Structure of Stockmen Collaboration Networks Under Two Contrasting Touristic Regimes in the Spanish Central Pyrenees

Hugo Saiz, Maite Gartzia, Paz Errea, Federico Fillat, Concepción L. Alados

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Authors: Hugo Saiz*[a,b,c], Maite Gartzia[d], Paz Errea[a], Federico Fillat[d], Concepción L. Alados[a]

Affiliations: [a] Instituto Pirenaico de Ecología (IPE) - CSIC Campus de Aula Dei, Avda. Montañana, 1005. 50059 Zaragoza (Spain).

[b] UMR 6553 Ecobio, CNRS - University of Rennes 1, Avenue du Général Leclerc. 35042 Rennes Cedex (France).

[c] Departamento de Biología y Geología, Física y Química Inorgánica, Universidad Rey Juan Carlos, C/ Tulipán s/n. 28933 Móstoles (Spain).

[d] Instituto Pirenaico de Ecología (IPE) - CSIC Campus de Jaca, Avda. Nuestra Señora de la Victoria, s/n. 22700 Jaca, Huesca (Spain).

*Corresponding author: saizhugo@gmail.com

Abstract

Ecosystem management is a difficult task because it must conciliate the ecological, economic, and social dimensions of socio-ecological systems. In those systems, the action of any single component can have an effect on the others, and result in a critical impact on the organization of the entire system. This study examined the collaboration networks among stockmen within two traditionally agro-pastoral regions in the Spanish Central Pyrenees which in the las 30 years included touristic activities: one under the influence of a National Park and centered on ecotourism, and the other in a region where there are ski resorts and local stockmen have turned to snow tourism. Our hypotheses were that economic regime affects the structure of the networks, and the type of collaboration (*e.g.* for economic reasons) influences the collaborations among stockmen. We built stockmen collaboration networks by connecting breeders within the same pastoral partnerships, and calculated the importance of collaborations (links density), the occurrence of collaborative subgroups (network modularity), and the existence of collaborations between stockmen in different regions (Krackhardt Ratio). In addition, we identified the distribution of links among types of pastoral partnerships. The network under the influence of the National Park presented higher link density and modularity than did the network influenced by ski resorts, where the presence of non-local stockmen is higher. Furthermore, economic partnerships played a major role connecting stockmen. In the study area, differences in the collaboration networks between the two regions suggest that changes in the economic trend in the last 30 years has influenced the collaborative structure of the stockmen. We discuss possible reasons behind these differences and propose some recommendations which could help to strengthen the collaborative bounds between stockmen in the area.

Keywords: Agro-pastoral practices, Collaboration networks, Ordesa-Monte Perdido National Park, Socioeconomic systems, Ski resorts.

1. Introduction

Ecosystem conservation is one of the most important challenges of our time. Global change driven by human activities has altered the natural balance and modified Earth processes significantly (Rockström et al., 2009). Those changes have created several threats to the preservation of ecosystems including global warming and biodiversity loss, which are among the most important issues that governments must face to preserve the ecological value of the environment (Sala et al., 2000; Vitousek, 1994; Vitousek et al., 1997). However, finding a balance between the conservation of ecosystems, economic development and the preservation of social values (*i.e.* sustainable development, Hopwood et al., 2005) can be difficult. Ecosystem management covers only one part of social-economical systems (SES), which combine ecological, economic, and social dimensions of human systems (Millenium Ecosystems Assessment, 2005; Ostrom, 2009). In SES, an effect on any single component can spread to the others and have a significant impact on the entire organization of the system (Holling, 2001; Young et al., 2006). Thus, to develop more effective conservation strategies, all different dimensions of SES have to be assessed simultaneously (Fiksel, 2006). Particularly, in recent times the importance of the social dimension to address the resilience of SES has been highlighted (Berkes and Ross, 2013; Davidson, 2010). For instance, considering the collaborative structure among the inhabitants in SES is central for the system resilience, as differences in the social organization of the system can have significant effects on the success of management practices (Berkes et al., 2000).

Management practices are particularly important in mountainous regions. In mountain areas, human activities have led to the development of a wide variety of ecosystems that are nowadays considered biodiversity hotspots (Korner and Spehn, 2002; Lomolino, 2001) and whose environmental value is recognized (mountain ecosystems are included within the European Habitat Conservation Strategy, Consejo de las Comunidades Europeas, 1992). Furthermore, those areas have been inhabited for centuries and are presented as examples of sustainable SES that preserve traditional economic activities, mainly agro-pastoral practices; together with the ecological value of the ecosystem (Jodha et al., 1992). For example, in the Spanish Central Pyrenees, the persistence of traditional pastoral habits such as transhumance (*i.e.* periodic movement of livestock between summer and winter pastures) led to the development of singular plant communities that have both high biodiversity and productivity (Caballero et al., 2011; Ruiz and Ruiz, 1986). Thus, traditional mountain human systems are good examples of sustainable development, where ecological, economic, and social dimensions of the SES are balanced.

In Europe, however, industrial development near cities at the beginning of the 20th Century led to massive migration from rural to urban areas (Alados et al., 2014; Mather, 2001; Pinilla et al., 2008). This dramatic reduction in human labor had a profound impact on mountain SES and, especially, on the conservation of mountain pastures. In Spanish Central Pyrenees land abandonment and the loss of sustainable pastoral practices have reduced pasture area due to changes in land use (García-Ruiz et al., 1996; Gartzia et al., 2016b, 2014) and 'shrub encroachment' (*i.e.* increase in the density of local shrubs in pastures to the detriment of herbs and grasses, Komac et al., 2011; Van Auken, 2000). For example, the substitution of pastures by shrublands and forests has been associated to the decrease in livestock numbers in the area (Gartzia et al., 2014). In addition, the loss of mountain pastures might be accelerated in near future as they are among the most vulnerable habitats to global climate change (Huber et al., 2006).

Livestock management is one of the main factors responsible for maintaining the ecological value of mountain pastures (Kohler et al., 2004; Zervas, 1998). Livestock grazing influences the growth of the consumed plants, modifies species cover, and changes the composition and structure of plant communities (Milchunas and Lauenroth, 1993; Van Auken, 2000). Furthermore, pastoral ecosystems have been recognized as important providers of ecosystem services (Oteros-Rozas et al., 2013). For example, livestock grazing can increase the productivity of an ecosystem, and transforms a dispersed, low-energy resource (grass) into a concentrated, high-energy resource (livestock meat, Frank et al., 1998). In addition, pastoral activities also help to preserve and transmit traditional local knowledge in mountain SES (*e.g.* location of water points and grazing paths, regulation of grazing intensities, Hassanein and Kloppenburg, 1995), which helps to accelerate the reorganization of the system after major disturbances (Berkes et al., 2008). Therefore, to preserve mountain pastures and their associated ecosystem services, the conservation of sustainable agro-pastoral activities is essential.

Traditionally, in the Spanish Pyrenees livestock production has involved a communal grazing system in which stockmen collaborate to expand grazing pastures and to preserve their pastoral value (Caballero et al., 2011). Today, this collaborative structure has led to the creation of different livestock partnerships whose duties include from economic to sanitary tasks (*e.g.* optimize the marketing of products, obtain quality designations for the livestock; or manage veterinary exams, Confederación de Cooperativas Agrarias de España, 2002). Remarkably, the implementation of Common Agricultural Policy (CAP, Consejo Europeo, 2005) has led in recent times to the apparition of several partnerships specialized in maximizing the capture of subsidies

(García-Martínez et al., 2009; Veysset et al., 2005). However, changes in mountain SES as depopulation and the reduction in agro-pastoral practices might modify this collaborative system and, ultimately, influence the viability of mountain pastures. Thus, economic and social dimensions of traditional mountain SES have to be reconciled to preserve the ecological value of mountain pastures.

In this study, we evaluate the collaborative structure of stockmen in two regions in Spanish Central Pyrenees. This mountainous area has been traditionally driven by agro-pastoral activities, but with the decline of livestock in recent times, inhabitants have supplemented livestock management with other economic activities associated to tourism. One region has supplemented agro-pastoral practices with ecotourism activities under the influence of a National Park. On the other hand, the other region has incorporated snow tourism activities organized around the development of big ski resorts. We studied the collaborative structure in the area through the analysis of their stockmen collaboration networks (SCN). In these networks, stockmen connect among them considering the different economic and cultural partnerships they belonged to. We hypothesize that the analysis of the SCN unveils valuable information about the organization of stockmen in our SES. For example, differences in the current economic trends between regions or the specific type of partnerships considered to represent the collaboration could have a reflection in the stockmen collaborative structure. We expect that the analysis of SCN improves our knowledge about the social dimension in the Spanish Central Pyrenees.

2. Methods

2.1. Study area and data collection

The study was conducted in the Central Pyrenees within the province of Huesca in northern Spain. The study area lies within the alpine mountain range (*sensu*, the zone above 1500 m, Fillat et al., 2012) with a maximum elevation of 3340 m. The climate is heterogeneous and strongly influenced by elevation, ranging from alpine in mountain grasslands to sub-Mediterranean at low elevations. Average annual temperature ranges from 5º C (Goriz Refuge at 2200 m, data from 1976 to 2005) to 12.4º C (Salinas de Bielsa at 760 m, data from 1961-1967) and average annual precipitation ranges from 1657 mm (Goriz) to 1307 mm (Salinas de Bielsa). Historically, grazing activities, which have involved moving livestock from mountain grasslands in summer to the Middle Ebro valley in winter, have driven the local economy (Caballero et al., 2011; Daumas, 1976). However, at the beginning of 20th Century urban development led to a rural depopulation in the area resulting in a reduction of grazing activity and the substitution of pastures and cultivated areas by shrublands and forests (Alados et al., 2014; García-Ruiz et al., 1996; Lasanta and Vicente-Serrano, 2007)

We selected two regions in the Spanish Central Pyrenees: Sobrarbe and Alto Gállego counties (Figure 1). Although both regions differ in their population densities (Table 1), their population trends in the 20th Century have been similar (strong decrease until 1980s, when population stabilized, Alados et al., 2014). Furthermore, both regions have experienced the same changes in agro-pastoral activities, with a substitution of sheep livestock by cattle (sheep livestock decreased from 1.4 ind/ha in 1940 to 0.2 ind/ha in 2000, while cattle increased from 0.05 ind/ha to 0.14. Data from Archivo Histórico de Huesca and Delegación Provincial de Huesca); principally because the cost of managing cattle is smaller (in the study area, livestock can reach the most remote pastures while cattle is concentrated in the most accessible ones, Gartzia et al., 2016a). Together with changes in shepherding, in recent times stockmen in both regions have supplemented pastoral practices with other sources of income mostly linked to services sector (Table 1). However, these sources differed between regions.

On one hand, Sobrarbe includes six municipalities (Torla, Broto, Fanlo, Puertolas, Tella-Sin and Bielsa) encompassing the area in and around Ordesa-Monte Perdido National Park (OMPNP, Figure 1). Ordesa-Monte Perdido National Park was created in 1918 and expanded to its current limits in 1982 (15,608 ha). The presence of OMPNP has induced the rise of ecotourism in recent years, resulting in the development of campsites and rural houses (Table 1). On the other hand, Alto Gállego includes five municipalities (Sallent del Gállego, Panticosa, Hoz de Jaca, Biescas, and Yésero) which comprise two ski resorts (Formigal and Panticosa, Figure 1). In the Central Pyrenees, between 1965 and 1976, five alpine ski resorts and associated tourist infrastructures were built, which led to significant changes in the population and pastoral activities in the area (Marín-Yaseli and Lasanta, 2003). Specifically, in this region the development of snow tourism has led to the increase in the number of apartments and hotels (Table 1). It is important to note that, although the touristic development in both regions is different, the number of beds available in touristic accommodations is similar between them (Table 1). However, the number of new building differs, suggesting differences in the presence of secondary residences between regions (Table 1). Thus, we compared two regions which have experienced different economic shifts in the last 30 years: Sobrarbe, which includes ecotourism under the influence of a National Park (NP); and Alto Gállego, which includes snow tourism under the influence of ski resorts (SKI).

2.2. Network construction and analysis

In both regions, we conducted personal interviews to all stockmen who transport their livestock to pastures within the study area. Interviews included questions about the stockmen (origin, current residence, age, years spent shepherding in the area, education level), and their thoughts about the current environmental situation in the region (changes in the landscape, land use and pastoral practices). We also recorded all the different partnerships which stockmen belonged to. We identified partnerships as groups of individuals which gather sporadically to pursuit a common interest, and used them as a proxy of local associations of stakeholders which collaborate among them (Olsson et al., 2004). All considered partnerships provided a service directly linked to livestock management, and were categorized in four groups according to their objectives: health partnerships, subsidy partnerships, cooperatives, and others (Table 2). It was possible for each stockman to belong to more than one partnership simultaneously, and for stockmen from different regions to belong to the same partnership. Specifically, within the study area, we identified 194 stockmen and 36 pastoral partnerships.

Using the data from stockmen and their partnerships, we built an X_{SxP} matrix. In the matrix X, stockmen (S) are rows and partnerships (P) columns, and $X_{ij} = 1$ when stockman i belongs to partnership j. Based on X, we built stockmen collaboration networks (SCN), in which a link exists between two stockmen if they belong to the same partnership (*sensu*, affiliation networks, Borgatti and Halgin, 2011). Although sharing a partnership is not an explicit measure of collaboration, as stockmen in the same partnership have common interests and group together to attain benefits related to agro-pastoral practices, we assumed that partnership sharing is a valid proxy of a collaborative link. Therefore, SCN was defined as a square matrix L_{SxS} where l_{ij} is the collaboration between stockmen i and j (l_{ij} = number of partnership shared by stockmen i and j). The number of links of a stockbreeder i (L_i) is the number of collaborative bounds he has with other stockmen, and the total number of collaborations in the system is L. We built one SCN for stockmen in each region, and another including both regions combined (TSA, total study area: stockmen in NP + stockmen in SKI). We drew the networks with NETDRAW (Analytic Technologies; http://www.analytictech.com/netdraw/netdraw.htm).

For each network we calculated isolation, linkage density, modularity and Krackhardt Ratio (Borgatti and Halgin, 2011; Krackhardt and Stern, 1988; Newman, 2006a), definition and abbreviations of indices are included in Table 3). All of those indices are related to the resilience, adaptive and information-spreading capacity of the network, and have significant effects on the robustness of the system (Janssen et al., 2006; Newman, 2006b). For example, indices related to network cohesion (Isolation, Density) and connection between subgroups (Modularity, Krackhardt Ratio) are related to the communication between subgroups within the system (Barnes-Mauthe et al., 2013), which can pose challenges to manage common resources (*e.g.* low cohesive systems), or can increase the productivity and innovative capacity (*e.g.* high connectivity between different groups) (Bodin and Crona, 2009). To quantify the significance of the indexes observed in each SCN, we simulated 1000 matrixes setting the number of links per row and column to that of X_{SxP}. We built the corresponding L_{SxS} for each simulated matrix and calculated all indices. Real values were significantly different from simulated values if they separated more than 2 standard deviations from the mean of the values from the simulations. We also evaluated differences in the SCN structure of both regions comparing the isolation, number of partnership per stockbreeder (A_i) and the number of links per stockbreeder (L_i). We used a Chi-square test to compare *Iso*, and a Generalized Linear Model (GLM) to compare A_i and L_i between regions. All calculus were performed with R (R Development Core TeamTeam, 2014).

We evaluated the effect of the type of partnership on the collaborations among stockmen in two ways. First, we used a Chi-square test to compare the proportion of collaborative bounds among stockmen between the two regions considering the partnerships categories. Second, we used a Generalized Linear Mixed Model (GLMM) to assess the effects of region and partnership category in A_i and L_i. Model included A_i and L_i as response variables, the interaction between region and type of partnership as an explanatory fixed variable, and stockbreeder identity as an explanatory random variable. In addition, to assess the influence of partnership category on the collaborations within and between regions, we built one individual SCN for each category of partnerships and calculated the Krackhardt Ratio of each network. All comparison tests were performed using R.

3. Results

3.1. Characteristics of stockmen

Stockmen groups presented similar characteristics in both regions, with most stockmen presenting similar age (more than 40 years) and education level (secondary level). Furthermore, most stockmen came from a family related to shepherding and have carried their livestock to pastures in the area for more than 30 years. We only found significant differences between regions in the origin of stockmen, with more proportion of foreign stockmen in SKI ($foreign_{NP}$ = 2/81 = 0.02; $foreign_{SKI}$ = 22/113 = 0.19; X^2 = 11.06, $p < 0.001$). All stockmen agreed that in recent times mountain pastures and landscape have changed noticeably (principally, through the substitution of pastures by shrubland and forest). From all stockmen in the study area, nine were not connected to others (*sensu*, they did not present any collaborative links with others). Connected stockmen organized in SCNs that had a big block composed by most of the stockmen, and few stockmen isolated in smalls blocks (Figure 2). Characteristics of the SCNs are presented in Table 4.

3.2. Network analysis

Network indices showed that the SCN for the whole study area had higher *Iso* and *Q* than expected (Table 5), which suggests that stockmen organized forming close collaborative groups. Focusing on the regions, both networks presented higher densities (*D*) than expected based on the simulations (Table 5). However, the network in SKI had higher *Iso* and lower *Q* than expected, while the network in NP had higher *Q* than expected. This suggests that in NP there were groups of stockmen who collaborated closely with each other, while in SKI there were not tight collaborative groups. Furthermore, in SKI there were also several stockmen who did not present any collaboration links.

Comparing both regions, SKI had significantly more isolated stockmen ($\chi^2 = 4.79$, df = 1, p-value = 0.029), and significantly fewer partnerships per stockbreeder and fewer links per stockbreeder than NP (Table 6). This suggests that stockmen established more collaborative associations in the region under the influence of the National Park than in the region with ski resorts. Furthermore, Krackhardt Ratio indicated that most of the collaborative links were between stockmen within the same region (Table 5), which suggests that stockmen preferred to partner with their geographic neighbors.

The effect of type of partnership on the collaborations among stockmen differed between the two regions ($\chi^2 = 1934.38$, df = 3, p-value < 0.001). Specifically, in NP all four types of partnerships were responsible of establishing collaborations, while in SKI, most of the collaborative links were through health and subsidy partnerships (Figure 3).

Furthermore, type of partnership and region had a significant interaction on the numbers of partnerships per stockbreeder and links per stockbreeder (Table 6). In NP, stockmen were most likely to belong to cooperatives and local partnerships, and had more collaborative links with other stockmen than stockmen in SKI; especially, through health, cooperative and local partnerships (Figure 4). In both regions, collaborations were significantly more concentrated in subsidy partnerships. Krackhardt Ratio indicated that stockmen associated more with others in the same region; independently of the type of partnership ($E/I_{sanitary}$ = -0.99; $E/I_{subsidy}$ = -0.56; $E/I_{cooperative}$ = -0.97; E/I_{local} = -1; all real *E/I* values were significantly lower than the simulations). Among the types of partnerships, the one which connected most stockmen from different regions was the subsidy partnership (had the highest *E/I Ratio*).

4. Discussion

4.1. Characteristics of Stockmen Collaboration Networks

In the Central Pyrenees, the analysis of the stockmen collaboration networks (SCN) helped to disentangle the structure of stockbreeder community. In the whole study area, the SCN presented a modular structure in which stockmen organized themselves into close groups, with this groups mainly formed by stockmen habiting within the same region. These collaborative groups can arise for different reasons. On one hand, study area is characterized by the presence of valleys and mountain ranges. The presence of mountain ranges can act as a geographical barrier to migration and cultural transfer between valleys, resulting in the partial isolation of regions within the area and the development of different cultural landscapes (Axelrod, 1997). Therefore, the historical relationship between human and environment in each region could result in landscapes and communities highly linked to local identity (Rössler, 2006). On the other hand, in social network analysis, typically, actors preferentially interact with those who are most similar to them (a property called homophily, McPherson et al., 2001) or share common interests (Feld, 1981). In the Spanish Central Pyrenees, stockmen have spent decades organizing the annual use of local pastures (Fernández-Giménez and Fillat, 2012). Because stockmen usually moved their livestock to the pastures closest to their dwelling, they mostly organized the use of pastures with their neighbors and, consequently, more collaborations appeared. This preference for collaborating with neighbors might explain why, in general, stockmen belong to few associations (in the study area, 50% of the stockmen belonged to two or less associations).

Considering the two regions, although stockmen communities were similar in age, education and experience in shepherding, we observed contrasting structures in their SCNs. In the region under the influence of the Ordesa-Monte Perdido National Park (OMPNP) and more focused on ecotourism (NP), the network was organized in close collaborative groups and stockmen established high number of collaborations. In the area near OMPNP, stockmen have been sharing pastures for centuries (Sal and Lorente, 2004), with the creation of historical local organizations such as 'Mancomunidad del Valle de Broto' and 'Casa de Ganaderos de Zaragoza' (founded in the 13th Century) to regulate grazing management. The necessity of sharing pastures in the same place has strengthened the interaction bounds, resulting in a very close collaborative system formed by neighbors and pastures partners. This can be seen in the importance of cooperatives and other partnerships in the region (Figure 3 and 4). The existence of these historical organizations is important in the region and they have been presented as important keepers of traditional knowledge in Pyrenees (Fernández-Giménez and Fillat, 2012). Furthermore, in recent times several partnerships have appeared to maximize the acquisition of subsidies intended for the maintenance of traditional agro-pastoral practices in the area (related to the presence of a National Park, Gobierno de España, 2007; and Common Agricultural Policy, Consejo Europeo, 2005), which have become the main source of income for stockmen in the area (Fernández-Giménez, 2015; Plieninger, 2006). For example, to defend the interests of livestock owners in the National Park, a specific partnership was formed ('Asociación de Ganaderos del Parque Nacional de Ordesa y Monte Perdido'). This partnership brings together the stockmen who move their herds to the pastures within the Park, and has greatly helped to strengthen the collaborative bounds in the area.

On the other hand, the SCN in the region including snow tourism (SKI) presented several stockmen with no collaborative links and was not organized in groups. In SKI the reduction in sheep and goats has resulted in a significant increase in the amount of ungrazed mountain pastures (García-Ruiz et al., 1996; Lasanta and Vicente-Serrano, 2007). Although the reduction in livestock was widespread in the Pyrenees (including the area within the National Park), the pastures in SKI region have been more attractive because they are easier to manage (*e.g.*, they are accessible by car, have shallow slopes, Gartzia et al., 2016a) and have been highly demanded to develop goods related to snow activities (Marín-Yaseli and Lasanta, 2003). This has resulted in a strong turn from an economy centered in agro-pastoral sector to another more focused on services, which is enhanced in the areas near ski resorts (Marín-Yaseli and Lasanta, 2003). Substitution of agro-pastoral practices by ski tourism is common in mountain areas (Gellrich et al., 2007; Teodoro Lasanta and Vicente-Serrano, 2007) and usually, in farms, different economical activities coexist (Riedel et al., 2007). However, the harmonious coexistence between shepherding and tourism strongly depends in the goals of the local stockmen (Gasson et al., 1993). In general, stockmen in the study area complained about the hardness of livestock management compared to other jobs and the lack of replacement by new generations (Fernández-Giménez, 2015). This lack of replacement has caused that in recent times, particularly in the SKI region, non-local stockmen have transported their herds to the region. These newcomers belonged to non-local partnerships before they arrived and so, did not require to join the local ones, resulting in a weakest collaborative structure.

4.2. Effect of type of partnership in the collaborative structure

The importance of the type of partnership structuring SCNs showed that, independently of the region considered, most collaborative links were based on economic profit (subsidy partnerships produced the most collaborations, even between stockmen from different regions, Figure 3). Since the implementation of Common Agricultural Policy (CAP) in 1986, subsidies have been the main force shaping the agro-pastoral sector in Spain, particularly replacing sheep farming by cattle (García-Martínez et al., 2009; Plieninger, 2006). Particularly, belonging to partnerships that facilitate the process of receiving funds has been profitable (*e.g.* partnership help its members to request subsidies properly), and consequently, stockmen prioritize most profitable partnerships over other factors as geographical proximity or neighbors preferences. The involvement of public and private services can help to sustain agro-pastoral systems (Bernués et al., 2003), but is central to identify the main drivers behind the organization of SES to apply efficient management practices.

Network structure has strong implications in the resilience of a system (Bodin and Crona, 2009; Olsson et al., 2004; Tompkins and Adger, 2004). In a system with a modular structure, information transfer from one module to another is difficult, but it might also result in the formation of smaller and more efficient working groups (Janssen et al., 2006). In the Spanish Central Pyrenees, stockmen have collaborated with whom they share pastures and coordinated to move their livestock along the year to optimize pastures forage production. Collaborative groups represented by the modules in the network might facilitate the efficient exploitation of pastures, which might help to maintain their ecological and pastoral value. However, most of those small groups were quite closed, which can obstruct the creation of a large-scale collaborative structure. Studies on adaptive management have suggested that non-modular organizations are more adaptive than modular ones, and they allow the inclusion of external information and the creation and reassembling of links in the system (Aldrich, 1999; Granovetter, 1973). Thus, non-modular organizations respond faster to changes in the external conditions of socio-ecological systems and can evolve to new possible equilibrium states (Holling, 2001). It is possible that the SES in the SKI region is still adapting to the presence of ski resorts, and it will take time before it is known whether this process leads to an equilibrium in which only one between local traditional practices and ski-related sources of incomes dominates, or both activities coexist becoming the main drivers of the economic development in the region.

The collaboration networks used in our study were based on affiliation networks (*sensu* (Borgatti and Halgin, 2011), and it is important to consider that these networks have limitations. For example, in our study we assumed that stockmen who belonged to the same partnership were collaborating, but this is only a proxy of a real collaboration. For example, almost all of the stockmen belonged to partnerships related to mandatory health controls imposed by Government (85% of stockmen belonged to one health association), which was the result of legal issues rather than truly collaborative bounds. Consequently, we did not find a significant effect of health partnerships between the two regions. Thus, is important to consider the actual contribution of a certain type of partnership to the collaborative structure of the system. Another possible limitation involves the transformation from affiliation to stockmen network. An affiliation network indicates which stockman belongs to each of the partnership, but SCN indicates the collaborative links between stockmen (Borgatti and Halgin, 2011). We could have used an affiliation matrix directly to test our hypotheses, but as we were interested in the specific organization among stockmen, we restricted our analyses to SCN. In addition to methodological issues, it is important to consider the effect of other factors on the collaborative structures of both regions. For example, differences in population between regions could influence the collaborative structure (*e.g.* smaller populations have less potential collaboration opportunities); or differences in pastures availability could require alternative management strategies (*e.g.* lower pastures availability needs better collaboration among stockmen). Therefore, although differences in touristic activities between our study regions seem the main reason behind the structure of SCN, we cannot exclude other possible causes.

Despite these limitations, our results suggest that differences in current economic trends in the study area might affect the collaborative structure between the inhabitants. In our study area, the collaborative system in the region influenced by the presence of the National Park and ecotourism was characterized by strongly connected groups of stockmen, while in the region turning to ski oriented tourism collaboration was weaker and less organized. Economic factors appeared to be the main reason behind the establishment of collaborations between stockmen, particularly, through partnerships specialized in getting subsidies which gathered most the connections between stockmen from different regions.

5. Implications

The success of environmental management practices depends on a correct assessment of the ecological, economic and social dimensions of the area under consideration (Fiksel, 2006), as the action of any dimension can spread to the others (Holling, 2001; Young et al., 2006). Particularly, in recent times the importance of the social dimension to address the resilience of SES has been highlighted (Berkes and Ross, 2013; Davidson, 2010). A proper understanding of the people living in the communities has been presented as central to include in resilience frameworks (Crane, 2010). For instance, economic changes can alter the social structure of a human community, and hence, modify the environmental management that the community requires (Alados et al., 2014; Isaac et al., 2007); or differences in the social organization of the system can significantly alter the success of management practices (Berkes et al., 2000). Thus, including the social dimension in the study of traditional agro-pastoral SES is essential to improve the management of mountain pastures and avoid unexpected effects on their preservation in the near future.

We suggest that the use of Stockmen Collaboration Networks (SCN) could improve the understanding of the social organization of the inhabitants in a region, helping to improve the implementation of management practices. The application of social networks to unveil the structure of stakeholders and help in the management of SES has been shown to be important in recent times (Barnes-Mauthe et al., 2013; Beilin et al., 2013). In our study area, we found that differences in the economic trends associated to tourism between regions affected the collaborative structure among the stockmen. While in the region under the influence of a National Park and ecotourism collaborative structure is characterized by strong bounds and highly connected groups, the development of ski resorts outside that region has caused stockmen near those resorts to turn to snow tourism-related services and the entrance of non-local stockmen, who have not created yet strong cooperative bounds with local stockmen. This separation between local and non-local stockmen can result in the loss of traditional ecological knowledge in the area leading to an inefficient exploitation of pastures, which might reduce their ecological and pastoral value. Thus, preserving the local knowledge would require strengthening the bounds between local and non-local stockmen. In our study area, economic gain appeared as the most important driver of collaborations. Specifically, subsidy-oriented partnerships included the highest number of collaborative links, and were the only partnerships which connected stockmen from both regions. This suggests that economic profit is mandatory to involve local populations. Therefore, including local and non-local stockmen in the same subsidy partnerships seems the most efficient strategy to strengthen the collaboration between them. This way, local knowledge would be more easily transmitted to all stockmen shepherding in the area, helping to preserve traditional ecological knowledge and improving the sustainable use of mountain pastures.

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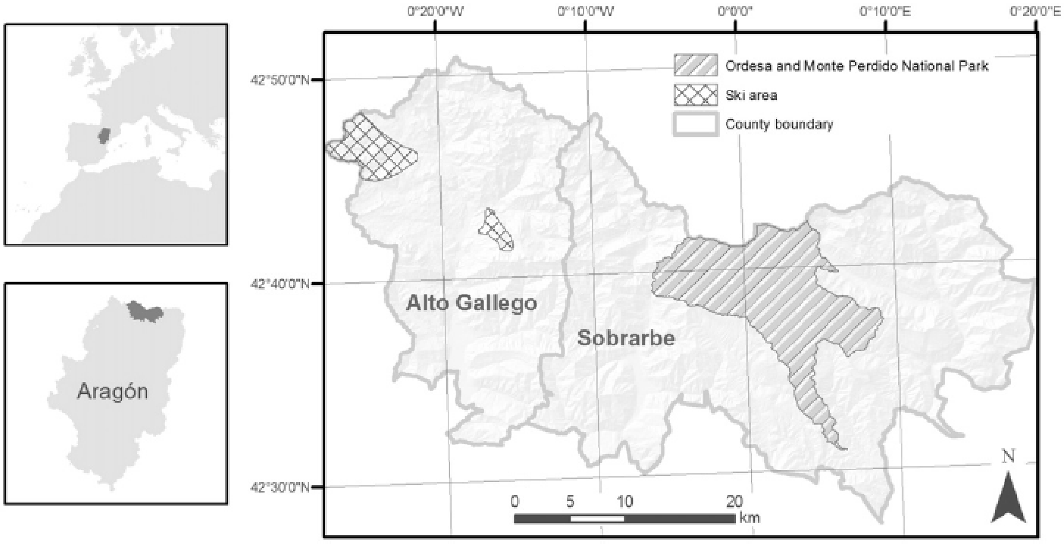

Figure 1. Study area in the Spanish Central Pyrenees. Study was conducted in the north side of the regional county of Aragón, Spain. Two study regions are adjacent, but one is strongly influenced by Ordesa-Monte Perdido National Park (NP, Sobrarbe, right), and the other is influenced by the presence of ski resorts (SKI, Alto Gallego, left). Highlighted parts in the map represent the area covered by the Ordesa-Monte Perdido National Park in Sobrarbe, and the area covered by ski resorts in Alto-Gállego.

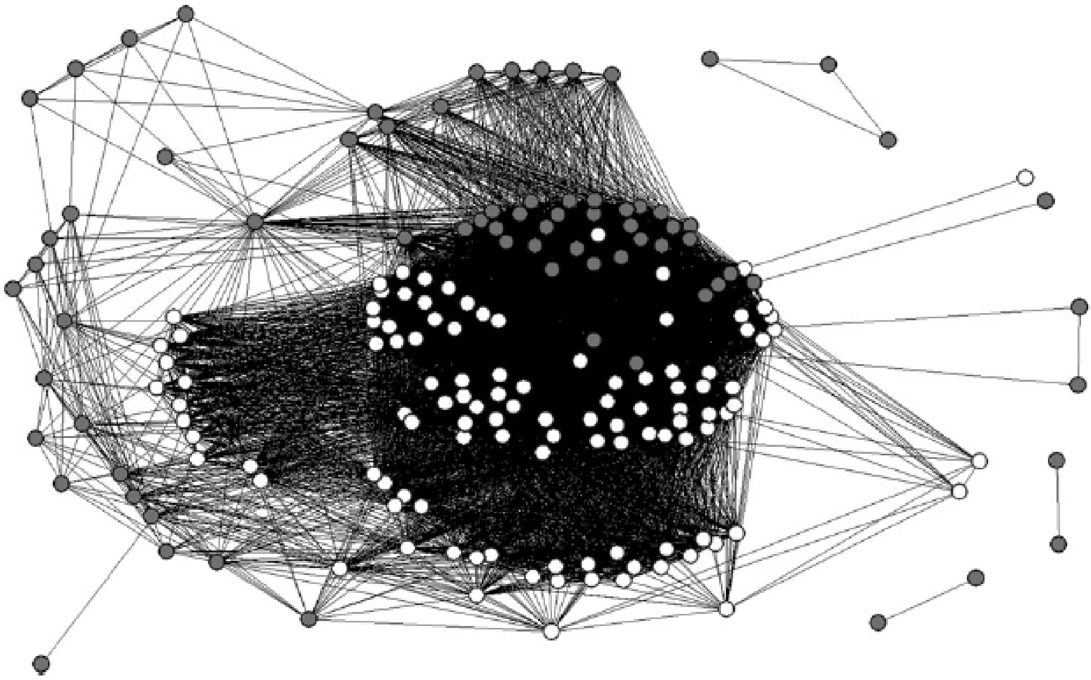

Figure 2. Stockmen Collaborative Network in Spanish Central Pyrenees. White nodes are stockmen in NP and grey nodes stockmen in SKI. Links are drawn under the assumption that all have the same strength ($l_{ij} = 1$ if $l_{ij} \geq 1$). Isolated stockmen (stockmen which did not connect to any other) are not included (9 nodes).

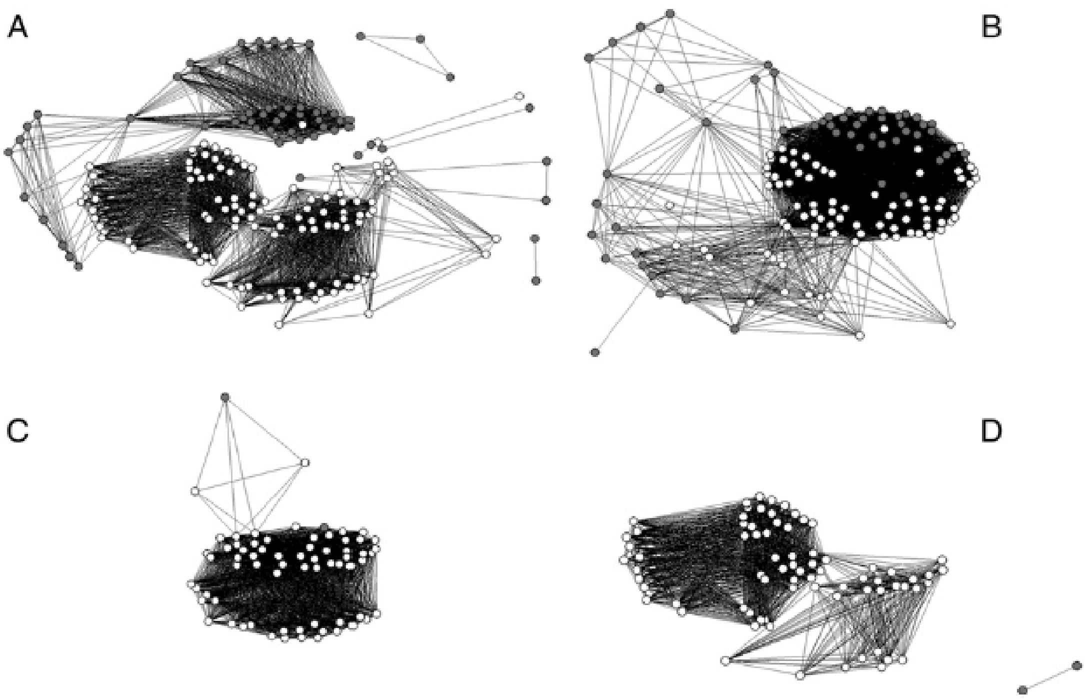

Figure 3. Stockmen Collaborative Networks in the Spanish Central Pyrenees depending on the type of association. A) SCN for health associations; B) SCN for subsidy associations; C) SCN for cooperative associations; D) SCN for local associations. White nodes are stockmen in NP and grey nodes stockmen in SKI. Links are drawn under the assumption that all have the same strength ($l_{ij} = 1$ if $l_{ij} \geq 1$). Isolated stockmen (stockmen who did not connect to any other) are not represented (9 nodes).

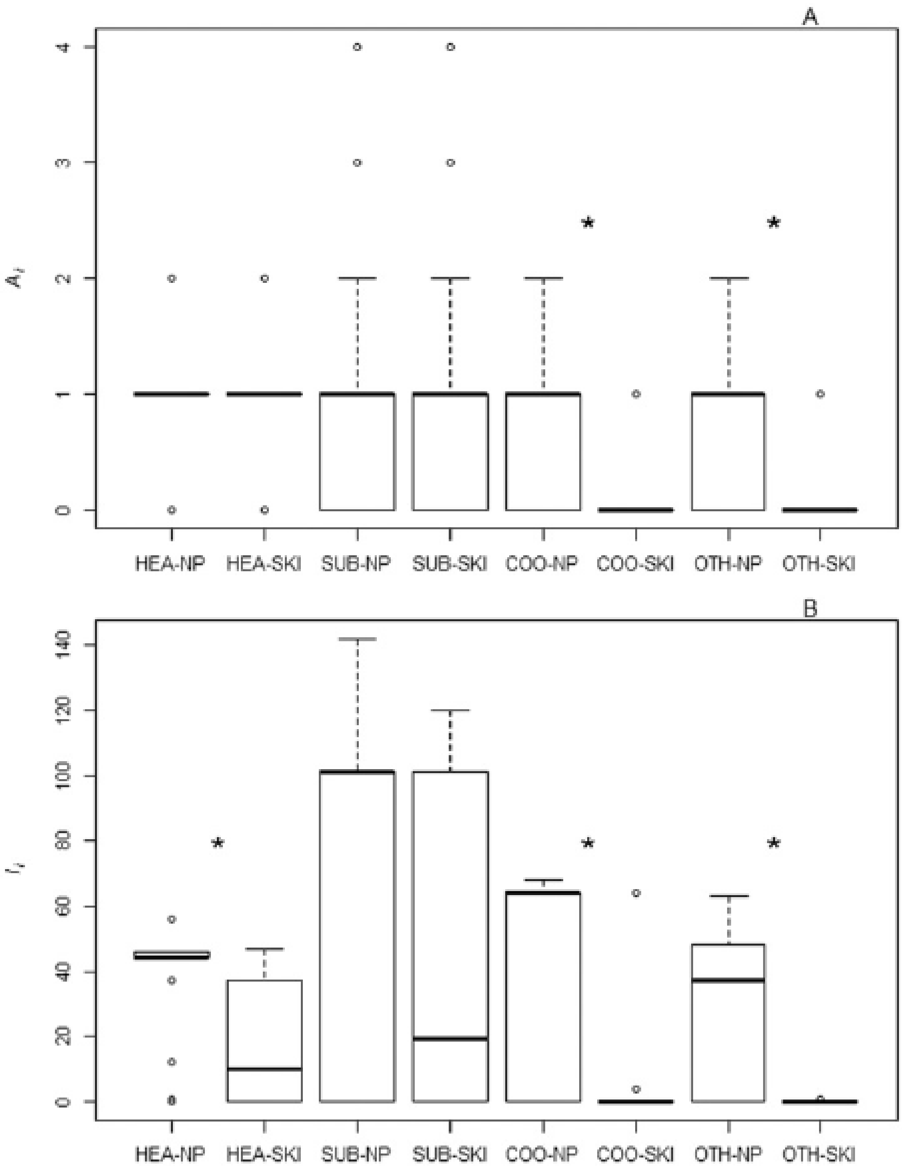

Figure 4. Effect of type of associations and region in the number of associations per stockbreeder and links per stockbreeder in the Spanish Central Pyrenees. A) A_i, number of associations per stockbreeder; B) l_i, number of links per stockbreeder. HEA, health-based associations; SUB, subsidy-based associations; COO, cooperative-based associations; OTH, others associations; NP, region that included a National Park; SKI, region that included ski resorts. * indicates significant differences between regions for a given type of associations (based on a post-hoc Tukey test).

Table 1. Current characteristics of the two study regions in the Spanish Central Pyrenees.

Variable	*Sobrarbe (NP)*	*Alto Gállego (SKI)*
Area	893.62 km^2	490.02 km^2
Population	2.27 hab/km^2	8.44 hab/km^2
Agro-pastoral activity	14% (*-35%*)	3% (*-29%*)
Touristic activity	74% (*+38%*)	87% (*+49%*)
Campsites and rural houses	5138 places	1377 places
Hotels and apartments	2196 places	4126 places
New buildings	1041 houses	11317 houses

Area, surface of the region ; *Population*, density of inhabitants; *Agro-pastoral activity*, proportion of the population mainly identified as working in agro-pastoral activities; *Services activity*, proportion of the population mainly identified as working in services activities (values in parentheses represent the change in proportion of the population identified as working in each activity since 1981); *Campsites and rural houses*, number of touristic places available in campsites and rural houses; *Hotels and apartments*, number of touristic places available in hotels and apartments; *New buildings*, number of new houses constructed since 1980. Sobrarbe region is under the influence of a National Park (NP); while Alto Gállego region is under the influence of Ski resorts (SKI). All the data were obtained from Instituto Aragonés de Estadística and Instituto Nacional de Estadística and represent year 2010.

Table 2. Partnerships of stockmen in the study area in the Spanish Central Pyrenees.

Partnership	*Number*	*Objective*	*Example of activity*
Health (HEA)	15	Maintain health standards of the animals	Periodically perform mandatory sanitary tests to animals (health protection associations)
Subsidy (SUB)	12	Obtain funds for pastoral activities	Help stockmen to obtain quality labels (protected breed associations)
Cooperatives (COO)	4	Improve marketing of livestock products	Coordinate and advises stockmen business (agro-pastoral cooperatives)
Others (OTH)	5	All other stockmen associations	Organize country markets (groups of stockmen from the same town)

Partnership, type of partnership according to the interest pursued by its members; *Number*, number of associations of each type in the whole study area; *Objective*, duty of the partnership; *Example of activity*, actions taken by partnerships which directly involve stockmen members.

707 **Table 3. Definitions of indices used in stockmen collaboration networks.**

Index	*Definition*	*Interpretation*
Isolation (*Iso*)	Number of nodes with no links.	High values indicate that many stockmen do not collaborate with others.
Density (*D*)	Mean number of links per node.	High values indicate that stockmen highly collaborate with others.
Modularity (*Q*)	Presence in the network of subgroups composed by highly connected nodes.	High values indicate that stockmen form groups inside which collaboration is strong.
Krackhardt Ratio (*E/I*)	Ratio between links from nodes in different and links from nodes in the same network.	Positive values indicate that stockmen principally collaborate with stockmen from other region, while negative values indicate that interact with stockmen from the same.

Table 4. Characteristics of the stockmen collaboration networks in study area in the Spanish Central Pyrenees.

Region	*S*	*P*	*P/breed*	*Iso*/*S*	*D*	*Q*	*E/I*
Total study area (TSA)	194	36	2.63	0.05	124.7	0.27	-0.79
Sobrarbe (NP)	81	21	1.88	0.02	145.2	0.25	
Alto Gállego (SKI)	113	26	3.69	0.1	32.97	0.12	

S, number of stockmen; *P*, number of partnerships that stockmen in the network belonged to; *P/breed*, mean number of partnerships which a stockbreeder belonged to; *Iso*/*S*, proportion of stockmen without links; *D*, density; *Q*, modularity; *E/I*, Krackhardt Ratio. Sobrarbe region is under the influence of a National Park (NP); while Alto Gállego region is under the influence of Ski resorts (SKI).

Table 5. Indices for Stockmen Collaboration Networks in the study areas of the Spanish Central Pyrenees.

Region	*Network*	*Iso*	*D*	*Q*	*E/I*
Total study area (TSA)	real	**9**	-	**0.27**	**-0.79**
	sim	6.39 (0.61)	-	0.11 (0.02)	-0.18 (0.02)
Sobrarbe (NP)	real	2	**145.2**	**0.25**	-
	sim	2.08 (0.28)	107.62 (0.29)	0.08 (0.02)	-
Alto Gállego (SKI)	real	**8**	**32.97**	**0.12**	**-**
	sim	5.57 (1.2)	25.23 (0.13)	0.22 (0.05)	**-**

Iso, stockmen without links; *D*, density; *Q*, modularity; *E/I*, E/I Ratio. Sobrarbe region is under the influence of a National Park (NP); while Alto Gállego region is under the influence of Ski resorts (SKI). Sim is the mean (standard deviation) of the index based on 1000 simulations. Indices were significantly different from simulated ones (indicated in bold) if they were more than 2 standard deviations above or below the mean values from the simulations. *D* was calculated for the two regions, individually, because the null model fixed *L* in the network, and *E/I* was only calculated for the two regions combined because it included the links with and between regions.

Table 6. GLM and GLMM for the number of partnerships per stockbreeder and links per stockbreeder in the Spanish Central Pyrenees.

Level	*Response variable*	*Explanatory variable*	*Df*	*SSE*	*MSE*	*F-value*	*p-value*
All data	A_i	**Region**	1	123.6	123.6	88.06	<0.001***
		Residuals	192	269.4	1.4		
	L_i	**Region**	1	503569	503569	107.5	<0.001***
		Residuals	192	899054	4683		
Type of partnership	A_i	**Region**	1	30.89	30.89	88.06	<0.001***
		Partnership	3	44.21	14.737	51.93	<0.001***
		Region x Partnership	3	14.57	4.857	17.11	<0.001***
		Residuals	576	163.47	0.28		
	L_i	**Region**	1	125892	125892	107.5	<0.001***
		Partnership	3	192.96	64321	82.77	<0.001***
		Region x Partnership	3	75.98	2533	3.26	0.021*
		Residuals	576	447638	777		

Ai, number of partnerships per stockman; *Li*, number of links per stockman. Statistically significant variables are indicated in bold. * $p<0.05$; ** $p<0.01$; *** $p<0.001$.