Change, Collective Action, and Cultural Resilience in Páramo Management in Ecuador

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Introduction

**Páramos** are the mountain grasslands of the humid tropical Andes. They extend from northern Peru to Venezuela, at elevations between ca 3200 and 4700 m. They host high levels of biodiversity and endemism (Luteyn 1992) and fulfill key hydrological functions, while having a significant capacity to store soil carbon (Buytaert et al 2007; Chimner and Karberg 2008). Water provision for both consumption and irrigation in the highly populated and urbanized Andes region of Ecuador and Colombia strongly depends on the páramos (Buytaert and De Biévre 2012). Conversion to agricultural uses, overgrazing, burning, and reforestation with exotic species are, however, significantly affecting the distribution and provision of ecosystem services (Farley et al 2004; Balthazar et al 2015). Ecuadorian and Colombian environmental legislation declares the páramos a fragile but strategic ecosystem for water production (MMAC 2002; PND 2017). Conservation instruments, such as water funds, protection of specific areas, and financial incentives, are being deployed by the governments to stimulate behavioral change, especially among peasant and indigenous communities (Bremer et al 2014; Hayes et al 2015).

In Ecuador, the páramos are the only areas in the high Andean mountains where communal land ownership exists alongside other forms of public tenure (eg protected areas) and large private land holdings (Medina and Mená-Vásquez 2001). The estimated surface area of the páramos in 2009 was 1.3 million ha, around 5% of the country’s area (Beltrán et al 2009), and was mostly under communal tenancy. The Comité de Páramo Nukanichik Urku (CPNU) is a multicommunal self-governed organization that manages ca 4380 ha of páramo in northern Ecuador. It has developed rules for collective resource management, while maintaining a high level of autonomy from governmental conservation initiatives. As is the case with other páramo communities today, CPNU must develop or strengthen its rules and institutions to ensure long-term water supply and adequate social organization to support it (Boelens et al 2014; Hayes et al 2015).

In light of this, the present article addresses 2 research questions: (1) How have agricultural frontier expansion and grazing practices developed in the social-ecological system (SES) of Nukanichik Urku? (2) How did current rules to control agricultural expansion and overgrazing emerge within communal governance? To answer these questions, we
use the analytical SES framework developed by McGinnis and Ostrom (2014). First, we examine the evolution of the SES and land use outcomes (eg agricultural frontier and grazing practices) over 60 years. We consider change in social, economic, and political contexts, its influence under the conservation conditions of the páramos as a resource system, evolution of resource units demanded by users, and their interactions in a long-term retrospective. Second, we analyze the emergence and enforcement of current rules to control overgrazing and crop expansion in recent communal governance structures. To do so, we use 2 theoretical lenses: (1) We understand the emergence of rules and institutions as a means to overcome the conditions of congestion and overuse involved in the use of common-pool resources (Hardin 1968; Ostrom 1990; Ostrom et al 1994). We thus focus on institutional change as the foundation for successful commons governance (Dietz et al 2003). (2) We rely on the normative dimension of cultural resilience, “the ability to maintain livelihoods that satisfy both material and moral (normative) needs in the face of major stresses and shocks” (Crane 2010), as a condition to achieve long-term support for communal páramo management. According to the categories developed by Baland and Platteau (1999), the CPNU’s collective management operates with social regulation, where a local authority is charged with laying down and enforcing rules. The governing structure of CPNU follows that of the Ecuadorian Andean comunas, where the cabildo, the main decision-making body, is generally directly accountable to the communal assembly (Korovkin 2001).

This study thus contributes to the discussion about contexts that motivate mountain communities to develop their own institutional arrangements to collectively manage natural resources (Baland and Platteau 1999; Dietz et al 2003; Hayes et al 2017). It acknowledges the importance of approaching institutional diversity as an evolutionary process (Becker and Ostrom 1995) to strengthen social organization. It also provides arguments for the importance of the cultural and political dimensions of those arrangements, in the context of the Andean commons.

Study area and methods

Páramo Ñukanchik Urko (PNU), or “Our Mountain” in English, is located in Cangahua parish, in the buffer zone of Cayambe-Coca National Park, which was created in 1979 (Figure 1). The area is about 70 km northeast of Ecuador’s capital, Quito, and a 30-minute drive to the city of Cayambe. It extends from ca 3700 m up to 4218 m (the highest point is on Mount Cangahua-Pucará). This herbaceous páramo hosts valuable fodder species (eg Stipa, Calamagrostis, Festuca, Poa), while a few remnants of humid montane scrub and bush are located in gulches. Up to an elevation of 3400 m, intensive soil erosion has occurred; above that, more intense agriculture is practiced because of the availability of fertile soils and irrigation. The lower areas of the valley, up to ca 2800 m in elevation, are densely covered with greenhouses of export-oriented flower plantations, while small-scale farming dominates at elevations above 3200 m. Local residents, mostly indigenous, are organized in comunas and associations that were legally recognized in the 1970s through early 1990s after Ecuador’s Agrarian Reforms came into force (in 1964 and 1973). These communities are politically ascribed to the Government of the Kayambis Indigenous Peoples.

Since hacienda times, communities using PNU lands have practiced agro-pastoralism based on the family farming model. They collectively use grazing areas, and functionally keep livestock as a capital reserve and for manure production (López-Sandoval 2004). Crop rotation (eg potato–Andean tubers–barley–beans–pasture) is typical of the agricultural frontier in the páramos. Bunching onion is the most important cash crop for families living at the lower limit of the PNU. Rain-fed farming is practiced in areas above the main irrigation canal (ca 3700 m). Up to the mid-1990s livestock was key to subsistence livelihoods, and as a result the páramo was used exclusively for grazing. Since the 1980s, many household economies have become dependent on off-farm employment, mainly in the flower agribusiness sector (Knapp 2017). The CPNU was created in 1995, as an intercommunitarian initiative to manage the páramo to improve water availability for both irrigation and consumption.

This analysis is part of broader land use and land-cover-change research carried out in 2015–2016 in two sites of the northern Ecuadorian Andes and the continuation of a study conducted between 2000 and 2002 (López-Sandoval 2004). For the present analysis, we used a mixed-methods approach. We evaluated changes in the agricultural frontier through a multitemporal analysis of air photos (IGM, 1:60,000 scale, years 1956, 1993, 2008). We considered the years in which...
agrarian reforms came into force and corresponding photo availability. After orthorectification, a visual analysis was conducted to identify recent and historical locations of the agricultural frontiers, dwellings, and changes in land fragmentation. Following the analytical framework of López-Sandoval (2004) for air photo analysis, we contrasted a temporal with a permanent agricultural frontier. The temporal agricultural frontier refers to the elevational limit of agricultural plots that are under long-fallow cultivation systems (Sarmiento 2000). The permanent agricultural frontier is the limit of permanent crops and dwellings, which extend from lower elevations into the páramo as fixed permanent parcels. In addition, for 2008, we defined an agreed agricultural frontier as an institutionalized landmark in an area of communal páramo management.

We conducted qualitative research through semistructured interviews, a narrative drive and walk, and group interviews. Participants were randomly selected according to the group they belong to: groups included (1) members of the CPNU, including local guides (N=3), settler-users (N=11, 1 group interview), urukumugas (N=4, 1 group interview), and local historians (N=2), and (2) external experts (N=5). We also drew from 2 life histories of the local historians (age 65 and 71), who were also former community leaders. These life histories were recorded as part of previous research in 2000 (López-Sandoval 2004) to recall the history of páramo use in the hacienda system and, specifically after the agrarian reforms, of access to land in the páramo and the expansion of agriculture. Given the limited narratives used for this analysis, we supported interpretations with literature review. We analyzed and coded N=18 transcripts. We used thematic analysis (Flick 2009) to identify codes and categories, which resulted in 4 thematic domains. The first 2, “historical grazing practices” and “communal rules and management in the CPNU,” were analyzed to recall the historical governance and land use change since hacienda times up to the establishment of CPNU. The further thematic domains “conservation knowledge” on water and páramo and “authority” for water and territorial rights were the basis for the analysis of drivers of rule emergence and conditions required to support rule enforcement. We organized and synthesized other narrative information to provide a deeper understanding of codes and categories (Appendix S1, Supplemental material, https://doi.org/10.1659/MRD-JOURNAL-D-19-00007.1.S1).

Results

Evolution of the socioecological system and land use change

During the 60-year observation period, PNU’s SES has evolved with changing social, economic, and political contexts (Figure 2). Agrarian reforms, the effects of overgrazing, and the strengthened political organization of the community significantly influenced the feedback loops between SES elements and outcomes of páramo conservation. Changes in, for example, grazing areas in the hacienda system, land for cultivation and residential uses after the agrarian reforms, and the use of water for drinking and irrigation also affected the evolution of governance arrangements. Among the actors historically involved in the SES (eg landowners, hacienda workers, state, and nongovernmental organizations [NGOs]) today, communities, water boards, and the CPNU are the most central to SES communal governance, which indicates an evolution of the system.

Our historical analysis shows how the outcomes of the SES are a result of evolution of the agricultural frontier and grazing practices, as well as of a changed context of governance fundamentally influenced by agrarian reforms. Pseudo-communal governance evolved over time starting with the hacienda up to the agrarian reforms. The users, the hacienda workers and landowners, shared pastoral practices, but rules for use and control of the pastures as the main resource unit of páramos were set by the landowners. As identified in the thematic analysis, historical grazing practices were institutionalized by the hacienda system. Permanent grazing (eg for fattening bulls or dry cows) at higher elevations enabled indigenous workers to access hacienda pastures by including their animals in the landowner’s herds. Through the daily and vertical displacement of herds, letting them graze in the lower grasslands close to the agricultural frontier, SES users took advantage of the hacienda’s páramos for fodder, manure production, and fertilization. Hence, shared pastoral practices, for example, a shift in herding labor by mountain guards (urukumugas), cattle round ups (rodos), or group herding by children, converted the páramos into “land of communal use” (Ibarra and Osipina 1994: 83). Although rules for checks and sanctions were defined by owners, all users of páramos reinforced the idea of communal tenure through grazing activities, as supported by literature on hacienda functioning (de la Torre 1980; Borchardt de Moreno 1989).

After the hacienda was dissolved in the 1970s and 1980s, indigenous workers strengthened communal organization up to the mid-1990s, focusing on the reinforcement of the political structures of the community, to acquire agricultural land and to regulate land partitions among community members (Barsky 1984; Martínez 2016). In this period, the páramos were under precommunal governance. Grazing practices were replicated from the hacienda, but no organized body steered communitarian forms of collective management of the páramos. A settler-user from Isacata said: “It was clear to us: what the hacienda did for years was what we thought we had to do as well: to use [the páramo] for animals and burnings.” Despite arrangements about grazing locations between each of the adjoining communities of the CPNU, no regulations on issues such as the amount of livestock, rotations, or calendars were established among community members.

As a result, grazing in the páramos increased dramatically, as did burning. Up to the mid-1990s, local narratives around grazing practices emphasized problems related to the high number of animals in the páramos. One member of the CPNU Board mentioned: “The problem was the same everywhere: before, animals used to be free in all of the páramo, every community took its animals there: sheep, pigs. Cattle in the upper part would be grazed in the swamps; the water only consisted of drops.”

Burning and overgrazing became a major concern for local communities, in light of a higher demand for water and changes in livelihood structures. In addition, the intervention of other actors, such as local environmental NGOs, became a key factor in the development of communal governance structures that were based on interactions of the CPNU, water boards, communities, and community members, as we analyze later.
These changes in the elements that structure the SES of Ñukanchik Urku influenced its land use changes, particularly those in the agricultural frontier (Figure 3). Aerial photos of the study area from 1956—before the first agrarian reform of 1964—show the location and structure of the settlements of land workers (huasipungueros) living in hacienda territory, with dwellings (N = 81) located on small agricultural plots (Figure 3A). With time, some of these settlements became the centers of communities (e.g., in the case of La Compañía, Los Andes, Larcachaca, Espiga de Oro, and Isacata centers). The highest elevation of the temporal agricultural frontier of cereal production was at ca 3900 m, while the permanent frontier of agriculture and dwellings was located at ca 3600 m. The increase of dwellings to N = 815 by 1993 is particularly notable, as well as the disappearance of the temporal agricultural frontier. While long-fallow cultivation plots were not observed in that year, permanent crops developed intensively at elevations between 3400 and 3700 m. This indicates the replacement of traditional, long-fallow agriculture by more intense, permanent cultivation. The expansion of the permanent agricultural frontier corresponds to increasing peasant occupations of land, which first took place in former haciendas and afterward swiftly expanded vertically to the higher páramos. As a result, between 1956 and 1993 the elevation of the permanent agricultural frontier and of settlements expanded by an average of ca 150 m (up to ca 3750 m).

This spatial evidence shows that páramo, besides being a pasture zone, became a land reserve to satisfy needs for housing and cultivation after the agrarian reforms. The expansion of the permanent agricultural frontier observed in the past 4 decades needed to be controlled to avoid its further rise. This explains the establishment of an agreed agricultural frontier, which became a landmark in 2013 to control grazing and the expansion of crops. Figure 3C shows the limits of permanent agriculture and the agreed...
agricultural frontier in 2008; despite the growth of isolated plots of permanent agriculture up to an elevation of 3820 m, the agreed agricultural frontier was demarcated as a straight line fluctuating between 3600 and 3900 m. Dwellings increased in the observed area to $N = 1529$, indicating a much higher population density in the agricultural zone bordering the páramo. All these land use changes, though, took place below the agreed agricultural frontier, which suggests a certain degree of effectiveness of the rules that had evolved since the late 1990s. As analyzed in the following section, communal governance developed around the environmental need for water protection, in the form of the creation of robust norms and rules for collective páramos management.
**Institutions for páramo management in current communal governance**

In a broader historical context, communal governance of CPNÚ was achieved relatively recently. Qualitative analysis found that current rules for páramo management in Nücknich Kurku have resulted in the creation of 3 institutions: (1) the CPNÚ and its Board, (2) the agreed agricultural frontier, and (3) rules to control grazing and crop expansion. The CPNÚ was created in 1995 and is currently supported by 15 organizations: 7 adjoining and 2 beneficiary communities and 6 water boards. The general assemblies of the CPNÚ are attended by around 2500 people on average, while the Board has around 35 members, including a president, vice president, treasurer, and secretary. In addition, each organization has a representative and an urkukama. Although the committee has no legal registration, local organizations and public institutions working in the area (other indigenous political organizations, local water boards, communities, NGOs, and governmental institutions) recognize and acknowledge its role, especially regarding the development and enforcement of rules and political coordination. The legitimacy of the committee ultimately relies on the broad recognition of its authority by communities and, particularly, by the water boards. As mentioned by a former leader of the CPNÚ: “The situation in Cangahua is highly complex because 7 or 8 communities are owners of the páramos, but through the water boards, for example, in Guanguilqui, between 45 and 48 communities are water beneficiaries. There is a lot of pressure on water use.”

The agreed agricultural frontier line (frontera agrícola) constitutes a further institutionalization of collective management. Testimonies concur that carrying through the strongly contested decision to eliminate all pastoral activities above this line was the main innovation introduced by the CPNÚ. This process was supported by the work of a local NGO, Instituto de Ecología y Desarrollo para las Comunidades Andinas (IEDECA). In 2000, the CPNÚ Board, community leaders, and tenants of land located in the frontier area started a process of complex negotiations, to finally define the agricultural frontier as a straight line between 3600 and 3900 m. Up to this line, CPNÚ would permit agriculture, house construction, and animal keeping or grazing. The agreed agricultural frontier was materially demarcated with a ditch where Polylepis trees were planted in 2013. In the area below the agreed agricultural frontier, there has been a progressive increase in agricultural plots and grazing activities at varying rates, according to individual and communitarian needs. Rules are applied above this line.

The rules crafted by the CPNÚ were developed to restrict land use change and grazing, to monitor restrictions and páramo conservation, and to sanction rule violations. Regarding restrictions, the main rule is to not surpass the agreed agricultural frontier, with crops, animals, or burning. Monitoring is carried out largely through (1) walks along the agreed agricultural frontier by urkukamas, who record rule-breaking, and whose role is set by CPNÚ assemblies, and (2) through mingas, collective visits to the upper zones of the páramo to observe vegetation conditions or to maintain canals or other water infrastructure. Sanctions consist of expensive fines, the confiscation of animals, and, sometimes, the application of indigenous justice.

**Drivers for rule development and compliance**

**Conservation knowledge:** The qualitative analysis of how rules for collective management emerged pinpoints that environmental knowledge about the relationship between water and páramo boosted institutional change and rule development. Informants of the 2 groups (CPNÚ leaders andsettler-users) agreed that the radical decision to stop agricultural expansion and grazing was needed to protect the páramos and allow water sources to recover. However, this currently agreed statement was shaped through negotiations, influenced by both local and expert knowledge, demands of water users, and diversification of domestic economies. The first CPNÚ leaders were aware of the environmental links between páramos vegetation, water availability, burning, and trampling. They asked IEDECA for assistance with environmental education to convince people to support the decision to move animals down and stop agriculture in the páramos. As an NGO expert stated: “I remember in 2000, in an assembly they set the goal to totally eliminate animals within 5 years. When I heard that, I thought these guys [estos compañeros] are crazy, they won’t make it.” We just wanted to help change pastoral practices.” Actually, the intervention of this NGO, which had previously carried out successful pioneer work on communitarian irrigation systems linked to páramo conservation in the region, became crucial to spreading conservation knowledge about the relationship between páramo and water.

Through environmental education activities, such as meetings, training, and field trips, users of PNU became more aware of the importance of páramo vegetation. Testimony of IEDECA staff included the following:

> At the beginning only communal and water board leaders agreed to take animals down. Users insisted they must have at least a few animals. Environmental education was needed to enhance [understanding of] páramo importance. Through that, people were convinced. We took them to other places: we took them to successful experiences in Ambato, but also to Chimborazo and Carihuayrazo where water problems and overgrazing were dramatic, with no water in sight.

In addition, pressure increased on the communities just outside the PNU who claimed tenancy rights. This pressure came from various water users directly, as well as indirectly through the water boards. For instance, the Guanguilqui and Porotog irrigation systems, members of CPNÚ, mobilized at least 2000 families around issues of water provision (Hoogesteger 2013).

**Authority for water and territory:** We identify the thematic domain “authority for water and territorial rights” as the factor that most effectively supports rule enforcement. The CPNÚ’s collective management operates with social regulation (Baland and Platteau 1999). The board lays down and enforces rules; however, this requires the authority’s legitimation and investment to initiate the regulatory tasks. Testimonies of páramo users indicate that although not all individuals in the area approved of the grazing prohibition, CPNÚ’s control and the authority of its Board were broadly acknowledged, partly because its election follows a similar process as those of a communal cabildo, through designation of CPNÚ’s general assembly. For some users, however, the...
rules and ways to shape normative behavior through rigid sanctioning mechanisms were perceived as excessive and unfair. Feelings of deprivation of the benefits of keeping animals in the grasslands were mentioned. These contested positions point to an impact of greater inequality between members, especially regarding the possibility of undertaking successful collective action (Baland and Platteau 1999). In other words, it is expected that better endowed participants will more easily contribute and cooperate. Hence, some users mentioned the need for at least monetary compensation or for rule modification.

According to our qualitative analysis, communitarian autonomy and territorial self-determination were further factors that contributed to the legitimization of CPNU’s authority. Communal CPNU leaders and external experts underlined the importance of the autonomy of the community, as a sign located at the lower limit of the agricultural frontier indicates: “Comité de Páramo Nukanchik Urku. With much effort we have recovered the vegetation to maintain our water sources; an achievement obtained through community organization.”

The unwillingness of the CPNU Board to get a legal status or to participate in conservation payment programs such as SocioPáramo reflect their political conviction that the outcomes of current collective páramo management should remain solely with the community. An urukukama explained: “In other places, foundations have now introduced contracts to take care of the páramo in exchange for money, but with conditions. We have not accepted this; where would all what we have done go? We have been working on this for 20 years. If someone wants to help, this is very welcome, but without conditions.”

Board members justify these actions to control the páramo by referring to the need for self-determination over its territory, recalling the International Labour Organization Convention 169, which recognizes “the ancestral territories of indigenous communities.” In the words of a former CPNU leader: “This páramo is our territory; it is not owned by haciendas or the state, or the ministries. We have made great efforts to convince everyone to take care of the páramo because it is ours.”

As pointed out by 2 external experts, the assistance of the Government of the Kayambis Indigenous Peoples has been important to generate a political discourse around páramo management, water conservation, and customary rights as forms of territorial self-determination. The recognition of the authority of the CPNU Board as legitimate tenants of the páramo is reinforced through written regulations (reglamento) about the functions and structure of the committee and—most importantly—the rules to control páramo use. This recognition has strengthened their capacity to collectively and normatively steer conservation outcomes.

We acknowledge that these drivers of rule development are contextualized in main changes of livelihood strategies that indicate less pressure over agriculture. Although not specifically addressed in this study, other research (Gasselin 2000; Martínez 2009; Knapp 2017) and narratives collected in the fieldwork suggest that domestic income diversification is important for the prioritization of water conservation in the páramo. Wage labor in flower plantations and bunching crop cultivation were repeatedly mentioned in the interviews when asked about domestic income composition. The short distances between dwellings at the lower limit of the páramo and flower plantations as well as improved roads now facilitate daily commutes to work in the plantations. As can be seen in the aerial photo analysis, the increase of dwellings in the lower limit of the páramo suggests higher demands for drinking water.

**Discussion and conclusion**

The goal of this study was to analyze how rules to control agricultural expansion and overgrazing have emerged and are enforced as a result of the evolution of communal governance in the SES of PNU. We found that, in the past 60 years, land use change involved the retreat of traditional long-fallow cultivation and the vertical expansion of permanent agriculture and of settlements, while overgrazing resulted from a lack of robust communal regulations. Collective páramo management is a recent phenomenon in the PNU that responds to a strong demand for water in the past 3 decades and to an increasing demand by local communities for their territorial rights. These findings concur with studies that show that communal regulations for páramo conservation have not taken place until in the past decade (Hayes et al 2017), mostly in the context of the development of collaborative multi-stakeholder models (Iniguez Gallardo et al 2013) and the recognition of the political agency of water-user movements (Boelens et al 2016).

Although less pressure over agricultural and grazing lands in the páramos is related to changes in livelihood strategies, we found that knowledge of páramo conservation, historical land use changes, and recognition of the community authority enforcing water and territorial rights boosted the emergence of collective management rules. In our study, increased conservation knowledge (Berkes and Turner 2006), strongly supported by NGOs, became key to the development and the enforcement of rules. This knowledge in turn was crucial in the discourse of leaders to legitimize the authority of the CPNU-Board and helped to deal with user resistance to rule compliance. As suggested by Boelens and Seeman (2014), legitimacy and authority are often invoked through claims on knowledge. In CPNU, this has influenced the view of positive outcomes of páramo management as being “autonomous” and “communitarian.” Given that páramo management occurs under social regulation, in light of the political structure of the Andean comunas, the authority’s work is fundamental to the coordination and the initiation of processes of collective action (Baland and Platteau 1999).

The political aspect of collective water management is hotly debated in the Andes, from a political-ecological perspective and in relation to the concept of hydro-social or water territories (Hoogesteger 2013; Boelens et al. 2016). These refer to spaces conceived as social–environmental and political relationships, which constitute home bases in terms of cultural belonging and socio-productivity for indigenous or peasant livelihoods and for the construction of a political community (Boelens et al 2014). Our analysis incorporates the cultural/political and territorial dimensions of collective páramo management from the perspective of normative cultural resilience, to interpret change in the social subsystems in the PNU. Resilience is considered central to the evolution of an SES (Folke et al 2016). However, there is a
strong critique to the approach of analyzing cultural resilience through concepts of ecosystem resilience (Cote and Nightingale 2012), pointing at a failure to consider the capacity of systems to absorb disturbances or to retain essential functions under stressors (Walker et al 2004).

Crate (2010) views cultural resilience as subjective and cultural processes that are needed to maintain the SES as a space that contextualizes and constitutes life experiences. In this sense, our analysis shows that SES outcomes, for example, control of land use changes and grazing, result from a long-term environmental and cultural/political evolution. Hence, SES resilience is not just an adaptation of the system to recover the ecological system’s functionality, but rather a milestone of wider historical change where communal management of páramo is a means of territorial control and of communal authority’s legitimation. Current communal governance in the CP ˜NU is an outcome of cultural resilience as it responds to both an environmental concern and a normative cultural process. Rules and institutions are also a means of exciting territorial rights. Hence, landmarks as the agreed agricultural frontier are not only an expression of spatial control and territoriality (Sack 1983) of the CPNU, but also the material representation of long-term, autonomous, and communitarian action for territorial self-determination. These elements have until now contributed to cultural resilience in PNU. However, this study is limited to the analysis of the diversity of positions on rule enforcement and authority recognition among the diverse groups of users involved in the CPNU. A deeper analysis of social and economic inequality among community members is needed to assess possible threats to the resilience of the SES.

We conclude that there is a need to understand the broader context of cultural change and resilience that motivates communities to overcome challenges of collective management. The focus of the analysis of communal management on present situations restricts the understanding of rule development as a response to scarcity and salience (Gibson et al 2007), while ignoring the history of cultural/political transformations that have motivated communities to mobilize. Such motivations must be acknowledged when supporting the strength of rules and institutional diversity to manage the commons, as Andean communities are now acting as the main stewards of water conservation and resistance to extractive models and uses, such as afforestation with exotic species or mining. Cultural and political aspects should be considered in transforming knowledge (Mathez-Stiefel et al 2017) required to maintain the functionality of Andean SES.

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Supplemental material

APPENDIX S1 Questionnaires, participants, thematic analysis of qualitative data.