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Source: Mountain Research and Development, 38(4) : 390-400

Published By: International Mountain Society

URL: https://doi.org/10.1659/MRD-JOURNAL-D-17-00075.1

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Mountain Research and Development (MRD)
An international, peer-reviewed open access journal
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Highlands in Transition: Urbanization, Pastoralism, Mining, Tourism, and Wildlife in the Argentinian Puna

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Land use change is a key component of regional environmental change. In mountain regions, where conditions for agriculture and human life are often difficult, land use trends are dominated by changes in the population's distribution across rural and urban areas and shifts in the main human activities. In the Argentinian puna—a high-elevation subtropical plateau of about 95,000 km^2 situated above 3200 masl—land is chiefly used for grazing, mining, and tourism. In this article, we analyze trends in these land uses over the last 57 years in the context of climatic changes toward drier and warmer conditions. Since 1960, the human population grew from 80,000 to 130,000; but this increase largely occurred in the scattered urban centers, while the rural population decreased. The main livestock—sheep—showed a net decrease of around 100,000 animals (–18.5%), with numbers increasing between 1960 and 1980 and then dropping markedly. The number of mining operations declined during the 1970s and 1980s and then rose sharply, reaching a 30% increase since the 1990s. Simultaneously, structural wild vicuña populations increased from a few thousand to around 130,000. These results show that environmental changes over the past half century involved a major wildlife recovery associated with a change from widespread extensive grazing to intensive but spatially limited impacts around mining operations and growing urban centers. Tourism emerged as a new activity over the last decades, but the environmental impacts have been poorly studied. To promote local development and regional conservation, research priorities should include (1) empirical assessments of the ecological consequences of land use changes, such as grazing regimes shifting from domestic to wild herbivores, as well as the impacts of mining, tourism, and urbanization on wetlands and hydrological regimes; (2) modeling of future scenarios of mining and tourism expansion and resulting conflicts with environmental conservation; and (3) coproduction of knowledge about interactions among land uses, climate change, and the different decision-making agents.

Keywords: *Land use transition; urbanization; grazing; mining; tourism; herbivory transition;* puna.

Reviewed by Editorial Board: *September 2018*
Accepted: *October 2018*

Introduction

Sustainable development has been acknowledged as a global aim (UN 2015); it also drives a specific mountain agenda (eg the Sustainable Mountain Development for Global Change program funded by the Swiss Agency for Development and Cooperation). The Sustainable Development Goals include social, environmental, and economic topics. Demographic trends and land use trends are the main components of the key social–environmental interactions driving development. They result from complex socioeconomic processes in which it is difficult to isolate simple cause–effect relationships. Land use science proposes a framework that relates demographic, economic, and land use changes, referring to them collectively as "land use transition" (Foley et al 2005). This framework accounts for land use intensification and recovery of natural ecosystems as a result of decreasing land use in marginal areas in the context of industrialization and urbanization. Such processes of ecosystem recovery have been studied above all in forested areas undergoing the so-called "forest transition" (Mather and Needle 1998, Rudel et al 2005). However, similar recovery processes may also occur in non-forested ecoregions, including deserts and montane ecosystems above the treeline (Grau and Aide 2008, Izquierdo and Grau 2009).

Changes in land systems have causes and consequences at different scales (Verburg et al 2015); these can range, for example, from local inhabitants' migration decisions to global trade forces. Urbanization is a global process, but it is partly driven by local decisions (Seto et al 2011)

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and has major local environmental and social implications (Elmqvist et al 2013). At the other extreme, globalized markets and related distant drivers influence local environmental management (Liu et al 2013), with hard-to-predict social and cultural effects (Evrard and Goudineau 2004; Friis et al 2016) that interact with national and local market and government drivers of land use (Sikor and Stahl 2012; Margulis et al 2013). Many mountain regions share a number of particular characteristics that determine how they respond to these globalization-related processes (Jodha 2000; Aide and Grau 2004): they are often of marginal importance for agricultural production, and many of them experience outmigration, attract tourism, and harbor mineral resources for which global demand is growing (Boillat et al 2017).

The subtropical highlands of Argentina—known as "puna"—are an ecoregion that exemplifies the interplay of these processes. Situated at over 3,200 masl and having an arid climate, the puna is characterized by very harsh living conditions. It is experiencing substantial outmigration (Longhi and Krapovickas 2018) coupled with a decrease in livestock and cropland (Izquierdo and Grau 2009). While the main traditional land use in the region was transhumant grazing (Quiroga Mendiola and Cladera 2018), the relative importance of mining and tourism has increased in recent years (Izquierdo et al 2015, Lencina et al 2018, Troncoso 2018). Puna inhabitants have managed wild vicuña (*Vicugna vicugna*) populations since prehistoric times (Lichtenstein and Vilá 2003). However, uncontrolled hunting of vicuña for their high-value fiber, combined with competition from livestock, pushed the species to the brink of extinction in the 1960s. Since the 1970s, it has experienced a strong recovery (Lichtenstein and Vilá 2003, SAyDSN 2008) as a result of better policing, international control of the fiber market, and reduced competition from livestock (Grau and Aide 2007). These changes in herbivory patterns should have important implications for ecosystem functioning, as well as for conservation and socioeconomic theory and practice. However, an integrated quantitative analysis of these implications has been lacking, as the interactions among socioecological variables and their effects on land use trends have not been studied at the regional scale.

In this article, we analyze how recent land use changes might be related to the more widespread social and demographic trends in the puna ecoregion and what implications they have for wildlife conservation. To answer these questions, we (1) describe trends in the human population, the livestock populations, mining, tourism, and the vicuña population (as a proxy of wildlife conservation) in the region over the past 57 years; (2) model the current spatial patterns of these variables and discuss the associations among them and their potential drivers; and, based on this analytical framework, (3) propose research priorities with a view to improving sustainable development in the region, taking into account trends in land use change, climate change, and ongoing policy initiatives (eg National Wetlands Law, management plans of protected areas).

We expect that this socioecological analysis will provide useful insights for further development of the theory of land use transition in mountain environments. As such, it will help to identify opportunities for nature conservation and sustainable development according to the Sustainable Development Goal frameworks.

Study area

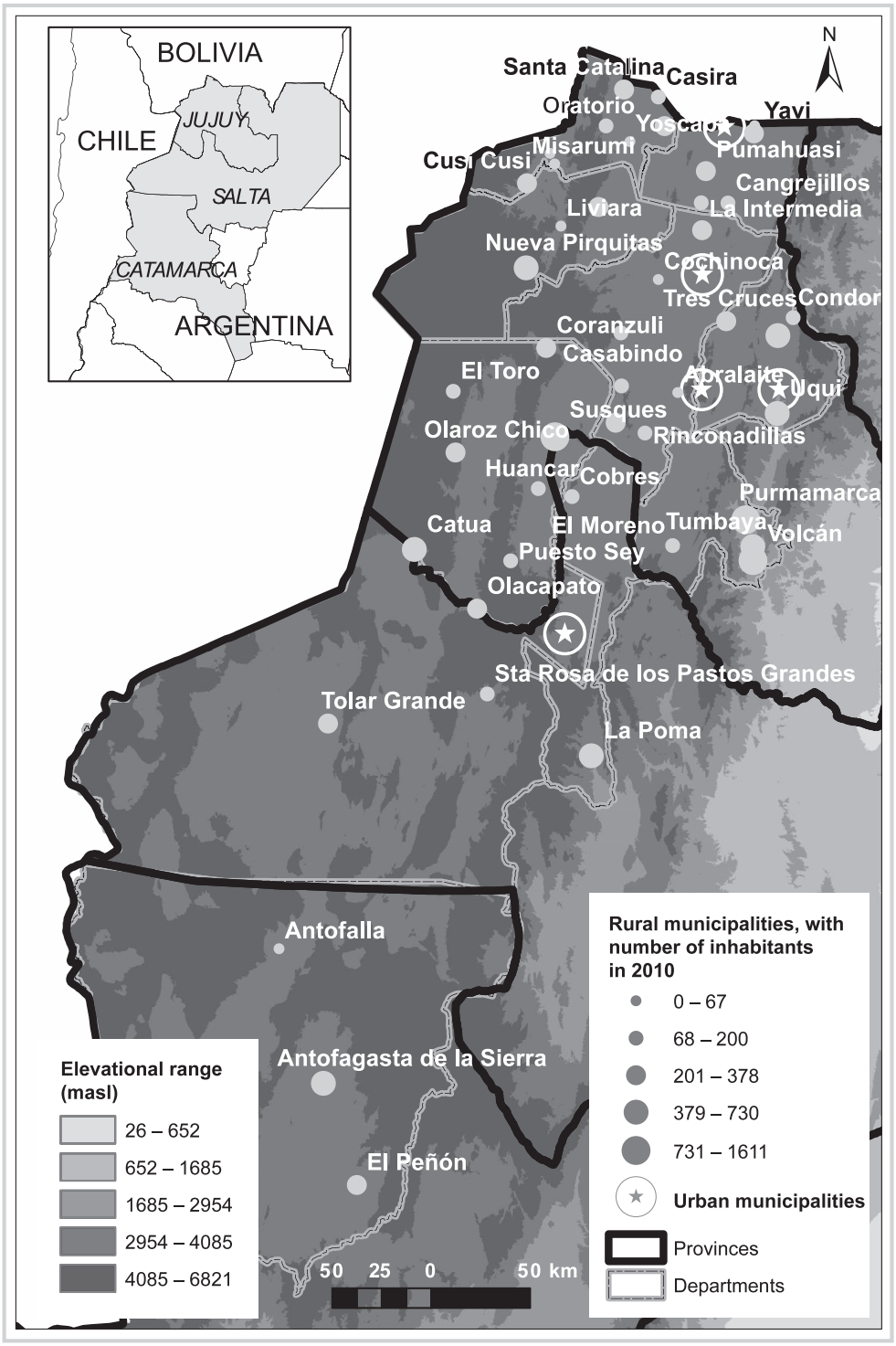
This study focuses on the Argentinian puna region in the provinces of Jujuy, Salta, and Catamarca. The region covers 95,683 km^2 at altitudes between 3200 and 6700 masl and counts a total of 57 municipalities in 10 administrative units (departments) (Figure 1). The climate is cold and dry, with average annual precipitation ranging between 100 and 400 mm and mean annual temperatures between 9 and –4°C (Cabrera 1976). Most climate scenarios for these high-elevation ecosystems predict a 2–4°C increase in temperature (Urrutia and Vuille 2009), as well as decreasing water availability and longer dry seasons (Buytaert et al 2010). While modeling uncertainties are greater with regard to precipitation trends, the most accepted scenario suggests a decrease in precipitation and cloudiness for the subtropical Andes (Vuille et al 2008). This is consistent with findings from an analysis of the historical range of variability based on dendroecological reconstructions of water balance and ecosystem productivity, which showed a drying trend over the past 30 years (Carilla et al 2013, Morales et al 2015).

The extreme environmental conditions in the puna have determined the patterns of human settlement and land use, including a transition from a hunter-gatherer to an agropastoral society during the Holocene (Grana et al 2016). Since the beginning of human occupation around 11,000 years ago, the main wildlife resources were camelids (López and Restifo 2012). The establishment of a sedentary lifestyle about 4000 years ago enabled the development of pastoralism (Martínez 2018, Olivera 2018), which came to be the main subsistence activity for millennia. Currently, pastoralism in the region includes the management of sheep, llamas, and goats for food and wool, as well as horses, mules, and donkeys for transportation.

Additionally, local people have managed wild camelids, particularly vicuñas, since the Inca period (Laker et al 2006). The vicuña population can be considered a proxy for wildlife, since vicuñas are the main native herbivore and, as such, likely associated to predators that feed on them and are subject to hunting (eg felids and foxes), as well as other major herbivores that compete with livestock for forage (eg rheas and guanacos). The vicuña is an endemic species of the tropical Andes of

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FIGURE 1 Distribution of rural and urban municipalities in the study area.



Perú, Bolivia, northwestern Argentina, and northern Chile. In Argentina, its distribution largely coincides with the puna region. The species has the highest animal biomass in the region (Cajal and Bonaventura 1998) and is a key link in trophic interactions, both in its role of herbivore and in its role of prey for carnivores (Donadio et al 2010). This makes the vicuña a structural species in regional communities.

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In the 20th and 21st centuries, puna inhabitants have combined pastoralism with activities related to the market economy (mining and services) and state employment. Mining also has a long tradition in the puna. Artisanal ("gold laundries") and small-scale underground mining has been practiced since pre-Columbian times (Gil Montero 2018, Lencina et al 2018). Medium-scale "modern" mining practices followed after the Spanish conquest, focusing on gold and silver (Gil Montero 2018). At present, mining attracts technologically advanced enterprises. Lithium, in particular, has become the most sought-after mineral resource (Wanger 2011, Izquierdo et al 2015, Anonymous 2017). Lithium reserves in the Argentinian puna are part of the so-called "lithium triangle"—the largest global reserve of lithium, which extends across northern Chile, southwestern Bolivia, and northwestern Argentina. Lithium production has boomed in recent years due to the rising demand for cellphone and electric-car batteries (Desselhaus and Thomas 2001; Scrosati and Garche 2010). While prospects for lithium mining are promising, and interest in it is growing, its consequences for ecosystem services and biodiversity are poorly understood (Wanger 2011, Izquierdo et al 2015). Tourism is another land use that has increased in recent years (Troncoso and Bertocello 2014, Troncoso 2018). Reflecting a global pattern, the environmental impact of tourism in the region is exacerbated by an increasing demand for alternative places and unconventional landscapes (Laing and Crouch 2009, Troncoso 2018).

Data and methods

Changes in human population were described based on data from the last 6 national population censuses (INDEC 1960, 1970, 1980, 1991, 2001, 2010) at the departmental and municipalities scales. Municipalities were considered rural if they had less than 2000 inhabitants and urban if they had 2000 or more inhabitants.

For our analysis of land use trends, we used livestock data from national agricultural surveys and censuses (INDEC 1969, 1988, 2002, 2008). As information about mining activities is not standardized, we compiled information from different sources, such as ministerial reports, the Argentinian Chamber of Mining Entrepreneurs (*Cámara Argentina de Empresarios Mineros*), and websites of mining firms. We recorded the years of operation opening and closure of each mining project active in the region from 1960 to the present. Regarding tourism in the puna, despite its rapid increase over the past decades (Troncoso 2018), there are no statistics disaggregated at the regional scale. As a proxy of regional tourism activity, we used visitor statistics of the National Parks Administration (AET 2015). There is one national protected area in the north of the study area: the Pozuelos Lagoon Natural Monument (established in 1990). Pozuelos is an isolated area and does not offer tourist services like accommodation or supplies (APN no date).

Our analysis of changes in wildlife during the studied period is based on vicuña population statistics. Data on Argentina's vicuña population are not historically systematized but have nonetheless been reliably monitored (SAyDSN 2008). We combined vicuña population data reported in peer-reviewed literature and in the National Census of Camelids carried out in 2006.

To model current spatial patterns, we mapped land use and wildlife indices to assess potential spatial interactions. Municipalities were mapped and classified as rural or urban. The mining projects that are or were active in the study area since 1960 were localized based on public information and companies' websites. To spatially model tourism activity we used GPS tracks uploaded to the wikiloc website (Wikiloc no date). We selected all tracks in our study area available by May 2017 and classified them by user-assigned activity (train, car, offroad car, offroad motorbike) to be able to consider the different impacts of these activities.

For wildlife, we used the data on estimated density of vicuñas presented in the National Census of 2006 in the form of a map showing quantitatively estimated density for some areas; no data for other areas; and qualitatively estimated density (as low, medium, or high) for a third set of areas (SAyDSN 2008). We digitized this map for our study area, grouping polygons with quantitative estimates into 5 ranges of animals per square kilometer (<1; 1–3; 3–5; 5–7; >7) and maintaining the original classes for polygons with qualitative density estimates and polygons with no data.

Finally, based on the described patterns of land use change and hypothesized relationships among them, we developed an agenda for research that will contribute to 2 aims. The first is to provide knowledge that supports local sustainable development, and the second is to advance the science of land use in mountain regions in the context of global environmental and socioeconomic change.

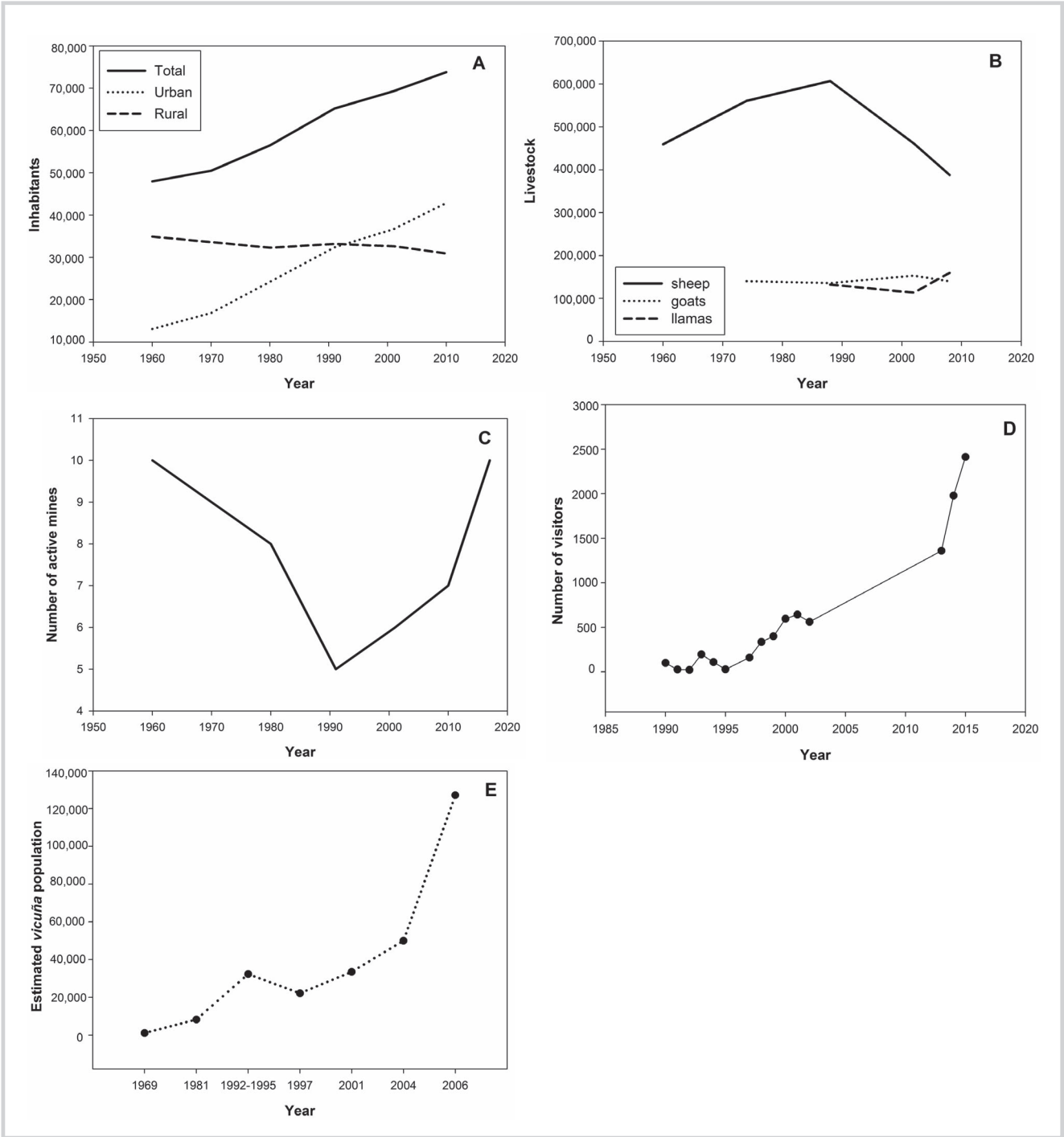
Results and discussion

Land use trends in the Argentinian puna

In 2010, the study area had a total of 73,789 inhabitants, of which 42,862 (58.09%) were classified as urban and 30,927 (41.91%) as rural. Between 1960 and 2010, the human population increased by 25,812 (53.80%). This growth resulted from an increase in the urban population (227.8%; 29,785 inhabitants), while the rural population decreased by 11.38% (3973 inhabitants) (Figure 2A). Only 2 municipalities (La Quiaca and Humahuaca) had an absolute increase by more than 2000 inhabitants, and one other (Abra Pampa) showed an increase by more than 1000 inhabitants. This general increase in urban population may be related to activities along the commercial corridor (National Road 9) between Bolivia

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FIGURE 2 Demographic and land use trends in the study area over the past 57 years. (A) total, rural, and urban inhabitants; (B) numbers of sheep, goats, and llamas; (C) active mines; (D) tourist visitors to national protected areas; (E) estimated vicuña population.



and Argentina, rather than to mining activities. These 3 localities achieved urban status (with 2000 or more inhabitants) in 1970.

Sheep are the main livestock in the region (~388,000), followed by llamas (~160,000) and goats (~140,000) (Figure 2B). Sheep experienced a net decrease of 18.5% between 1960 and 2008, with an increase of 32% between 1960 (459,521) and 1980 (606,953) followed by a decrease of 63.9% between 1980 and 2008 (387,908). Goats and llamas remained comparatively stable according to the available census data (covering 1970–2008 for goats and 1988–2008 for llamas).

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There were 10 active mines in the study area in 1960; a drastic drop during the 1980s was followed by a recovery back to 10 active mines at present (Figure 2C). The decrease during the 1980s was mainly due to the closure of old mines. Since 2000, 2 new gold mines opened, as well as 3 lithium mining operations in salt flats. It is estimated that 81% of all mining projects in Argentina are in the exploration phase (MRECIC 2010). At least 13 projects in the study area are in preoperational phases (CAEM 2018). The lithium boom is particularly relevant in our study area (Izquierdo et al 2015). Currently, there are 52 projects of lithium in the study area; 6% of these are in the production phase, 43% in the exploration phase, and 44% in the prospection phase (USGS 2017). There is no obvious link between the expansion of mining operations and prospecting activities after 2000 and population changes.

Alternative tourism activity is reflected in national protected area visitor statistics (Figure 2D). Data for Pozuelos show a sustained increase from 101 visitors in 1990 to 2547 in 2015 (Figure 2D). Although Pozuelos accounts for only 1% of visitors to all national protected areas, the rate of increase in visitors here (Figure 2D) has been 10 to 100 times greater than the average across all national protected areas (AET 2015).

Despite discontinuities in vicuña population data and methodological differences in how they were collected, the compiled information shows that the vicuña population recovered significantly—increasing about a hundredfold—in the past decades (Figure 2E). The total vicuña population in the Argentinian puna was estimated at 1000 head in 1969 (SAyDSN 2008). Based on these estimations, the species was listed in Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), and the governments of Bolivia, Chile, Ecuador, and Peru adopted the Convention for the Conservation and Management of the Vicuña. Since then, the population has shown a sustained increase (Figure 2E), and the International Union for the Conservation of Nature (IUCN no date) has labeled the current population trend as "increasing," with the present population estimated above 100,000. The wild vicuña populations of Jujuy and Catamarca and the semi-captive populations in Salta, La Rioja, and San Juan are included in Appendix II of CITES (CITES 2017), which allows for trade in wool and derived products under strict regulations.

At present, these dynamics shape complex spatial interactions between the land system's components (Figure 3). Although the puna is remote and isolated, land use components are well distributed and present throughout the whole region; even tourism, a historically restricted activity, is becoming more widespread due to increased access by means of four-wheel-drive vehicles (Figure 3A). Mining projects frequently open new tracks that are then also used by tourists (Figure 3A), thus easing access to areas that would otherwise have remained untouched. Areas where grazing activities are concentrated also function as nodes in a network of tourism tracks (Figure 3A). Finally, all components, including the highest vicuña densities (Figure 3B), are concentrated in the northern part of the puna, where rainfall is more abundant and forage productivity is higher.

Interactions among drivers of land use change

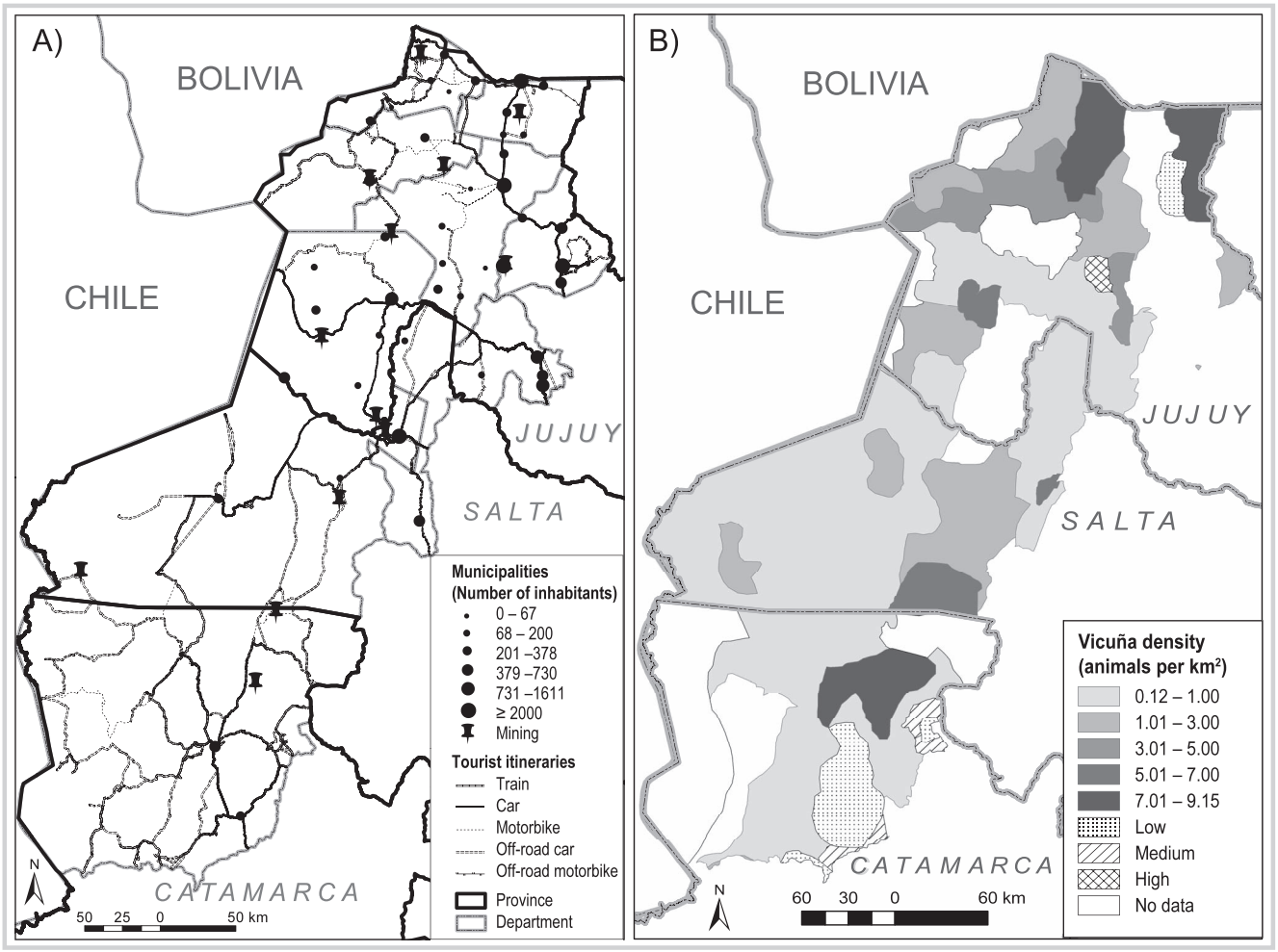
Exogenous drivers and interactions among social and environmental components in the Argentinian puna form a complex system. Given our 2 objectives of understanding scenarios of change and developing a research agenda, we propose a conceptual scheme of these interactions in the region that is based on quantitative trends (Figures 2, 3) and on our informal knowledge of the system. This framework describes the main ongoing transitions and forcing factors influencing these transitions, as well as mechanisms through which we hypothesize that these components interact (Figure 4).

Urbanization is the main demographic change (Figure 2A). This is a global and largely inevitable process (UNFPA 2007) driven mostly by the pull factors of urban centers providing jobs, services, and education opportunities. In addition, the urbanization process may be reinforced by environmental degradation and social disruption in rural areas (UNFPA 2016). Urbanization in the Argentinian puna follows the global pattern. The most likely drivers are harsh living conditions in rural areas and people's desire to increase their well-being and make use of opportunities in urban areas. In addition to migration from the countryside to urban areas, urbanization in the puna is likely also linked to a growing services economy based on commerce and state employment in the 2 largest cities (La Quiaca and Abra Pampa, along the highway to Bolivia) and all other, smaller urban and quasi-urban agglomerations with 500 to 2000 inhabitants. These frequently offer public-service jobs, for example, at schools, at municipal governments, or in road maintenance.

The declining rural population is likely the main driver of the decrease in grazing by domestic herbivores (Figures 2A, B) and, combined with wildlife protection policies, could be the reason for the recovery of vicuña populations (Figure 4). However, the relative importance of the 2 factors (and their interaction) has not been assessed. These changes in herbivore populations may reflect an herbivory transition (Grau and Gasparri 2018) (Figure 4) that involves both spatial and herbivory changes. The recent sharp trends in sheep (decreasing) and vicuñas (increasing) might suggest that herbivory pressure from domestic livestock is becoming more restricted to areas near human settlements, while wildlife is expanding in more remote areas—a development that

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FIGURE 3 Spatial interactions of land use indicators: (A) municipalities, mining operations, and tourism tracks; (A) vicuña density according to the 2006 national census.

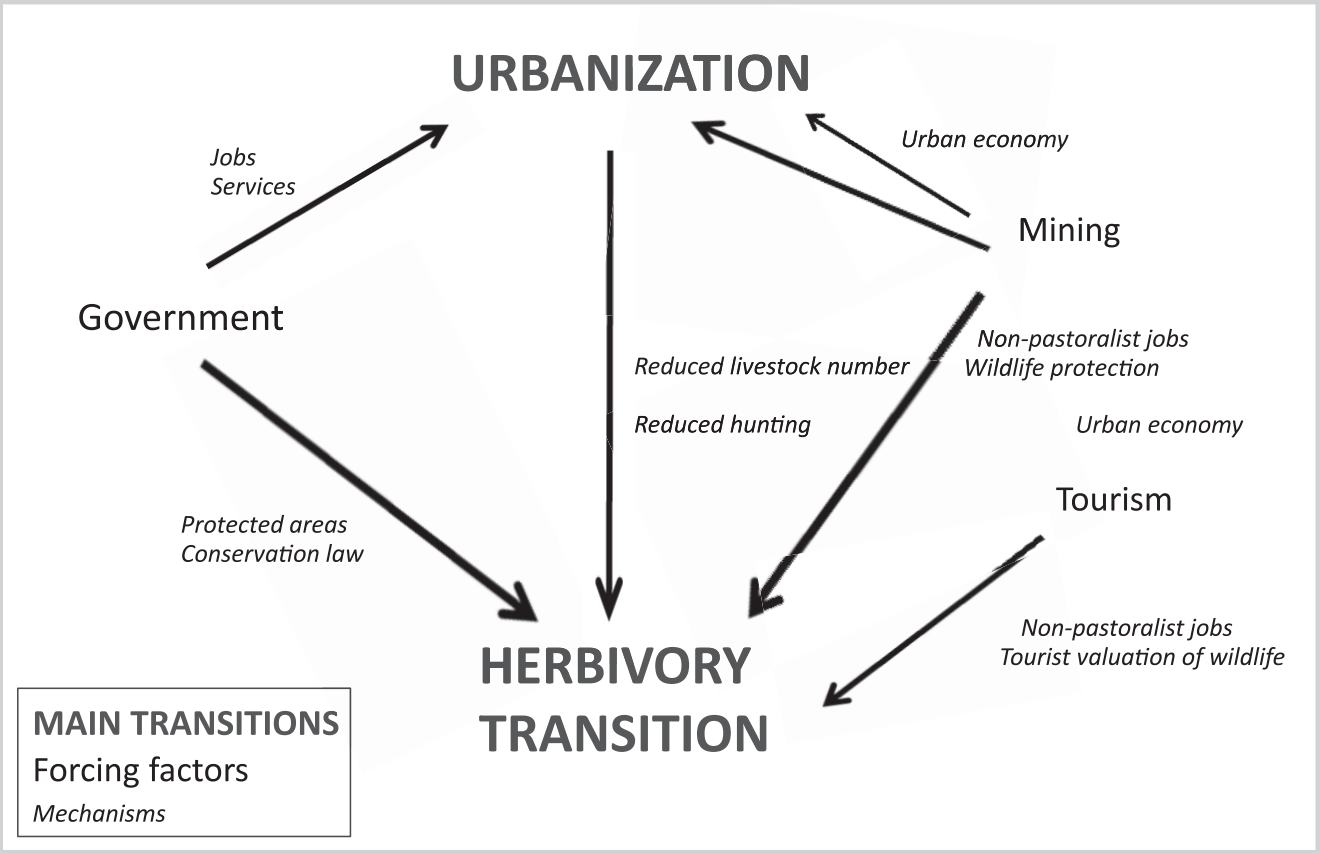


will likely lead to a divergence in other ecological components as well. For example, we might expect growing carnivore populations as a result of greater availability of prey (Iriarte et al 1990) in less accessible areas as well as changes in the flora and soil characteristics as a result of differences in plant preferences (Salvador et al 2005) and trampling characteristics (Genin and Alzérreca 2006) between camelids and sheep and goats. The consequences of these processes are unknown but in some cases may involve mutual reinforcement. For example, conflicts between pumas and livestock may be an additional factor driving the decrease in grazing activities in more remote areas.

Despite the fact that the number of mining operations was the same at the beginning and at the end of the studied period (Figure 2B), their development went through a significant change. The way in which mining activity has fluctuated might result from the interplay between the telecoupled dynamic of drivers (eg new markets for lithium) and the fluctuating domestic policies on natural resource exploitation. The initial decrease in the analyzed period was due mainly to the closure of old mines in view of depressed global commodity prices (Wanger 2011), combined with a different state management model where the national state acted as the main consumer and participated substantially in exploration activities (Tolón Estarelles 2011). The increased activity since the late 1980s was fueled initially by the global metal price boom and later by growing global demand for lithium and other, non-metalliferous minerals (potassium, borates). Additional factors include infrastructure development (2 puna gas pipelines crossing from the Argentinean gas fields to the Chilean coast) and tax cuts (reduction of the tax from 10% and 6% for borates and perlite, respectively, to 3% in 1993) (Figure 4)—although the overall Argentinean tax burden remains heavier the Chilean or Peruvian tax burdens. Furthermore, during the early 1990s the national political

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FIGURE 4 Main transitions and forcing factors influencing the land use system of the Argentinian puna and hypothesized mechanisms through which they interact.



context led to the implementation of reforms of the regulatory framework for mining activities and changes in the Foreign Investment Law (Decree No. 1853 of 1993) that were decisive for expanding investments in the mining sector (Moori Koenig and Bianco 2003).

There is no clear association between mining expansion and demographic trends. The latter follow a relatively continuous pattern that shows no sign of response to the decrease and regrowth in mining activities. A possible reason is that the number of jobs generated by mining activities is much smaller than the number of state and commercial jobs available in urban areas or that qualified mining jobs are not registered in the censuses due to their seasonal nature. Another possible explanation is that mining operations are in fact providing jobs for local rural inhabitants, thereby contributing to the reduction in grazing activities (Figure 4; Abeledo 2017) without resulting in a regional demographic change.

Tourism is another global and largely unavoidable process associated with globalization. Currently, the tourism industry accounts for 10% of world gross domestic product and generates 9% of jobs worldwide. It represents 30% of world services exports and 7% of total exports (ie accounting for goods and services) (UNWTO 2016). This global increase is promoted in particular regions, such as the puna, by a change in the interests and motivations of tourists, who seem to be increasingly seeking isolated and little-frequented areas and new forms of "alternative tourism" (Troncoso 2018). This driver has socioeconomic implications that are widely considered as favorable: it generates monetary income and local employment opportunities (Chok et al 2007). However, social and cultural adjustment may be necessary (Chok et al 2007; Brandth and Haugen 2011), and strategy and policy planning are indispensable to achieve this.

Vicuñas are a charismatic species, highly valued by both the traditional local culture and tourism (Garrido Patrel 2016). This circumstance might activate another reinforcing feedback loop with current herbivore transition patterns in the puna. Additionally, in the past decades, legal community-based management of wild vicuña populations for fiber production may also have reinforced the increase in the species (Castilla 2014, Vilá et al 2018).

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In the past, mining and the related cash flow may have contributed to an increase in poaching, as it facilitated the access to firearms and ammunition and contributed to a network of roads to remote places. In contrast, modern mining operations usually take measures to prevent poaching on their property. Nevertheless, exploration mining tracks and four-wheel-drive vehicles facilitate access to remote areas (Figure 3A) that were seldom visited in the past, including by outsiders from urban areas. This represents a potential localized risk factor. Studies have documented a range of ways tourism affects highly sensitive ecosystems, including negative effects on vegetation, birds, and mammals (Barros et al 2015). These risks may become much greater with the increase in movements of off-road vehicles, which have not been counted so far but are widespread in the region.

Our results show the complexity of the system and the networks among the stakeholders involved, all of which should be taken into account when planning for the future. Similar to other social–ecological systems, the Argentinian puna requires scenario building. It has been widely identified that scientific research should embrace knowledge coproduction with stakeholders to achieve this (Nature Editorial 2018).

An agenda for research on land use transitions in the Argentinian puna

Based on the described characteristics of the puna land use system and the hypothesized interactions between its components, we have developed a research agenda that will contribute to 2 aims. The first is to provide knowledge that supports regional sustainable development. The second is to advance the science of land use in mountain regions worldwide. To achieve these aims, research should focus on the following:

1. Further improvement of our empirical knowledge of the effects of changing land use patterns on nature and society; for which this paper provides baseline information and a hypothetical framework (Figure 4).
   - Determine the effects of grazing regimes shifting from livestock to wildlife.
   - Determine the direct effects of mining operations on environmental services (eg via water consumption or pollution) and their indirect effects on the socioecological system.
   - Quantify the impacts of tourism on conservation of biodiversity and ecosystem services as well as their socioecological interactions with nature conservation.
2. Modeling land use changes under different climate change and economic development scenarios to inform policy and management.
   - Model the future expansion of different mining activities under different scenarios of price fluctuation and global economic development.
   - Model spatial conflicts among mining, urbanization, and conservation of biodiversity and environmental services; in particular water resources.
3. Interdisciplinary assessment of complex interrelations.
   - Determine the implications of land use processes for regional territoriality processes in view of the existing diversity of legal land-tenure forms.
   - Examine the role of the state—the main employer and provider of local services—as a forcing factor of land use decisions and incentives or disincentives for other economic activities such as mining, tourism, commerce, and wildlife conservation.
   - Study interactions between different land use processes in the context of ongoing and predicted climate change.
   - Analyze local perceptions and implement mechanisms to co-design transparent and environmentally sound research with the main stakeholders, including local inhabitants, governments, and mining and tourism developers. Explore and develop operational tools that can translate empirical information and well-parameterized models into analyses of trade-offs involved in land use decisions.

Conclusions

The dry puna is a biodiversity hot spot (Myers et al 2000) and is currently undergoing land use changes that are poorly understood. Our analysis shows that the region is experiencing novel environmental changes, including a redistribution of the population (concentration in urban centers), a decrease in livestock, expansion of mining and tourism, and recovery of wildlife. These changes occur in the context of climate change toward drier conditions and a strong influence of state employment on the economy. Accelerated climate change, urbanization, and expansion of mining and tourism in response to globalized demands are common to many mountain regions around the world, and therefore the insights from this case study are of interest beyond the study region. The trends and patterns described here might result in a development scenario that is compatible with environmental conservation, given that urbanization and associated economic development improve people's health and education, the observed transition in herbivory favors wildlife recovery, and, at current levels, mining activities do not conflict severely with these trends. Furthermore, tourism—which is partially dependent on the scenic characteristics associated with wildlife and archaeology—is potentially favorable to an environmentally friendly development pathway. However, climatic trends and possible nonlinear interactions among the different components (eg mining or tourism expansion well beyond sustainable levels) need to be carefully assessed to ensure that these opportunities

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are not jeopardized. This assessment requires a combination of dynamic modeling, participatory research where knowledge is coproduced with stakeholders, conceptual developments regarding the functioning of socioecological systems, and the generation of empirical information to fill the identified gaps.

ACKNOWLEDGMENTS

This work was funded by CONICET through grants PICT 2012-1565 and PICT 2016-2173 of FONCYT. We would like to thank Roberto Lencina for his contribution in reviewing the mining data.

REFERENCES

Abeledo S. 2017. Minería de boratos en la Puna argentina: participación en la actividad extractiva y su incidencia en el modo de vida local en Santa Rosa de los Pastos Grandes, Provincia de Salta. *Revista Iberoamericana de viticultura, agroindustria y ruralidad* 3:139–161.

AET [Anuario Estadístico de Turismo]. 2015.Ministerio de Turismo, Presidencia de la Nación. Buenos Aires, Argentina. http://www.yvera.gob.ar/estadistica/documentos/descarga/59f0080a467fb.pdf.

Aide TM, Grau HR. 2004. Globalization, migration, and Latin American ecosystems. *Science* 305:1915–1916.

[Anonymous]. 2017. The white gold rush: A battle for supremacy in the lithium triangle. *The Economist*. 15 June 2017. http://www.economist.com/news/americas/21723451-three-south-american-countries-have-much-worlds-lithium-they-take-very-different; accessed on 11 July 2017.

APN [Administración de Parques Nacionales]. No date. Monumento Natural Laguna de los Pozuelos. Parques Nacionales de Argentina. https://www.parquesnacionales.gob.ar/areas-protegidas/region-noroeste/mn-laguna-de-los-pozuelos/; accessed on 28 October 2018.

Barros A, Monz C, Pickering C. 2015. Is tourism damaging ecosystems in the Andes? Current knowledge and an agenda for future research. *Ambio* 44(2):82–98.

Boillat S, Scarpa FM, Robson JP, Gasparri I, Aide TM, Aguiar APD, Anderson LO, Bastitella M, Gesteira Fonseca M, Futemma C, Grau HR, Mathez-Stiefel S, Metzger JP, Balbaut Ometto JPH, Pedlowski MA, et al. 2017. Land system science in Latin America: challenges and perspectives. *Current Opinion in Environmental Sustainability* 26:37–46.

Brandth B, Haugen MS. 2011. Farm diversification into tourism: Implications for social identity? *Journal of Rural Studies* 27(1):35–44.

Buytaert W, Vuille M, Dewulf A, Urrutia R, Karmalkar A, Celleri R. 2010/ Uncertainties in climate change projections and regional downscaling in the tropical Andes: Implications for water resources management. *Hydrology and Earth System Sciences* 14:1247–1258.

Cabrera AL. 1976. *Regiones fitogeográficas argentinas*. Buenos Aires, Argentina: Editorial Acme.

Cajal JL, Bonaventura SM. 1998. Densidad, biomasa y diversidad de mamíferos en la Puna y Cordillera Frontal. *In:* Cajal JL, Tecchi R, García Fernández J, editors. *Bases para la conservación y manejo de la Puna y Cordillera Frontal de Argentina: el rol de las Reservas de la Biósfera*. Montevideo, Uruguay: United Nations Educational, Scientific and Cultural Organization, pp 191–213.

CAEM [Cámara Argentina de Empresarios Mineros]. 2018. Proyectos Mineros. http://www.caem.com.ar/proyectos/; accessed on 2 November 2018.

Carilla J, Grau HR, Paolini L, Morales M. 2013. Lake fluctuations, plant productivity and long-term variability in high-elevation tropical Andean ecosystems. *Arctic, Antarctic, and Alpine Research* 45:179–189.

Castilla C. 2014. *Informe provincial de conservación y uso sustentable de la vicuña (*vicugna vicugna*)*. Catamarca, Argentina: Secretaría de Estado de Ambiente y Desarrollo Sustentable, Gobierno de Catamarca.

Chok S, Macbeth J, Warren C. 2007. Tourism as a tool for poverty alleviation: A critical analysis of 'pro-poor tourism' and implications for sustainability. *Current Issues in Tourism* 10(2–3):144–165.

CITES [Convention on International Trade in Endangered Species of Wild Fauna and Flora]. 2017. *Apéndices I, II y III*. https://cites.org/esp/app/appendices.php. Accessed on 14 July 2017.

Desselhaus MS, Thomas IL. 2001. Alternative energies technologies. *Nature* 414:332–337.

Donadio E, Novaro AJ, Buskirk SW, Wurstten A, Vitali MS, Monteverde MJ. 2010. Evaluating a potentially strong trophic interaction: Pumas and wild camelids in protected areas of Argentina. *Journal of Zoology* 280:33–40.

Elmqvist T, Fragkias M, Goodness J, Güneralp B, Marcotullio PJ, McDonald RI, Parnell S, Schewenius M, Sendstad M, Seto KC, Wilkinson C, editors. 2013. *Urbanization, Biodiversity and Ecosystem Services: Challenges and Opportunities. A Global Assessment*. Dordrecht, The Netherlands: Springer.

Evrard O, Goudineau Y. 2004. Planned resettlement, unexpected migrations and cultural trauma in Laos. *Development and Change* 35:937–962.

Foley JA, De Fries R, Asner GP, Barford C, Bonan G, Carpenter SR, Chapin FS, Coe MT, Daily GC, Gibbs HK, Helkowski JH. 2005. Global consequences of land use. *Science* 309:570–574.

Friis C, Nielsen JØ, Otero I, Haberl H, Niewöhner J, Hostert P. 2016. From teleconnection to telecoupling: Taking stock of an emerging framework in land system science. *Journal of Land Use Science* 11:131–153.

Garrido Patrel AM. 2016. *Propuesta de líneas de acción de la vicuña (*vicugna vicugna*) en el Ecuador para el aprovechamiento turístico del patrimonio cultural* [Master's thesis]. Riobamba, Ecuador: Universidad Nacional de Chimborazo.

Genin D, Alzérreca H. 2006. Campos nativos de pastoreo y producción animal en la puna semiárida y árida andina. *Science et changements planétaires/ Sécheresse* 17:265–274.

Gil Montero R. 2018. Historia socioambiental: entre la conquista y el siglo XX. *In:* Grau HR, Babot J, Izquierdo A, Grau A, editors. *La Puna Argentina: naturaleza y cultura*. Serie Conservación de la Naturaleza 24. Tucumán, Argentina: Fundacíon Miguel Lillo, pp 343–361.

Grana L, Tchilinguirian P, Hocsman S, Escola P, Maidana NI. 2016. Paleohydrological changes in highland desert rivers and human occupation, 7000–3000 Cal. yr BP, South-Central Andes, Argentina. *Geoarchaeology* 31:412–433.

Grau HR, Aide TM. 2007. Are rural–urban migration and sustainable development compatible in mountain systems? *Mountain Research and Development* 27:119–123.

Grau HR, Aide TM. 2008. Globalization and land-use transitions in Latin America. *Ecology and Society* 13(2):16.

Grau HR, Gasparri NI. 2018. Los socioecosistemas de la Puna en contexto nacional y global. *In:* Grau HR, Babot J, Izquierdo A, Grau A, editors. *La Puna Argentina: naturaleza y cultura*. Serie Conservación de la Naturaleza 24. Tucumán, Argentina: Fundacíon Miguel Lillo, pp 484–497.

INDEC [Instituto Nacional de Estadísticas y Censos]. 1960. *Censo nacional de población y vivienda 1960*. Buenos Aires, Argentina: INDEC.

INDEC [Instituto Nacional de Estadísticas y Censos]. 1969. *Censo nacional agropecuario 1969*. Buenos Aires, Argentina.

INDEC [Instituto Nacional de Estadísticas y Censos]. 1970. *Censo nacional de población y vivienda 1970*. Buenos Aires, Argentina: INDEC.

INDEC [Instituto Nacional de Estadísticas y Censos]. 1980. *Censo nacional de población y vivienda 1980*. Serie D: población. Buenos Aires, Argentina: INDEC.

INDEC [Instituto Nacional de Estadísticas y Censos]. 1988. *Censo nacional agropecuario 1988*. Buenos Aires, Argentina: INDEC.

INDEC [Instituto Nacional de Estadísticas y Censos]. 1991. *Censo nacional de población y vivienda 1991*. Buenos Aires, Argentina: INDEC.

INDEC [Instituto Nacional de Estadísticas y Censos]. 2001. *Censo nacional de población y vivienda 2001*. Buenos Aires, Argentina: INDEC.

INDEC [Instituto Nacional de Estadísticas y Censos]. 2002. *Censo nacional agropecuario 2002*. Buenos Aires, Argentina: INDEC.

INDEC [Instituto Nacional de Estadísticas y Censos]. 2008. *Censo nacional agropecuario 2002*. Buenos Aires, Argentina: INDEC.

INDEC [Instituto Nacional de Estadísticas y Censos]. 2010. *Censo nacional de población y viviendas 2010*. Buenos Aires, Argentina: INDEC.

Iriarte JA, Franklin WL, Johnson WE, Redford KH. 1990. Biogeographic variation of food habits and body size of the America puma. *Oecologia* 85:185–190.

IUCN [International Union for the Conservation of Nature]. No date. Red List. https://www.iucnredlist.org/species/22956/9402796; accessed on 2 November 2018

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Izquierdo AE, Grau HR. 2009. Agriculture adjustment, ecological transition and protected areas in northwestern Argentina. *Journal of Environmental and Management* 90:858–865.
Izquierdo AE, Grau HR, Carilla J, Casagranda E. 2015. Side effects of green technologies: The potential environmental costs of lithium mining on high elevation Andean wetlands in the context of climate change. *GLPNEWS* 12:53–56.
Jodha NS. 2000. Globalization and fragile mountain environments: Policy challenges and choices. *Mountain Research and Development* 20:296–299.
Laing JH, Crouch GI. 2009. Myth, adventure and fantasy at the frontier: Metaphors and imagery behind an extraordinary travel experience. *International Journal of Tourism Research* 11:127–141.
Laker J, Baldo J, Arzamendia Y, Yacobaccio HD. 2006. La vicuña en los Andes. *In:* Vilá B, editor. *Investigación, conservación y manejo de vicuña*s. Buenos Aires, Argentina: Proyecto MACS-Argentina, pp 37–50.
Lencina R, Peralta E, Sosa-Gómez J. 2018. La actividad minera en la Puna argentina: caracterización sociohistórica, presente y perspectivas. *In:* Grau HR, Babot J, Izquierdo A, Grau A, editors. *La Puna Argentina: naturaleza y cultura*. Serie Conservación de la Naturaleza 24. Tucumán, Argentina: Fundacíon Miguel Lillo, pp 406–421.
Lichtenstein G, Vilá B. 2003. Vicuña use by Andean communities: An overview. *Mountain Research and Development* 23:198–202.
Liu J, Hull V, Batistella M, DeFries R, Dietz T, Fu F, Hertel TW, Izaurralde RC, Lambin EF, Li S, Martinelli LA, McConnell JW, Moran EF, Naylor R, Ouyang Z, et al. 2013. Framing sustainability in a telecoupled world. *Ecology and Society* 18(2):26.
Longhi F, Krapovickas J. 2018. Población y pobreza en la Puna Argentina en los inicios del siglo XXI. *In:* Grau HR, Babot J, Izquierdo A, Grau A, editors. *La Puna Argentina: naturaleza y cultura*. Serie Conservación de la Naturaleza 24. Tucumán, Argentina: Fundacíon Miguel Lillo, pp 364–379.
López G, Restifo F. 2012. Middle Holocene intensification and domestication of camelids in north Argentina, as tracked by zooarchaeology and lithics. *Antiquity* 86:1041–1054.
Margulis ME, McKeon N, Borras SM Jt. 2013. Land grabbing and global governance: Critical perspectives. *Globalizations* 10:1–23.
Martínez JG. 2018. Sociedades prehispánicas de la Puna Argentina: desde el poblamiento temprano hasta los inicios de la producción pastoril y agrícola. *In:* Grau HR, Babot J, Izquierdo A, Grau A, editors. *La Puna Argentina: naturaleza y cultura*. Serie Conservación de la Naturaleza 24. Tucumán, Argentina: Fundacíon Miguel Lillo, pp 273–294.
Mather AS, Needle CL. 1998. The forest transition: A theoretical basis. *Area* 30:117–124.
Morales M, Carilla J, Grau HR, Villalba R. 2015. Multi-century lake area changes in the Andean high-elevation ecosystems of the southern Altiplano. *Climate of the Past* 11:1821–1855.
Moori Koenig V, Bianco C. 2003. *Industria minera*. Buenos Aires, Argentina: Comisión Económica para América Latina y el Caribe (CEPAL) y Secretaría de Política Económica, Ministerio de Economía de la Nación. http://www.funcex.org.br/material/redemercosul_bibliografia/biblioteca/ESTUDOS_ARGENTINA/ARG_97.pdf; accessed on 18 July 2017.
MRECIC [Ministerio de Relaciones Exteriores, Comercio Internacional y Culto]. 2010. *Informe Sectorial: Sector Minería*. Buenos Aires, Argentina: Subsecretaría de Comercio Internacional, MRECIC.
MT [Ministerio de Turismo]. 2015. *Anuario Estadístico de Turismo*. Presidencia de la Nación Argentina; Buenos Aires, Argentina.
Myers N, Mittermeier RA, Mittermeier CG, da Fonseca GAB, Kent J. 2000. Biodiversity hotspots for conservation priorities. *Nature* 403:835–858.
Nature Editorial. 2018. The best research is produced when researchers and communities work together. https://www.nature.com/articles/d41586-018-06855-7; accessed on 2 November 2018
Olivera DE. 2018. Arqueología del formativo: los inicios de la agricultura y la ganadería. *In:* Grau HR, Babot J, Izquierdo A, Grau A, editors. *La Puna Argentina: naturaleza y cultura*. Serie Conservación de la Naturaleza 24. Tucumán, Argentina: Fundacíon Miguel Lillo, pp 297–318.
Quiroga Mendiola M, Cladera J. 2018. Ganadería en la Puna Argentina. *In:* Grau HR, Babot J, Izquierdo A, Grau A, editors. *La Puna Argentina: naturaleza y cultura*. Serie Conservación de la Naturaleza 24. Tucumán, Argentina: Fundacíon Miguel Lillo, pp 387–402.
Rudel TK, Coomes OT, Moran E, Achard F, Angelsen A, Xu J, Lambin E. 2005. Forest transitions: Towards a global understanding of land use change. *Global Environmental Change* 15:23–31.
Salvador FM, Alonso MA, Ríos S. 2005. Avances sobre los pastos de turberas en los Andes centrales peruanos (Lauricocha, Huánuco). *Producciones agroganaderas: gestión eficiente y conservación del medio natural* 84:947–953.
SAyDSN [Secretaria de Ambiente y Desarrollo Sustentable de la Nación]. 2008. *Manejo de Fauna Silvestre en la Argentina: Primer Censo Nacional de Camélidos Silvestres al Norte del Río Colorado*. Buenos Aires, Argentina: Secretaría de Ambiente y Desarrollo Sustentable de la Nación.
Scrosati B, Garche J. 2010. Lithium batteries: Status, prospects and future. *Journal of Power Sources* 195:2419–2430.
Seto KC, Fragkias M, Güneralp B, Reilly MK. 2011. A meta-analysis of global urban land expansion. *PloS ONE* 6:e23777.
Sikor T, Stahl J, editors. 2012. *Forests and People: Property, Governance, and Human Right*s. London, United Kingdom: Routledge.
Troncoso CA. 2018. Valorización turística: tendencias recientes. *In:* Grau HR, Babot J, Izquierdo A, Grau A, editors. *La Puna Argentina: naturaleza y cultura*. Serie Conservación de la Naturaleza 24. Tucumán, Argentina: Fundacíon Miguel Lillo, pp 426–440.
Troncoso CA, Bertoncello R. 2014. Turismo extremo en Argentina. Nuevas formas de valorización del patrimonio natural y cultural. VI Congreso Iberoamericano de Estudios Territoriales y Ambientales. San Pablo. Brazil.
Tolón Estarelles G. 2011. *Situación actual de la minería en la Argentina*. Serie Aportes 13. Buenos Aires, Argentina: Fundación Friedrich Ebert.
UN [United Nations]. 2015. *Transforming Our World: The 2030 Agenda for Sustainable Development*. A/RES/70/1. https://sustainabledevelopment.un.org/post2015/transformingourworld/publication; accessed on 28 October 2018.
UNFPA [United Nations Population Fund]. 2007. State of world population 2007: Unleashing the potential of urban growth. New York, NY: UNFPA. http://www.unfpa.org/swp/2007/english/introduction.html; accessed on 11 July 2017.
UNFPA [United Nations Population Fund]. 2016. *Urbanization*. https://www.unfpa.org/urbanization; accessed on 28 October 2018.
UNWTO [United Nations World Tourism Organization]. 2016. *Tourism Highlights: 2016 Edition*. Madrid, Spain: UNWTO. http://marketintelligence.unwto.org/publication/unwto-tourism-highlights-2016-edition; accessed on 18 October 2018.
Urrutia R, Vuille M. 2009. Climate change projections for the tropical Andes using a regional climate model: Temperature and precipitation simulations for the end of the 21st century. *Journal of Geophysical Resources* 114:D02108.
USGS [United States Geological Survey]. 2017. Argentina Lithium Map: Data Sources and Explanatory Notes. Reston, VA: USGS. Available at: https://www.minem.gob.ar/servicios/archivos/7674/AS_15115524941.pdf; accessed on 28 October 2018.
Verburg PH, Crossman N, Ellis EC, Heinimann A, Hostert P, Mertz O, Nagendra H, Sikor T, Erb K, Golubiewski N, Grau HR, Grove M, Konaté S, Meyfroidt P, Parker DC, et al. 2015. Land system science and sustainable development of the earth system: A global land project perspective. *Anthropocene* 12:29–41.
Vilá B, Marcoppido G, Lamas H. 2018. Camélidos. *In:* Grau HR, Babot J, Izquierdo A, Grau A, editors. *La Puna Argentina: naturaleza y cultura*. Serie Conservación de la Naturaleza 24. Tucumán, Argentina: Fundacíon Miguel Lillo, pp 443–462.
Vuille M, Francou B, Wagnon P, Juen I, Kaser G, Mark BG, Bradley RS. 2008. Climate change and tropical Andean glaciers: Past, present and future. *Earth Sciences Review* 89:79–96.
Wanger TC. 2011. The lithium future: Resources, recycling, and the environment. *Conservation Letters* 4:202–206.
Wikiloc. No date. Wikiloc: Trails of the World. https://www.wikiloc.com/; accessed on 30 May 2017.

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