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Change and Continuity in a Pastoralist Community in the High Peruvian Andes

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Abstract Pastoralists of the high Andes Mountains raise mixed herds of camelids and sheep. This study evaluates the land use of herdsmen who are confronted by both socioeconomic and climate changes in Huancavelica, central Peru. Land use/ land cover change (LULCC) was measured through satellite imagery, and pastoralists' capacity to adapt to socio-environmental changes was evaluated through interviews and archival research. The most dynamic LULCCs between 1990 and 2000 were large increases in wetlands and a loss of permanent ice. We conclude that the people's responses to these changes will depend on availability of institutions to manage pastures, other household resources, and perceptions of these biophysical changes. Socioenvironmental change is not new in the study area, but current shifts will likely force this community to alter its rules of access to pastures, its economic rationales in regards to commodities produced, and the degree of dependence on seasonal wage labor. In this scenario, households with a greater amount of livestock will fare better in terms of assets and capital that will allow them to benefit from the increasing presence of a market economy in a landscape undergoing climate change.

Keywords Andes · Climate change · Land use/land cover change (LULCC) · pastoralism

Introduction

Land use/land cover change (LULCC) is an important aspect of global change that can be studied with approaches linking social science and remote sensing (Bradley and Millington 2006; Fox *et al*. 2003; Jiang 2003; Liverman *et al*. 1998; Rindfuss *et al*. 2003; Rindfuss and Stern 1998; Rindfuss *et al*. 2004). Though there are recent studies conducted in the Andes that use remote sensing to understand vegetation dynamics (Bradley and Millington 2006; Bustamante Becerra 2006; Millington and Jehangir 2000) and pastoralist societies (Alzérreca *et al*. 2006; Molinillo and Monasterio 1997; 2006), there are fewer studies examining LULCC of mountain pastoralism. Methodological problems (Fox *et al*. 2003) related to the topography of mountainous landscapes, to the mobility of the pastoralists (i.e., transhumance or nomadism; BurnSilver *et al*. 2003), or to the marginal importance of mountains within urban-oriented policies (Fox *et al*. 2003; Sarmiento 2000) may partially explain the lack of research.

In order to evaluate the consequences of landscape change for Andean pastoralists it is important to examine (1) extent, nature, and rate of environmental (biophysical) change, (2) concomitant socioeconomic and demographic changes, and (3) social capital available for adaptation or adjustments. Extensive pastoral land use systems cover approximately 25% of the world's land surface, producing 10% of meat consumed by humans and supporting 20 million pastoral households (FAO 2001). In Peru, there are 170,000 households of pastoralists (Sociedad Peruana de Criadores de Alpacas y Llamas—SPAR 2005) living above 4,000 m elevation in communities with little or no agriculture. Instead, they utilize communal pasturelands for grazing mixed herds of alpaca (*Lama pacos*), llama (*Lama glama*) and sheep (*Ovis aries*). They also barter animal products for other necessities such as potatoes, salt, and maize. Their grazing pastures and wetlands are dependent primarily on groundwater flows. The majority of pastoralist studies have focused on Africa and Asia

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(Azarya 1999; Bennett 1988; Blench 1999; Fabietti and Salzman 1996; Gebre 2001; Johnson 1969; 1991; McCabe 1990; McPeak 2005; Mishra *et al*. 2003), and some have considered pastoralism to be an activity carried out exclusively in Europe, Asia or Africa (Markakis 2004; Salzman 2004). In the Andes it was neglected by social scientists until the early 1960s (Flores Ochoa 1968, 1977b; Markakis 2004).

Typically, pastoralist productive systems have been defined either as a mode of production providing subsistence products (de Vries *et al*. 2006; Markakis 2004) or as an adaptive process to natural conditions (Browman 1974; Salzman 2004). As such, pastoralism is a land use system that either occupies extensive lands to maintain herds year round (through a system of free-range grazing) or that moves periodically within or between specific grazing territories according to economic and ecological needs (Browman 1974; Khazanov 1984, 1998, 2001; Orlove 1982). Interestingly, Andean pastoralism encompasses elements of both definitions; it provides subsistence to pastoralists (Flores Ochoa 1968), and in general it appears to be a successful adaptation process to mountain conditions (Flores Ochoa 1977b). The adaptive process includes domestication of camelids (Baied and Wheeler 1993; Gade 1977; Wheeler 1988) and plants (especially potatoes [*Solanum tuberosum*] and *quinua* [*Chenopodium quinoa*]; Custred 1977), and the biological adaptations of humans (Baker 1976; Thomas 1977; Thomas 1997; Thomas and Winterhalder 1976; Velásquez 1976) and vegetation (Wilcox *et al*. 1987). Though pastoralists' subsistence is achieved through livestock husbandry, barter and trade, and seasonal migration, social relationships and cultural constraints seem to prevent wealth accumulation (in this case, herd size) that would lead to social differentiation and overexploitation of limited resources (Browman 1974; Orlove 1982). Further, livestock serve as a mobile "secure food base" (Browman 1974:189) and a producer of exchangeable goods, key aspects of pastoralist adaptation to harsh and changing climatic conditions. Andean pastoralism transforms (and is transformed by) its environment in a dynamic interplay that includes species domestication, pasture management, and climate change.

The peasant (or c*ampesino*) community is one of the most examined concepts in Andean anthropology (Alberti and Mayer 1974; Fonseca and Mayer 1988; Fuenzalida 1969, 1982; Golte 1992; Mayer 2002; Mossbrucker 1990; Sendón 2001), particularly as some scholars (i.e., the *indigenistas* such as Castro Pozo 1924; 1973, and Mariátegui 1981) incorrectly equated current institutions with those of the Inca state (Adams 1962; Jacobsen 1993). Under this conceptualization, household agency and any inter- or intra-communal differences vanish because every decision appears to occur at a level higher than the household, and differences within and among communities in the high Andes are harder to explain. By examining both household and community-level perspectives in this study, we can better explain the dynamics of a community that participates in market economic relationships, transforms its land tenure system and cultural values, and experiences increased tension between community and household needs. Since Adams (1962), the concept of *campesino* community has been understood as a group of households where individual households control different resources in diverse ecological zones and where production occurs through a dynamic set of social relationships that vary according to the ultimate destination of the product (Fonseca and Mayer 1988; Golte 1980; Golte and de la Cadena 1983; Murra 1975). Acknowledging that social relationships are dynamic emphasizes specific issues within each community and recognizes that relationships may change over time or even elapse in order to attend to the changing needs of a group or an individual household (Adams 1962; Mossbrucker 1990). Alber (1999) defined "community" as an institution under transformation rather than as a fixed principle of social organization, thereby avoiding a definition based upon social functions that can change. The relevance of this perspective is in the understanding of community as an open system in dynamic adaptation to environmental and demographic change (Zimmerer 1994). Since the 1990s the concept of community often has focused on land tenure and the resources under its control (Laos 2004; Urrutia 2004), the legal status of the community (Burneo de la Rocha 2007; Castillo Castañeda 2007), and conflicts between (and within) communities and with different actors (e.g., government or private companies, Bebbington 2007) on diverse scales (Alzadora and Gironda 2004; Burneo and Ilizarbe 2004; Laos 2004).

The methodology of our study combines three perspectives to generate an understanding of the responses of pastoralist societies in the Peruvian highlands to outside drivers of change. The first perspective links social research with GIScience (geographic information science) at household, community, and regional levels (Rindfuss *et al*. 2003; Walsh *et al*. 2004). The second addresses the local adaptations of pastoralists to climatic variations as well as to social transformations through history (Walker and Peters 2007). The final perspective involves linking scientific knowledge of the social dynamics of land use/land cover change (Lambin *et al*. 2001; Meyer and Turner II 1994) with development projects carried out in the area. Specifically, this evaluation involves analyses of historical archives, remotely sensed data, and field studies of current land use practices in a peasant community of pastoralists in the Peruvian highlands. Our overall goal is to elucidate how high elevation pastoralist systems have responded to disturbances from the complex drivers of change (Lambin *et al*. 2001) external to the pastoral society itself (Dyson-Hudson and Dyson-Hudson 1980; Ginat and Khazanov 1998; Khazanov 1984, 1998, 2001). After describing in detail the study area and the qualitative and quantitative methods used, we present the institutions associated with access to pasturelands and how land use connects to household decision making (Ostrom 1990). We then use remote sensing methods to quantify landscape change occurring in the last decades, especially in regards to land cover change that has implications for pastoralism. The last section provides perspectives and recommendations for further evaluations of LULCC in highland pastoralist systems.

Study Area

The village of Pilpichaca is located at an elevation of 4,000 m along a 1.3 km strip of land beside the road that connects the city of Huancavelica to the *Vía de Los Libertadores* highway. Pilpichaca (13°19′34″ S, 74°59′51″ W) is a peasant (*campesino*) community in the province of Huaytara, department of Huancavelica, in the south-central Peruvian highlands. Its population is 500 inhabitants and the extent of its territory is 35,903 ha. This section of the Peruvian highlands is part of the Central Andean puna, or wet puna (Custred 1977; Troll 1968; Wilcox *et al*. 1987), with tropical dry alpine vegetation, and elevations ranging from 3800 to 5200 m. Most of the lands are covered by puna grassland (Troll 1968; Wilcox *et al*. 1987) or native pastures (*Calamagrostis rigecens*, *Festuca dolichophylla*, *Stipa ichu*; Custred 1977; Sotomayor 1986; Tapia Núñez and Flores Ochoa 1984; Wilcox *et al*. 1987) and wetlands often dominated by mosaics of cushion plants (Miranda 1995; Tapia Núñez and Flores Ochoa 1984). The topography is of a highland plateau with some peaks, some of which were identified by local people as sites of ice caps that do not exist anymore. The landscape includes lakes, Andean forest dominated by "queñua" (*Polylepis tarapacana*), stands of the large terrestrial bromeliad *Puya raimondii*, and the Pampas and Carhuancho Rivers. The dry season occurs in summer, whereas the rainy season occurs in winter, with rains starting around late November and finishing approximately in March.

The land tenure system is based upon communal ownership of the land. Each active *comunero*, i.e., any male older than 18 who is a head of household, uses one or two pastures for grazing, depending on availability. The main economic activity is husbandry of alpaca, llama, and sheep. Commodities needed by households are obtained by bartering livestock products such as wool, or by purchasing with money from the sale of livestock.

The first evidence of human occupation dates to the Intermediate horizon (800 to 1200 A.D.), when the Wari state imposed its rule over the study area. In the Late Intermediate (1200 to 1440 A.D.), the population was independent but constant wars, competing kingdoms, local lords, and confederations led by a lack of stability encouraged mobile pastoralism in high mountain pastures located away from areas of social unrest. During the Late Horizon (1440 to 1532 A.D.) camelid raising intensified as land holdings spread, and wool craftwork developed (Directiva Comunal Pilpichaca 2005) and more high pastures became used.

The Spaniards arrived in the Pilpichaca area around 1620 seeking gold and silver. They founded the original village next to the Pampas River and constructed a mill and water channels to process ore. Soon afterwards, Pilpichaca changed from being one of the centers of regional mining to serving as a collection point for the silver and gold bars that were then sent on to Spain (Directiva Comunal Pilpichaca 2005; Maldonado Auris 2004). Although the land was expropriated from the local population (Castellares 1922; Zorrilla 1975), these same sources together with a legal claim from 1686 indicate that Pilpichaca lands belonged to and were transferred as inheritance to local residents, were kept out of the ownership of civil Spanish colonists, and that there was a degree of social stratification among local residents, some of whom were landowners whereas others had less land, livestock, and generally less wealth and power.

During the second half of the twentieth century, local residents of Pilpichaca actively defended their lands from attempts of local landlords to expand their holdings, and since 2000, they have had to defend their lands from exploitation by mining companies. At the same time, intergenerational tensions have arisen as a result of changing ideas about the primacy of either communal or individual land entitlement. Though the sources of tensions and conflicts over access to and control of land and water have changed with time, they remain one of the most important unresolved issues in Pilpichaca.

Methods

A combination of qualitative and quantitative methodology was used that involved gathering primary and secondary information, combining classical social science methodology with GIScience methods and tools, and analyzing archival and privately held documents. The local data collection was carried out in June and July 2005. Research was conducted in the archives of the community of Pilpichaca and other local institutions, such as municipal offices, the Ministry of Agriculture, the Regional Government, and NGOs (nongovernmental organizations).

First-hand information was obtained through semi-structured interviews, focus groups, participant observation, and the collection of 70 geographical positional coordinates (using a GPS unit) from areas of different land use and covers, including roads, a plaza, and bridges. The coordinates were used as reference or ground control points and were selected because they were features of the landscape that would be identifiable in satellite imagery. Twenty semi-structured interviews were carried out by the first author, including two with professionals working in the area (one obstetrician and one anthropologist), one with the mayor, one with a wool merchant, and sixteen with herdsmen who included people of different ages, including four community officials, a teacher, an elder considered the "community's memory," one herdswoman, and other community inhabitants. Participant observation was carried out during daily household activities, a communal assembly, a district meeting, communal work sessions, and religious celebrations. During the fieldwork the first author also had conversations with different professionals and technicians of the nongovernmental organization DESCO (Center of Studies and Development Promotion), which is active in development projects in the area. Some data collected were verified through informal conversations with inhabitants while observing events of pastoralists' daily life. The focus groups (Bloor *et al*. 2001; Edmunds 1999; Kitzinger 1994 cited by Bloor *et al*. 2001:78; Morgan 1988) were designed to be informal. Two were conducted outdoors and took advantage of already planned activities, the first during a communal work session (nine men), and the second after a neighbors' meeting (eight people, including one woman). A third was done in the Huancavelica offices of DESCO.

Two satellite images, one from Landsat Thematic Mapper 5 (TM 5) taken 25 May 1990 and another Landsat 7 Enhanced Thematic Mapper (ETM+) from 29 June 2000, were used to assess LULC of Pilpichaca and surrounding territories (path/row 06/069). Maps of the study area at 1:25,000 scale provided community boundaries. The satellite images were coregistered using a master–slave process with the ETM as the master and geometrically corrected using a second order polynomial geometric model, with a relatively low Root Mean Square Error (RMSE) of 22.3 m. The image was resampled through the nearest neighbor method. In order to analyze local LULCC, a rectangular area of interest (86,550 m by 102,150 m, area of 884,108.25 ha) was created around Pilpichaca. There was a data error in the original 1990 image that involves stripes running from the eastern edge almost to the western edge. In order to avoid distorted data, masks were created excluding these areas from the analysis, a total of 174.81 km^2.

Image preprocessing, classification, change detection, and GIS analysis were performed using ERDAS IMAGINE 8.7 and ESRI's Arc Gis 9.1. The imagery was classified using a hybrid unsupervised/supervised classification method (Messina *et al*. 2000; Walsh *et al*. 2004). First, the Iterative Self-Organizing Data Analysis Technique (ISODATA) clustering algorithm was performed giving an unsupervised classification scheme of 255 classes generated with a maximum number of iterations of 20 and a convergence threshold of 0.980. Second, the signature file was edited with a transformed divergence table to remove signature pairs with low spectral separability in order to maximize the variance between signatures (criterion used was a value of 1950). The edited training signatures were used for supervised classification (Jensen 2005; Kintz *et al*. 2006). The spectral classes obtained were attributed to LULC classes (Table 1) based on knowledge of the study area and following Anderson *et al*. (1976) and Polk *et al*. (2005). The "healthy green vegetation", so named because of its reflectance in the imagery, was interpreted to be wetland (locally called *bofedal*). It has a higher biomass than the tropical alpine vegetation (locally known as "puna"), which is a short and open herbaceous vegetation above 3,800 m elevation in areas with plant cover. For the "healthy green vegetation", "puna," and "barren soil" classes, a second level of classification was utilized based upon the levels of dryness detectable in the imagery as registered by the electromagnetic reflectance of band 5. In order to discriminate water/shadow and snow/ice classes, a cluster busting procedure was carried out for each image. The process was successful in the case of water/shadow, but unsuccessful in separating snow from ice because of Landsat limitations.

An accuracy assessment was performed on the 2000 image using 360 stratified random points on the panchromatic image with ≥10 points per class (Table 1). The overall classification accuracy is 34.72%; the overall Kappa statistic is 0.1798. The sources of error explaining this relatively low level of accuracy are (1) the frequency of different patches of LULC classes that may be so small that they are overwhelmed by the matrix, and (2) the lack of some detail in the panchromatic image that limited identification of the second level of LULC classes or the

Table 1 Classification scheme with categories and abbreviations

Level I	Level II (dryness level)
Water body	
Snow/ice	
Shadow/water	
Cloud	
Healthy green vegetation	High (HGVHi)
	Low (HGVLo)
Puna	High (PunaHi)
	Medium (PunaMe)
	Low (PunaLo)
Barren soil	Light vegetation high dryness (BaLvHi)
	No vegetation high dryness (BaNv)

diverse levels of dryness per class. The highest producers accuracy were for HGVHi (66.7%) and Puna Medium Dryness (47.1%), the lowest were for PunaHi (0%) and BaLvHi (1.8%). The highest user's accuracy were for Water Body (38.5%) and HGVHi (32%); the lowest were for PunaHi (0%) and HGVHi (8.7%). In order to overcome the limitations of the panchromatic image, for some purposes classes were collapsed, which increased overall accuracy to 57.38%. The highest resulting producer's accuracies in this manner were for HGV (68%) and Puna (67.16%); the lowest producer's accuracy was for Barren Soil (52.3%). The highest user's accuracy was for Barren (93.28%), with the lowest for Puna (31.25%).

Results

Land Tenure and Land Use

Pilpichaca's land tenure system is based upon both communal property and household usufructary rights. Generally, each active *comunero* has access to one or two pasturelands, although this access is dependent on the approval of the entire community. New households must request access to pasturelands from the community because most of the available lands in community territory are already allocated. The community evaluates claims for pastureland one or two times per year during General Assembly. The procedure (Fig. 1) is as follows: (1) the head of a new household presents a claim in the Assembly and indicates the location of the pastureland requested; (2) community officials visit the area mentioned, talk to current land users about the possibility of dividing their pasture to share with a new family; and (3) after gathering all the information, community officials reach a final decision to either accept, reject, or give alternative pastureland to the new household. If the household's request is rejected, it can be resubmitted the next time the community takes requests (generally one or two years later). Newly formed households whose claims were rejected remain at their parent's house (generally the husband's parents). Thus, new households have access to pasturelands either indirectly through their parent's lands, or directly through the lands the community gives them. Consequently internal pastureland borders fluctuate through time, while community borders remain the same.

As in many rural Andean communities (Mayer 2002; Orlove and Custred 1980), households are the main unit of production and consumption in Pilpichaca. From the data collected in situ, the mean number of livestock per species per household was 119 alpacas (standard deviation=73), 42 llamas (SD=34), and 117 sheep (SD=92). Some households did not have any llama or sheep, but every household had alpacas. The least number of alpacas per household was 29, and the greatest was 292. The number of sections of pasture that any household has access to is related to explicit and implicit conditions. The most obvious are conditions such as pastureland availability, size of the household's flock, and the sizes of neighbors' flocks. Less obvious but equally important are conditions that affect

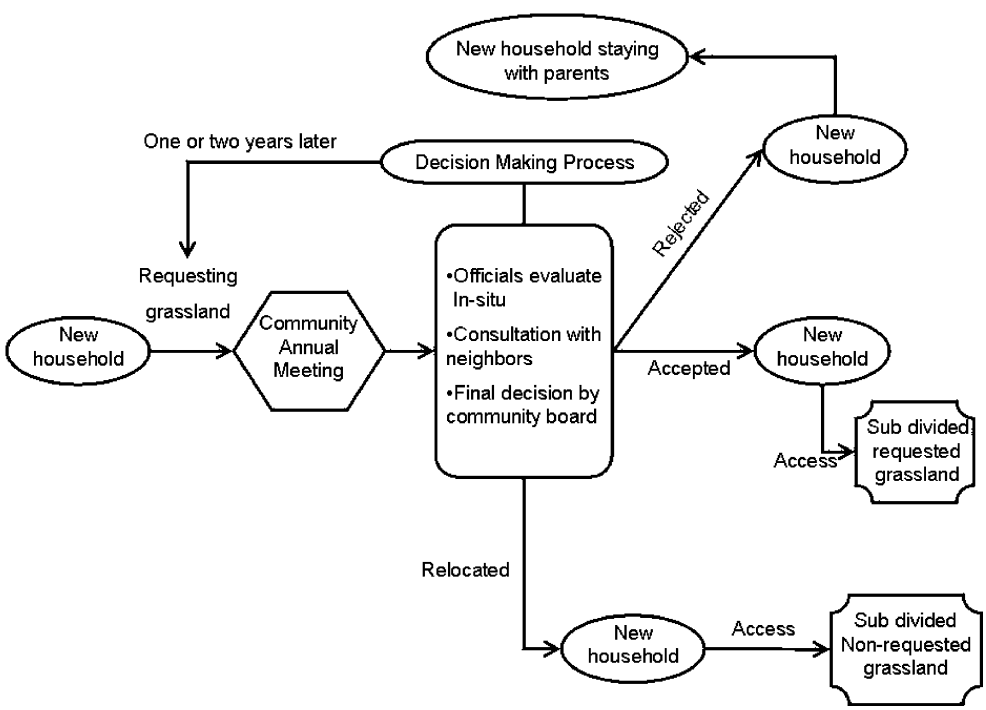

Fig. 1 Rules of access to Pasturelands

community decision making, including kinship relations with community officials or potential neighbors, fulfillment of communal duties, and observance of social norms and rules. Though the formal communal decision-making procedure shown in Fig. 1 is always followed, decisions are influenced by the particular conditions and traits of the family requesting pastureland, that is whether they obey communal rules, are a good neighbor, and comply with requested labor exchange.

Livestock husbandry implies mobility patterns that take into account the need to feed both the family and the flock, and on occasion the need for goods from outside the community. Thus, pastoralists travel to different areas depending on what they want to obtain in exchange for their products. These journeys usually require travel of more than 100 km and are made with llamas instead of alpacas, because there is a breed of llama specially developed to be a beast of burden, well-suited to long-distance travel by being more resilient, by feeding on a wider range of vegetation, and by having very short hair. Thus llamas can carry cargo to the destination and once there they can be slaughtered for food or used as a commodity for trade.[1]

When a family controls only one pasture the flock is moved to a different feeding site every two to four days, depending on the quality (distance to water, type of forage) and size of the site. This is a case of limited transhumance. When a household has access to two pastures, one is used in rainy season and the other in the dry season. The wet-season pasture is located at a lower elevation than the dry-season pastureland because there are more wetlands in the lowlands during this season (Browman 1983; Bryant and Farfan 1984; Custred 1977; Flores Ochoa 1977a; McCorkle 1987). The higher elevation sites are also more risky for young animals (usually born in December and January) as the young animals can drown in lakes or channels, get stuck in boggy sites, or even freeze at low temperatures (Browman 1987; Orlove 1982). In the dry season the flock is shifted to the higher pasture for summer wetlands or pastures irrigated by springs (Browman 1983, 1987; Orlove 1982; Palacios Rios 1977).

Pastureland borders are imprecise although there are some landmarks such as paths, lakes, and watersheds. Each species grazes separately: alpacas prefer flat-lying wetland vegetation, whereas llamas prefer well-drained native grasslands on slopes or hills. Herdsmen stated that sheep and alpaca must be grazed in different locations, otherwise "the alpaca get bored" and move to a different place or simply refuse to eat. Herdsmen also said that conflict between sheep and alpaca occurs because the sheep harass the alpaca, and uproot the pasture, making it unattractive to alpaca and more prone to soil erosion.

Every year livestock owners must pay a form of rent to the community for their households' right to use community pastures (*derecho de herbaje*): US $0.05/alpaca/year, and US $0.08 sheep/year. Some families hire a herder, who is paid with a combination of wages (between US $30.00 and $35.00 per month), food (potatoes, maize, barley, rice, noodles, and oil), and other supplies (a pair of shoes, candles, and kerosene). The herders are members of the community (a few are from neighboring communities) who either do not have livestock or have only a few animals that are grazed with the household herd. Although only the male herder is formally hired, he and his wife both do the work. A gendered division of labor exists such that the man is in charge of the alpacas and llamas, while the wife is responsible for the sheep. The explanations given for this division are that a male herder is needed because alpacas are bigger and more difficult to manage than sheep, and because women have domestic duties that require them to temporarily leave their herd under the care of their children (making sheep a more obvious choice than the larger alpaca). Additionally, because alpacas are considered the most valuable assets of the household they are under the care of the strongest and fastest member of the couple. If the male herder is absent, usually his eldest son is in charge of the alpacas.

The vast majority (~90%) of the wool produced is sold in the village of Pilpichaca, where traders buy and store it until they gather enough to fill a truck. The typical wool producer cannot afford transportation costs and has no direct relationship with the wool industry, but rather depends on itinerant traders to get wool to market. The wool is transported to Arequipa in southern Peru where it is transformed first into yarn and then into fabric that is ultimately delivered to transnational textile industries, as has happened since the nineteenth century (Burga and Reátegui 1981; Flores Ochoa 1977a; Postigo 2000). Traders are said to make the trip in three stages, changing trucks because nobody does the whole trip from Pilpichaca to Arequipa at once, paying in total US $5.00 per 45.4–68.1 kg to the truckers. The money from the sale of wool is used to buy staples such as sugar, rice, and kerosene, which are then either consumed by the pastoralist or sold in the community. Men and women also use the wool to make socks, ponchos, and hats that are sold in local or regional markets, bartered for agricultural produce, or used by household members. Some of the interviewees indicated that they barter one alpaca's wool for four *arroba* (approximately 11.3 kg per *arroba*) of maize in the city.

[1] In order to provide some reference for exchange value at the time of this fieldwork, 11.3 kg of maize approximately equals US $1.14. A general estimate is that five sheep are equivalent to potatoes for a year for a family of average size.

Table 2 Change in the study area in hectares (All classes)

1990/2000	Water Body	HGVLo	HGVHi	PunaLo	PunaMe	PunaHi	BaLvHi	BaNv	Snow/Ice
Water body	9,213.48	837.09	76.14	362.25	71.82	7.47	9.63	3,138.12	46.17
HGVLo	84.87	2,693.61	1,113.3	799.56	294.66	31.23	9.09	408.24	0.27
HGVHi	10.53	1,777.32	10,062	865.71	3,825	565.38	64.35	441.63	0.27
PunaLo	575.73	17,841.42	9,933.57	41,816.34	13,106.61	1,030.23	1,225.35	72,653.4	28.71
PunaMe	222.84	5,068.62	23,074.83	63,848.7	121,267.4	10,950.12	3,443.04	73,050.21	3.96
PunaHi	5.67	40.59	498.42	491.04	13,031.82	8,446.14	564.48	832.68	0.09
BaLvHi	16.11	8.82	60.75	49.5	375.3	1,241.46	8,229.96	937.8	17.01
BaNv	2,610.63	14,971.5	3,578.31	20,352.33	44,528.49	20,958.3	26,397.81	149,945.6	134.19
Snow/ice	405.81	2,678.49	3,960.27	4,379.31	4,235.31	1,375.2	5,346	30,358.53	2,606.76

Abbreviations are as in Table 1.

Another commodity produced is meat. Alpaca and sheep are slaughtered either at herdsmen's houses or at Pilpichaca's slaughterhouse. Use of the slaughterhouse requires that the herdsmen bring their animals alive to the facility, and then pay for their slaughter at US $0.86 per alpaca. The herdsmen either sell the meat immediately to traders or keep it for barter, for sale in a local market, or for self-consumption.

Activities of the NGO in the area include initiatives for modernizing livestock husbandry through alpaca breeding, cultivation of pastures, strengthening social organization, and diversifying the economic uses of alpacas, e.g. skin and meat production instead of only wool. Not all the community members participate in the projects or receive improved alpaca breeds; only those who are selected by the community, who fulfill conditions related to amount and quality of livestock, and who commit to comply with the requirements of the project are invited to participate. Planted pastures need to be enclosed and irrigated thereby excluding those lands from the commons.

Landscape Change

During 2004, two major structures were added to Pilpichaca. The first was the redesign of the main square of the village with a fountain in the center surrounded by a butterfly motif (honoring the name of the town in Quechua: "bridge of butterflies"). The second was a slaughterhouse built with funds from the municipality and from international development sources. The purpose of this facility is to provide a clean and safe slaughter service, facilitating the provision of local meat to urban markets.

Using the collapsed LULC classes (results for all the classes are shown in Table 2) at the regional level (Table 3) shows that the most dynamic classes between 1990 and 2000 were wetland (326%; Fig. 2) and snow/ice (−95%; Fig. 3). Overall 56% of the study area was stable and 44% unstable in terms of LULCC. The larger stable classes were puna and barren soil, the former located mainly in the northern and southeastern areas of the territory. Large areas of barren soil are located mainly in the southwest. Puna accounts for 56% of the total stable classes, while barren soil accounts for 38%.

For the entire study area, deglaciation had resulted in the finding that 95% of the snow/ice of 1990 melted by 2000 (Fig. 3). It is clear that once the snow and ice has melted one of the major subsequent processes is the development of barren soil (64% added to the two types of barren soil classes). In some cases, vegetation colonizes the open area perhaps taking advantage of the accumulated moisture. The glacial runoff has undoubtedly been flowing over some areas of barren soils with and without light vegetation. These barren soils once vegetated, formed puna vegetation with different levels of dryness (Table 2).

At the local level, in an area that corresponds to Pilpichaca itself, wetland increased 172% and barren soil increased 45%, whereas snow/ice diminished by 99%. Thus, the increase of wetlands in the community is consistent with enlargement of the wetlands in the whole study area (compare Tables 3 and 4; Fig. 4). The total area

Table 3 Change (to–from changes) in the study area in hectares (collapsed classes)

1990/2000	Water body	Wetland	Puna	Barren soil	Snow/ice
Water body	9,213.48	913.23	441.54	3,147.75	46.17
Wetland	95.4	15,646.23	6,381.54	923.31	0.54
Puna	804.24	56,457.45	273,988.4	151,769.2	32.76
Barren soil	2,626.74	18,619.38	87,505.38	185,511.2	151.2
Snow/ice	405.81	6,638.76	9,989.82	35,704.53	2,606.76

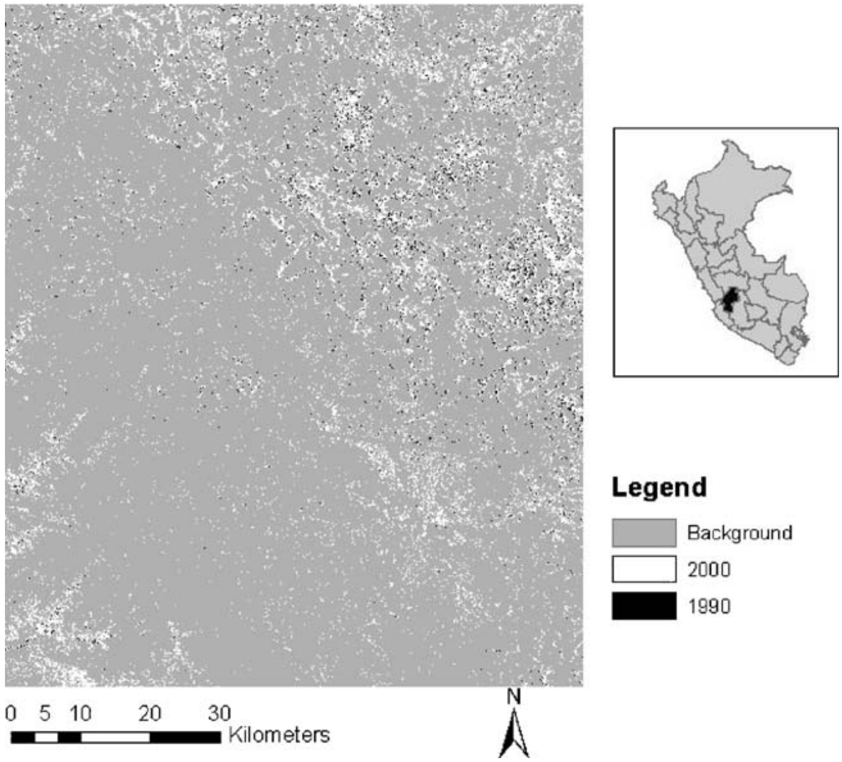

Fig. 2 Wetlands in the study area in 1990 and 2000

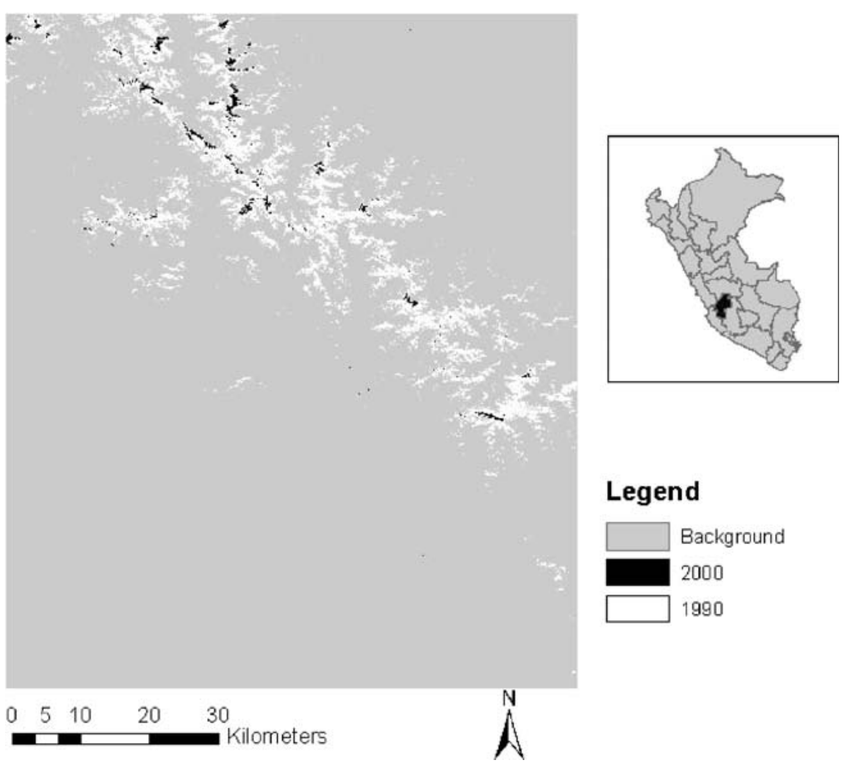

Fig. 3 Snow/ice cover in the study area in 1990 and 2000

Table 4 Percentage of change in Pilpichaca and the entire study area

Classes	Change in Pilpichaca	Change in the study area
Wetland	172.11	326.41
Puna	−24.20	−21.68
Barren soil	44.57	28.07
Snow/ice	−99.49	−94.87

of wetland in 1990 (23,047 ha) increased in ten years to 98,275 ha (Fig. 2). More detailed trajectories can be extracted from Table 2, however with the caution merited by the relatively low accuracies discussed in Methods. Some 68% of pixels classified as wetland in 1990 remained as wetland in 2000, but also 18% became puna with a medium level of dryness, and 7% changed to puna with a low level of dryness. The wetland in 2000 was formed not only from pixels that were classified as wetland in 1990, but also were derived 29% from puna with medium levels of dryness, 28% from puna with low level of dryness, and 19% from barren soil without any vegetation. Besides areas always in wetland, there were also sites (pixels) showing shifts towards puna vegetation (presumably through dessication and/or ecological succession), while large areas of barren soil in 1990 became wetland ten years later due to increased water flows in some places. The expansion of wetland is crucial as it increases the area of pasturelands preferred by alpacas. However, field observations and

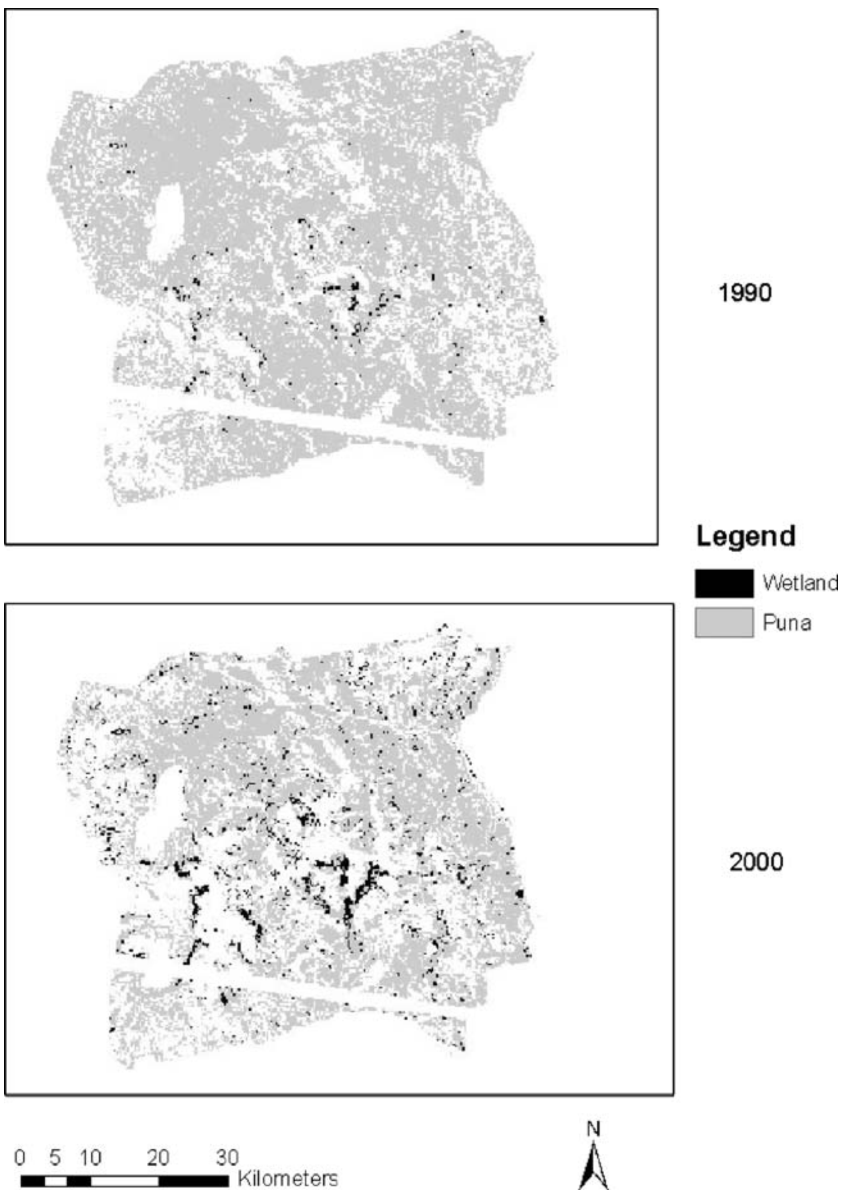

Fig. 4 Wetland and Puna in Pilpichaca in 1990 and 2000

interviews reveal that the increased wetland area is not only the result of biophysical factors. In fact, irrigation channels built by the pastoralists in the highlands provide an infrastructure to preserve and enlarge wetlands, especially important for dry season grazing. Thus, human intervention modifies and improves grazing opportunities. There are also irrigation furrows created by National Program of Watersheds and Soils Managements (PRONAMACHS) that are meant to increase the infiltration of runoff, foster grassland development, and control erosion.

Although older inhabitants acknowledged the glacier retreat, they did not seem to connect it to enlarged wetlands. Climate change indicators they and other inhabitants commented on were perceptions of hotter temperatures during the day and colder temperatures at night. They also consistently mentioned a reduced—from mid December through mid-February—but more intense rainy season. A female pastoralist mentioned that a climate change of this magnitude had never before been experienced. In the short term the impacts of the glacier retreat appear to be positive given larger wetlands, although debates about who has access to these benefits (water, pasture) may raise tensions within the community.

In conversations and at the focus group meeting, the NGO employees and managers suggested that despite the breadth of their programs, including about three dozen projects covering aspects of agricultural and community improvement, and product marketing, they would not find it easy to respond quickly to the magnitude and rate of biophysical change in the central Andean highlands. In particular, they mentioned concerns about shifts in elevations where crops can be grown, less water flow down to inhabited areas in intermontane valleys, and lack of reliable predictions of future climate change.

Discussion

This study has analyzed a peasant (*campesino*) community of pastoralists interacting with its environment over the course of three different time spans: long-term, during a recent decade, and present time. The use of historical data allows a more comprehensive understanding of Pilpichaca's uniqueness not as novel, but as part of an ancient pattern of change in the face of socio-environmental transformations. This uniqueness is related to the complex social relations among pastoralists of Pilpichaca. The community owns the lands in which the households sustain productive activities by usufructing pasturelands which may change as land is allocated to new households; therefore, households' pasturelands are dynamic areas with changing borders within the fixed borders of the community. Current community boundaries are part of a living history of the community struggling against landlords, and other communities. Though severe punishments and high fines are issued when members of other communities graze their livestock on Pilpichaca's pastures (without permission), there is more tolerance within the community when livestock graze outside of a particular household's designated lands. This double standard reveals not only the difference between members and non-members of the community, but also the fluid nature of the pastureland borders within the community and a communal or shared view of land.

The three main outputs of livestock production in the study area are wool, meat, and hides. Each one follows a path towards either the market or subsistence economies. Thus, different amounts of these products are used or transformed and sold by household members. Pastoralists incorporate herd mobility, seasonal use (and irrigation; Palacios Rios 1977) of pastureland, and vertical (Brush 1977; Murra 1975) and horizontal transhumance to diminish and share the risks of a harsh changing environment (Browman 1987).

The increasing presence of the "outside world"—factors outside the pastoralist society itself (Dyson-Hudson and Dyson-Hudson 1980; Khazanov 1984), is evident in Pilpichaca through infrastructure (e.g., paved roads) and development projects (e.g., irrigation furrows, improved alpaca breeds, and the construction of the slaughterhouse). This presence has increased the involvement of Pilpichaca in the market economy. The 1969 agrarian reform (AR) was the most important transformative social and development process in Peru during the twentieth century (Browman 1982; Caballero 1981; Diez Hurtado 2007; Eguren 2006; Kay 1982, 1988; Valderrama 1976). It aimed to end exploitation by modernizing and mechanizing production, establishing wage labor, abolishing feudal relations, bringing an end to the *haciendas*' regime, forcing pastoralists to settle in communities, and creating peasant communities which received a share of the land (Browman 1982; de Janvy 1981; Kay 1988, 2002; Orlove 1982).

Since the early 1990s, neoliberal land policies in Peru have been counteracting AR by fostering decollectivization, allowing individual land titling (Kay 2002), and focusing a new concentration of land, capital, and knowledge in agribusiness (Eguren 2006). These policies have additionally diminished governmental participation in agrarian development. Programs of agrarian extension, technical support, and credit no longer exist.

Though development projects aim to modernize livestock husbandry through rangeland management, alpaca breeding, and social capital improvement (Browman 1983; Renieri *et al*. 2006), other potential consequences are the increase of social differentiation and the exclusion of some pastures and water resources from the public domain, benefiting only a subset of the population who are involved in the projects. In December 2005 the community of Pilpichaca made an agreement to sell 2,000 kg of alpaca meat fortnightly to *Salchichería Alemana* (a business which produces sausage, ham, hot dogs, etc.). As a result, they now have to slaughter approximately 800 alpacas each year. This arrangement could potentially impact livestock husbandry patterns as they shift production from extensive to intensive forms, increase the amount of enclosed land for cultivated grasslands, and create more water diversions for irrigated pasture. Further, this potential change represents a movement away from a subsistence to market economy with an increasing presence of money instead of barter and reciprocity, an enlarged inequity between the hired herders and property-owning pastoralists, and an increase in the pressure on pasture with the likely consequence of overgrazing (Browman 1983; Lesorogol 2003).

The land tenure system and livestock mobility patterns in Pilpichaca reveal the dynamic relationship between the community and households (McPeak 2005). The struggles between new households and the community over access to and control of the pastures are longstanding tensions, as documented in this study. The social dynamics that cause household pasture borders to change while community limits remain fixed shed light on how solutions to land use occur at the communal level and are applied to individual households. These rules of use reinforce the community's identity as the true owner of land. Conflicts over control of pastures also represent the situation where households struggle for access to natural resources and where the community intervenes to ensure relatively fair distribution of scarce resources among households (Ashenafi and Leader-Williams 2005).

Households also respond to resource scarcity by enacting strategies such as livestock rotation in each pasture, small irrigation channels for pasture improvement and for maintenance of wetlands during dry season, and areas with cultivated grasslands, to maximize their effective use of limited land. This diverse and flexible productive system is an adaptive response of the Andean population (Golte and de la Cadena 1983; Mayer 2002; Young and Lipton 2006) and can be seen among dwellers from other ecosystems (Arriaga-Jordán *et al*. 2005; Baker and Hoffman 2006; Hoffmann 2004; Mishra *et al*. 2003).

In addition to social struggles for land rights, changes in the environment of Pilpichaca create physical limitations that add pressure to these ancient social tensions between community and households. Such tensions between the household and the community are often of concern in communities of agropastoralists (Desta and Coppock 2004; Fonseca and Mayer 1988; Hardin 1968; Lesorogol 2003; Mayer and de la Cadena 1989) as in Pilpichaca; however, the unfixed pasture borders of Pilpichaca provide a unique element.

The pastoralists in Pilpichaca do not have as many reciprocal relations as described by Alberti and Mayer (1974) among families who carry out the productive activities of the household. However, Pilpichaca pastoralists are very active in communal work (*minka*) that generates some collective benefit. Fulfilling these communal duties is a way of maintaining household access to resources that are collectively guaranteed. For instance, household members are more likely to help build infrastructure that benefits the community than to help a neighbor graze livestock. Thus, there is relatively little labor exchange between households, but each household makes labor contributions to the community. This latter relationship can be understood as a particular form of exchange: the household gives labor and obtains access to communal services or facilities that it would not be able to build or provide by itself.

The increased presence of the "outside world" in Pilpichaca, seen through the agreement with *Salchichería Alemana*, raises important issues that may guide future research. Is the coexistence of market and subsistence economy mutually beneficial? Does the increasing participation of pastoralists in the market economy make them more or less vulnerable? What role can the government and NGOs play to support community development and modernization under shifting biophysical regimes? What role should the government play? Given the Peruvian government's decision not to actively mediate the relationship between society and the market economy, in this case, between pastoralists and the "outside world", how is sustainable and equal development among pastoralist households to be fostered?

Biophysical Change

This study used satellite imagery from 1990 and 2000 to analyze LULCC, by establishing different LULC classes, and by elucidating trends. Future research on this topic should include different inter-annual ranges, intra-annual imagery, and climatic data in order to model ecological succession and social dynamics while depicting seasonal variations, year-to-year variations, and directional climatic trends that influence LULC in the Andean highlands.

The glacier melting process is the most conspicuous element of landscape change in the study area. The process of snow/ice retreat (Barry 2006) is consistent with Kaser (1999), who concluded that data from the 1930s and 1940s indicate that glacier retreat during those decades was primarily due to drier conditions and, to a lesser extent, increases in temperature. He also states that in the Cordillera Blanca of north-central Peru only one-third of the glacial retreat can be attributed to variations in air temperature, while the other two-thirds are due to changes related to air humidity. The 1960s and 1970s had minor increases of glacial mass that coincided with slightly higher levels of precipitation. However, patterns of accelerated glacial retreat can be seen all over the tropics since 1980s and appear to be due to increased air temperature and altered water vapor (Thompson *et al*. 2003; Vuille *et al*. 2003). Glacier retreat has been increasing runoff, which will increase the size of lakes and wetlands in downslope areas, opening up new terrain for colonizing plants and grazing of livestock, and making more water available for irrigation and wetland expansion as long as the permanent ice continues to exist. In fact, however, the ice is now gone in the study area meaning that this kind of environmental buffering is vanishing also.

All the vegetation-related LULCC described in this study for the newly exposed substrates are likely combinations of facilitation, inhibition, and tolerance processes of plant interactions during ecological succession (Glenn-Lewin and van der Maarel 1992; Walker 1999). Assigning glacial runoff the role of a trigger factor or driver that allows plant growth and ecological succession to begin is consistent with the general statement that climate controls vegetation through direct and indirect effects, and as mediated by soils (Prentice 1992) and that soil humidity and grazing pressure are crucial factors (Bustamante Becerra 2006:163). The succession in the study area could be characterized as both primary and secondary considering that there are both bare soils and soils with previous vegetation cover. Though this ecosystem change is a case of ecological succession, there are also likely to be multiple successional paths (Glenn-Lewin and van der Maarel 1992) that constitute Pilpichaca's landscape dynamism. The dynamics of the wetlands and the hypothesized successional trajectories gleaned from the satellite imagery are consistent with Molinillo and Monasterio's (2006) study, which argued that aside from areas of *puna,* the remainder of their high Andean study area showed "transitional forms between dry flatlands and wetlands" (Molinillo and Monasterio 2006:142).

To establish the multiple pathways of the vegetation dynamics, (e.g., convergence, cycles, Glenn-Lewin and van der Maarel 1992) occurring in the study area, it will be necessary to conduct a detailed analysis of species diversity, the floristic composition of the area, the dominant patterns of the vegetation community, and the mechanisms of ecological succession (Chapin *et al*. 1994). Animals also play a role in the plant succession by pollination and herbivory (Walker 1999); in this regard pollinators and herbivores (e.g., alpaca, llama and sheep for the study area) will need to be integrated into future research in order to understand ecological succession pathways. More ground truthing and additional processing approaches might yield data on the nuances of vegetation change to be found in remotely sensed images.

Climate change (both the current situation and its potential impacts) in the Andes still needs to be studied; however, none of the "outside world" agents of change—governmental agencies and NGOs in the study area have included climate change as a variable in their projects. The weather (usually rainfall), is usually only considered as a condition that may affect pasture and crop growth. The national and regional governments could design programs to monitor glacial retreat and water (both surface and groundwater) availability and to predict impacts on both the ecology of the mountains and the human groups along the Andes and the Andean piedmonts. Potential water scarcity may alter agriculture and may negatively impact urban water use as limited water will restrict drinking water and hydroelectricity. Integrated programs that combine research, development activities, and policy changes, which include local, national and international stakeholders, should be implemented. Local populations have been coping with climate and social changes for centuries using local knowledge; this local knowledge could be used to supplement technical knowledge to generate a more comprehensive understanding of problems resulting from climate change.

Land Use Decision

The amount and composition of livestock found in Pilpichaca is consistent with Bustamante Becerra (2006), who found that households with higher socioeconomic status (greater amount of livestock owned) tend to have a greater diversity of species. The majority of Pilpichaca's population consists of pastoralists who care for their own or their family's flock using a system of reciprocity without the use of salaries. However, a few hire herders who are paid with a salary. The origin of livestock accumulation varies: inheritance, acquisition through marriage, or by purchase with money saved from working (coastal agribusiness, mining, construction, selling wool). The resulting social differentiation is expressed politically. To be an authority is to affect decision-making about resources management (such as access and control of pasture and water) and the setting of internal and external community borders. For instance, herders who do not have livestock cannot request pasture. Therefore, they have limited influence over the community, barely participate in community assemblies, and rarely are made community authorities. This dynamic is also related to an individual's ability to write, read, and speak in Spanish for administrative purposes; this implies literacy is needed, although it is only achieved by members of families with better socioeconomic conditions.

Though the pastoralists have been involved to some degree in the market economy since the 19th century through the alpaca wool trade (Burga and Reátegui 1981;

Flores Ochoa 1977a; Jacobsen 1993; Orlove 1977), they still have several economic relationships beyond the market (Mayer 2002). The herdsmen reported that they prefer to barter for goods whenever possible, although they buy products that are not available through barter such as sugar, batteries, tuna, matches, etc.

The decision to sell, barter, or use a product is based upon a desire to maximize profits. In the best-case scenario, sellers hope to obtain more for the good than the cost it took to produce it. In this regard, estimating the so-called costs of production means including the pastureland used, rent of land, cost of the animals, cost of labor, cost of transportation, etc. Although most of these factors are part of household or community resources (as lands and labor), they still imply a subsistence cost for the worker, or a communal cost in terms of access to lands. However, pastoralists and most Andean peasants have a strategy of livelihood diversification so that they do not depend heavily on any one resource (Alberti and Mayer 1974; Golte 1980; Mayer and de la Cadena 1989; Murra 1975). They also avoid involvement in the market economy if their costs are higher than their potential profits (Golte and de la Cadena 1983) or in order to enjoy fixed exchange rates instead of changing prices of the market (Orlove 1982). According to the information obtained in this study, Pilpichaca's household's economic decision-making is based upon a combination of variables that include access to and control over land, labor force and means of production, and if the production is for subsistence or for market. This rationale has been described for a number of other agropastoralist Andean communities (Golte and de la Cadena 1983).

An increase in the income of some families means increased social and economic differentiation between households that own enough animals to participate in the market economy and those that do not. Though the community has social norms that regulate access to resources (e.g., pasture, water) and the distribution of profits from communal businesses, these new relationships with the market economy may increase tension between the community and the households over control of lands, water, and profits. They potentially could limit or constrain other adaptations needed for climate change, especially in the absence of a state role as regulator and mediator of the relationships between the society and the market.

The causes of LULCC in the study area originate at both global and local scales and result from both social and environmental dynamics. Past, current, and potential responses of the people to these changes have shown that the community has a body of knowledge pertaining to the environment, and flexible but strict social and political relationships that manage the use of limited natural resources and social capital. The emigration of some people to urban areas can be understood as a cultural response to the growing population and the scarcity of natural resources. Though the migrants left their community, they maintain active linkages that may play a role in the land use of Pilpichaca. For instance their remittances to the community can be invested to increase the quality of the natural resources or to hire herders. Further, migrants that return with technical qualifications can apply these skills to develop modern livestock management.

Conclusion

Evidence from Pilpichaca suggests that pastoralists in the Peruvian highlands survive with a subsistence economy based upon livestock husbandry that is carried out by household labor and limited wage labor (herders), by bartering for agrarian products, and by selling alpaca wool, meat, and skin. Pilpichaca is a dynamic group of households who have some social differentiation based upon livestock ownership and some uneven power relationships expressed through pastureland access and distribution. In this regard, rural policies that include the nuanced differences within Andean communities (in terms of spatial location, productive activities, environmental conditions, community rationality, and the will of the population) should be designed and implemented in order to establish a comprehensive development of the *campesino* communities in the Andes given likely future changes. Further, the case of Pilpichaca shows how a *campesino* community based upon longstanding social relationships such as reciprocity and communality not only responds adaptively to demographic pressure, market economic forces, and environmental changes, but also selectively uses these processes to its own benefit. Pilpichaca changes in order to remain the same.

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