placement

The 1830 CE cadaster lists 122 inholdings within the commons associated with 68 named Cayolar. The shape and size of inholdings ranges from 0.1 ha to 167 ha with a median of 8.4 ha. As a rule,

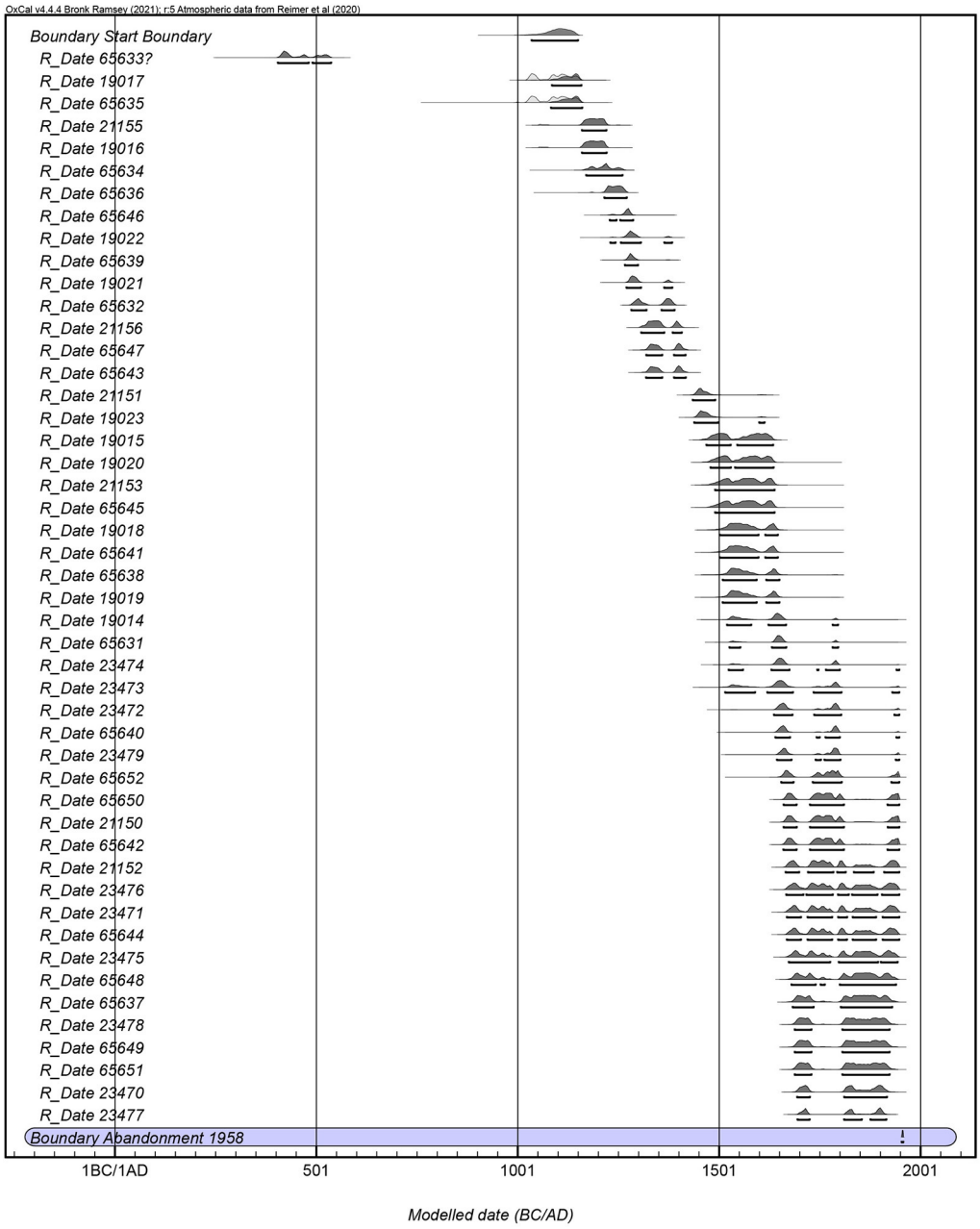


FIGURE 5
Simple bounded-phase model of 47 dates from seven high elevation pastoral sites. The probability density function for the calibrated date of each sample is shown in outline, while the posterior density estimate of the sample date is shown in black. The distribution start boundary is calculated by the model while the end boundary is set to the known or estimated date of abandonment.

inholdings held by one individual or organized group of individuals are on the small end of the size distribution whereas inholdings held by a parish-commune are larger and include both the typical infrastructure of a Cayolar inholding as well as rangeland used for sheep grazing. Some named Cayolar furthermore comprise two or three separate inholdings at different elevations that are distinguished by suffixes to the name of the Cayolar: *Pekoa-Olha* (lower), *Arteko-Olha* (middle), and *Gaineko-Olha* (upper) (Lefebvre, 1928). Twelve named Cayolar organizations in the Soule Valley operated from three inholdings at different elevations, 22 operated from two inholdings at different elevations, and 32 operated from one inholding.

Inholdings are further distinguished by whether they contained structures taxed as shepherd huts (*cabane*, FR $n = 95$) or structures taxed as barns (*grange*, FR $n = 17$). These are mutually exclusive types of inholdings and there are no instances of a Cayolar inholding having both a shepherd hut and a barn. We then evaluated landscape position of inholdings overall and relative to the number of inholdings per Cayolar using a 5 m^2 resolution digital elevation model (DEM) by taking the elevation of the

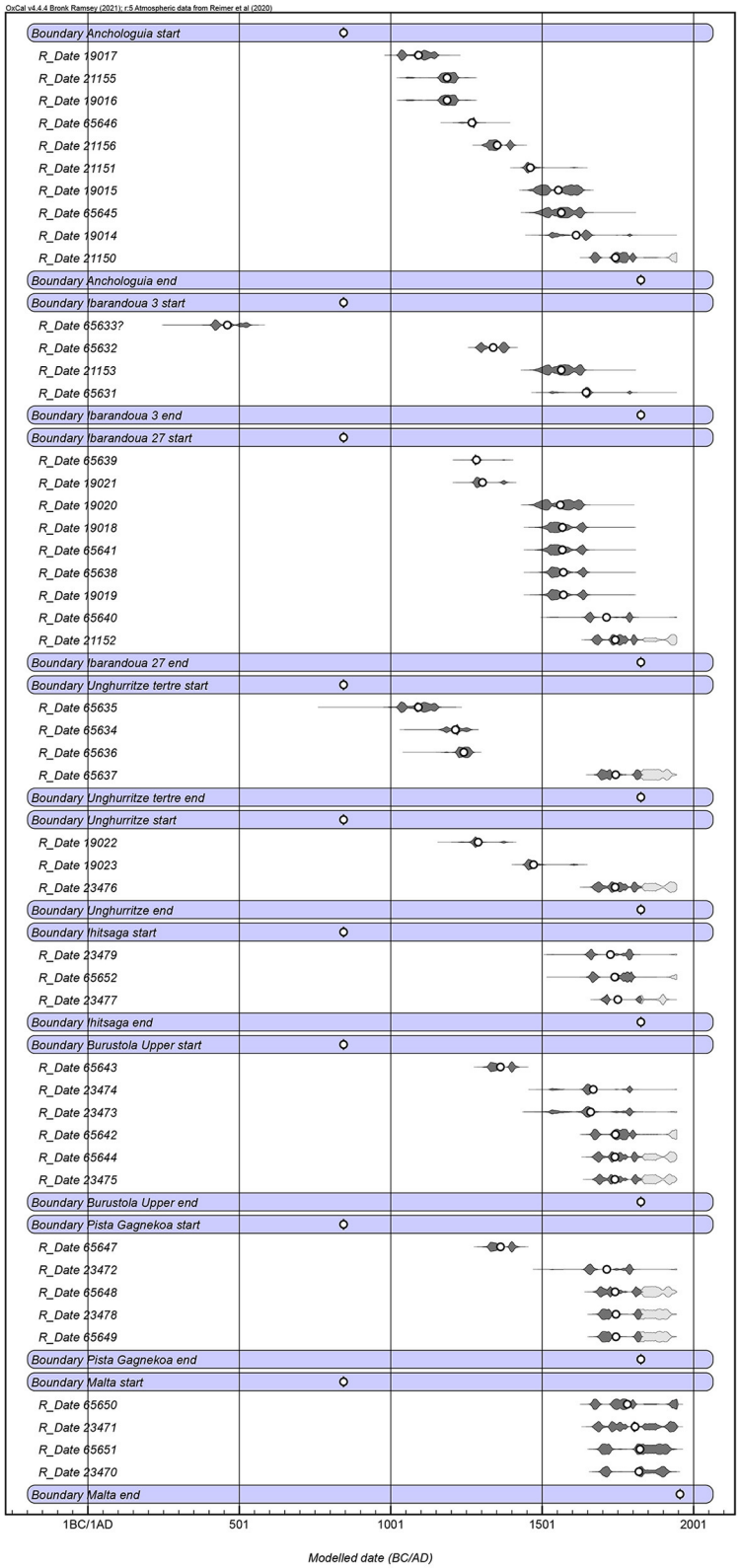


FIGURE 6
Bounded overlapping phases model of 47 dates from seven high elevation pastoral sites. The probability density function for the calibrated date of each sample is shown in outline, while the posterior density estimate of the sample date is shown in black. The start boundary for all distributions is set to 840–850 CE, while the end boundary is set to known or estimated *terminus anti quem* date of abandonment of each site based on cadastral records.

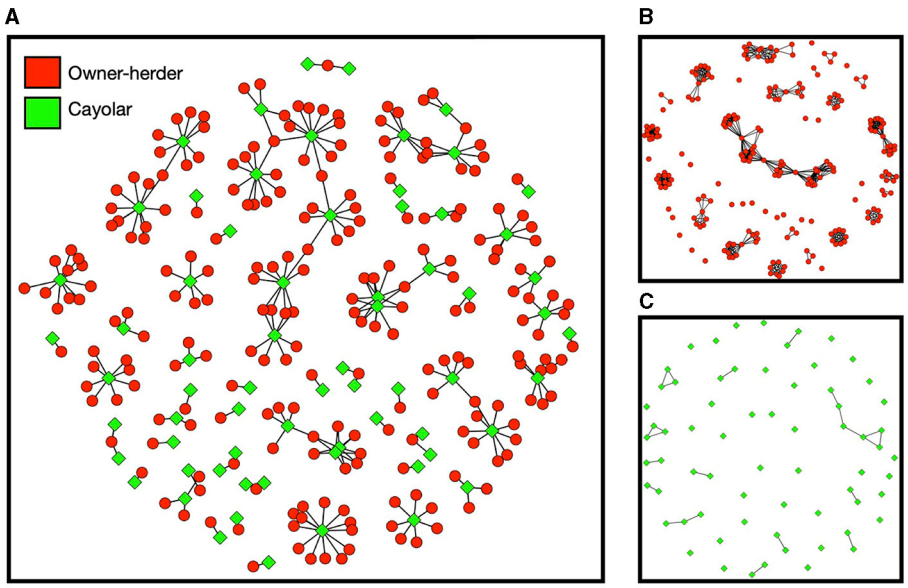
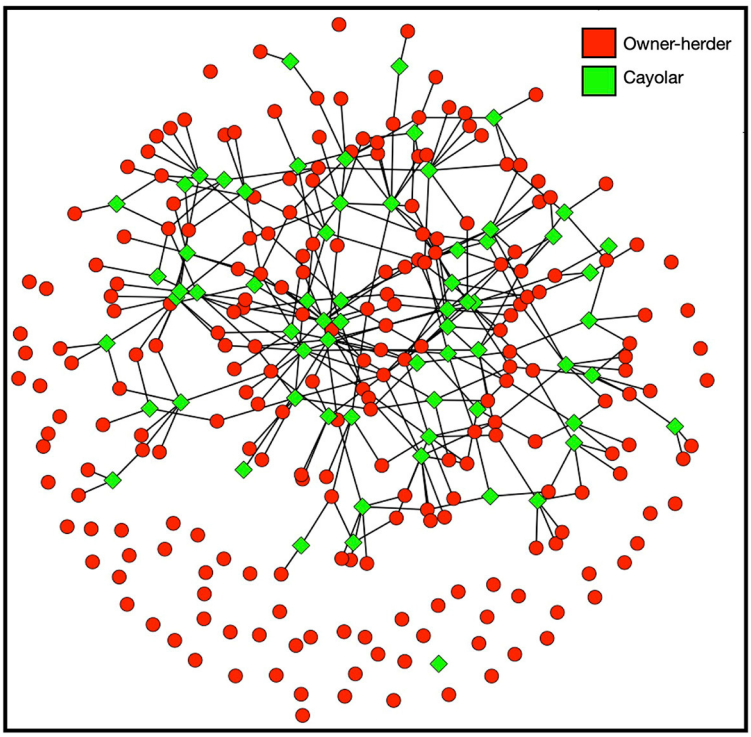
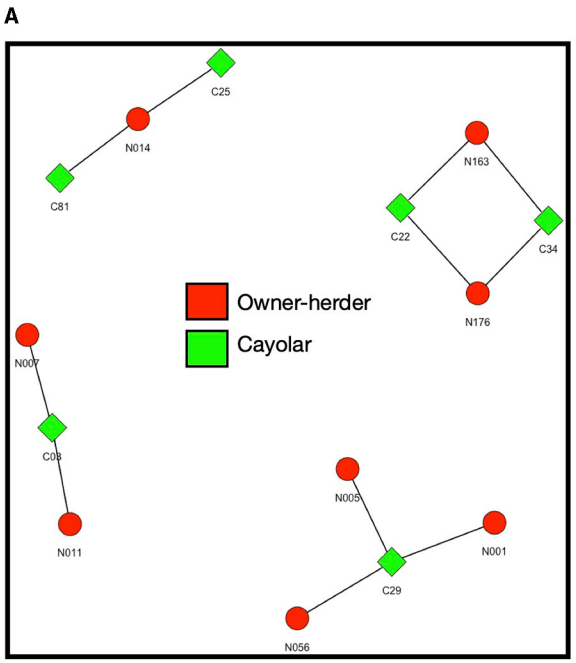


FIGURE 7
Bipartite owner/herder × Cayolar network consisting of 231 herders from 34 parish-communes associated with 68 named Cayolar distributed across four grazing districts: **(A)** empirical bipartite network, **(B)** one-mode projection of owner/herders linked through common membership in at least one Cayolar, **(C)** one-mode projection of Cayolars linked by having at least one owner/herder in common.



	Estimate	Std. Error	MCMC %	Z-value	Pr(>|z|)
Edges	-4.0311	0.0614	0	-65.66	<1e-04 ***

FIGURE 8
One realization of the Erdös-Rényi random graph model based on the properties of the observed network along with the log-likelihood estimate of the fit based on all model runs (AIC = 2,723; BIC = 2,731).



	Estimate	Std. Error	MCMC %	z value	Pr(>|z|)
edges	-4.1746114	0.08456265	0	-49.367086	0.000000000
b1nodematch.TwnID	0.6067073	0.20877901	0	2.905978	0.003661068

FIGURE 9
Dyad dependent structures: **(A)** empirical structures within the owner/herder × Cayolar network, **(B)** correspondence between counts of observed and simulated dyad structures, **(C)** model results of the Homophily test.

shepherd hut or the barn on the inholding (Table 2). Without distinguishing the number of inholdings or type of structure, Cayolar are located at a mean elevation of 1,192 masl (range: 1,497–689 m). This is well above the mean elevation of etxe or barns that are part of fragmented etxe inholdings within communal woodlands and heathlands (i.e., Borda). There are no significant differences between the absolute range in elevation values of shepherd huts or barns for Cayolar operating from one, two or three inholdings other than the tendency for a narrowing of the elevation range for each elevation class as the number of inholdings per Cayolar increases.

However, there is significant unexplained elevational overlap in Borda vs. Cayolar inholdings that is both subtle and largely invisible archaeologically. Indeed, both Borda and Cayolar occur as inholdings within the heathland commons and while Borda are always associated with barns, they sometimes have huts; while most Cayolar are associated with huts, some instead have barns. The main differences between the two inholdings are difficult to parse archaeologically either by *ownership* (Borda are held by individual etxe and Cayolar are held by a collective) or *use* (Borda barns are used to shelter animals and to store hay from their associated meadows while Cayolar barns are used for shelter only). To evaluate the differences between these two types of inholdings, we used ArcGIS Pro 3.2 and the 5 m^2 DEM to calculate slope and construct a topographic position index (i.e., deviation from mean elevation) both resampled to a 250 m window (De Reu et al., 2011). We then calculated distance to nearest stream and the amount of pasture vs. other land use types recorded in the 1830 cadaster (Coughlan, 2014) within 250 m of private Borda barns and Cayolar huts and barns. These were then used as independent variables in a simple binomial Generalized Linear Model analysis in SPSS v.29 of differences between the two farming infrastructures (Cayolar = 1, Borda = 0). Significant variables in our model include elevation, slope (250 m), and access to pasture within 250 m (Table 3). Cayolar as a class are on higher, steeper terrain with greater access to pasture than Borda even when limiting the analysis to the elevational zone in which Cayolar and Borda co-occur (c. 640–1,050 m asl).

4 Discussion

Collective herding in France and the work of authors such as Lefebvre (1933), Noussy Saint-Saëns (1955), Ott (1993), and Etchegoyhen (2012) lie within a national debate that predates by centuries the French Revolution. The debate centers on the normative and rational role of the state in managing the selfish and unruly behavior of individuals (Vivier, 1998; Testart, 2003). Legal experts sought to suppress collective enterprises like the Cayolar because they viewed them as an obstacle to modernization and tried demonstrating that collective herding led to failure in pastoral production. Social historians in turn, promoted such collective enterprises as exemplars of a lifestyle insulated from the damaging effects of modernity and tried to demonstrate their productive success (Bloch, 1930a,b; Vivier, 1998; Testart, 2003). Neither side,

TABLE 2 Elevational attributes of Etxe farmhouses, Borda barns, and Cayolar huts.

n	Infrastructure	Type	Structure type	Mean	SD	Max	Min	Range
178	Etxe	Private	House or house with barn	629	92	886	333	553
226	Borda	Private	Barn	686	139	1,026	344	682
116	Cayolar	Syndicate/private/communal	All	1,192	174	1,497	689	808
70	Gaineko Olha	All Cayolar	All	1,215	177	1,497	739	758
46	Pekoa Olha	All Cayolar	All	1,158	166	1,480	690	790
12	Gaineko-Olha	3-inholding Cayolar	Hut	1,300	68	1,426	1,206	220
12	Arteko-Olha	3-inholding Cayolar	Hut	1,240	59	1,333	1,127	206
12	Pekoa-Olha	3-inholding Cayolar	Hut	1,024	150	1,235	690	545
17	Gaineko-Olha	2-inholdings Cayolar	Hut	1,284	131	1,489	939	551
17	Pekoa-Olha	2-inholdings Cayolar	Hut	1,191	156	1,480	926	554
25	Olha	1-inholding Cayolar	Hut	1,194	197	1,497	740	758
7	Olha	1-inholding Cayolar	Barn	971	61	1,055	896	158
5	Gaineko-Olha	2-inholdings Cayolar	Barn	1,247	200	1,411	990	421
5	Pekoa-Olha	2-inholdings Cayolar	Barn	1,136	222	1,326	824	502

"n" = number of observations in the cadastral dataset. Type indicates type of infrastructural arrangement, elevation expressed in meters above sea level.

TABLE 3 Results of binomial GLM for Cayolar (1) vs. Borda (0).

Variable	*B*	SE	Sig. (*p*-value)	Exp(*B*)
Pasture within 250 m	0.242	0.076	0.001	1.273
Slope (mean 250 m window)	0.356	0.109	0.001	1.427
DEV (250 m window)	0.178	0.858	0.835	1.195
Euclidian distance to streams	−0.007	0.004	0.059	0.993
Elevation (meters above sea level)	0.031	0.017	<0.001	1.032

Significant variables shaded.

however, gave much attention to the empirical reality of how herders collectively coordinated their actions in or through time across complex social-ecological landscapes.

4.1 Alliance formation

The Cayolar organization is the day-to-day operational unit of pastoral activity on the high mountain commons in the Soule Valley. The nested assembly levels of free houses represented by the maîtres de maisons, however, hold the authorities of supply, commitment, and monitoring of collective action on the commons (Ostrom, 1990). While the regime operates within the framework outlined in the Coutume de Soule published in 1521 CE during the reign of Francis I (1515-1547 CE), this is not a "pure" Basque institution of governance. The western Pyrenees were incorporated into the administrative structure of the Kingdom of France in 1461 CE during the reign of Louis XI (1461–1483 CE). The institutional details in the Coutume were assembled in response to a 1483 CE royal order that charged royal representatives to record oral and customary practices (not impose normative French law) from all local communities of interest across the realm.

The organizational principals contained in the Coutume, if not always the details, are common to Aragonese, Basque, Béarnaise and Gascogne valley communities either side of the western Pyrenees Mountains. Like Soule, these valley communities are recognized as customary countries—*pays coutumier* in France and *comunidad de villa y tierra* or *comunidad de aldeas* in Spain. The first written accounts of oral tradition and customary practice in this region (called coutume in French and fuero in Spain) date to the 12th century (Noussy Saint-Saëns, 1955; Lefebvre, 1963; Cursent, 1998; Vivier, 1998; Fernández Mier and Quirós Castillo, 2015). A unique period document (Urrutibéhéty, 1983) from a court case on August 1, 1455 CE, references a public ordinance from August 15, 1395 CE that stipulates the inhabitants of Larrau were exempt from tribute and had free use of forests and pasturelands since the establishment of Larrau in 1174 CE.

There is also proxy material evidence of the Soule Valley institutional framework in the form of legacy structures. For example, the National Convention of 31 October 1793 CE suppressed parish-communes across France and created the

communes still used today. When geometricians collected the field information to develop the national cadaster, in nearly every case in southern France and with known certainty in Soule, they simply recorded the geographic properties of the existing parish-communes, agricultural parcels, commons, etc. (Clergeot, 2007; Motte and Vouloir, 2017). At least five parish-communes in the Soule Valley have been in existence since the 11th century CE, and all parish-communes and many etxe with their associated stem families have been stable since at least 1377 CE (Noussy Saint-Saëns, 1955; Urrutibéhéty, 1983; Cierbide, 1994). The earliest record of a Cayolar operating on the commons within the territory of the parish-community of Larrau dates to 1024 CE and it has operated continuously up through the present on the same inholding and under the same name (Coughlan et al., 2023). The first mention of the Silviet dates to the 13th century (Noussy Saint-Saëns, 1955, p. 339; Lafourcade, 2010b).

The Cayolar organization in Soule lies within a class of pastoral institutions common to the western Pyrenees and Cantabrian mountains, and comparable institutions identified among mountain herders across Europe (Poumarede, 1984; Couturier, 2000; Agnoletti, 2007; Bordessoule, 2007). These pastoral institutions take the form of an annually iterated *n*-person public goods assurance game in which the contribution of each member is essential to the production of resource units. The most obvious resource units produced by members of a Cayolar organization are sheep wellbeing and cheese, but a variety of secondary benefits also derive from this alliance of herders (e.g., friendship, assistance-in-time-of-need, etc.). A Cayolar is an enduring place-based organization as demonstrated by our chronology from multiple sites across the commons indicating a use-span of 850 years for the infrastructure on Cayolar inholdings. Rarely is documentary evidence for the use of a Cayolar inholding available much before the 16th century with the occasional exception as the just noted Cayolar that has been operating for 1,000 years (Coughlan et al., 2023).

Cayolar organizations endure because the members have a regulatory interest in enforcing the contribution of others in the collective herding efforts and little incentive to defect since they must trust each other to cooperate (Heckathorn, 1996; Kitts, 2006; Takács et al., 2008). Hardin (1968) parable speaks to the conflicts of interest and challenges of coordination that undermine cooperation among herders leading to a future tragedy for all as each individual overexploits the grazing commons in the present. Unlike Hardin's herders, herders in a Cayolar share a past and expect to share a future as members of the Soule Valley community of interest. More immediately, each herder represents an etxe that holds proportional title to the Cayolar and contributes the sheep share the herder is cooperatively managing with the other members of the organization. Herders in both instances attribute less value to future benefits than they do to present benefits. However, Hardin's herders exist in the moment and discount the future so severely that they choose to capture all their benefits in the present. The Cayolar herders, on the other hand, do not discount the future as severely and are willing to forgo some present benefits because they or the members of their etxe can be expected to benefit in the future. The Cayolar herders are also likely to have other opportunities to benefit by virtue of the alliances they have with the other members of the Cayolar.

Our homophily test parallels the logic of how discount rates and the tradeoffs between present vs. future benefits influence a herder's decision to collaborate with others. Homophily, sociality and ethnicity are traditionally viewed as the global property of a population and thus unsuitable for explaining the agency of individuals or the alliances they form with others. ERGM reveals how an aggregate phenomenon such as homophily emerges from the tendency of variably conditioned individuals to form links with similarly conditioned neighbors (Granovetter, 1978; Goodreau et al., 2009). Netting (1981) offers a reduced set explanation for affiliation in collective herding in the Swiss Alps that is equally applicable to Cayolar herding in Soule: herders depend on each other to avoid labor shortages that would arise if households were forced to tend their own herds alone.

As for the placement of Cayolar inholdings, the results do not confirm but they do suggest the Cayolar organization emerged as a way to govern grazing lands unsuitable for the cultivation of crops or storable forage. Theory suggests that elevational constraints guide the settlement ecology of household vs. collectively owned farming infrastructure (Rhoades and Thompson, 1975; Netting, 1981). We previously analyzed parcel land use change and etxe abandonment between 1830 and 1958 CE (Coughlan and Gragson, 2016). The results reveal the complex processes by which etxe farmhouses within the Borda zone were functionally repurposed as Borda in response to changing socioeconomic conditions. There is no hard rule governing what constitutes high pasture or which terrain falls under the purview of the Cayolar institution. Temporal variability in elevational constrains on farming are climate-driven and subject to change, thus, the degree of elevational co-occurrence of the two institutions suggests flexibility over time in whether a place functioned as a Cayolar or a Borda. Figure 10 summarizes elements of this spatial flexibility in the Cayolar system.

4.2 Collective action antecedents

There are no indigenous Basque accounts before the 9th century CE and the few period documents that do refer to the Basque are often written by individuals in open conflict with them (Larrea, 1998, p. 114). While there is physical, documentary and proxy evidence for Cayolar-based herding at high elevation in Soule beginning c. 1000 CE, neither we nor others have yet to identify structural remains conclusively associated with pastoralism above 800 masl prior to this date. We previously established that charcoal production associated with the establishment and maintenance of pastures above 800 masl in Soule increases dramatically after 1000 CE following a production hiatus that began c. 1000 BCE (Coughlan et al., 2023). The increase in charcoal production occurs in tandem with the establishment of farming households below 800 masl organized into neighborhood communities (Coughlan and Gragson, 2016; Gragson et al., 2021).

The well-known accounts of pastoralism by Lefebvre (1928, 1933), Cavaillès (1931a,b), Ott (1993) and others largely limit their analysis of the Cayolar organization to the operational level (Ostrom, 1990). When pastoralism is further colored by the debate between legal experts and social historians the organization is both taken out of time as well as separated from evidence about

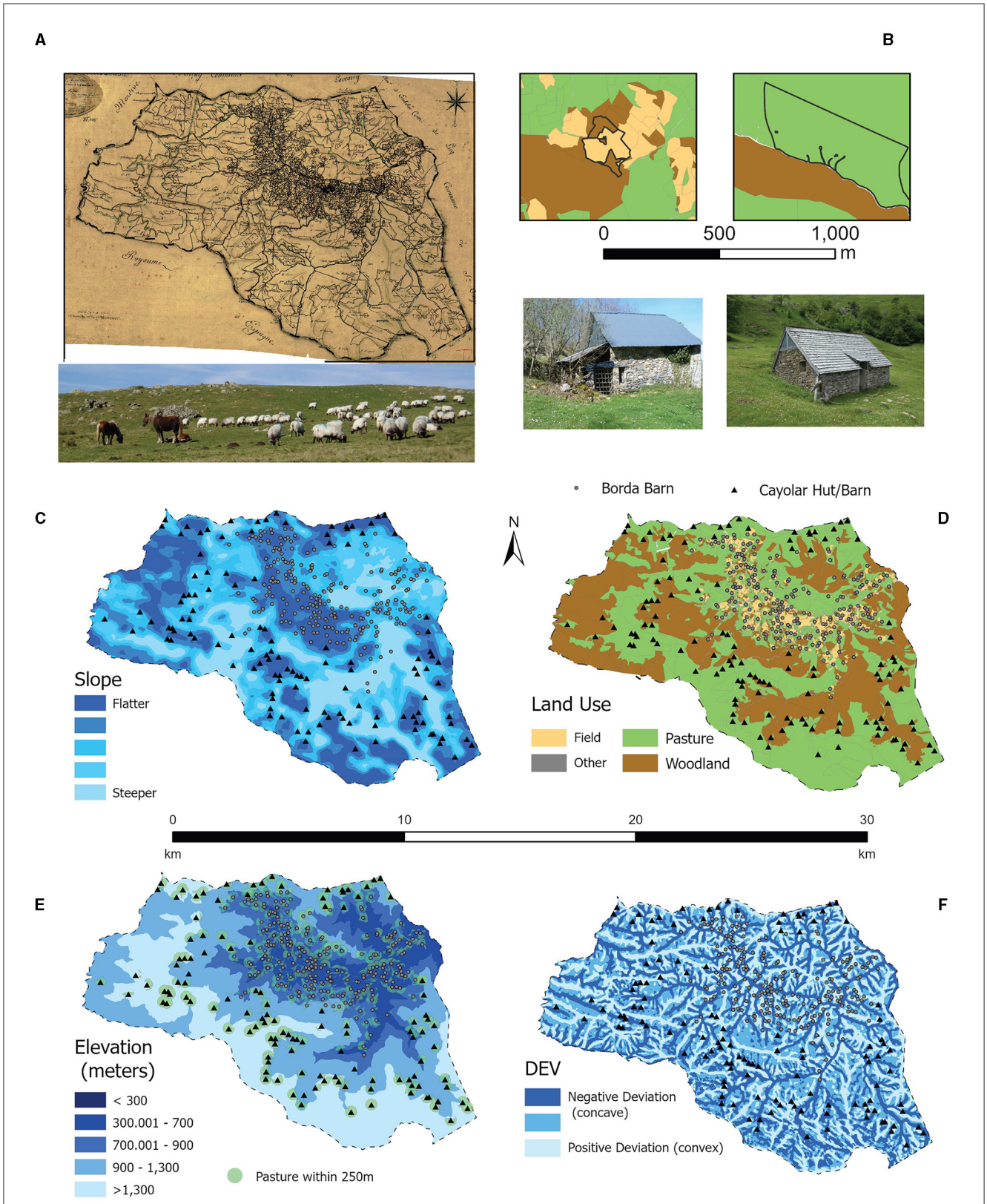


FIGURE 10
Data layers used in the generalized linear model analysis of Cayolar and Borda structures. **(A)** 1830 cadaster with digitized parcels, **(B)** examples of Borda parcel inholdings (upper left) and barn (lower left), and Cayolar parcel inholdings (upper right) and hut (lower right), **(C)** slope, **(D)** land use ca. 1830, **(E)** elevation in meters above sea level, **(F)** deviation from mean elevation. Cayloar locations indicated by black triangle and Borda locations indicated by gray circles in maps **(C–F)**.

individual agency and affiliation networks so that it is not possible to understand the endurance of this organization over time. Ostrom shattered the conviction that local collective dilemmas could only be solved by external authorities imposing private property and centralized regulation. The emergence and persistence of Basque institutions for self-regulating grazing of the commons reveal their capacity to shape and reshape the situations in which individuals make day-to-day decisions and bear the consequences of their actions. This is precisely the space we need to consider in order to investigate the process of change over time in collective action.

Documentary evidence indicates that Basque settlement was impacted over time by military activity at the onset of the Roman era in 180 BCE, the Germanic invasions beginning c. 400 CE, military action between Franks, Visigoths and Vascones along with Bagaude/brigand marauding between 500 and 700 CE, and the Moorish invasion of 711 CE (Larrea, 1998). Major Basque settlements starting in Antiquity such as Pamplona and Calahorra were on the plains adjacent to the Ebro River while extensive agro-pastoral activities were concentrated in the pre-Pyrenees valleys of Guipuzcoa and the inland territory of Álava (Larrea, 1998; Martín Duque, 2002a; Pavón Benito, 2018; Quirós Castillo, 2020). After 700 CE, Basque expanded their territory from the Ebro Basin in Iberia across the western Pyrenees to the Aquitaine Plain in France, which was then referred to in period documents as Guasconia (Fredegar, 1981). Shortly thereafter, the Ravenna Cosmographer (Anonymous, 1860) produced the first map showing Basque lands as spanning the Pyrenees up to the Adour-Ouse River corridor in France.

After the Basque defeated the Carolingian army at the Second Battle of Roncevalles in 824 CE, Íñigo Arista established the Basque kingdom of Navarra: c. 5,000 km^2 centered on Pamplona with close ties to the Catholic Church against their common enemy, the Moors (Martín Duque, 2002b; Pavón Benito, 2018). Íñigo Arista set the course for reopening the Soule Valley to agropastoral use by making donations that combined with donations from Wilesindo, Bishop of Pamplona, led to the establishment in 842 CE of the Benedictine monastery of Leyre (in Navarra). Few details are available, but Leyre is known to have operated a significant pastoral enterprise in the small valley of Bezula within the territorial limits of what would become the parish-commune of Larrau (Brocas and Legaz, 2005). The monastery of Leyre was later acquired by Cistercian monks who with subsequent land donations initiated large scale sheep herding in the mountain reaches of the kingdom of Navarra including Soule. The Cistercian monks from Leyre were followed into Soule by Cistercian monks from the Sauvelade Abbey in the lower reaches of the Soule Valley in France while other monastic orders established themselves in the western Pyrenees in areas surrounding the Soule Valley (Cursent, 1994; Larrea, 1998; Unzu Urmeneta, 2021).

Following a series of land donations with grazing rights for large and small livestock, Larrau was established in 1174 CE as a priory of the Cistercian Abbey of la Sauvelade; the church of Sanctus Johannes de Larraun was built in 1193 CE as a chapel for the ospitau de Larraun that served as the nucleus of what would become the parish-commune of Larrau (Urrutibéhéty, 1983). Our chronology and documentary evidence for Cayolar-based activities on the commons within the territorial limits of the parish-commune of Larrau pre-date by over 150 years the construction of the church and establishment of the population center of Larrau. Understanding the process of settling down in the western Pyrenees and Europe have been intellectually dominated by the argument that agropastoral spaces are the inevitable consequence of first establishing a hamlet, village or town. The sequence of events in Larrau and comparable settings in northern Iberia such as Tobillas (Quirós Castillo et al., 2023) point to just the opposite. It is land use and management activities that lead eventually to the materialization of alliance in the form of a settlement and its social institutions.

The understanding of settling down even when individual agency and alliance networks are acknowledged has been colored by assumptions about the length of time it must take for such a phase shift to occur. However, without refined chronologies we deny people their history and render them powerless (Whittle, 2018). Monasteries turned their attention to the Pyrenees Mountains as the Catholic Church issued its "Peace of God" policy in response to the civil unrest that had prevailed in southern France since at least 840 CE from the abuses perpetrated by the landed gentry on the peasantry. One consequence of the policy was the establishment of safe-have (*sauvete*, FR) churches, towns, and castles that guaranteed safety to fugitives (e.g., Sauvelade Abbey).

While safe havens were developing to the north of the Pyrenees Mountains in France, there were equally significant events unfolding to the south in Iberia. The collapse of the Califate of Cordoba in 1032 CE led to the emergence of multiple taifas (i.e., Moorish kingdoms) who paid an annual protection tax (*paria*, Spanish) in gold to Christian kingdoms such as Navarra. King Sancho Ramirez of Aragón and Pamplona (1042–1094 CE) and king Alfonso VI of Castilla (1040–1109 CE) used this tax to underwrite the Fuero de Jaca and the Fuero de Estella. These primordial fuero encouraged resettlement and repopulation of the Pyrenees Mountains by creating safe corridors through the mountains (Martínez González, 2012) and reducing the initial cost of developing the institutional structure for individuals to collaborate for common benefit. The result was dramatic local economic development and a significant increase in regional exchange between the Kingdoms of Navarra, Aragón and Castilla in Spain and Béarn in France.

The Fuero de Jaca (Aragón) and the "Fuero" de Estella (Navarra) were direct royal agreements with "*personas libres, francas e ingenuas*" (SP)—freemen able to hold property free and clear who worked the land with their own hands (Orella Unzué, 2017; Pavón Benito, 2018). The king would personally sign a fuero with representatives of a community of interest bypassing local elites, and personally promised protection for pilgrims, travelers and merchants who agreed to use the routes the king specified for crossing the Pyrenees including in the western Pyrenees the passes of Larrau, Somport and Ibañeta. Individuals who agreed to these terms were exempted from all taxes and tribute and given the authority to form councils to decide local affairs; the king in turn would sponsor construction of bridges, lodges, and hospitals using the paria taxes. The concessions and infrastructure in turn attracted representatives from diverse professions and guilds including money changers, master builders, merchants, and hoteliers accelerating the establishment of churches, monasteries, hospitals and way stations.

Two examples clarify the scale and speed of the social, economic, and political transformation in the western Pyrenees from overcoming conflicts of interest and the commitment to enforce rules supporting collective action. The Order of Cannons Regular of Prémontré formed in 1120 CE put in place at least 34 establishments in southern France including the Basque and Gascogne regions in the western Pyrenees between the 12th−13th centuries CE (Abadie, 2019). The kingdom of Béarn (France) adjacent to Soule and the kingdom of Aragón became close allies c. 1100 CE. To facilitate and protect pilgrims, traders and troops following the old Roman road from Lescar (France) to Zaragoza (Spain) crossing the Pyrenees by the Pass of Somport, the partners established the order of Sainte-Christine du Somport. By the early 13th century, the order included over 20 religious establishments linked to agropastoral domains distributed across the Ossau Valley and the eastern portion of the Soule Valley in France, and the adjoining valleys of Salazar, Roncal, Ansó and Echo in Spain (Lassègues, 2019).

There is a tendency to view monarchs through Hobbe's parable of man in a state of nature who seeks his own good yet ends up fighting with other men only avoiding ruin by the coercive, outside force of Leviathan. The primordial fueros of King Sancho Ramirez and King Alfonso VI are an example of the benign model of select benefits for the provision of public goods between advantaged and disadvantaged social groups (Van Zomeren and Iyer, 2009; Jagers et al., 2020). Opposing the categories of mobile and settled has obscured our grasp of what settling down means to individuals with agency capable of autonomous decision-making. In the same vein, we still lack an evidence-based understanding of the temporal causes of collective action involving a wise and advantaged king contracting with persecuted and disadvantaged individuals to the mutual benefit of both (Thomas et al., 2020).

5 Conclusion

Collective pastoral management regimes in France have continuously challenged the notion of the state as the necessary entity capable of managing the selfish and unruly behavior of individuals. We cannot always predict, however, the solution that herders will arrive at to collaborate with each other. In the Massif Central a sub-component of herders in a commune holds non-transferable title and exclusive use-rights to a section of a single land parcel which exceeds 100 ha in area (Couturier, 2000). By comparison, collective lands in the Alps, the Jura and the Vosges tend to be held by all herders of a single commune interspersed with a legacy feudal form of collective property (i.e., alpages, FR, Duparc, 1964). In the eastern Pyrenees herders in a single commune collectively use state lands (i.e., *propriété domanial*, FR) that originate from 17th century land reforms (Bordessoule, 2007). In the central and western Pyrenees of France and Spain herders from a community of villages or a valley republic use and manage pastoral resources through the Cayolar system first materialized in the Coutume of 1521 CE yet first recorded as a structural institution c. 1000 CE.

Traditional common property systems are complex and their persistence is contingent on interactions over time between broad-scale drivers, local resources, institutions and the agency of individuals (Berkes, 2006; Rammel et al., 2007). Their success or failure at any given moment is an emergent property of social dynamics between individuals. The representation of traditional common property regimes as cultural archetypes—static and timeless—provides little more insight on the dynamics of resource use and governance than Hardin's or Hobbe's parables. The refined chronologies we provide on the use of Cayolar structures combined with the bottom-up details about social alliances that in turn materialize on the landscape as pastoral inholdings serve to reveal herder's lived experiences in Soule along with the institutions that govern their daily existence. It also gives back to the people their history placing them into the time continuum from their past to their potential future (Birch et al., 2022).

Olson (1965) expressed the problem of collective action as one of balancing the contradictory forces of selfishness and cooperation among individuals united through the self-reflected cohesive force of an institution with the capacity to mobilize shared resources. In France, traditional mountain pastoralism effectively ended in 1960 CE although dispersed remnants can still be encountered in places around the country such as the Soule Valley (Bordessoule, 2007). While pastoralism is now a vestigial practice, examining the Cayolar organization from its antedecents through the early 19th century in the Soule Valley provides critical insights into how herders realize the mutual benefits of cooperation while suppressing individual self-interest with guile (Hecter and Brustein, 1980; Lichbach, 1996; Blanton and Fargher, 2008).

The vulnerability of agropastoralism across European mountain landscapes has led to serious efforts to preserve and reinvigorate the practice (Plieninger and Bieling, 2013). Pastoralism is a millennial practice (Agnoletti, 2007) yet there is still a tendency to abstract communities from history and ignore the situational variables leading local communities to develop solutions by trial-and-error to achieve success over time (Ostrom, 1990). Herding is neither the expression of a rational egoist or an invariant cultural norm. Even though getting things done among the members of our species is always social (Kowalewski and Birch, 2020), individuals still retain free will and use it to make decisions about whether to participate in collective activities or not. By recognizing a herder's agency to choose between opportunities, we acknowledge the creativity of humans to solve situational problems and move past belief toward empirically grounded understanding of human social alliances and institutions in the past as well as the present.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

TG: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing—original draft, Writing—review & editing. MC: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration,

Resources, Software, Supervision, Validation, Visualization, Writing—original draft, Writing—review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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References

Abadie, S. (2019). "La circulation des chanoines prémontrés à travers les Pyrénées (xiie-xve siècle)," in *Monastères et Couvents de Montagne : Circulation, Réseaux, Influences au Moyen Âge,* ed. D. le Blévec (Paris: Éditions du Comité des Travaux Historiques et Scientifiques), 4887. doi: 10.4000/books.cths.4887

Agnoletti, M. (2007). The degradation of traditional landscape in a mountain area of Tuscany during the 19th and 20th centuries: Implications for biodiversity and sustainable management. *For. Ecol. Manag.* 249, 5–17. doi: 10.1016/j.foreco.2007.05.032

Anonymous (1860). *Ravennatis Anonymi Cosmographia et Gvidonis Geographica*. Berolini: Aedibvs Friderici Nicolai.

Arnold, E. R., and Greenfield, H. J. (2006). *The Origins of Transhumant Pastoralism in Temperate Southeastern Europe: A Zooarchaeological Perspective from the Central Balkans*. Oxford: Archaeopress. doi: 10.30861/9781841719702

Arrizabalaga, M.-P. (1997). The stem family in the French Basque country: sare in the nineteenth century. *J. Fam* Hist. 22, 50–69. doi: 10.1177/036319909702200103

Arrizabalaga, M.-P. (2005). Succession strategies in the Pyrenees in the 19th century: the Basque case. *Hist.* Fam. 10, 271–292. doi: 10.1016/j.hisfam.2005.03.002

Barandiaran, J.M.d., Manterola, A. (2000). *Atlas Etnográfico de Vasconia: Ganadería y Pastoreo en Vasconia.* Bilbao: Etniker Euskalerria.

Berkes, F. (2006). From community-based resource management to complex systems: the scale issue and marine commons. *Ecol.* Soc. 11:45. doi: 10.5751/ES-01431-110145

Birch, J., Hunt, T. W., Lesage, L., Richard, J.-F., Sioui, L. A., Thompson, V. D., et al. (2022). The role of radiocarbon dating in advancing Indigenous-led archaeological research agendas. *Humanit. Soc. Sci. Commun.* 228, 1–6. doi: 10.1057/s41599-022-01249-7

Blanton, R., and Fargher, L. (2008). *Collective Action in the Formation of Pre-modern States*. New York, NY: Springer. doi: 10.1007/978-0-387-73877-2

Bloch, M. (1930a). La lutte pour l'individualisme agraire dans la france du XVIIIe siècle: première partie: l'œuvre des pouvoirs d'ancien régime. *Ann. Hist. Écon. Social.* 2, 329–383. doi: 10.3406/ahess.1930.1227

Bloch, M. (1930b). La lutte pour l'individualisme agraire dans la France du XVIIIe siècle: deuxième partie. Conflits et résultats. *Ann. Hist. Écon. Social.* 2, 511–543. doi: 10.3406/ahess.1930.1264

Bordessoule, É. (2007). "Appropriation et gestion collective des pâturages d'altitude en France: Crese et adaptation des formules traditionnelles," in *Les Espaces Collectifs dans les Campagnes: XIe-XXIe Siècle*, eds P. Charbonnier, P. Couturier, A. Follain, and P. Fournier (Clermont-Ferrand, FR: Presses Universitaires Blaise-Pascal), 399–418.

Borgatti, S. P., Everett, M. G., and Freeman, L. C. (2002). *UCINET for Windows: Software for Social Network Analysis*. Harvard, MA: Analytic Tehnologies.

Brocas, D., and Legaz, A. (2005). "La montagne Basque: sources et ressources. Les pâturages et les bois dans les Pyrénées occidentales (XI-XIX siècles)," in: *Les Ressources Naturelles des Pyrénées du Moyen Age a l'époque Moderne: Exploitation, Gestion, Appropriation*, eds A. Catafau (Perpignan: Presses Universitaires de Perpignan), 49–69.

Bronk Ramsey, C. (1995). Radiocarbon calibration and analysis of stratigraphy: the OxCal program. *Radiocarbon* 37, 425–430. doi: 10.1017/S0033822200030903

Bronk Ramsey, C. (2009). Bayesian analysis of radiocarbon dates. *Radiocarbon* 51, 337–360. doi: 10.1017/S0033822200033865

Bronk Ramsey, C. (2017). Methods for summarizing radiocarbon datasets. *Radiocarbon* 59, 1809–1833. doi: 10.1017/RDC.2017.108

Cavaillès, H. (1931a). *La Transhumance Pyrénéenne et la Circulation des Troupeaux dans les Plaines de Gascogne.* Paris: Librairie Armand Colin.

Cavaillès, H. (1931b). *La vie Pastorale et Agricole Dans les Pyrénées des Gaves, de l'Aour et des Nestes.* Paris: Librairie Armand Colin.

Champagne, A., Contamine, T., Coughlan, M., Gragson, T., and Haley, B. S. Le Couédic, M.l. (2014). *Rapport de Prospection et Sondages Larrau, Pyrénées-Atlantiques, ITEM (EA 3002)*. Pau: Université de Pau et des Pays de l'Adour, 129.

Cierbide, R. (1994). *Le Censier Gothique de Soule.* St. Etienne de Baïgorry: Editions Izpegi.

Clergeot, P. (2007). *Cent Millions de Parcelles en France: 1807 - Un Cadastre Pour l'empire.* Paris: Editions Publi-Topex.

Coase, R. H. (1937). The nature of the firm. *Economica* 4, 386–405. doi: 10.1111/j.1468-0335.1937.tb00002.x

Coughlan, M. R. (2013). Errakina: pastoral fire use and landscape memory in the Basque region of the French western Pyrenees. *J. Ethnobiol.* 33, 86–104. doi: 10.2993/0278-0771-33.1.86

Coughlan, M. R. (2014). Farmers, flames, and forests: historical ecology of pastoral fire use and landscape change in the French Western Pyrenees. *For. Ecol.* Manag. 312, 55–66. doi: 10.1016/j.foreco.2013.10.021

Coughlan, M. R. (2015). Traditional fire-use, landscape transition, and the legacies of social theory past. *Ambio* 44, 705–717. doi: 10.1007/s13280-015-0643-y

Coughlan, M. R., and Gragson, T. L. (2016). An event history analysis of parcel extensification and household abandonment in Pays Basque, French Byrenees, 1830-1958 AD. *Hum. Ecol.* 44, 65–80. doi: 10.1007/s10745-016-9808-y

Coughlan, M. R., Gragson, T. L., and Leigh, D. S. (2022). Landscape conservation and the ancient technique of pastoral fire in the western Pyrenees. *PAGES* 30, 38–39. doi: 10.22498/pages.30.1.38

Coughlan, M. R., Leigh, D. S., Gragson, T. L., and Le Couédic, M. (2023). "Holocene anthropization of mid-elevation landscapes around Pic d'Orhy, Western Pyrenees,"

in *Archaeology of Mountain Landscapes: Interdisciplinary Research Strategies of Agro-Pastoralism in Upland Regions*, ed A. Garca-Molsosa (Albany, NY: State University of New York), 277–301.

Couturier, P. (2000). *Sections et Biens Sectionaux dans le Massif Central.* Clermont-Ferrand: Presses universitaires Blaise Pascal.

Cronk, L., and Leech, B. L. (2013). *Meeting at Grant Centrla: Understanding the Social and Evolutionary Roots of Cooperation.* Princeton, NJ: Princeton University Press. doi: 10.1515/9781400845484

Cursent, B. (1994). "Église et habitat dans les villages gascons: quelques aspects topographiques (XIe-XVe s.)," in *L'environment des Églises et la Topographie Religieuse des Campagnes Médiévales,* eds M. Fixot, and E. Zadora-Rio (Paris: Éditions de la Maison des Sciences de l'homme), 223–238. doi: 10.4000/books.editionsmsh.40213

Cursent, B. (1998). *Des Maisons et des Hommes: La Gascogne Médiévale (XIe - XVe Siècle).* Toulouse: Presses Universitaires du Mirail. doi: 10.4000/books.pumi.18031

Dalla-Rosa, G. (1984). La zone de montagne dans les Pyrénées Atlantiques : une délimitation controversée. *Rev. Géogr. Alp.* 72, 347–361. doi: 10.3406/rga.1984.2576

De Reu, J., Bourgeois, J., De Smedt, P., Zwertvaegher, A., Antrop, M., and Bats, P. (2011). Measuring the relative topographic position of archaeological sites in the landscape, a case study on the Bronze Age barrows in northwest Belgium. *J. Archaeol. Sci.* 38, 3435–3446. doi: 10.1016/j.jas.2011.08.005

Duparc, P. (1964). Les tenures en hébergement et en abergement. *Bibl. Ec. Chartes* 122, 5–88. doi: 10.3406/bec.1964.449668

Etchegoyhen, P. (2012). *Mémoires Souletines - Tome 2, Bergers et Cayolars.* Donostia: Elkar Argitaletxea.

Euskaltzaindia (2022). *Basque Onomastics Database (EODA).* Bilbao: Royal Academy of the Basque Language.

Falque-Vert, H. (1997). *Les Hommes et la Montagne en Dauphiné au XIII Siècle.* Grenoble: Presses Universitaires de Grenoble.

Feeny, D., Berkes, F., McCay, B. J., and Acheson, J. M. (1990). The tragedy of the commons: twenty-two years later. *Hum.* Ecol. 18, 1–19. doi: 10.1007/BF00889070

Feinman, G. M., and Neitzel, J. E. (2020). Excising culture history from contemporary archaeology. *J. Anthropol.* Archaeol. 60:101230. doi: 10.1016/j.jaa.2020.101230

Feinman, G. M., and Neitzel, J. E. (2023). The social dynamics of settling down. *J. Anthropol. Archaeol.* 69:101468. doi: 10.1016/j.jaa.2022.101468

Fernández Mier, M., and Quirós Castillo, J. A. (2015). El aprovechamiento de los espacios comunales en el noroeste de la Península Ibérica entre el período romano y el medieval. *Cap. Cult.* 12, 689–717. doi: 10.13138/2039-2362/1196

Fredegar, V. P. (1981). *The Fourth Book of the Chronicle of Fredegar*. Westport: Greenwood Press.

Galop, D., Rius, D., Cugny, C., and Mazier, F. (2013). "A history of long-term human–environment interactions in the french pyrenees inferred from the pollen data," in *Continuity and Change in Cultural Adaptation to Mountain Environments*, ed. L. Lozny (New York, NY: Springer), 19–30. doi: 10.1007/978-1-4614-5702-2_3

Goodreau, S. M. (2007). Advances in exponential random graph (p*) models applied to a large social network. *Soc. Netw.* 29, 231–248. doi: 10.1016/j.socnet.2006.08.001

Goodreau, S. M., Kitts, J. A., and Morris, M. (2009). Birds of a feather, or friend of a friend? Using exponential random graph models to investigate adolescent social networks. *Demography* 46, 103–126. doi: 10.1353/dem.0.0045

Goyheneche, E. (1973). *Instituciones Administrativas dels Pais Vasco Frances en la Edad Media.* Madrid: Instituto Nacional de Estudios Jurídicos.

Gragson, T. L., Coughlan, M. R., and Leigh, D. S. (2020). Contingency and agency in the mountain landscapes of the western Pyrenees: a place-based approach to the long anthropocene, *Sustianability* 12:3882. doi: 10.3390/su12093882

Gragson, T. L., Coughlan, M. R., and Leigh, D. S. (2021). "Response diversity and the evolution of pastoral landscapes in the western Pyrenees," in *Transhumance,* eds M. Bowden, and P. Herring (Oxford: Archaeopress Publishing Ltd), 63–75.

Gragson, T. L., and Thompson, V. D. (2022). Legacy radiocarbon dates and the archaeological chronology of the western Pyrenees. *J. Archaeol. Sci.* 43:103483. doi: 10.1016/j.jasrep.2022.103483

Granovetter, M. S. (1978). Threshold models of collective behavior. *Am. J. Sociol.* 83, 1420–1443. doi: 10.1086/226707

Grosclaude, M. (1993). *La Coutume de la Soule.* Pau: Editions Izpegi.

Hamilton, W. D., and Krus, A. M. (2018). The myths and realities of Bayesian chronological modeling revealed. *Am. Antiq.* 83, 187–203. doi: 10.1017/aaq.2017.57

Hardin, G. (1968). The tragedy of the commons. *Science* 162, 1243–1248. doi: 10.1126/science.162.3859.1243

Heckathorn, D. D. (1996). The dynamics and dilemmas of collective action. *Am. Sociol. Rev.* 61, 250–277. doi: 10.2307/2096334

Hecter, M., and Brustein, W. (1980). Regional modes of production and patterns of state formation in western europe. *Am. Sociol. Rev.* 85, 1061–1094. doi: 10.1086/227125

Hodgson, G. M. (2001). How *Economics Forgot History*: The *Problem* of *Historical Specificity* in *Social Science*. London: Routledge.

Jagers, S. C., Harring, N., Lofgren, A., Sjostedt, M., Alpizar, F., Brulde, B., et al. (2020). On the preconditions for large-scale collective action. *Ambio* 49, 1282–1296. doi: 10.1007/s13280-019-01284-w

Kahneman, D. (2011). *Thinking, Fast and Slow.* New York, NY: Farrar, Straus and Giroux.

Kenny, D. A., Kashy, D. A., and Cook, W. L. (2006). *Dyadic Data Analysis.* New York, NY: The Guilford Press.

Kitts, J. A. (2006). Collective action, rival incentives, and the emergence of antisocial norms. *Am. Sociol. Rev.* 71, 235–259. doi: 10.1177/000312240607100204

Kowalewski, S. A., and Birch, J. (2020). "How do people get big things done?" in *The Evolution of Social Institutions: Interdisciplkinary Perspectives,* ed. Bondarenko (New York, NY: Springer), 29–50. doi: 10.1007/978-3-030-51437-2_2

Krivitsky, P. N., Handcock, M. S., Hunter, D. R., Butts, C. T., Klumb, C., Goodreau, S. M., et al. (2003–2022). *statnet: Software Tools for the Statistical Modeling of Network Data*. Statnet Development Team. Available online at: https://statnet.org

Krivitsky, P. N., Hunter, D. R., Morris, M., and Klumb, C. (2023). ergm4: new features for analyzing exponential-family random graph models. *J. Stat. Softw.* 105, 1–44. doi: 10.18637/jss.v105.i06

Lafourcade, M. (2006). Le statut juridique des groups sociaux en Iparralde sous l'Ancien Régime. *Iura Vasconiae* 3, 159–191.

Lafourcade, M. (2010a). La démocratie basque. *Boletín JADO* 8, 171–209.

Lafourcade, M. (2010b). L'autonomie administrative du Pays Basque de France sous l'Ancien Regime. *Boletín JADO* 8, 111–139.

Lafourcade, M. T. (2003). Les assemblées provinciales du Pays Basque Français sous l'Ancien Régime. *Rev. Int. Estud.* Vascos 48, 589–619. doi: 10.4000/lapurdum.1580

Larrea, J. J. (1998). *La Navarre du IVe au XIIe Siècle: Peuplement et Societe.* Brussels: De Boeck Universite.

Lassègues, J. C. (2019). "Le réseau canonial de Sainte-Christine du Somport : mécanismes de son développement sur le versant nord," in *Monastères et Couvents de Montagne : Circulation, Réseaux, Influences au Moyen Âge,* ed. M. le Blévec (Paris: Éditions du Comité des Travaux Historiques et Scientifiques), 4914. doi: 10.4000/books.cths.4914

Lefebvre, H. (1963). *La Vallée de Campan: Étude de Sociologie Rurale.* Paris: Presses Universitaires de France.

Lefebvre, T. (1928). La transhumance dans les Basses-Pyrénées. *Ann. Géogr.* 37, 35–60. doi: 10.3406/geo.1928.9198

Lefebvre, T. (1933). *Les Modes de vie Dans les Pyrénées Atlantiques Orientales.* Paris: Librairie Armand Colin.

Leigh, D. S., Gragson, T. L., and Coughlan, M. R. (2015). Chronology and pedogenic effects of mid- to late-Holocene conversion of forests to pastures in the French western Pyrenees. *Z.* Geomorphol. 59, 225–245. doi: 10.1127/zfg_suppl/2015/S-59212

Leigh, D. S., Gragson, T. L., and Coughlan, M. R. (2016). Colluvial legacies of millennial landscape change on individual hillsides, place-based investigation in the western Pyrenees mountains. *Quat. Int.* 402, 61–71. doi: 10.1016/j.quaint.2015.08.031

Lichbach, M. I. (1996). *The Cooperator's Dilemma.* Ann Arbor, MI: University of Michigan Press. doi: 10.3998/mpub.13808

Manning, S., and Birch, J. (2022). A centennial ambiguity: the challenge of resolving the date of the Jean-Baptiste Lainé (Mangle), Ontario, Site - Around AD 1500 or AD 1600? - the case for wood-charcoal as a terminus post quem. *Radiocarbon* 64, 279–308. doi: 10.1017/RDC.2022.23

Martín Duque, Á. J. (2002a). La comunidad del Valle de Salazar: orígenes y evolución histórica. *Príncipe* Viana 63, 635–666. Available online at: https://revistas.navarra.es/index.php/PV/article/view/2408

Martín Duque, Á. J. (2002b). Algunas observations sobre el carácter originario de la monarquía pamplonesa, *Príncipe Viana* 227, 835—839. Available online at: https://binadi.navarra.es/registro/00012842

Martínez González, A. J. (2012). "El fuero de Estella: Instrumento de atracción en las peregrinaciones europeas," in *IX Congreso Internacional de Asociaciones Jacobeas: El Mediterráneo en el Orígen*, ed. A. Sánchez Ribes (Valencia: Asociación Amigos del Camino de Santiago de la Comunidad Valenciana), 75–92.

McCabe, J. T. (1990). Turkana pastoralism: a case against the tragedy of the commons. *Hum. Ecol.* 18, 81–103. doi: 10.1007/BF00889073

McCay, B. J., and Acheson, J. M. (1987). *The Question of the Commons: The Culture and Ecology of Communal Resources.* Tucson, AZ: University of Arizona Press.

Motte, C., and Vouloir, M.-C. (2017). *Des Villages de Cassini aux Communes D'aujourd'hui.* Paris: Ecole des Hautes Études en Sciences Sociales.

Netting, R. M. (1972). Of men and meadows: atrategies of Alpine land use. *Anthropol. Q.* 45, 132–144. doi: 10.2307/3316527

Netting, R. M. (1976). What alpine peasants have in common: observations on communal tenures in a Swiss village. *Hum. Ecol.* 4, 135–146. doi: 10.1007/BF01531217

Netting, R. M. (1981). *Balancing on an Alp*. Cambridge: Cambridge University Press.

North, D. C. (1990). *Institutions, Institutional Change and Economic Performance.* Cambridge: Cambridge University Press. doi: 10.1017/CBO9780511808678

Noussy Saint-Saëns, M. (1955). *Le païs de Soule: Essai sur la Coutume Basque.* Bordeaux: Clèdes and Fils.

Olson, M. (1965). *The Logic of Collective Action: Public Goods and the Theory of Groups.* Cambridge: Harvard University Press.

Orella Unzué, J. L. (2017). Sistema jurídico pirenaico versus el mesetario Español. *Lurralde* 40, 273–313. doi: 10.52748/lurralde.2017.40.51

Orpustan, J.-B. (2010). *Nouvelle Toponymie Basque: Noms des Pays, Vallées, Communes et Hameaux Historiques de Labourd, Basse-Navarre et Soule.* Bordeaux: PU BORDEAUX, 148.

Ostrom, E. (1990). *Governing the Commons: The Evolution of Institutions for Collective Action.* Cambridge: Cambridge University Press. doi: 10.1017/CBO9780511807763

Ott, S. (1993). *The Circle of Mountains: A Basque Shepherding Community.* Reno: University of Nevada Press.

Palu, P. (1992). Rapports entre organisation sociale et écosytème dans la société pastorale souletine. *Soc.* Contemp. 11, 239–264. doi: 10.3406/socco.1992.1090

Pavón Benito, J. (2018). Poblamiento medieval en Navarra. *Cuad. Arqueol.* 3, 271–300. doi: 10.15581/012.3.27823

Plieninger, T., and Bieling, C. (2013). Resilience-based perspectives to guiding high-nature-value farmland through socioeconomic change. *Ecol. Soc.* 18, 20. doi: 10.5751/ES-05877-180420

Poumarede, J. (1984). Les syndicats de vallée dans les Pyrénées Françaises. *Rec. Soc. Jean. Bodin.* 43, 385–409.

Quirós Castillo, J. A. (2020). Archaeology of early medieval peasantry in the Basque country: landscapes, economic trands and societal change in Álava. *Hist.* Agrar. 82, 209–243. doi: 10.26882/histagrar.082e04q

Quirós Castillo, J. A., Narbarte, J., and Iriarte, E. (2023). What is a village? Agroscapes, collective action and medieval villages in northern Iberia. *Antiquity* 97, 1279–1295. doi: 10.15184/aqy.2023.125

R Core Team (2013). *R: A Language and Environment for Statistical Computing.* Vienna: R Foundation for Statistical Computing.

Rammel, C., Stagl, S., and Wilfing, H. (2007). Managing complex adaptive systems — a co-evolutionary perspective on natural resource management. *Ecol. Econ.* 63, 9–21. doi: 10.1016/j.ecolecon.2006.12.014

Reimer, P., Austin, W., Bard, E., Bayliss, A., Blackwell, P., Bronk Ramsey, C., et al. (2020). The IntCal20 Northern Hemisphere radiocarbon age calibration curve (0–55 cal kBP). *Radiocarbon* 62, 725–757. doi: 10.1017/RDC.2020.41

Rhoades, R. E., and Thompson, S. I. (1975). Adaptive strategies in alpine environments: beyond ecological particularism. *Am.* Ethnol. 2, 535–551. doi: 10.1525/ae.1975.2.3.02a00110

Richer, M. (1998). Le Cayolar en soule. *Azpilcueta* 13, 123–130.

Rius, D., Vannière, B., and Galop, D. (2009). Fire frequency and landscape management in the northwestern Pyrenean piedmont, France, since the early Neolithic (8000 cal. *BP). Holocene* 19, 847–859. doi: 10.1177/0959683609105299

Robins, G., Elliott, P., and Pattison, P. (2001). Network models for social selection processes. *Soc. Netw.* 23, 1–30. doi: 10.1016/S0378-8733(01)0 0029-6

Robins, G., Pattison, P., Kalish, Y., and Lusher, D. (2007). An introduction to exponential random graph (p*) models for social networks. *Soc. Netw.* 29, 173–191. doi: 10.1016/j.socnet.2006.08.002

RStudio Team (2015). *RStudio: Integrated Development for R.* Boston, MA: RStudio, Inc.

Smith, E. A., and Wishnie, M. (2000). Conservation and subsistence in small-scale societies. *Ann. Rev. Anthropol.* 29, 493–524. doi: 10.1146/annurev.anthro.29.1.493

Snijders, T. A. B., van de Bunt, G. G., and Steglich, C. E. G. (2010). Introduction to stochastic actor-based models for network dynamics. *Soc. Netw.* 32, 44–60. doi: 10.1016/j.socnet.2009.02.004

Takács, K., Janky, B., and Flache, A. (2008). Collective action and network change. *Soc. Netw.* 30, 177–189. doi: 10.1016/j.socnet.2008.02.003

Testart, A. (2003). Propriété et non-propriété de la terre: L'illusion de la propriété collective archaïque (1re partie). *Etud. Rurales* 165-166, 209–242. doi: 10.4000/etudesrurales.8009

Thaler, R. H. (2015). *Misbehaving: The Making of Behavioral Economics.* New York, NY: W. W. Norton and Company.

Thomas, E. F., Zubielevitch, E., Sibley, C. G., and Osborne, D. (2020). Testing the social identity model of collective action longitudinally and across structurally disadvantaged and advantaged groups. *Pers. Soc. Psychol. Bull.* 46, 823–838. doi: 10.1177/0146167219879111

Thompson, V. D., Marquardt, W. H., Walker, K. J., Thompson, A. D. R., and Newsom, L. A. (2018). Collective action, state building, and the rise of the Calusa, southwest Florida, USA. *J. Anthropol. Archaeol.* 51, 28–44. doi: 10.1016/j.jaa.2018.05.003

Unzu Urmeneta, M. (2021). Excavacions arqueológicas en Ibañeta: resultados e hipótesis. *Pregón* 59, 17–21.

Urrutibéhéty, C. (1983). Casas *Hospitalisa. Diez Siglos de Historia en Ultrapuertos.* Pamplona: Institution Príncipe de Viana.

Van Zomeren, M., and Iyer, A. (2009). Introduction to the social and psychological dynamics of collective action. *J. Soc. Issues* 65, 645–660. doi: 10.1111/j.1540-4560.2009.01618.x

van Zomeren, M., Postmes, T., and Spears, R. (2008). Toward an integrative social identity model of collective action: a quantitative research synthesis of three socio-psychological perspectives. *Psychol. Bull.* 134, 504–535. doi: 10.1037/0033-2909.134.4.504

Vivier, N. (1998). *Propriété Collective et Identité Communale. Les Biens Communaux en France 1750-1914.* Paris: Publications de la Sorbonne.

Wang, P., Robins, G., Pattison, P., and Lazega, E. (2013). Exponential random graph models for multilevel networks. *Soc. Netw.* 35, 96–115. doi: 10.1016/j.socnet.2013. 01.004

Wasserman, S., and Pattison, P. (1996). Logit models and logistic regressions for social networks: I. An introduction to Markov Graphs and p*. *Psychometrika* 61, 401–425. doi: 10.1007/BF02294547

Whittle, A. (2018). *The Times of their Lives: Hunting History in the Archaeology of Neolithic Europe.* Oxford: Oxbow Books. doi: 10.2307/j. ctvh1dm57