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Electronic version

URL: <https://journals.openedition.org/irpp/3332>

DOI: 10.4000/irpp.3332

ISSN: 2706-6274

Publisher

International Public Policy Association

Electronic reference

Irene Pérez-Ibarra, Alicia Tenza-Peral, Diego Soler-Navarro, Diego Arahuetes-de la Iglesia and Carmen Garate-Marín, "Evolution and diversity of institutions: Using institutional grammar to analyze governance changes in traditional crop-livestock systems", *International Review of Public Policy* [Online], 5:2 | 2023, Online since 01 August 2023, connection on 02 November 2023. URL: <http://journals.openedition.org/irpp/3332> ; DOI: <https://doi.org/10.4000/irpp.3332>

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DJSN and DAI were supported by a predoctoral grant from the Government of Aragón (Spain) and the University of Zaragoza (Spain) respectively, and IPI by grant RYC2019-027247-I funded by MCIN/AEI/10.13039/501100011033 and by “ESF Investing in your future”. Financial support was provided by the European Research Council, European Union (RESILIENT RULES, 101044225) and the Spanish Ministry of Science and Innovation (SOSLIVESTOCK PID2019-104020RA-I00).

Introduction

- 1 Shared or common-pool resources are natural or cultural resources, such as water, pastures or fisheries, shared by many people. Due to their high subtractability and high difficulty of exclusion, a sustainable management of valuable resources is extremely difficult to implement (Ostrom, 1990), and thus easily ends in the social dilemma known as the “tragedy of the commons” (Hardin, 1968). Since Hardin (1968) suggested that state control or the establishment of private property regimes was the only solution to avoid the tragedy, many studies have shown that in some cases, resource users are able to self-organize to avoid overexploitation of shared resources (McEvoy, 1986; Berkes et al., 1989; Feeny et al., 1990; Ostrom, 1990). In all these cases, effective institutions that limit access and regulate harvesting practices enhance the capacity of individuals to use these resources sustainably over long periods of time (Ostrom, 1990). Some well-known examples of long-enduring common-pool resource

institutions include irrigation systems in the east of Spain, or the hybrid systems of private and communally owned institutions in the Swiss Alpine meadows (Ostrom, 1990).

- 2 The diversity of institutions is widely recognized as essential for the sustainable use of shared resources (Becker & Ostrom, 1995; Ostrom et al., 1999; Ostrom, 2005; Ostrom, 2012). Empirical studies have shown that imposing uniform institutional blueprints is often inefficient or even counterproductive, since no single type of institution works efficiently, fairly, and sustainably in relation to all common pool resources or in every social or ecological situation (Ostrom et al., 1999). When policies are imposed on entire regions without taking into account their diverse ecological, socio-cultural, and economic structures, the costs of failure can be partially reduced in probabilistic terms if institutional diversity is protected (Ostrom, 2012).
- 3 Here, we use Ostrom's theoretical framework for the study of institutions (Ostrom, 1990, Ostrom, 2005) to analyze 1) the diversity and 2) temporal changes of institutions used in small-scale crop-livestock systems in a semi-arid area of Spain. We focus on rules-in-use, collected through in-depth interviews with local farmers, to analyze the impact of recent policy changes and social and environmental changes on institutional adaptation. Along with the study by Watkins and Westphal (2016), this study represents one of the few attempts to codify institutions from qualitative interviews. Our findings reveal the important diversity of institutions that local communities use to adapt to the quantity and quality of grazing land and historical property rights, the high dynamism of the rules-in-use, and how current socio-demographic and policy dynamics are having profound effects on the resilience of these systems, threatening their long-term sustainability.

Methodology

Conceptual framework

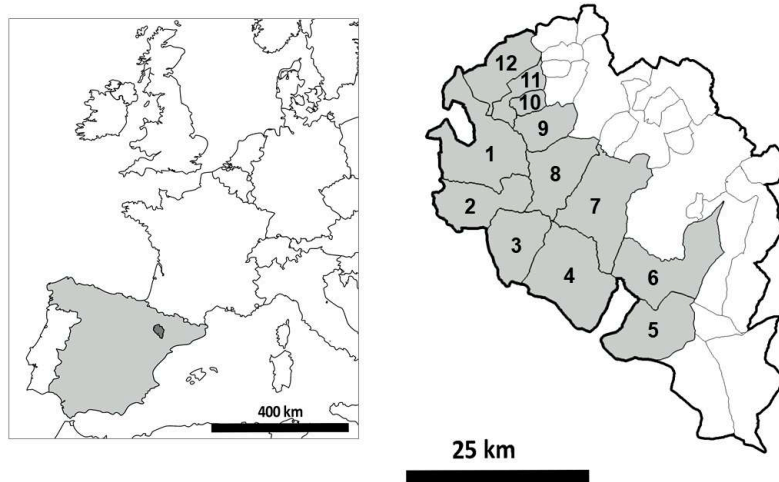
- 4 The institutional analysis and development (IAD) framework (Ostrom 2005) provides a structure for analyzing institutional arrangements, establishes a typology of rules, as well as the three types of institutional statements: rules, norms, and strategies (Crawford & Ostrom, 1995; Ostrom & Crawford, 2005). These institutional statements are created from different combinations of the ABDICO grammatical syntax (Crawford & Ostrom, 1995; Ostrom & Crawford, 2005; Schlüter & Theesfeld, 2010; Siddiki et al., 2011; Basurto et al., 2010), an acronym that stands for six subcomponents of an institutional statement: *attribute* (A, an actor that carries out the aim), *object* (B, the receiver of the action described in the aim and executed by the agent in the attribute), *deontic* (D, what is permitted, obliged, or forbidden), *aim* (I, the goal or action of the statement), *condition* (C, what, when, where, how), and *or else* (O, punitive sanction). Strategies include ABIC, norms include ABDIC, and rules consist of the entire ABDICO syntax. The seven types of rules (Ostrom, 2005) are: position (roles to be filled by individuals), boundary (prerequisites of individuals), information (level of information available to actors), payoff (rewards or sanctions to actors), aggregation (actions that require more than one individual), choice (specify actions), and scope (required, desired, or prohibited outcomes).

- 5 The institutional grammar tool (IGT) (Frantz & Siddiki, 2021, Frantz & Siddiki, 2022) consists in coding the seven main types of rules by parsing the syntax of institutional statements. Institutional statements can also have the form of institutions-in-form (i.e., formal institutions found in written institutions) and institutions-in-use (i.e., unwritten or informal institutions). Examples of the recent application of the IGT include the analysis of contrasting cases with regard to compliance of aquaculture regulations (Sikkiki et al., 2012; Siddiki, 2014), the implementation of a new Nicaraguan water law (Novo & Garrido, 2014), organic farming regulations in the US (Carter et al., 2016), an ecological restoration decision in a wilderness region (Watkins & Westphal, 2016), and payment for ecosystem services of 21 water quality programs (Lien et al., 2018).
- 6 The rule typology of the IAD framework and the IGT are used here to analyze the diversity and dynamics of the institutions of small livestock systems in Spain in order to understand the institutional adaptations to social and environmental contexts and changes that have occurred in recent decades, such as higher uncertainty and variability of resources and markets.

Case study

- 7 We studied institutions of traditional crop-livestock farming systems in a semiarid area in Spain (Figure 1). Producing 44% of agriculture and 50% of livestock worldwide, traditional livestock farming systems in arid and semiarid regions are of special relevance and vulnerability (FAO, 2014; Graeub et al., 2016). Farming systems in these environments provide the livelihood and main source of employment for more than two billion people, half of them living in poverty (IFAD, 2016). Some paradigmatic cases include nomad pastoralists in Africa or transhumant pastoralists in Spain and Italy. Livestock farming systems are an example of a social-ecological system in which long enduring institutions are adapted to specific social and environmental contexts. However, current changes at regional and global scales are challenging the adapting capacity of traditional small-scale crop-livestock farming systems. Analyzing the diversity of institutions of livestock farming systems and the dynamics of institutional change in the last decades, it is thus important to better understand their capacity of adaptation to global changes.

Figure 1: Location of the study area. 1: Leciñena, 2: Perdiguera, 3: Farlete, 4: Monegrillo, 5: La Almolda, 6: Castejón de Monegros, 7: Lanaja, 8: Alcubiere, 9: Robres, 10: Senés de Alcubierre, 11: Torralba de Aragón, 12: Tardienta.



Source: The authors

- 8 The studied area is located in *Los Monegros* Desert (Spain) (Figure 1). Of semiarid nature (average annual temperature 15.0°C, annual total precipitation 318mm), *Los Monegros* has an area of 2765ha and is in the middle basin of the Ebro River, encompassing 31 municipalities of the provinces of Huesca and Zaragoza. It has a total population of 21641 inhabitants and a low population density (7.8hab/km²). The landscape is composed of natural steppe vegetation and cereal monocultures in irrigated and extensive dry land. Livestock production is one of the main economic activities in the area. It is dominated by sheep and sedentary livestock with a strong association to agriculture and the contribution of external forage (Olaizola et al., 1995). There are currently 75 sheep farms with an average of 654 heads/farm. The great structural diversity and availability of forage resources explains the use of the territory by the farms (Olaizola et al., 1999). The highest concentration is found in municipalities with a predominance of irrigated cereal production, where livestock density exceeds 4 heads/ha, while in rainfed agricultural areas, the livestock density is reduced to <1 head/ha (data from 1998) (Olaizola et al., 1995). This study area was chosen because the accelerated decline of extensive livestock activity in the area (71% reduction of the farms in the last decade), together with the risk of desertification due to agricultural intensification and climate change, and the important influence of policy and demographic changes, make it a paradigmatic example of the vulnerability of livestock farming systems in arid and semiarid environments. Also, we focused our study on the municipalities located around the Alcubierre Mountain, which is a natural barrier between municipalities with irrigated crops (north) and with rainfed crops (south) (Figure 1), representing a relatively important variability in the management of natural resources.

Collection of institutional statements from interviews

- 9 We interviewed between one to two farmers of eight livestock farming communities in *Los Monegros* (Figure 1). As the interviews were designed to analyze both current institutions as well as institutional changes in the last four decades, only farmers aged 65 and above were interviewed to ensure that they were familiar with/involved in current institutions and had a recollection of past institutions. Although the small size of the communities studied (Table 1), together with the significant rural-urban migration and the decline in livestock activity suffered, resulted in a small number of eligible participants, the respondents were well representative of the farmers' population and provided very valuable information, demonstrating a deep knowledge of the current and past functioning of the systems. In one of the communities (*Senés de Alcubierre*), where there were no more farmers, we interviewed the daughter of a former farmer from the community, who was able to explain how livestock production was organized before it stopped in the community. The average age of interviewees was 80 years old, most of them were retired (67%) male (89%) (Table 2).

Table 1: Characteristics of the studied communities.

Community ID	Community	Surface (ha)	Population	Livestock heads	Farms
A	Alcubierre	11,530	372	1,249	4
B	Castejón de Monegros	16,530	497	4,443	8
C	Farlete	10,410	378	6,670	13
D	La Almolda	13,130	555	1,834	6
E	Lanaja	18,370	1163	3,781	9
F	Leciñena	17,860	1146	6,180	6
G	Monegrillo	18,320	394	5,228	15
H	Perdiguera	10,980	572	175	2
I	Robres	6,430	514	5,765	12
J	Senés de Alcubierre	2,050	40	0	0
K	Tardienta	9,060	948	2,670	7
L	Torralba de Aragón	4,040	113	2,986	4

Source: The authors

Table 2: Sociodemographic characteristics of interviewees.

Community	Gender	Age	Occupation
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			School leaving age	
Alcubierre	Male	73	12 years old	Livestock farmer (herd size: 6 sheep)
Castejón de Monegros	Male	76	14 years old	Livestock farmer (herd size: 50 sheep)
Lanaja	Male	80	14 years old	Retired livestock farmer
Leciñena	Male	85	10 years old	Retired livestock farmer
Monegrillo	Male	67	16 years old	Retired livestock farmer
Perdiguera	Male	86	11 years old	Livestock farmer (herd size: less than 200 sheep)
Senés de Alcubierre	Female	86	14 years old	Retired. Daughter of livestock farmer
Tardienta	Male	85	14 years old	Retired livestock farmer
	Male	82	14 years old	Retired livestock farmer

Source: The authors

- 10 The interview guide included open-ended questions designed to collect existing rules-in-use for the governance of key resources (i.e., animals owned, grazed pastures, and water) and public infrastructure used to feed and move animals to different locations (e.g., drove roads) as well as changes in institutions during the last 40 years. This timeframe overlaps with some of the most important environmental and socioeconomic changes that have occurred on a global scale, including globalization and climate change, within a timeframe an adult older than 65 years old can remember.
- 11 For each resource, questions designed to identify the regulative institutional statement's (Frantz & Siddiki, 2021) and rule's typology were asked. Some examples include (see Appendix A for the complete interview guide): Boundary rule, e.g., *who has the right to use the pasture?* After each question, we asked about the changes that had occurred and the causes of those changes. For example, when talking about boundary statements, interviewees were asked: *Has it always been the same? If not, how has it changed? When did it change? Why did it change?*

Codification of institutions from interviews

- 12 We used available protocols of the IGT (Brady et al., 2018; Frantz et al., 2013; Frantz & Siddiki, 2021) and the IAD framework (Ostrom, 2005) to code the collected rules-in-use. The codification followed three main steps. First, all the institutional statements that specify what actors are permitted, required, and forbidden to do within certain temporal, spatial, and procedural parameters in relation to key resources were detected. To do this, we selected and extracted fragments of the interviews that were referring to a specific institution. These fragments usually included both question and answer in order to extract parts that included all the context needed to be self-

explanatory. We then reduced the extracted text into one simpler sentence. See Appendix B for an example of institutional statements selection.

- 13 Second, each institutional statement was categorized as one of the seven rule types (Ostrom, 2005). These rules are: Position (creates the set of positions that participants occupy and states how many participants occupy each position); Boundary (defines who is eligible to enter a position, the process for determining which eligible participants may enter a position, and how an individual may leave a position); Choice (specifies what a participant occupying a position must, must not, or may do); Aggregation (specifies whether a decision by a single participant or multiple participants is required before an action at a node can be taken); Information (affects the amount of information available to participants); Payoff (assigns external rewards or sanctions to particular actions or outcomes); Scope (affects a known outcome variable that must, must not, or may be affected as a result of actions taken).
- 14 Third, institutional statements were coded according to the IGT (Frantz & Siddiki, 2021), which decomposes all institutional statements into six basic elements. These elements are: Attribute (the actor who performs the aim), oBject (the receiver of the action described in the aim and performed by the agent in the attribute), Deontic (what is allowed, required, or forbidden), aIm (the goal or action of the statement), Condition (what, when, where, how), Or else (punishment or reward). Based on the presence of different syntactic elements, institutional statements were classified as strategies (ABIC), norms (ABDIC), or rules (ABDICO), which helped to understand how institutions affect the incentives faced by actors in action situations.
- 15 Three of the authors (CGM, DSN, IPI) were responsible for coding the interviews. First, CGM and DSN independently extracted the interview fragments and wrote the institutional statements from each interview and institutional statements which was subsequently reviewed by IPI. In case of disagreement, she annotated an alternative institutional statement which was discussed with other authors and a final statement was agreed upon by consensus. Second, four of the authors (CGM, DAI, DSN, IPI) were responsible for coding the final statements following the ABDICO syntax.

Analysis of institutional diversity and evolution of institutions

- 16 We used the results of the codification of the interviews to describe the institutional diversity of the communities studied. First, we used the extracted institutional statements to describe this diversity using a discourse analysis approach. Second, we examined institutional diversity by considering the rule typology. And third, we used the IG to understand in which grammatical components of the institutional statements this diversity is mainly located. We also used the institutional statements to describe changes in the rules-in-use and the reasons for these changes as described by interviewees. We measured institutional change as the coded institutional statements that interviewees indicated had been used in the past but were not currently in use.

Results

- 17 In total, we extracted 235 interview fragments from which we detected 334 institutional statements (Table 3).

Table 3: Summary of institutional statements codification.

Community	Num. Statements	Num. Rules (%)	Num. Norms (%)	Num. Strategies (%)
Study area	331	32 (9.58)	101 (30.24)	200 (59.88)
Alcubierre	50	3 (6.00)	12 (24.00)	35 (70.00)
Castejón de Monegros	57	8 (14.04)	17 (29.82)	32 (56.14)
Lanaja	19	6 (31.58)	5 (26.32)	8 (42.11)
Leciñena	36	4 (11.11)	8 (22.22)	24 (66.67)
Monegrillo	46	1 (2.17)	16 (34.78)	28 (60.87)
Perdiguera	48	8 (16.67)	18 (37.50)	22 (45.83)
Senés de Alcubierre	19	2 (10.53)	15 (78.95)	2 (10.53)
Tardienta	59	0 (0.00)	10 (16.95)	49 (83.05)

Source: The authors

Description of institutional diversity

- 18 To describe institutional diversity, we organized the institutional statements extracted from the transcripts into four main themes: access and distribution of the grazing land and other natural resources, creation and maintenance of public infrastructures, decision-making process, and identification of owned animals.

Access and distribution of the grazing lands and other natural resources

- 19 In each community, farmers used different forms to govern access to existing communal grazing lands. In most of the cases, only farmers from the community were allowed to use the pastures (*Castejón de Monegros*, *Alcubierre*, *Leciñena*): “*There is a Monte Blanco society here, [...this society is] for the people of this town*” (ID: B); while in other cases there was open access to any farmer (*Perdiguera*): “*No [there was no requirement to be a farmer here nor a limit to how many farmers there could be] [...] now it is the same. [Even farmers from outside] could. But without corrals or livestock facilities, it is challenging.*” (ID: H); and/or to transhumant pastoralists coming from the Pyrenees mountains during the winter (*Lanaja*, *Monegrillo*, *Senés de Alcubierre*, *Tardienta*): “[Here, the pastures] *were almost all private property, but the municipality also leased many communal lands. There were also transhumant pastoralists from the mountains who leased those common lands. But the rest were private properties, and everyone leased what they could or what the owners allowed them to lease.*” (ID: E).

- 20 In all studied communities, farmers needed to pay a specific tax to the municipality or farmers' association before using the communal lands. The amount of the tax was proportional to the number of livestock heads owned by the farmer or to the surface of the rented land: *"To enter the Monte Blanco society, you have to declare the number of sheep, and then, you pay an amount per sheep. [...] When the farmers harvest the fields, so the sheep can use the stubble, you also pay an amount per sheep."* (ID: B).
- 21 In addition to communal lands, farmers used private land for grazing, either owned or leased through private arrangements. The cost of leasing was proportional to the size of the plot: *"You had to pay the municipality for using the pastures. And if you used another farmer's farm, well, you also had to pay him for using his pastures [...] you paid a certain amount per hectare."* (ID: H).
- 22 In relation to how farmers distributed grazing lands, there were three different strategies among the studied communities. In some communities the land was divided into plots that were then assigned to individual farmers (Castejón de Monegros, Lanaja, Leciñena): *"[They organized themselves to divide up the pastures] Yes, maybe if it was a very large farm, they would divide it up, "you from here to here, and you from here to there". But normally, each one rented what he needed."* (ID: E) or group of farmers (Tardienta, Alcubierre): *"In Tardienta, there were ten polygons. Of those ten polygons, each one had a herder. There were 20 or so [farmers] in each polygon."* (ID: K).
- 23 In some cases, the size of the plots was homogeneous but in others decreased with the quality of the pasture: *"[The plots] some have three hectares, and others have four hectares, depending on the quality of the land. If the land has poor quality, it is more extensive."* (ID: B). Also, plots with bad pasture quality were not assigned to the same farmer more than two years in a row: *"[There may have been better lands than others], so they were raffled yearly. No one could protest. Maybe you are here now, but tomorrow you will be there and can no longer protest. This plot is better or bigger or smaller. [...] But since they were raffled every year, there was no problem."* (ID: K).
- 24 In some cases (Leciñena), after the assignment of plots by the community, there was an auction and farmers could try to get a better plot, usually by increasing the number of livestock heads that will use the plot until a limit of the number of heads based on the quality of the pasture: *"Here, in the town, the grazing lands were divided into plots and raffled. And each plot could support a certain number of sheep. The better the plot, the more sheep could be maintained on it. The plots were not equal in size, and some had much better land than others. And we all wanted them. [...] There was a raffle, but, for example, if I obtained a good plot, there was an auction. Then, the others would try to take it away from you or send more animals so that you would send more. For example, I had a plot with 300 sheep, and another farmer said he had 350 sheep. Then, if I wanted to keep the plot, I had to send more sheep; if I didn't, I had to leave it to him. That's what was done. [But there was a limit], yes, there was."* (ID: F).
- 25 In other communities (Monegrillo, Perdiguera) the communal land was open and there were no restrictions about where or when to use the land by each farmer: *"Each one went where he wanted to go. There were times when two herds would get together, and both would go the same way. On another day, they would go on different paths because each one took a different route."* (ID: H). In those cases, farmers could make oral agreements to decide where and when each farmer could go daily: *"They used to ask each other, What route do you have today? Well, I'm going down the ravine; well, I'm going to take the other way."* (ID: H).

In Casetejón de Monegros, Lanaja, Leciñena, and Monegrillo there was no limit to the number of animals each farmer could own and to the use of the communal lands: “no, each one had as many as he wanted. If there was the possibility of having more, one tried to have more.” (ID: F).

- 26 None of the interviewees mentioned important conflicts about the distribution of the land.

Creation and maintenance of public infrastructures

- 27 The cost of creating new public infrastructures was usually borne equally by all farmers: “If there were plans to build a new pond or anything else, this was paid for by everyone, [...] since the land was raffled, everyone wanted to do whatever it took.” (ID: F).

- 28 In all the studied communities, farmers, other inhabitants, and the municipality were responsible for maintaining public infrastructures such as roads, water tanks, and water canals. In some cases, every time an infrastructure needed to be cleaned or repaired, the municipality or the farmers’ association assigned a group of people responsible to do the maintenance (*Senés de Alcubierre, Monegrillo, Perdiguera*): “[The ponds were kept clean] by the municipality. [...] But it had to be done by the people of the town.” (ID: J).

- 29 In other cases, the maintenance of public infrastructure was done *a vecinal* (to neighbors) meaning that all villagers needed to spend some time each year to contribute to the maintenance (for example, cleaning roads or water rafts) (*Lanaja, Alcubierre, Senés de Alcubierre, Tardienta*): “[The maintenance of ponds] since there was not much money to pay for anything, it was done *a vecinal* (by the neighbors). The people in the town were notified. Or even to build roads [...]. That was voluntary. But come on; everyone had an obligation, so to speak.” (ID: J).

- 30 Finally, in other cases (*Leciñena*), the maintenance was done by both the municipality and the farmers, including cleaning and maintaining the *parideras* (i.e., small constructions made of rocks located outside the villages for the use of farmers and livestock), *aljibes* (cistern), ponds, and *escorrederas* (i.e., canals made in the mountains to collect water from the rain to a pond) of the assigned plots: “[About the maintenance of *parideras, aljibes* or *escorrederas*], each one was in charge of fixing what he had in his own plot.” (ID: F).

The decision-making process

- 31 To organize decision-making, most of the studied communities had organizations, known as *hermandad* (fraternity) or *junta* (board), which were composed by farmers to decide about the use of natural resources and creation, and the use and maintenance of public infrastructure: “[When we had to talk and make decisions among all the farmers], we met in the *hermandad*. We were notified, receiving a note with the date and hour of the meeting to talk about pastures, or whatever it was. Then, we would get together and make the decisions.” (ID: H).

- 32 Both the municipality and these organizations had competences for the management of common resources and infrastructures. These organizations had a president, members, and a treasurer. These positions were voted annually: “And every year they elected a secretary, a treasurer and a president, and those were the ones who kept the accounts and paid

the pastor and charged a certain amount per head." (ID: A); or until the farmer occupying a certain position did not want to continue: "[They were there until] *they got tired. Maybe there was one who got tired and said: Hey, I'm tired of being in charge. Then we would get together and vote for someone else.*" (ID: H).

Identification of owned animals

- 33 Finally, in all the studied communities, each farmer used a family mark to identify their animals. The mark was inherited from father to son or daughter and comprised a specific pattern of cuts in one of the ears of the animals. These marks helped farmers to monitor their animals: "*We used to mark the sheep. The mark on the ears was simply to know which ones were ours because they were all together, and they were indistinguishable from the sheep of other farmers. [And each family had] a mark.*" (ID: G).

Diversity of rules and grammatical elements

- 34 More than half of the institutional statements referred to choice (65%), followed by payoff (17%), and boundary statements (10%). With a frequency lower than 5%, we coded aggregation, information, position and scope statements (Table 4).

Table 4: Rules typology.

	Rules	Norms	Strategies	Total
Aggregation	1 (3.13)	1 (0.99)	2 (1.00)	4 (1.20)
Boundary	2 (6.25)	10 (9.90)	20 (10.00)	32 (9.61)
Choice	9 (28.13)	74 (73.27)	135 (67.50)	218 (65.47)
Information	0 (0.00)	0 (0.00)	9 (4.50)	9 (2.70)
Payoff	20 (62,50)	14 (13.86)	22 (11.00)	56 (16.82)
Position	0 (0.00)	1 (0.99)	11 (5.50)	12 (3.60)
Scope	0 (0.00)	1 (0.99)	1 (0.50)	2 (0.60)

Source: The authors

- 35 Most of the coded institutions were strategies (60%), followed by norms (30%) and rules (10%) (Table 3). Most of the rules were payoff rules (63%) followed by choice rules (28%) (Table 4). Institutional statements coded as information, position, or scope were all classified as strategies. (Table 4).
- 36 Considering the rule typology and the grammatical elements present, our results show that aggregation and payoff rules were very diverse, as they were almost equally divided between norms, rules, and strategies. On the contrary, information and position rules were less diverse because almost all of them were strategies, while

boundary, choice, and scope rules had a moderate diversity because they were split between norms and strategies.

37 Table 5 shows grammatical elements found in the institutional statements codified. In terms of diversity, we found that the grammatical component with the most variability was the attribute and the aim in which 61% and 55% were found in only one of the communities, respectively. Most of the attributes referred to livestock farmers (48%), followed by the municipality or associations of farmers (11%). The most frequent aims verb found were: to pay (presented in 14% of the statements), to have (9%), to use (6%), to share (6%), and to maintain (5%); the rest of the aims component had a frequency less than 5%. We found the following verbs: can, could, should, must, cannot, and should not. Regarding the Or else component, most of them referred to the impossibility of doing a certain activity (e.g., use the pasture) if the actor was not a registered resident of the village or if the actor did not pay a certain tax (41%). Less frequently, we found consequences related to being reported to the guard or going to court (10%), or having consequences for the agent’s position (10%). Only 2% of the consequences were related to paying a fine. In 59% of the rules, the Or else component was written by the coders as a default condition (e.g, could not use communal land, could not be a member of a certain association) because the interviewees did not specify the consequences of not complying with a rule.

Table 5: Summary of grammar codification.

Location	Attribute	Object	Deontic	Aim	Condition	Or Else
Alcubierre	12	13	4	33	24	4
Castejón de Monegros	11	11	4	33	30	8
Lanaja	10	9	4	12	10	4
Leciñena	5	11	4	23	40	4
Monegrillo	8	15	3	30	26	1
Perdiguera	15	17	4	25	15	6
Senés de Alcubierre	11	9	2	17	33	1
Tardienta	20	18	3	31	26	0

38 Source: The authors

Institutional dynamics

Description of institutional changes and drivers

39 Farmers interviewed mentioned four main dynamics in the studied communities with an effect on institutions: changes in resource level, sociodemographic changes, changes in the public infrastructure conditions, and policy changes.

- 40 Interviewees mentioned the disappearance of springs in the mountains and the decrease of the water available for the animals and of the quality of the pastures due to processes of bush encroachment, i.e., expansion of woody plants, and expansion of irrigation agriculture: “[When I was a child] *there was spring water everywhere. There were ravines with springs. [But by the time I married], they had all disappeared. There were still 2 or 3 places with springs, but then the springs disappeared because it used to rain more than it does today.*” (ID: F).
- 41 They also complained about the bad conditions of the public infrastructures such as *parideras* and ponds: “[The *parideras* were maintained] *by the owners, but not very well, because they have been damaged, but... besides, the owners of the rich houses here, they have all died, and even their houses have disappeared; not the houses, but the families. They usually had daughters instead of sons. And the daughters got married, and they all left. And there were still two or three strong houses, but the rest had disappeared. And the *parideras* collapsed.*” (ID: A).
- 42 Farmers associated the reduction of the quality of the pastures and of the maintenance of the public infrastructures with the decrease of livestock farming and with changes in the way of life of farmers: “[The quality of the pasture has worsened]. *Nothing is left on the mountain because the sheep don't eat it, and it has all dried up. It's not used every year, so it's all dried up and not coming back. Who is going to be a shepherd now in those places? That's impossible. The sheep used to do the work of clearing the land.*” (ID: H). Currently, farmers do not use most of the traditional public infrastructures associated with livestock farming since there are less farmers and they use, for example, trucks to bring water to the animals to avoid depending on rain-fed ponds: “*I had two cisterns, one of 2000 liters and the other of 3000 liters, and I carried them with the Land Rover. But I had to take the water from here in the village. At night, I would fill the cistern, take the Land Rover... and go ahead. I would take the water from here 15 km away. [...] There were ponds [in the rangeland], but there has always been very little rain in this area. We had to carry the water to the rangeland.*” (ID: F).
- 43 Also, there has been a change in the collective action for the maintenance of public infrastructures. In the past, most of the villages used the collective work of their neighbors to clean and maintain public roads or ponds. Currently, the farmers pay a tax to the municipality to maintain the public infrastructures: “*Before there were no tractors, the farmers would go with their mules [to clean the ponds]. They would notify four or five farmers. And then three days later others would go. That's how they did it. Now they don't. Now they go with machinery, two people, and they clean it... in one day they clean it, and the society and the farmers pay them.*” (ID: B).
- 44 In terms of policy change, respondents mentioned some changes in the Common Agricultural Policy that have affected the usual agreements between agricultural farmers and livestock farmers for grazing stubbles: “*And the pastures, because in the old days there was a law about the pastures and the stubble fields, and they were allocated to the livestock farmers. On the first of May the distribution was made and everyone stayed in the area where they had the *paridera* or closer to the pastures. [...] After that, the law of pastures and stubble fields was abolished and the livestock began to disappear. Because now those who have animals have to rent pastures. [That changed] 12 or 14 years ago. And now it's much more complicated with direct sowing; it's ruined livestock farming.*” (ID: A). “*Now, with this direct sowing, they don't want to let the sheep into the fields to graze the stubble.*” (ID: B).
- 45 Finally, traditional ear cuts or fire prints to track animals are underuse since they have been substituted with ear tag or rumen bolus: “[In the past, each farmer had his own

family mark on the sheep], a little fire print on the back, a little letter as a sign. They were always marked on Holy Thursday. This was because Easter was when the sheep were released into the fields. [There were also ear cuts], which many people made when the lambs were born. But since they put the ear tags on, the fire prints have not been done. (ID: K)".

Quantification of institutional changes

- 46 We found that 76% of the coded institutional statements are no longer in use. *Castejón de Monegros* is the only community where most of the rules are still in use (82%), while in the rest of the communities 70% or more of the rules have disappeared in the last decades. Scope is the type of rule that has the highest stability, followed by payoff and choice rules. All the rules related with the traditional way of identifying animals and 90% of decision-making processes are no longer in use, while 27% of the rules related with the access and distribution of the grazing lands and the creation and maintenance of public infrastructures are still in use.

Discussion

- 47 The adaptation of long-lived agricultural systems to the local conditions, such as recurrent variability in the natural resources, makes institutional diversity, i.e., the variety of the norms, rules, and strategies that communities use to manage shared resources, an essential component of resilient governance and sustainable resource use. Here, we studied institutional diversity in a semi-arid area of northern Spain, composed of 13 small-scale communities traditionally focused on mixed crop-livestock farming. By interviewing nine elderly farmers, we were able to analyze the diversity of traditional institutions, how they have changed in recent decades and their relationship to the sustainability of the system.

Diversity of institutions

- 48 The size of the resource and of the resource users are widely recognized as important factors for the successful governance of shared resources (Agrawal & Goyal, 2001; Poteete & Ostrom, 2004; Yang et al., 2013). In our studied communities, the amount of land available to feed animals, including both pasture and crop stubble, appears to be an important factor in explaining how farmers shared grazing land. In most of the small areas studied (approximately less than 10,000 ha), institutions existed to divide the territory into plots distributed among farmers and to limit the number of animals that each farmer could keep. On the contrary, in most of the larger areas, there was no limit to the number of animals each farmer could have (e.g., in *Lanaja*, *Monegrillo*, *Castejón de Monegros*), or the land was not divided into plots, so that more than one farmer could use the same area at the same time (*Perfiguera*). The size and quality of the pasture affected not only the number of animals a farmer could have, but also the boundaries of the community, i.e., whether outsiders were allowed to graze on the community's land, the latter being transhumant herders or farmers from other villages. Also, in some of the smallest areas (*Tardienta*, *Senés de Alcubierre*), the farmers hired a shepherd to look after the villagers' livestock.

- 49 The effectiveness of collective action to maintain public infrastructure also depends on the size of the community (Khwaja, 2001; Cao et al., 2020). In the communities we studied, we found three main strategies. In the smallest villages, all residents were required to contribute a certain number of hours per year to maintenance activities such as cleaning the canals or ponds. In larger villages, the farmers or the municipality were responsible for maintaining the public infrastructure or organizing the groups of farmers or villagers that needed to do communal work each time.
- 50 The rule typology and grammar of institutions also show the great institutional diversity among the communities studied. Decomposing the interview fragments into institutional statements, rule types, and grammatical components helped us to understand where this diversity lies. We found that, when considering obligation and consequences, information and position rules are less diverse, and that most of the diversity lies in the attribute, and the aim elements of the grammar, while the or else component is very similar across the communities studied. Taken together, these findings may indicate the importance of boundary and choice rules in adapting natural resource management to different social and ecological contexts.

Policy changes, institutional dynamics, and resource use sustainability

- 51 The institutions of the communities studied are changing at an impressively rapid pace. These changes are the result of the communities' adaptation to the social, ecological, and policy changes that have occurred in recent decades.
- 52 Since its establishment in the '50s to secure food security after Second World War, the Common Agricultural Policy (CAP) has undergone a series of reforms with important consequences for agricultural systems. The reforms have shifted the objectives from production to the support of food security, then to the recognition of the environmental and social impacts of agriculture. Reforms have had a profound impact on the decisions of individual farmers (Barnes et al., 2016). In our study area, reforms affected farmers' decisions about the number of animals per farm, or whether to continue farming.
- 53 In addition to economic subsidies, rural depopulation and the subsequent farmers' generation relay (Collantes & Pinilla, 2004) are associated with institutional changes. The number of farms in the study area has decreased significantly in recent decades, while the use of food inputs, machinery, and new technologies has allowed the remaining farms to have more animals. While our interviewees remembered that in the '50s or '60s each family in the villages had a few animals, with the largest farms not having more than 300 animals, currently each village has a maximum of 15 farms with an average of almost 500 animals per farm (Table 1).
- 54 These dynamics have made some of the traditional institutions for the distribution of pastures between farmers useless. In addition, the decrease in the number of farms has led to the most remote pastures not being grazed by local or transhumant farmers (Manzano & Casas, 2020), with subsequent bush encroachment (Anadón et al., 2014; Sanjuán et al., 2017) and increased fire risk (Lasanta et al., 2018).
- 55 Sociodemographic changes in recent decades have also had an impact on collective action. As the communities became wealthier, villagers' need for collective work was

replaced by taxes paid to the municipality to hire external workers to maintain the public infrastructure. At the same time, some of the public infrastructures were no longer needed and are now abandoned.

- 56 Finally, changes in the policy regulating the use of crop stubble by livestock farmers have hindered livestock grazing (Sánchez Hernández 2005). The interviewees lamented the current impossibility of using crops for livestock, and the consequences for the long-term continuity of the traditional mixed crop-livestock systems in the study area.

Challenges of using interviews to study institutions and institutional dynamism

- 57 Watkins and Westphal (2016)'s work was a pioneering study in the use of in-depth qualitative interviews to extract institutional statements from interview data. In their study, they interviewed individuals involved in decision-making for ecological restoration in the Chicago Wilderness region (Watkins & Westphal, 2016). Their study highlighted the challenges and great potential of applying the grammar of institutions to data types based on in-depth, qualitative interviews and participant observation. Based on our coding efforts and findings, we agree with all of the methodological challenges that they highlighted in coding institutions from qualitative interviews, including, difficulties in distinguishing choice and scope rules, and rules, norms, and strategies.
- 58 We found that using qualitative interviews instead of questionnaires allowed flexibility in communicating with farmers and helped to capture the diversity of institutions used in each community. In most cases, the differences between institutions were very subtle and therefore difficult to distinguish when using closed questions. The grammar of institutions helped to clearly identify how the institutions used differed among the communities studied.
- 59 In order to facilitate the coding of institutions when planning to use the grammar from interviews, it is important to ensure during the interview that the interviewer gets all the elements of the grammar from the interviewees' responses, for example, by specifically asking who can or must do a certain activity in a choice rule. During the codification of institutions, we often had to use a default condition because during the interviews, interviewees tended to leave statements partially stated and context-dependent during interviews. As Watkins and Westphal (2016), we needed to "imply components when they are not explicitly provided" (Siddiki et al., 2011, p. 89) and often had to use default conditions such as "at all times", "in all places" or "under all circumstances" (Crawford & Ostrom, 1995). It is good practice to ask respondents specifically about the "what", "where", "how", and "when" conditions.
- 60 Another important challenge when coding institutions from interviews is deciding whether an institutional statement is a rule, a norm, or a strategy, i.e., whether it has a deontic and or else component. Asking interviewees about the concrete deontic element or the consequences of not following a particular institutional statement can facilitate this decision. For example, one of our interviewees said that farmers from their village hired a shepherd to be with the animals of a group of farmers and that the shepherd was someone from their own village. In order to decide whether this is a norm or a strategy, it is important to continue asking about the obligation of this statement. Finally, it is important to emphasize that, unlike Watkins and Westphal

(2016), we did not ask about the emotional sanctions of not following a particular statement (Schlüter & Theesfeld, 2010). This may have influenced our coding of norms and rules. Most of our interviewees mentioned that they did not need sanctions because all community members followed the existing rules, probably because emotional sanctions (e.g., reputation) were more important than monetary or tangible sanctions.

Conclusions

- 61 Diversity and adaptability are essential characteristics of institutions for resilient and sustainable resource use. By interviewing farmers in a semi-arid area of Spain, we found not only the great institutional diversity that exists to adapt to even small contextual social and environmental differences, but also that traditional institutions are changing quite rapidly. It therefore seems urgent to document traditional institutions that are disappearing, because with their loss we lose an important part of our intangible cultural heritage.
- 62 The lack of written documents of regulations in many small-scale farming communities makes interviews a necessary tool for studying institutions. This work contributes to the development of appropriate protocols for analyzing institutions by means of qualitative data and the subsequent use of the rule typology and institutional grammar. Our findings show that institutional diversity and evolution varies between grammatical elements and rule types. Our work therefore provides an interesting approach to understanding where institutional diversity lies and to identifying the components of institutions that are rapidly evolving.

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APPENDIXES

Annex

Table 6: Percentage of rules-in-use extinct.

Location	Aggregation	Boundary	Choice	Information	Payoff	Position	Scope	Total
Total	50.00	45.90	43.08	50.00	39.78	45.45	33.33	76.05
Alcubierre	50.00	50.00	47.14	-	33.33	50.00	-	88.00
Castejón de Monegros	-	27.27	12.50	-	14.29	-	-	17.54
Lanaja	50.00	-	43.48	-	50.00	50.00	-	84.21
Leciñena	-	50.00	48.94	-	50.00	50.00	-	97.22
Monegrillo	-	50.00	39.62	50.00	38.46	50.00	-	69.57
Perdiguera	50.00	50.00	47.17	50.00	35.71	-	-	83.33
Senés de Alcubierre	50.00	-	50.00	-	50.00	-	-	100.00
Tardienta	-	50.00	49.25	50.00	50.00	50.00	50.00	98.31

ABSTRACTS

Traditional mixed crop-livestock systems face increased social and environmental uncertainties that arise from both endogenous (i.e., socio-demographics) and exogenous drivers of change (i.e., policy interventions). Adaptations are thus needed for their long-term continuity. The Institutional Analysis and Development Framework's rules typology and the Institutional Grammar are used here to analyze institutional diversity in relation to the use of natural resources and temporal changes in institutions. We used data obtained from qualitative interviews with local farmers within communities in a semiarid area in Spain. Our objective was to analyze the institutional arrangements used over the last few decades relative to sharing common resources (pastures and water) and maintaining public infrastructures. Results show great diversity in institutional arrangements in the farming communities studied, associated mainly with the type of property rights of pastures (communal, public, private) and the level of collective actions needed in response to endogenous and exogenous drivers of change. This study allows us to propose a robust methodological approach to qualitatively analyze institutional arrangements associated with the use of natural resources in farming systems, and to discuss how institutions adapt to policy changes and to new social and environmental realities.

INDEX

Keywords: Collective-action, common-pool resources, institutional diversity, institutional evolution, pasture management, social dilemma, social-ecological systems, resilience, water management

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