Original research

ETHNOBIOLOGY AND CONSERVATION

Linking local knowledge, conservation practices and ecosystem diversity: comparing two communities in the Tunari National Park (Bolivia)

Sébastien Boillat[1, *], Sarah-Lan Mathez-Stiefel[2] and Stephan Rist[2]

[1] Department of Geography and Environment, University of Geneva, Uni Mail, 40, Bd du Pont-d'Arve, CH-1211 Genève, Switzerland
[2] Centre for Development and Environment, University of Bern, Hallerstrasse 10, CH-3012 Bern, Switzerland
* Corresponding author
✉E-mail adresses: SB (Sebastien.Boillat@unige.ch; sboillat@hotmail.com), SLM (Sarah-lan.Stiefel@cde.unibe.ch), SR (Stephan.Rist@cde.unibe.ch)

Ethnobiology and Conservation 2013, 2: 8 (22 October 2013)
ISSN 2238-4782

doi: 10.15451/ec2013-8-2.8-1-28

ethnobioconservation.com

Abstract

Combined approaches to conserve both biological and cultural diversity are seen as an alternative to classical nature conservation instruments. The objective of this study was to examine the influence of urbanization coupled with exclusive conservation measures, on land use, local knowledge and biodiversity in two Quechua speaking communities of Bolivia located within the Tunari National Park. We assessed and compared the links between land use, its transformation through conservation practices, local institutions and the worldviews of both communities and the implications they have for biodiversity at the level of ecosystems. Our results show that in both communities, people’s worldviews and environmental knowledge are linked with an integral and diversified use of their territory. However, the community most affected by urbanization and protected area regulations has intensified agriculture in a small area and has abandoned the use of large areas. This was accompanied by a loss of local environmental knowledge and a decrease in the diversity of ecosystems. The second community, where the park was not enforced, continues to manage their territory as a material expression of local environmental knowledge, while adopting community-based conservation measures with external support. Our findings highlight a case in which urbanization coupled with exclusive conservation approaches affects the components of both cultural and biological diversity. Actions that aim to enhance biocultural diversity in this context should therefore address the impact of factors identified as responsible for change in integrated social-ecological systems.

Keywords: *Biocultural diversity - Bolivian Andes - Ecosystem diversity - Protected areas - Traditional ecological knowledge*

Introduction

Classical nature conservation instruments, such as those implemented in protected areas, are being challenged by the emerging concept of biocultural diversity. Though there has been a gradual shift in protected areas governance to more inclusive, community-based and participatory approaches, in many cases this change seems to have been merely rhetorical (Galvin and Haller 2008). Exclusive conservation strategies are still widespread and often have negative effects on local people (e.g. Adams and Hutton 2007; Almudi and Berkes 2010) and, under certain conditions, may even harm biological diversity (Torri 2011). This is especially the case in cultural landscapes, where humans have been interacting with their environment for a long time. To address these issues, alternative approaches to conservation have emerged in the past decade associated with the concept of biocultural diversity, which has been defined as the “diversity of life in all its manifestations – biological, cultural, and linguistic – which are interrelated within a complex socio-ecological adaptive system” (Maffi 2005: 601). The concept is based on the observation that there is an “inextricable link” between biological and cultural diversity (International Society of Ethnobiology 1988; Posey 1999), and that these two kinds of diversities often face common threats (Harmon 2002; Lepofsky 2009). Advocates of the concept of biocultural diversity thus stress the need to address both biological and cultural diversity in a combined strategy, and see this as a promising approach for integrating human development and biodiversity conservation initiatives, especially when indigenous and traditional communities are involved (Lertzman 2009; Maffi and Woodley 2010; Oviedo et al. 2000; Rozzi et al. 2006).

However, the mechanisms that link biological and cultural diversity are still not well understood at the local scale, as most studies on biocultural diversity have focused on the distribution of biological and cultural (usually assessed via language) diversity at the global and continental scales (e.g. Collard and Foley 2002; Loh and Harmon 2005; Moore et al. 2003). Several authors have stressed that more studies at finer scales are needed to gain better understanding of the processes that link biological and cultural diversity (Collard and Foley 2002; Maffi 2005; Maffi and Woodley 2010, Smith 2001, Zent 2009). Such studies, at a scale at which one can reasonably observe and analyze the interactions of social and ecological systems (Berkes and Folke 1998) should focus on possible causal links between biodiversity and cultural values, beliefs, institutions, knowledge systems, practices, and languages, as well as changes that may affect continuation or loss of these links (Maffi and Woodley 2010). This means that in order to make operational the concept of biocultural diversity and apply it in conservation strategies, a second generation of studies that achieves “an integrated understanding of the coupled dynamics of social and ecological systems” (Lertzman 2009: 339) is needed. In a previous article (Mathez-Stiefel et al. 2007), we developed an approach aimed at examining cultural and socio-economic variation within an ethno-linguistic group at the local scale. We proposed to address cultural diversity based on the concept of “ontological communities”, defined as social groups that share “basic assumptions about what does exist and how the natural, human and spiritual worlds are” (Mathez-Stiefel et al. 2007: 70). We showed that several ontological communities can co-exist within a single ethno-linguistic group. We concluded that to understand the relationships between a specific human group and its natural environment, the focus should be on ongoing transformations of several integrated aspects of culture, namely on ontology, epistemology, normative orientations, and practices, with consideration of how such endogenous factors are related to exogenous factors such as the top-down implementation of a protected area.

This paper examines the specific case of the Tunari National Park (TNP) and its effect on the vigor of biocultural diversity in local communities. The TNP has the distinction of having been inhabited by Quechua farmers for centuries and of being adjacent to a large city, Cochabamba, the third largest urban cluster of the country. The implementation of the park has been strongly linked to urbanization and seen by local conservation organizations as an instrument for limiting urban sprawl. The park’s legal framework prohibits traditional pastoralism and restricts agriculture, but its enforcement has been very limited up to now and has concentrated on a few areas (Boillat et al. 2008). In other areas, however, community-based conservation initiatives not related to the TNP have been implemented. In order to examine how the combined top-down implementation of the park and the process of urbanization have influenced local biocultural diversity, we adopted the analytical frameworks proposed by Mathez-Stiefel et al. (2007) and Pretty et al. (2009). As a starting point, we compared land use practices and their transformation in two “peasant communities” located within the TNP that have similar ethno-linguistic backgrounds, but that have been affected differently by urbanization and park enforcement. We then compared the existing links between these practices and local environmental knowledge, institutions and worldviews in each community. Finally we show how these integrated cultural aspects affect biological diversity at the level of ecosystems. Assessing biological diversity at this level represents an attempt to balance existing bias in favor of biodiversity at the genetic and species level (Millennium Ecosystem Assessment 2005; Noss 1996) and provide a more appropriate assessment of a cultural landscape shaped by traditional farming. In this study, each “peasant community” is considered as a dynamic social-ecological system, understood as a complex system that includes human and biophysical subsystems which are interdependent, coupled by feedback mechanisms, and co-evolve (Berkes 2011).

Material and Methods

Study area

The Bolivian inter-Andean valleys are characterized by a high degree of biological diversity together with the dominance of a few language groups (Mathez-Stiefel et al. 2007). They have been cultivated since at least 500 BC (Rafiqpoor and Ibisch 2004), with development first centered on the supratropical ecological belt (3,200 to 4,000 m) and then in the valleys under Inca rule (Wachtel 1981). Spanish colonization in the 16th Century led to a further depletion of native forests with increased timber and firewood use (Fjeldsa and Kessler 1996) and established the current coexistence of pastoralism and cultivation with the introduction of European livestock and crops (Godoy 1991).

Our study focuses on two “peasant communities” organized in peasant syndicates, Chorojo and Tirani, located in central Bolivia’s Tunari Mountain Range (Figure 1). The Tunari Mountain Range extends from 2,700 to 5,000 m. The average annual temperature decreases from 17°C to 2°C according to altitude, and the average annual rainfall increases from below 500 mm in the valley of Cochabamba to 1,600 mm at higher elevations (Navarro and Maldonado 2002). The area features a very diverse landscape, including irrigated croplands in the valleys, rain-fed croplands and shrubs on the slopes, and grasslands and peat bogs in the highlands. Because the Tunari area harbors remnant patches of native *Polylepis spp.* forest with important biological diversity and endemism, it has been deemed a priority area for biological conservation (Fjeldsa and Kessler 1996). In 1962, the mountainous area that lies North of Cochabamba, and which includes the community of Tirani, was declared a National Park in order to protect the city from landslides and to curb urban sprawl in the absence of land planning policies. With the enactment of the Tunari National Park Law in 1991, the entire mountain range including the community of Chorojo was included within the park. The TNP law prohibits grazing, establishes the expropriation of uncultivated plots, and promotes state-based reforestation of the area (Boillat et al. 2008).

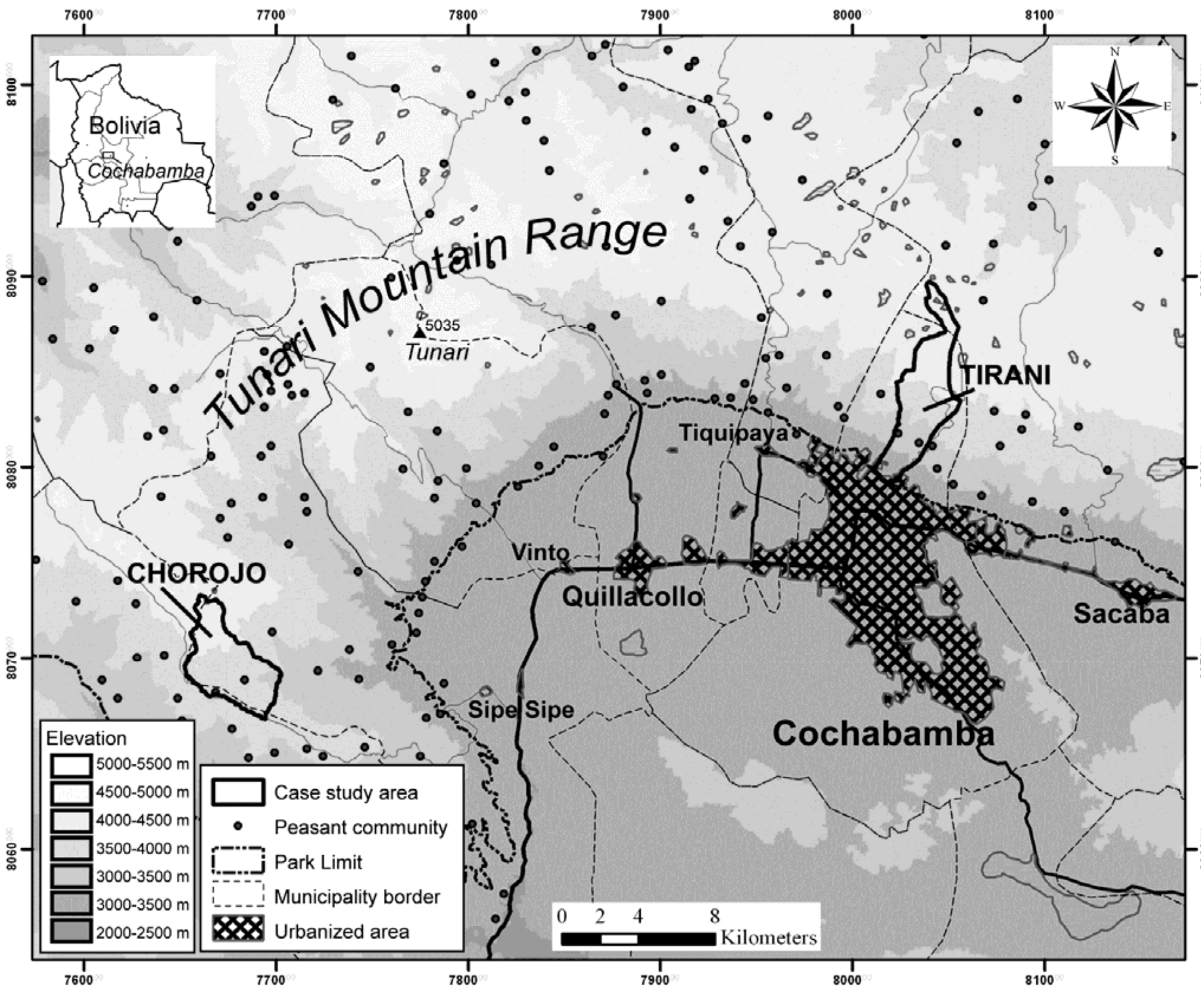

Figure 1. Location of the two case study areas.
Data sources: elevation: NASA Shuttle Radar Topography Mission (SRTM); park limits: Servicio Nacional de Areas Protegidas (SERNAP); municipality borders: Instituto Nacional de Estadística and UNDP (2005); community limits (not authoritative): communities of Chorojo and Tirani; location of peasant communities: Aguilar (2006); urban area: authors' visual interpretation of Landsat 7 images of 2005. Datum: WGS 84; Projection: UTM 19S

In the study area, peasant communities were constituted after the Bolivian agrarian reform, which began in 1953 and expropriated the *mestizo* landlords who were descendants of the Spanish in favor of their indigenous workers (*pegujaleros*), who were organized in peasant syndicates. Since then, the syndicates have held collective land titles that govern specific patterns of land use in terms of a continuous "territory" and the natural resources is contains. In this sense, the peasant community constitutes a privileged sphere of interaction between a social group and elements of the environment, and can be considered a dynamic social-ecological system, understood as a complex system that includes human and biophysical subsystems which are interdependent, coupled by feedback mechanisms and co-evolve (Berkes 2011). In this context, we assume that community members are likely to interact sharing their knowledge and designing institutions to manage biological diversity contained within what they consider their territory. For this reason, we chose the peasant community as our main level of analysis.

Table 1 shows the main characteristics of the two communities studied. The Chorojo and Tirani people are Quechua native speakers, although some also speak Spanish. At the time of the agrarian reform, 48 households in Chorojo were granted an area of 16.4 km^2 while in Tirani 58 households were granted an area of 19.8 km^2. In both cases, the largest part of the territory is found between 3,200 and 4,000 m. Since 1953, however, the communities have experienced differing processes of transformation due to their distance from the urban center of Cochabamba. Because Tirani is only 10 km away from the city center, the village has been strongly influenced by urbanization and the enforced park regulations, which have limited people's access to natural resources. Population has grown due to the arrival of migrants, mainly from Potosí and Oruro mining areas. These migrants have settled in separate "new neighborhoods"; they are not part of Tirani's agrarian syndicate, do not own land apart from their dwelling sites and do not have access to common lands. By contrast, most families native to Tirani cultivate plots as a secondary economic activity, but only a few ones practice agriculture as a main source of income. In Chorojo, 60 km away from the city center, access to services is limited and people cannot work in the city without migrating out. There, virtually all families who reside permanently in the community rely on agriculture complemented by temporal migration, and all are part of Chorojo's agrarian syndicate. Park regulations have not been enforced in this area due to insufficient funding, poor governance and active opposition from local peasant organizations (Boillat et al. 2008, 2010; Serrano et al. 2006).

Table 1. Main characteristics of the two communities studied.

	Chorojo	Tirani
Area	16.4 km^2	19.8 km^2
Altitude range	3,400-–4,600 m	2,700-–4,500 m
Population in 1952	~340[1] people (48 households)	~400[1] people (58 households)
Population in 1992	225 people (INE 1992)	793 people (INE 1992)
Current population	230 people (INE 2001); 190 (own census 2011)	2972 people (Health post census 2011)
Access	60 km from the city of Cochabamba, seasonal track road	Adjacent to the city of Cochabamba's neighborhoods
Education offered	Up to fifth grade	Up to high school, university in the city
Health services	Health post since 2009	Health post, hospital in the city
Languages spoken	Most Quechua monolingual; young men and some women bilingual Quechua/ Spanish	Most bilingual Quechua-/Spanish, some older women Quechua monolingual
Economy	Subsistence and some market-oriented agriculture, off-farm migration	Market-oriented agriculture and floriculture, temporary jobs in the city
Relation with conservation and TNP	Park regulations not applied; community-based conservation	Park regulations applied; ban on grazing, exotic tree plantations

[1]Estimated on the basis of the average fecundity rate of 5 children per woman in Bolivian rural areas in 1950 (INE-UNDP, 2005)
Source: Modified from Boillat (2007: 130)

Material and Methods

Ethnographic field research was carried out in Chorojo and Tirani between 2003 and 2006. Informed consent was obtained from the participants of the two communities involved via oral agreements made at monthly community meetings. People's participation was voluntary and confidential, following the guidelines of the Declaration of Helsinki and Tokyo amendment (World Health Organization 2001). Detailed objectives and milestones of the research process were defined and negotiated at an initial multi-stakeholder meeting involving representatives from the communities, the paramount peasant syndicate organization, municipalities, and the Park's authorities. The study was part of a broader action-research project studying conflicts between peasant and state actors in the management of the Tunari National Park (Boillat et al. 2008), and implemented in partnership with the Centre for Agroecology (AGRUCO) of the Universidad Mayor de San Simón of Cochabamba, which already had many years of experience interacting with peasant communities in the area. The project included studies on specific aspects of local knowledge such as weather forecasting (Chirveches 2006, Ponce 2003) and local institutions governing land access and livestock tenure (Serrano 2003). In the case of Chorojo, research also built on previous studies in the community that examined native forest management (Hensen 1993, Mariscal and Rist 1999) and livestock management (Rodriguez 1994). In this framework, this study represents a synthesis of these different works coupled with further research on traditional ecological knowledge and ecosystem management in the area (Boillat 2007).

In order to explore the different facets of existing land use practices, local environmental knowledge, institutions and worldviews among community members, we chose a qualitative ethnographic approach in the two communities studied. The objective of this approach was to get in-depth understanding about the possible different links between cultural aspects and biological diversity in each one of the studied communities. The first data collection phase consisted of carrying out participant observation of cultivation, pastoralism and forestry activities in both communities. The main author spent approximately one week per month in each community between January 2003 and December 2004. Field notes by the first author, including observations and transcriptions of participants' comments on their own activities, were later classified into four categories: 1) land use, 2) local knowledge, 3) institutions and 4) worldviews.

In the second phase of data collection, this information was deepened through semi-structured interviews with key informants aged 19 to 80 (6 men and 5 women in Chorojo; 7 men and 4 women in Tirani). The informants were selected under the principle of theoretical sampling (Strauss and Corbin 1998), with the objective of capturing diverse situations and maximizing the variability of land use practices, local environmental knowledge, institutions and worldviews expressed by the participants. We started interviewing the people who showed interest at the community meetings in which the agreement to perform the study was made, and then we included people from all age and gender groups as well as different dwelling locations in the community. In Tirani, only people native from the community were interviewed because migrants do not use land apart from their dwelling sites. The interviews were carried out in Quechua with the help of a local interpreter with monolingual participants and in Spanish with bilingual participants. The interviews included open-ended questions and free listing exercises (Quinlan 2005) in order to obtain thorough descriptions concerning the four topics mentioned above (e.g. How is cultivation carried out in the community? What do you know about weather signs? How is land and water access regulated? What are the main rituals and customs?). Elder informants (2 men and a woman aged 60+ from each community) were also asked about past practices since the Bolivian agrarian reform of 1953 and their transformation up to the present day. The second phase also included field transects (14 one-day field transects in Tirani and 3 in Chorojo) with 4 to 6 villagers (men and women aged 20 to 60 chosen by the community organization) who commented on the ecological, productive, ritual and historical characteristics of the different elements of the landscape. In Tirani, as requested by the community, a participatory video was produced on the topic of tree plantation management, in which community members explained their vision of this practice.

The third phase of data collection consisted of discussing the preliminary research results obtained from the two first phases with the participants during community workshops. The workshop dates were agreed during the syndicate's monthly meetings and all people present at the meeting were invited with their families. Four workshops were carried out in each community, sometimes divided into two stages, with participation ranging from 20 to 60 people. The workshops dealt with validating information on cultivation practices, pastoralism and forestry, local knowledge of topography, weather forecasting and knowledge of plants and animals; ritual practices and worldviews, and mapping main land use zones and land access types in the community on the basis of 1:7000 printed satellite images obtained from Google Earth (© Google). Finally, two "inter-communal" workshops were carried out, in which members from both communities participated, discussed, and compared their practices and customs.

All recorded interventions during the workshops and field transects as well as interviews and field notes were transcribed, segmented, and iteratively coded using Atlas.Ti software (© Scientific Software Inc.) and then grouped and analyzed according to the four categories mentioned above.

Biological diversity in the area was estimated using plant communities as a proxy for local ecosystem diversity (Forman 1995; Muller-Dombois and Ellenberg 1974). Though ecosystem processes are now well understood, ecosystem diversity is more difficult to assess because there is no fundamental criterion for defining ecological units (Bisby et al. 1995). In agricultural landscapes, however, boundaries between ecosystems are often much sharper than in natural landscapes (Forman 1995) and can be recognized by observing vegetation structure and composition (Finegan et al. 2001). In this study, we assume that units of relatively homogenous vegetation structure and composition correspond to local ecosystems that underlie specific ecological processes (Forman 1995). A phytosociological survey was conducted with 82 vegetation samples in Tirani and 74 in Chorojo in which all plant species cover was estimated using Braun-Blanquet's scale (1964). The plots were chosen among patches with homogenous vegetation structure and ranged from 400 m^2 (forests, shrublands and agroforestry areas), to 25 m^2 (scrublands, grasslands, fallows and crops) and 1m^2 (trampling grasslands). These plots were then classified in 40 plant communities using cluster analysis (Mulva-5 software, Wildi and Orloci 1996), identification of differential species, and vegetation structure. The communities were then described using the nomenclature of Navarro and Maldonado (2002).

The identified plant communities were then mapped and related to different degrees of intensity of human use. Relation to agricultural use was assessed with information on years of fallow obtained from local participants. Grazing use was assessed with the adscription of an approximate range of average stocking rate (in ovine units per hectare) supported by each plant community. The average stocking rate was calculated for each land use zone according to the monthly amount of livestock in each zone and the availability of cultivated fodder during the year (provided by Rodriguez 1994). The average stocking rate on plant communities was then estimated geographically, according to the distribution of these plant communities in land use zones with different stocking rates, and ascribing a value from 0 (no grazing) to 5 (very intensive grazing) to each plant community. Detailed calculation methods for these data are described in Boillat (2007).

Results

Current land use practices

In Chorojo, about one-third of all households have their main dwellings in the middle area and the rest in the lower area. However, most people have seasonal dwellings spread over the community's territory. In Tirani, all people dwell in the lower area with the exception of a few families who dwell in the highlands. During the validation workshops, participants from Chorojo and Tirani summarized their practice of different combinations of small-scale crop and livestock production according to altitude and ecological conditions, and they agreed on the use of the Quechua terms *ura* ("below"), *chawpi* ("middle"), and *pata* ("above") for the designation of ecological belts. Figures 2 and 3 show the different land use practices according to altitude and local zoning, and Tables 2 and 3 list the cultivated crops according to altitude. The validation workshops also yielded the following general information on land use practices in the communities:

Cultivated fields are usually small (less than 1 ha) and plowed using oxen. While irrigated plots can be sown from August onwards, rain-fed plots are sown at the beginning of the rainy season in November. In Chorojo, most plots are left fallow for at least one year and then opened up to sheep grazing. Rain-fed or irrigated plots in the lower areas are fallowed for 1 to 5 years, depending on the decision of each family. In the highlands (between 3,800 and 4,000 m), the cultivation area is divided into *aynoqas*, which are adjacent cultivable hillside sectors held as common fields. As in other areas of the Andes, each sector is cultivated for three years, with potato in the first year and cereals in the second and third years. The plots are then left fallow for 9-12 years and livestock is allowed to graze, while the next adjacent sector is opened up for cultivation. The *aynoqa* is said to "walk" (*purin*) during the rotation process. In Tirani, fallow is limited to 1 to 5 years in the higher areas and on rain-fed plots, and is a family-based decision. In the lower area of Tirani, between 2,700 and 3,000 m, there are irrigated plots, which are intensively cultivated with annual crops, fruits and flowers, and are never fallowed.

In addition to oxen and donkeys kept for field labor, the peasants in Chorojo own approximately 3,200 head of sheep as well as some llamas and goats (Rodriguez 1994). Higher dwelling families, 13 in total, hold an average of 190 head of sheep each, the so-called *puna* herds. The 24 lower dwelling families hold an average of 30 head of sheep each, the so-called *valle* herds. Figure 2 shows the movements of higher and lower dwelling livestock with the months of the year during which livestock stay in each area. There are no fences and women and children are the principal herders. The *aynoqas* in pasture are intensively grazed all year round. In winter, livestock also graze on stubble and fodder on plots lying in the lower areas, while they graze in the forest and the shrublands (middle area) in the spring. In Tirani, four families of herders graze a total of about 100 head of llama, 60 head of sheep, and 20 head of bovine in the highlands (Figure 3). In order to enhance edible native pastures, they burn a sector of the higher area grasslands once a year before the rains begin. Each area is burnt approximately once every five years. In the lower area with irrigated plots, some people own oxen mainly fed on purchased fodder, and they sporadically graze them in adjacent non-irrigated areas.

Chorojo's native forest, called *monte*, is dominated by *Polylepis subtusalbida* (Bitter) M. Kessler & Schmidt-Leb. trees. Tree felling and firewood collection are strictly internally regulated, and forest products are never marketed. In Tirani, there are smaller *Polylepis subtusalbida* native forest patches, but large areas covered by plantations of non-native pines (*Pinus radiata* D.Don and *P. pseudostrobus* Lindl.) and eucalyptuses (*Eucalyptus globulus* Labill.). There, the park regulations have banned timber and firewood harvesting on plantations and in native forests. Some people gather non-timber forest products such as edible mushrooms (*cf. Boletus spp.*), and market them.

Table 2. Land use zones and corresponding plant communities in Chorojo. Source: Adapted from Boillat (2007)

	Land use zones with elevation in m	
PATA	***Pata Loma***: (4,200 – 4,600) Ovine and llama grazing in summer (November to February); burning banned; communal tenure	
PATA	***Loma***: (3,800 – 4,200) Shifting sector fallow cultivation (***aynoqas***): potato for one year, oats for two years, fallow 7 to 20 years; ovine grazing year round (higher grazing circuit in winter; lower grazing circuit in summer); houses, Waka Playa village nearby; communal tenure	
CHAWPI	***Chawpi Loma:*** (3,600 – 3,800) Cultivation on rain-fed plots: potato, oca, ulluco, wheat, barley; ovine and bovine grazing in winter (June to October); family tenure. Two hillsides:	
CHAWPI	*Wet hillside*	*Dry hillside*
CHAWPI	Fallow one to five years ***Monte***: Native forest with plots in agroforestry; ovine grazing after stubble and fodder depletion (August to October); trees under communal tenure	Fallow 3 to 10 years; grazing stubble and shrublands in winter (June to October)
URA	***Ura Rancho***: (3,400 – 3,600) Cultivation of irrigated plots: potato, wheat, corn, vegetables; grazing stubble from June to mid-August; fallow zero to five years; Houses; family tenure	

Ecolo-gical belt	*Plant communities*	Grazing intensity	Years of fallow
Orotropical/ upper supratropical (3,800–4,600 m)	*Deyeuxia vicunarum–Werneria villosa* tussock grassland	3	-
	Tetraglochin cristatum –Azorella compacta scrubland	5	-
	Deyeuxia vicunarum– Aciachne acicularis low grassland	4	-
	Deyeuxia vicunarum low grassland with *Paspalum sp.* And *Muhlenbergia peruviana*	4	5–15
	Stipa ichu pioneer tussock grassland with *Stipa hans-meyeri*	4	5–15
	Tarasa tenella fallow forb community with *Astragalus peruvianus* and *Plantago orbignyana*	4	1–5
	Plantago tubulosa – orotropical peat bog	3	-
Supratropical (3,400–3,800 m)	*Polylepis subtusalbida – Berberis commutata* higher forest with *Solanum circaefolium* and *Campyloneurum sp.*	4	-
	Polylepis subtusalbida – Berberis commutata lower forest with *Cosmos peucedanifolius*	2	30+
	Berberis commutata – Clinopodium bolivianum thick shrubland with *Baccharis yunguensis* and *Cajophora canarinoides*	3	-
	Berberis commutata – Clinopodium bolivianum open shrubland with *Agalinis bangii* and *Calceolaria buchtieniana*	3	-
	Adesmia miraflorensis– Cortaderia rudiuscula streamflow riverine shrubland	3	-
	Puya glabrescens – Trichocereus tunariensis xeric shrubland	2	-
	Juncus ebracteatus – Gentianella dielsiana rush grassland	4	-
	Vulpia myuros – Medicago polymorpha fallow grassland	4	2–5
	Baccharis dracunculifolia open fallow shrubland	3	5–15
	Oxalis macachin –Lepechinia meyenii fallow forb community	3	2–7
	Weed forb community with *Bromus catharticus*	-	0
	Pennisetum clandestinum – trampling grassland	5	1–7
	Aciachne acicularis– Cyperus andinus grassland	5	?
	Cortaderia rudiuscula riverine tussock grassland	3	-
	Eucalyptus globulus tree plantation on *Baccharis dracunculifolia* shrubland	4	-

Table 3. Land use zones and corresponding plant communities in Tirani**.** Source: Adapted from Boillat (2007)

	Land use zones with elevation in m
PATA	***Puna***: (4,200 – 4,500) Llama and ovine grazing in summer (November to April); grassland burning in August or September; communal tenure
	Puna: (4,000 – 4,200) Grazing in winter; also burning; cultivation on a few plots: potato, oats; fallow three to four years; communal tenure
CHAWPI	***Alturas***: (3,800 – 4,000) Grazing in winter; also burning; cultivation on a few plots, potato, oats, fallow three to four years; family tenure
	Alturas: (3,400 – 3,800) Forest plantations (*Pinus radiata, P. pseudostrobus, Eucalyptus globulus*) protected by the National Park, without management or use; cultivation plots: potato, oca, barley, fallow three to four years; open native forest patches (*Polylepis subtusalbida*); gathering of wild non-forest products; family tenure; restricted use due to the National Park
	Cerro: (3,200 – 3,400) Forest plantations (*Eucalyptus globulus*) and gathering, occasional grazing in winter; communal tenure
URA	***Cerro***: (3,000 – 3,200) Cultivation on rain-fed plots; fallow three to four years, winter grazing; communal tenure
	Ura Rancho: (2,800 – 3,000) Intensive cultivation with irrigation: floriculture, fruit crops, corn, vegetables; no fallow; houses; family tenure
	Temporal: (2,600 – 2,800) Grazing in summer, most of the area is now urbanized and no longer belongs to the community (communal tenure before)

Ecolo-gical belt	*Plant communities*	Grazing intensity	Years of fallow
Orotropical/ upper supratropical (3,800–4,600 m)	*Deyeuxia filifolia – Festuca dolichophylla* tussock grassland	1	-
	Stipa ichu – Festuca dolichophylla tussock grassland	1	-
	Festuca orthophylla tussock grassland	1	-
	Deyeuxia vicunarum– Aciachne acicularis low grassland	1	-
	Tarasa tenella supratropical fallow forb community with *Agrostis tolucensis* and *Hypochoeris eremophila*	1	0–5
	Plantago tubulosa – orotropical peat bog	2	-
Supratropical (3,400–3,800 m)	*Polylepis subtusalbida– Berberis commutate* supratropical open forest with *Deyeuxia cf. orbignyana* and *Asplenium guillesii*	1	-
	Berberis commutata – Clinopodium bolivianum thick shrubland with *Baccharis yunguensis* and *Cajophora canarinoides*	3	-
	Oxalis macachin –Lepechinia meyenii fallow forb community	1	2–7
	Puya glabrescens – Trichocereus tunariensis supratropical xeric shrubland	1	-
	Stipa ichu – lower supratropical pioneer tussock grassland	1	2–12
	Pinus radiata tree plantation	1	-
Lower supratrop. (3,200–3,400 m)	*Eucalyptus globulus* tree plantation on former *Polylepis* forest	1	-
	Lepechinia graveolens and *Schinus andinus* lower supratropical thick shrubland	1	-
	Stipaichu – lower supratropical pioneer tussock grassland	1	2–12
	Elyonurus muticus lower supratropical tussock grassland	1	-
	Eucalyptus globulus tree plantation on *Lepechinia graveolens* shrubland or on *Stipa ichu* tussock grassland	1	-
Mesotropical (2,600–3,200 m)	*Puya glabrescens – Anthericum tunarianum* meso. xeric shrubland	0	-
	Kageneckia lanceolata – upper mesotropical shrubland	1	-
	Dodonaea viscosa – upper mesotropical open scrubland	1	2–15
	Schinus molle and *Zanthoxyllum coco* mesotropical fan shrubland with *Viguiera australis* and *Tecoma garrocha*	2	-
	Schinus molle – Zanthoxyllum coco mesotropical streamflow riverine shrubland with *Clematis alborosea*	1	-
	Euphorbia maculata – Bromus catharticus meso. forb community	0	0
	Pennisetum clandestinum – Guilleminea densa grassland	5	1–7
	Datura stramonium – Cynodon dactylon nitrophile forb com.	3	-

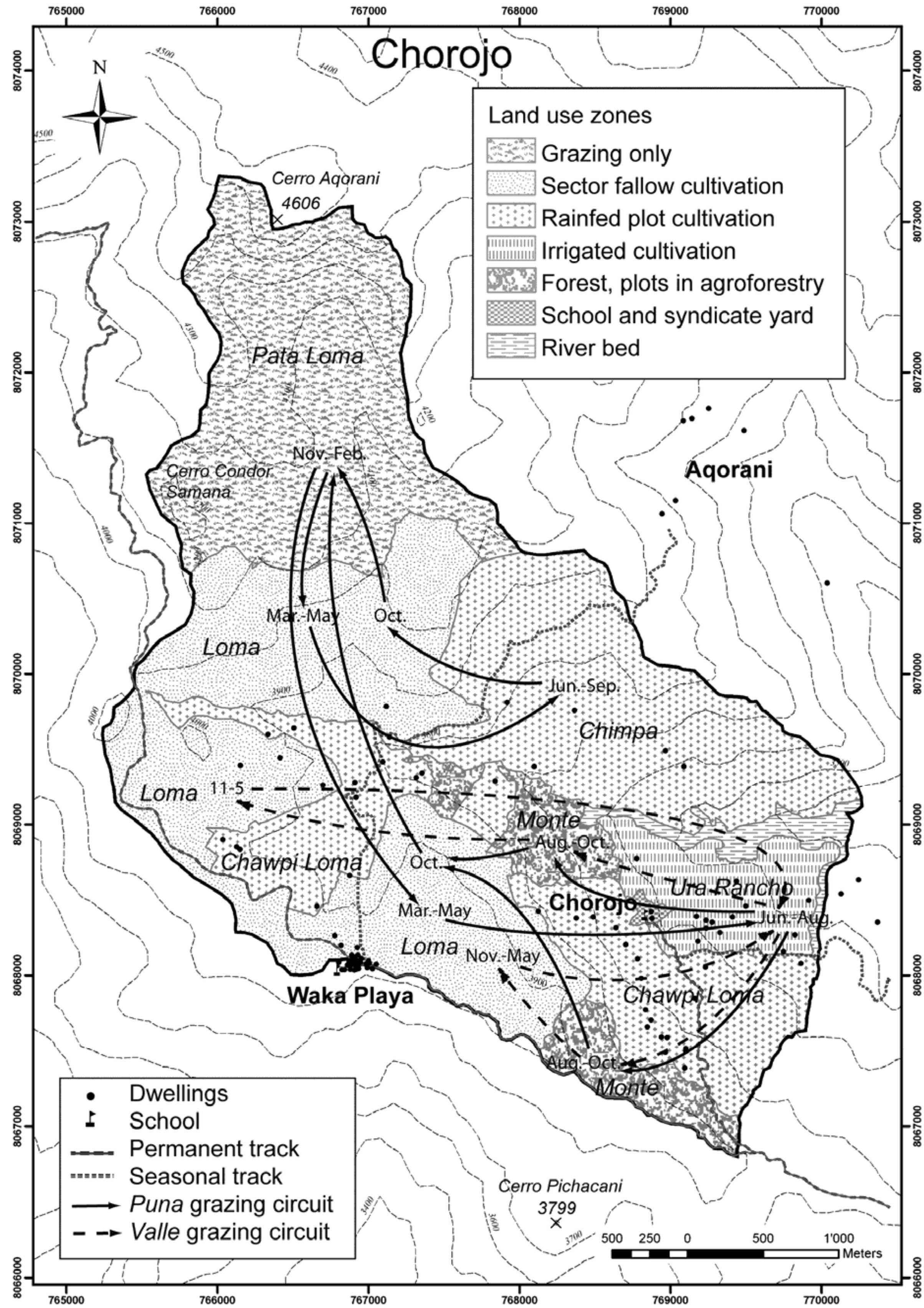

Figure 2. Land use and grazing circuits in Chorojo.
Data sources: land use zones: community of Chorojo, S.Boillat, E.Serrano; grazing circuits: modified from Rodriguez (1994); level curves: NASA Shuttle Radar Topography Mission (SRTM); roads: Instituto Geográfico Militar (IGM); dwellings: authors' visual interpretation of Google Earth images. Datum: WGS 84; Projection: UTM 19S

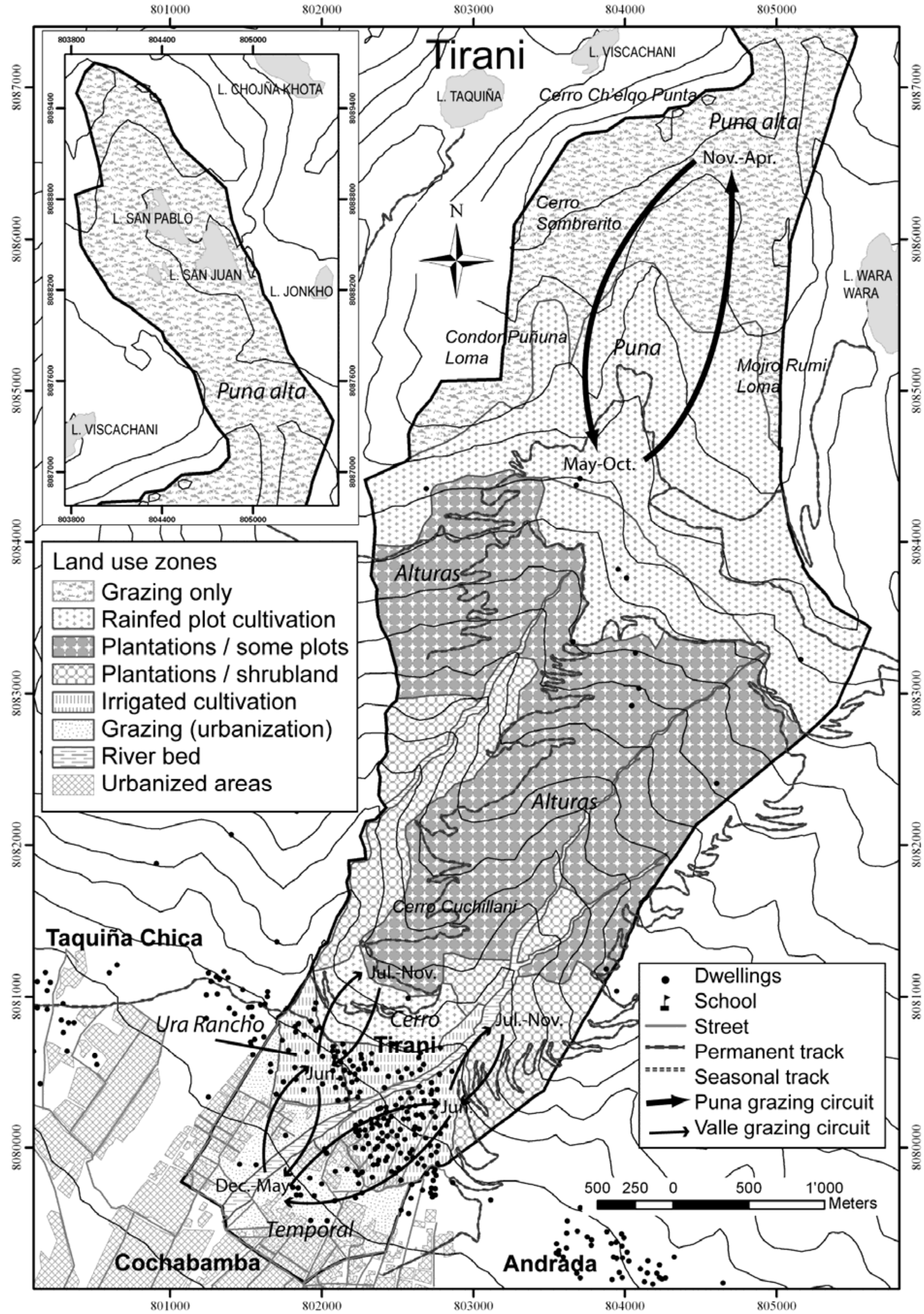

Figure 3. Land use and grazing circuits in Tirani.

Data sources: land use zones and grazing circuits: community of Tirani, S.Boillat, E.Serrano; level curves: NASA Shuttle Radar Topography Mission (SRTM); roads: Instituto Geográfico Militar (IGM); dwellings and urban areas: authors' visual interpretation of Google Earth images. Datum: WGS 84; Projection: UTM 19S

Land use changes and conservation practices in Chorojo

During the interviews, elders from Chorojo recalled that prior to the Bolivian agrarian reform, the landlord-owned fields were located in the lower irrigated zone as well as in the highland cultivation areas, where land was already cultivated under the *aynoqa* system. In exchange for free labor for the landlord, the farmers were allowed to cultivate small plots located on the slopes in the middle area. With the reform, these small plots, irrigated land, and *aynoqa* land was distributed among the 48 families that worked for the landlord in accordance with their years of service. Since then, population increase due to high fertility rates has been compensated by out-migration to the city and the Bolivian lowlands, leading to a more or less constant, and more recently slightly diminishing, permanent population in the community (Table 1). Agricultural intensification was very limited, and the practice of long fallow was maintained. Between 2000 and 2005, the community opened up a small new *aynoqa* area above 4,100 m. Eight of the interviewed informants of all ages and both sexes spontaneously mentioned that these areas had been cultivated in Inca times (15th Century). There are no historic data on livestock population in the area. According to elder informants, the amount of livestock increased until the early 1990s and then remained constant or diminished slightly.

Landlords once used the area's native *Polylepis subtusalbida* forest for charcoal production, but charcoal production and the burning of vegetation were banned after the agrarian reform, and the forest area has been used for agroforestry plots, some logging, and firewood gathering since then. Traditional norms of use included limited grazing in the forest during springtime for people owning large herds. Though Chorojo was included within the TNP in 1991, no measures to enforce the park regulations have been taken up to now in the area. However, from 1992 onwards, the community organization of Chorojo formally enacted written internal regulations on timber and firewood use. These regulations included exclusive access for community members to the forest resources, a ban on vegetation burning, tree cutting only in exceptional cases authorized by the community, firewood use restricted to already dry trees, and a ban on commercial use of forest products. These rules were built on already existing normative orientations that were further enhanced through the support of a community-based forest conservation project[1].

Land use changes and conservation practices in Tirani

Elder informants from Tirani recalled that the fields of the hacienda were located in the lower, irrigated areas and the farmers' plots in the higher, rain-fed area where they had summer dwellings. In order to enable grazing for several thousand heads of llama and sheep, controlled burning was practiced across the entire area above 3,200 m. The highland grazing circuit was complemented by a valley grazing circuit that led livestock to the slopes in winter and, in summer, to the area below the irrigated fields (Table 3; Figure 3). With the agrarian reform, the syndicate distributed land so that each of the 58 families got between one and two hectares in the irrigated area, five hectares on the slopes, and access to communal grazing areas in the highlands.

---

[1] The project was led by AGRUCO and supported by the Programme for Andean Native Forest Conservation (PROBONA) of the Swiss Agency for Development and Cooperation. Its outcomes have been described in detail by Mariscal and Rist (1999).

Land use in the community changed radically after the enactment of the Tunari National Park in 1962: tree plantations (with *Pinus spp.* and *Eucalyptus spp.*) were established on the slopes located between 3,200 and 4,000 m, first by the military, then by the community members in the framework of a forestation project supported by German and Swiss development agencies. To avoid damage to young trees, livestock amounts were drastically reduced. The original objective of producing timber was stymied by the application of the 1991 park law which 1) banned tree felling and the extraction of wood, 2) banned livestock grazing and 3) provided for the expropriation of uncultivated land by the State. Though not enforced, this last measure acted as a strong disincentive to the practice of long fallow in rain-fed fields. Besides these restrictions, economic opportunities and the presence of services led the whole population of the community to settle in the lower area with irrigated fields, with the exception of four families who remained in the highlands. Out-migration was reduced by the existence of job opportunities in the city and since the 1980s, an important immigrant population from other highland mining areas of the country has settled in the area below the irrigated fields where villagers have sold their land to urban promoters. These migrants have an urban lifestyle and do not use land in the community apart from their dwelling plots.

Local environmental knowledge

The analysis of the interviews and free listings revealed three main categories of local knowledge which are directly related to land use practices in the communities: 1) local land use concepts; 2) weather forecasting knowledge, and 3) people's descriptions of ecological conditions.

Local land use concepts agreed upon by the workshop participants from Chorojo and Tirani include the basic Quechua terms *chaqra*, designating cultivated plots, and *purma*, meaning uncultivated, but potentially cultivable lands. In Chorojo, people make a distinction between short fallow, called *sumpi,* and long fallow, called *purma*. The term *sumpi* specifically designates land fallowed for 1 to 5 years and is related to the verb *jump'iy* ("to sweat"), as land is said to "get warmer" with fertilization through livestock and vegetation development. *Purma* designates land fallowed for 10 years or more, as in the *aynoqa* area. Chorojo people also refer to *inca purmas*, which are "virgin lands" that are seen as cultivable and highly fertile, and suitable for the establishment of new cultivation plots. In Tirani, nobody mentioned any difference in the use of terms to designate short and long fallow: all uncultivated arable lands, whether fallow plots or not, are simply designated *purma*. In both communities, the interviews evoked references to the observation of plants, animals, atmospheric and astronomic phenomena to forecast the weather – especially rainfall, and its use in making decisions regarding land use practices. In Chorojo, everyone interviewed could mention at least one indicator for weather forecasting. Three of them said they did not use it, but relied on the observations of more knowledgeable people. Moreover, weather forecasting involves collective observations, such as on August 1st when people climb on a hill to observe the soil humidity below rocks, called *rumi jump'iy* ("the sweat of stones"). In Tirani, only two elders as well as a man and a woman who own livestock and practice rain-fed agriculture knew weather forecasting indicators. The indicators mentioned included the prediction of dry or wet years by observing the size and brightness of the Pleiades stars in June, the flowering pattern of the *muña* [*Clinopodium bolivianum*

(Benth.) Kuntze], the behavior of the Andean fox (*Lycalopex culpaeus* Molina), and the *rumi jump'iy*. Those who mentioned these indicators also explained that yearly weather forecasting has an influence on cultivation patterns: if a dry year is predicted, one has to sow more in *meq'a* ("concave") fields, use horizontal furrows, choose drought-resistant potato varieties, and spread sowings over a longer time span.

During the workshops, participants described the spatial and temporal variability of ecological conditions they perceived in their communities and their interplay with land use. They mentioned three pairs of opposites relating to temperature, altitude, and humidity: *chiri* ("cold") vs. *q'oñi* ("warm"); *pata* ("high") vs. *ura* ("low"); *ch'aki* ("dry") vs. *joq'o* or *húmedo* ("humid"). In Chorojo, two men and three women gave detailed explanations of how they order ecological concepts according to opposites. They consider higher and colder areas to be drier as well, while lower and warmer areas are considered more humid, and they take for granted that the lower areas are more humid due to the irrigation system in place, even though these areas receive less rainfall. Moreover, they associate these ecological conditions with gender, with low and humid areas associated with the feminine term *Pachamama* ("Earth's mother") and high and dry areas associated with the masculine term *Auki* ("prince" or "ancestor") (for more details see Serrano et al. 2006). These concepts were discussed at the validation workshop and considered accurate by the participants. The traditional division of labor recorded during participant observation reflected the idea that cultivated land becomes colder when plowed by the men, who are said to have "cold hands," and that fallow land becomes warmer when manure is spread by the livestock led by the women, who are said to have "warm hands." In Tirani, such cold–dry and warm–humid associations were not mentioned, either during workshops or interviews: valley lands were observed to be dry, and the workshop participants described the irrigation system as clearly separate from the territory's natural characteristics. According to them, the community has two watersheds, one more humid than the other, and the humidity gradient is separated from the elevation gradient. Though they acknowledged the general representation of productive places such as *Pachamamas*, they made no mention of gendered representations of mountains or ecological conditions.

Institutions

Table 4 summarizes the characteristics of community organization and natural resources governance in Chorojo and Tirani. In both areas, community affairs, including issues related to land use, are discussed at monthly meetings which all community members are expected to attend. The communities have two parallel governance systems: agrarian syndicates (*sindicatos agrarios*) and the "traditional" organization (*organización tradicional*). The agrarian syndicates establish and manage the basic institutions regulating land use access and practices at community level and/or between different households. The traditional organization governs specific natural resources, such as water, which is managed and distributed by an annually elected *juez de aguas* ("water judge"). Moreover, in Chorojo, community members elect an *alcalde de campo* ("field mayor") each year who is in charge of safeguarding the development of crop and livestock production, including monitoring of *aynoqa* areas, managing conflicts (especially damage to crops from livestock), and preserving cultural heritage through rituals and festivities. In Tirani, the community was temporally divided into two rival factions due to internal conflicts about selling collective lands to urban migrants in the lower areas of the community.

Table 4. Community organization and natural resource governance in Chorojo and Tirani.

	Chorojo	Tirani
Community organization		
Agrarian syndicate	Meetings once per month with mandatory attendance, a directory is elected each year	Meetings once per month with mandatory attendance, every 2-3 years a directory is elected
Syndicate membership	Must be an heir of the 48 *pegujaleros* ; one vote per family Must be married and have a family to assume functions	Must be an heir of the 58 *pegujaleros* ; one vote per “ancestor” Also young syndicate members can assume functions, especially those with good formal education
Traditional organization	A “water judge” and an “alcalde de campo” elected each year responsible for water and pasture management, respectively	Two “water judges” elected, each year one per watershed, responsible for water management
Traditional organization membership	Same as syndicate members	People with water use rights
Stability of organization	Syndicate and traditional organization stables and unified	The syndicate split into two rival factions in 2005 and re-unified in 2008
Governance of local natural resources		
Formal land property	Collective title to the syndicate dating back to 1957, few individual titles	Collective title to the syndicate dating back to 1953, plus individual titles for each family
Land trade	Restricted to community members	In theory, restricted to community members, but selling to outsiders has occurred
Land rent	Most by sharecropping or barter, restricted to community members	Most by rent involving money or contract, restricted to community members
Collective arable land	Access to *aynoqas* according to inheritance	Free access, but few collective lands available
Sowing time	Agreed collectively	Decision of each family
Grazing	Collective, must follow the annual grazing circuits and avoid cultivated *aynoqas*	Collective, but restricted by the park, allowed above tree line
Irrigation water	Access in function of community membership	Access in function of inherited water rights
Timber	Tree felling with special community permission and yearly limit	Tree felling banned by park, claim for communal regulation
Firewood	Only dry trees and for self-consumption only	Firewood extraction banned by park
Non-timber forest products	Access to community members and for self-consumption only	Access to community members, marketing allowed
Fire	General ban on vegetation burning decided by the community	Highland pasture burning allowed by the community but banned by the park

Source: Modified from Boillat (2007: 468)

At both study sites, land tenure and access is mainly internally regulated and land is formally held by the syndicates in the form of a collective title dating back to the agrarian reform. This title includes a map and a list that registers plots belonging to the original *pegujaleros* at the time of agrarian reform. These plots sometimes have corresponding formal individual property titles dating back to the agrarian reform, but have rarely been updated since. On these plots, tenure is internally regulated between the *pegujaleros*' heirs and subject to the community's customary norms; landholders have the right to cultivate plots for their own gain, the right to build dwellings, and the right to access irrigation water. Tenure transfers are rare and limited to transactions between community members. People who migrate out of the community usually keep their land and come to cultivate their plots sporadically. In Tirani, restrictions on individual land transfer are claimed but not enforced; in the lower area, some community members have sold land to outsiders.

In Tirani as in Chorojo, areas not included on the registered plots are managed collectively, and there each community member has the right to graze livestock, use firewood, harvest wild plants and animals and log trees with the community's permission. The *aynoqa* cultivation area of Chorojo belongs to collective lands, but cultivation plots have also been informally distributed to families through the agrarian reform. In both communities, participant observation showed that people with more land and less workforce (usually elders) usually rent their plots to other community members. They practice sharecropping (called *compañía*) which consists of splitting the harvest between the one who provides the land, seed, and manure and the one who prepares the soil and cares for the crops. Sharecropping is widespread in Chorojo and also used in Tirani, but there land contracts, leasing, and renting that involve money are more frequent.

Beliefs and Worldviews

When asked about rituals and customs, nearly all people in Chorojo and Tirani[2], assigned a central role to the *Pachamama*, a maternal figure linked to the earth and crop production. Belief in the *Pachamama* influences deeply land use practices at both study sites. The *Pachamama* is thought to enable production, but she may also send hail or drought according to her will, particularly in response to inappropriate human behavior. Offerings to the *Pachamama* are made in the fields at the start of the sowing and the harvest time by preparing a ritual table (*mesa* or *q'oa*) bearing incense and a mixture of plant and symbolic figures made of sugar, and by pouring alcoholic beverages onto the earth (*ch'alla*). In Chorojo, when droughts occur around Christmas time, all male household heads are requested to take part in an Infant Jesus procession to ask the *Pachamama* for rain. They must walk to a lake in the highlands from which they take water to pour into the community's springs and rivers.

Participant observation of *q'oa* and *ch'alla* offerings in both communities revealed that involved people also direct them to a larger spiritual community, including the "places" that are said to be the keepers of crop and livestock production. In corresponding rituals and prayers, they cite place names of high mountains, rocks with specific shapes, dense forests, rivers and lakes, all of which are thought to be capable of "getting angry" (*phiña*) in response to immoral human behavior. Elders from Chorojo and Tirani explained that these "places" are more dangerous the further their location from humans. They believe it is important to carry

[2] 10 of 11 interviewed people in Chorojo and 9 of 11 in Tirani spontaneously mentioned the importance of the *Pachamama*. Only one informant from Tirani, who belongs to an evangelical church, explicitly denied his belief in the *Pachamama*.

out productive activities in such areas with corresponding rituals, enabling these places to be “befriended” (*mansos*) by humans, and express concerns when an area is left unused.

The *Pachamama* includes the Quechua term *pacha* which means both “space” and “time” simultaneously. However, the term is rarely used in Tirani or Chorojo, having been replaced by *lugar* and *tiempo* respectively, borrowed from Spanish. There is nevertheless the idea that remoteness in space corresponds to remoteness in time, with the corresponding belief that any areas with little human presence were inhabited in the past. In Chorojo, this is expressed by the idea described above that the higher area, where only grazing is possible, is thought to have been cultivated during the time of the Incas. Another community member mentioned that “the native trees were as old as the Incas”. In Tirani, an elder also explained that natural caves in the highlands are said to be ancient mines that were exploited during colonial times.

Other beliefs involve human interaction with wild and domestic animals and plants. In Tirani, an elder explained that the condor (*Vultur gryphus* L.) hunts lambs but, after consuming its prey, recites a prayer that fosters livestock reproduction in return. During communal workshops, the participants distinguished clearly between domestic and wild plant and animal species. This distinction determines the potential use of a plant or an animal: sown plants and domestic animals are considered the responsibility of people and must be cared for, and in turn may be marketed. The same is true for planted trees. In the video made on forest management in Tirani, participants expressed great concern about their inability to “take care” of the tree plantations because of the National Park’s regulations, and compared pruning and thinning activities to “educating the trees.” By contrast, wild plants are said to be “sown by God or the *Pachamama*” and may only be used for personal consumption. Wild animals are rarely hunted, and never hunted for commercial purposes.

Finally, a belief found in both communities is that adverse weather phenomena are associated with immoral human behavior: human bloodshed in the form of an abortion is thought to provoke hail. In Chorojo, a community meeting in 2005 showed that the majority of community members acknowledge this idea: they asked girls affected to pay for crop damage due to hail. No such measures were observed in Tirani, but the belief was mentioned by some elders.

Ecosystem diversity and its relation to land use

Tables 2 and 3 show the 40 plant communities identified by the phytosociological survey in Chorojo and Tirani, as well as their link to grazing intensity and period of fallow. There are 22 plant communities in Chorojo and 25 in Tirani. In the supratropical and orotropical ecological belts (3,400 to 4,600 m), however, there are more plant communities in Chorojo (22) than in Tirani (13). This is despite Tirani having a larger area at this altitude than Chorojo (1820 ha and 1640 ha respectively).

In Chorojo, a mosaic of vegetation types are grazed at different intensities: three plant communities are linked with very intensive grazing (5), eight with intensive grazing (4), eight with high grazing (3) and two with moderate grazing (2). Only a single plant community – the weed community accompanying crops – has virtually no grazing influence. Moreover, eight plant communities are linked to fallow land and include all successional stages from forb communities to secondary forest. Four plant communities are linked to fallow periods longer than five years. Succession patterns differ on both hillsides, as the drier hillside is treeless. The supratropical belt from 3,400 to 3,800 m is covered by a mosaic of native forest patches, rain-fed cultivation plots with different fallow periods, and grazing areas; it also features the greatest diversity of plant communities. Above 3,800 m, however, very intensive grazing prevents succession beyond the grassland stage.

In Tirani, the influence of grazing is still visible above 4,000 m, which corresponds to the limit of tree plantations. There, llama herding and management through burning has fostered tall tussock grasslands. Some plant communities with moderate to high grazing are also found in the densely populated and partly urbanized lower area. However, as a consequence of plot-based cultivation with short fallow, plant communities linked to long fallow are absent in Tirani, with the exception of the *Dodonaea viscosa* Jacq. shrubland in the lower areas, which also occurs in uncultivated places. Between 3,200 and 4,000 m, the exotic tree plantations cover large areas and coexist with some residual plots, as well as areas with open native forests, shrub-encroached grasslands, and shrublands. These plant communities are the result of past grazing and burning practices and their eventual abandonment.

Discussion

Our findings show that two communities with similar socio-cultural and physical environments have been differently affected by top-down park implementation and urbanization processes in the last 60 years. These transformations led to different outcomes in terms of biological and cultural diversity.

In the case of Chorojo, land use and the corresponding cultural landscape have experienced relatively few changes since 1953. The community has maintained a high diversity of ecosystems, linked with the conservation of native forest patches and the persistence of short and long fallows and grazing circuit practices. This cultural landscape reflects a high degree of integration and coordination of cultivation, pastoralism and forest management. This integration is strongest in rain-fed cultivation areas, where the diversity of plant communities is also the highest. In contrast with Chorojo, the community of Tirani has experienced many changes in recent decades. Livestock production, forestry and intensive crop production have been permanently ascribed to specific zones which are clearly differentiated spatially. Rain-fed cultivation and grazing areas have been widely replaced by tree plantations. The enforcement of conservation measures that limited traditional land use had the effect of encouraging the abandonment of these areas and the concentration of people in peri-urban areas. These changes have led to less diversity of ecosystems, with the loss of plant communities linked to the practice of long fallow and grazing circuits. The loss is not total, however: the higher areas where pastoralism and small-scale cultivation are still practiced harbor extensive tussock grasslands that are known to support a great diversity of species (Pestalozzi 1999).

Land use practices in Chorojo appear to be clearly linked to a visible body of local knowledge¸ which includes 1) a detailed classification of fallow types, 2) a widespread use of weather forecast, and 3) a “gendered” perception of ecological conditions around complementary opposites. This body of knowledge allows people to interpret inter-annual variability of rainfall and adapt their land use practices to existing local ecological conditions. Compared with Chorojo, the body of knowledge observed in Tirani appears poorer, with less complex use of local terms and a lack of "gendered" perception of ecological conditions, clearly linked with the absence of long fallow and management in cycles. Yet some community elders have knowledge of weather forecasting, reflecting the fact that traditional rain-fed agriculture and grazing circuits did exist in the past. However, the abandonment of these practices makes its use obsolete: Chirveches (2006) found that traditional weather forecasting is no longer learned by most children in Tirani[3].

The case of Chorojo also shows the relations between institutions and traditional practices: the *aynoqa* system is backed up by the position of *alcalde de campo*, and the effective ban on selling land has prevented land tenure concentration. As a result of land distribution and the practice of sharecropping (Serrano 2003), most households have access to 10 to 20 cultivation plots scattered at different altitudes and hillsides, enabling them to distribute crop failure risks (Boillat and Berkes 2013). Chorojo faces however the challenge of out-migration. Though the absence of population growth allowed the persistence of the practice of long fallow and rain-fed cultivation, the increase of out-migration and an aging resident population could be a threat to the whole social-ecological system of Chorojo. This situation can threaten community institutions, as observed in Mexico by Robson and Berkes (2011), and labor shortages can foster soil erosion linked with the lack of soil conservation practices (Zimmerer 1993). Furthermore, though out-migrating people usually still work on their lands and preserve their local knowledge, this might not be the case for their children. In Tirani, institutions are less diverse and less stable and reflect a lower degree of collective organization. Furthermore, they are weakened by the urbanization process. On the one hand, the great pressure on land value encourages individualized land tenure and land marketing (Ledo Garcia 2009) and exacerbates land disputes and internal divisions. On the other hand, the significant population growth due to immigration brings people who lack the same bond to land as the natives, and might further influence the loss of local knowledge, institutions and worldviews in the community.

The worldview expressed by people from Chorojo is also in line with observed practices, knowledge and institutions, and is permanently enforced at community level through collective ritual expressions. Its characteristics are consistent with the ones found in many other Andean traditional communities (e.g. Estermann 1998; Platt 1992; Rist and Dahdouh-Guebas 2006; Van den Berg 1990) and include 1) beliefs related to places and spiritual beings with an ideal of integral land occupation and use (see also Boillat et al. 2013), 2) a relational rather than instrumental perspective on the landscape, as observed in other indigenous social-ecological contexts, such as the Rarámuri landscape in Northern Mexico (Wyndham 2009), 3) a cyclical perception of time and space, which expresses the cultural bonds to crop-fallow rotation and grazing cycle practices (Boillat 2007), and 4) a view that does not postulate a fundamental separation between nature and culture, as highlighted for many indigenous societies (Descola 2005).

These principles were also found in many statements expressed by people from Tirani and in the persistence of offering rituals, which still play an important role in the familial sphere. Many people from Tirani expressed the wish to maintain the bond with their territory while integrating new elements from external knowledge systems, like for example in their proposals to perform forest plantation management according to their own principles. This persistence might be linked to the fact that, as

[3] According to this study, in Tirani, of 29 school children aged 12 to 13, only five who belong to farming families had knowledge of weather forecasting indicators. In Chorojo, 15 of 19 children aged 8 to 14 had knowledge of such indicators.

observed in other regions of Bolivia (e.g. Stoian 2005), peri-urban people still rely partly on rural resources for their livelihoods, but also that livelihood changes have not compromised the essence and current relevance of their worldview. This second hypothesis supports the idea of culture as a “selective force” (Cocks 2006) through which political affirmation, and “cultural resilience” are evident in people’s efforts to establish coherence between realistic management practices and an ideal-typical imagination of their “own worldview,” even in the context of transformed livelihoods. Such ideological orientations might work in favor of maintaining local knowledge as shown by Mathez-Stiefel et al. (2012) with some aspects of indigenous medicine that are revalorized and reflexively maintained against the tentative hegemony of biomedicine as an external knowledge system.

The integrative approach to both cultural and biological diversity to compare two specific configurations like Chorojo and Tirani further highlighted the unexpected negative impacts of protected area enforcement. Unexpected and detrimental outcomes of protected areas have also been observed in other contexts (Adams and Hutton 2007, Almudi and Berkes 2010; Hoole and Berkes 2010). In our case, the TNP enforcement in Tirani led to a lower cultural and biological diversity linked with the division between unused and intensively used areas. This observation is in sharp contrast with the forest transition theory, which has seen the abandonment of rural areas and urbanization as an opportunity for conservation in Latin America (Aide and Ricardo Grau 2004). As stated by Perfecto et al. (2009), the forest transition theory tends to overlook cultural landscapes, in which the suppression of human activities does not necessarily have positive outcomes for biological diversity. Indeed, it has been shown that in such landscapes, rural livelihoods and biological diversity may be strongly linked (Persha et al. 2010). The abandonment of small-scale agriculture has direct consequences on the dynamic of entire habitats and ecosystems created by past and present traditional management techniques (Pretty 2007; Wieser and Lepofsky 2009). Studying biodiversity at ecosystem level proves to be especially useful to assess these links. Concepts like the “landscape footprint” (Killeen et al. 2008) and the “agroecological matrix” (Perfecto et al. 2009) may provide further insights to characterize the interactions between cultural and biological diversity.

The observed combined effect of park enforcement and urbanization also highlights the need to investigate further how both phenomena are related. Up to now, relatively little attention has been paid to the interaction between protected areas and urbanization, and focused mainly on the effects of urbanization on biodiversity and conservation values within protected areas (Tryzna 2007; McDonald et al. 2009). The case of the TNP is particular because it has been created as a measure to limit urban sprawl and protect the city of Cochabamba, thus can be considered a consequence of urbanization. As suggested by McDonald et al. (2009), the proximity of an urban center to a protected area might increase the value given to the area. However, as the case of Tirani showed, this might have unexpected consequences when both cultural and biological aspects are considered. We further suggest that the top-down approach of the TNP may be linked with its urban proximity because it represents a value to the emerging urban middle class, a social group that has often been overlooked in developing countries (Mawdsley et al. 2009).

Finally, our findings on the effects of a combined external factor on biological as well as on cultural diversity also contribute to the understanding of the dynamics of biocultural diversity. They support the hypothesis of historical determinism, described by Nabhan et al (2002) using the example of the Colorado Plateau, which postulates that biological as well as cultural diversity remain high in certain areas because they have remained at the margin of agricultural development (Nabhan et al. 2002), or because other factors such as urbanization combined with conservation have played a role, as in our case.

Conclusions

Our case study highlighted the effects of top-down protected area enforcement combined with urbanization processes on the diversity of ecosystems and on the different aspects of cultural bonds between people and their environment. It showed that measures that restrict the traditionally diversified use of natural resources can lead to “dual landscapes” which represent a simplification and fragmentation of an existing social-ecological system, and ultimately leads to a reduction of ecosystem diversity and use of local knowledge.

The concept of biocultural diversity provides a useful starting point to perform more integrative studies that take into account several aspects of culture like land use practices, local knowledge, institutions and worldviews in relation with biological diversity. To become operational, we propose that the concept must also be extended to assess cross-scale interactions. We observed that biocultural diversity is not fully under the control of local communities, and that factors generated at higher levels, such as the creation of protected areas, urban and agricultural development and migration policies affect the vigor of biocultural diversity. Their reach is however uneven, and economically “marginal” areas such as small-scale, rain-fed and highland cultivation areas may act as repositories of both biological and cultural diversity, but might also be threatened by out-migration of their residents. In this sense, traditional agricultural landscapes should be increasingly recognized as an important component of biocultural diversity (Cocks 2006; Pretty 2002).

The observed relative persistence of native worldviews in a changing social context may provide a starting point for actions aimed at enhancing biocultural diversity. These actions should focus on providing the higher-scale institutional and structural conditions for the material expression of these world views. This includes more participatory and integrative development approaches that allow striking a balance among the needs of culturally led development, nature conservation, urban development needs and the adjustments of political structures required to achieve such endeavors.

Acknowledgements

The research for the present study was conducted within the framework of the Swiss National Centre of Competence in Research (NCCR) North–South: Research Partnerships for Mitigating Syndromes of Global Change. The NCCR North-South is co-funded by the Swiss National Science Foundation (SNSF), the Swiss Agency for Development and Cooperation (SDC), and the participating institutions. Fieldwork was supported by the Swiss Commission for Research Partnerships with Developing Countries (KFPE). We wish to thank the communities of Chorojo and Tirani, especially (in alphabetical order) Epifanio Aguilar, Andrea Chacón, Aquino Heredia, Susana Heredia, Encarno Mayrana, Prudencio Mejía, Donato Mérida, Marcial Romero, Eliseo Vallejos, and Ignacio Vargas (†) for sharing their knowledge. Thanks are also due to AGRUCO’s director Freddy Delgado and the fieldwork team including Angel Aguilar, Miguel Chirveches, Jaime Delgadillo, Gilberto Lisperguer, Policarpio

Nina, Dora Ponce, Danny Salvatierra, and Elvira Serrano, as well as the National Herbarium “Martin Cardenas” staff of Cochabamba for their contribution to plant collection and identification. Ted Wachs and Anu Lannen (University of Bern) performed language editing. Finally, we thank Fikret Berkes and James Robson as well as two anonymous reviewers for their valuable comments on the paper.

References

Adams W, Hutton J (2007) **People, Parks and Poverty: Political Ecology and Biodiversity Conservation**. *Conservation and Society* 5:147-183

Aguilar AR (2006) **Tipología y caracterización sociocultural de los 10 municipios del Parque Nacional Tunari**. Undergraduate thesis, Universidad Mayor de San Simón, Cochabamba, Bolivia

Aide TM, Ricardo Grau H (2004) **Globalization, Migration, and Latin American Ecosystems**. *Science* 305:1915-1916

Almudi T, Berkes F (2010) **Barriers to empowerment: fighting eviction for conservation in a southern Brazilian protected area**. *Local Environment* 15(3):217-232

Berkes F (2011) **Restoring Unity. The Concept of Marine Social-Ecological Systems.** In: Ommer R, Perry I, Cochrane KL, Cury P (eds) World Fisheries: A Social-Ecological Analysis. Wiley-Blackwell, New York, pp. 9-28

Berkes F, Folke C (1998) **Linking social and ecological systems: Management practices and social mechanisms for building resilience.** Cambridge University Press, Cambridge, UK

Bisby FA et al. (1995) **Characterization of Biodiversity.** In: Heywood VH, Watson RT (eds) Global Biodiversity Assessment. UNEP/Cambridge University Press, Cambridge, pp. 21-106

Boillat S (2007) **Traditional Ecological Knowledge, Land Use and Ecosystem Diversity in the Tunari National Park (Bolivia). An ethnoecological approach to dialogue between traditional and scientific ecological knowledge.** PhD Thesis, University of Bern, Bern, Switzerland

Boillat S, Berkes F (2013) **Perception and interpretation of climate change among Quechua farmers of Bolivia: indigenous knowledge as a resource for adaptive capacity.** *Ecology and Society* [In press]

Boillat S, Rist S, Serrano E, Ponce D, Delgadillo J (2008) **Struggling ‘ontological communities’: transformations of conservationists’ and peasants’ discourses in the Tunari National Park in Bolivia.** In: Galvin M, Haller T (eds) People, Protected Areas and Global Change: Participatory Conservation in Latin America, Africa, Asia and Europe. Geographica Bernensia, Bern, pp. 37-80

Boillat S, Alca J, Alvarez A, Bottazzi P, Ponce D, Serrano E, Biffi V, Mathez-Stiefel SL, Larsen PB, Rist S (2010) **Protected Areas and Indigenous Peoples in Bolivia and Peru: Dilemmas, Conflicts, and Ways Out.** In: Hurni H, Wiesmann U (eds) Global Change and Sustainable Development: A Synthesis of Regional Experiences from Research Partnerships. Geographica Bernensia, Bern, pp. 501-515

Boillat S, Serrano E, Rist S, Berkes F (2013) **The importance of place names in the search for ecosystem-like concepts in indigenous societies: an example from the Bolivian Andes.** *Environmental Management* 51(3):663-678

Braun-Blanquet J (1964) **Pflanzensoziologie.** Springer, Wien, Austria

Chirveches M (2006) **Percepción campesina del clima y gestión de riesgo en la actividad agropecuaria en el Parque Nacional Tunari. El caso de las comunidades de Tirani (municipio de Cercado) y Chorojo (municipio de SipeSipe).** MSc dissertation, Universidad Mayor de San Simón, Cochabamba, Bolivia

Cocks M (2006) **Biocultural Diversity: Moving Beyond the Realm of 'Indigenous' and 'Local' People.** *Human Ecology* 34:185-200

Collard IF, Foley RA (2002) **Latitudinal patterns and environmental determinants of recent human cultural diversity: do humans follow biogeographical rules?** *Evolutionary Ecology Research* 4:371–383

Descola P (2005) **Par-délà nature et culture.** Gallimard, Paris, France

Estermann J (1998) **Filosofía Andina. Estudio intercultural de la sabiduría autóctona Andina.** 1. ed. Abya-Yala Editing, Quito, Ecuador

Finegan B, Palacios W, Zamora N, Delgado D (2001) **Ecosystem-level Forest Biodiversity and Sustainability Assessments for Forest Management.** In: Raison J, Brown A, Flinn D (eds) Criteria and indicators for Sustainable Forest Management. CABI International, New York, pp. 341-378

Fjeldsa J, Kessler M (1996) **Conserving the biological diversity of Polylepis woodlands of the highland of Perú and Bolivia.** NORDECO, Copenhagen, Denmark

Forman RTT (1995) **Land Mosaics. The Ecology of Landscapes and Regions.** Cambridge University Press, Cambridge, UK

Galvin M, Haller T (2008) **People, Protected Areas and Global Change: Participatory Conservation in Latin America, Africa, Asia and Europe.** Geographica Bernensia, Bern, Switzerland

Godoy R (1991) **The Evolution of Common-Field Agriculture in the Andes: A Hypothesis.** *Comparative Studies in Society and History* 33(2):395-414

Harmon D (2002) **In Light of Our Differences: How Diversity in Nature and Culture Makes Us Human.** Smithsonian Institution Scholarly Press, Washington D.C., USA

Hensen I (1993) **Vegetationsökologische Untersuchungen in Polylepis-Wäldern der Ostkordillere Boliviens.** PhD Thesis, Universität Göttingen, Göttingen, Germany

Hoole A, Berkes F (2010) **Breaking down fences: Recoupling social–ecological systems for biodiversity conservation in Namibia**. *Geoforum* 41:304-317

Instituto Nacional de Estadística de Bolivia (INE) (1992). **Censo Nacional de Población y Vivienda.** [http://www.ine.gob.bo/indice/poblacion92.aspx] Accessed 14 March 2013

Instituto Nacional de Estadística de Bolivia (INE) (2001). **Censo Nacional de Población y Vivienda.** [http://www.ine.gob.bo/comunitaria/comunitaria.aspx] Accessed 14 March 2013

Instituto Nacional de Estadística and United Nations Development Programme (2005) **Atlas estadístico de municipios 2005.** Plural Editores, La Paz, Bolivia

International Society of Ethnobiology (1988) **Declaration of Belem.** [http://www.ethnobiology.net/_common/docs/DeclarationofBelem.pdf] Accessed 14 January 2013

Killeen T, Guerra A, Calzada M, Correo L, Calderon V, Soria L, Quezada B, Steiniger MK (2008) **Total Historical Land-Use Change in Eastern Bolivia: Who, Where, When, and How Much?** *Ecology and Society* 13(1):36

Ledo García C (2009) **Urbanización y Pobreza en la ciudad de Cochabamba.** In: Wanderley F (ed) Estudios urbanos en la encrucijada de la interdisciplinaridad. CIDES-UMSA/Plural Editores, La Paz, pp. 117-150

Lepofsky D (2009) **The Past, Present and Future of Traditional Resource and Environmental Management.** *Journal of Ethnobiology* 29(2):161-166

Lertzman K (2009) **The Paradigm of Management, Management Systems, and Resource Stewardship.** *Journal of Ethnobiology* 29(2):339-358

Loh J, Harmon D (2005) **A global index of biocultural diversity.** *Ecological Indicators* 5(3):231-241

Maffi L (2005) **Linguistic, cultural, and biological diversity.** *Annual Review of Anthropology* 34:599-617

Maffi L, Woodley E (2010) **Biocultural Diversity Conservation: A Global Sourcebook.** Earthscan Publishers, London, UK

Mariscal JC, Rist S (1999) **Tipos de Relaciones Bosque-Comunidad y Normas Tradicionales de Uso y Acceso a la Vegetación Boscosa.** PROBONA, La Paz, Bolivia

Mathez-Stiefel SL, Boillat S, Rist S (2007) **Promoting the diversity of worldviews: an ontological approach to biocultural diversity.** In: Haverkort B, Rist S (eds) Endogenous Development and Bio-cultural Diversity. The interplay of worldviews, globalization and locality. ETC/COMPAS, Leusden, pp. 67-81

Mathez-Stiefel SL, Vandebroek I, Rist S (2012) **Can Andean medicine coexist with biomedical healthcare? Comparison between two rural communities in Peru and Bolivia.** *Journal of Ethnobiology and Ethnomedicine* 8:26

Mawdsley E, Mehra D, Beazley K (2009) **Nature Lovers, Picnickers and Bourgeois Environmentalism.** *Economic & Political Weekly* 44(11):49-59

McDonald RI, Forman RTT, Kareiva P, Neugarten R, Salzer D, Fisher J (2009). **Urban effects, distance, and protected areas in an urbanizing world.** *Landscape and Urban* Planning 93:63-75

Millennium Ecosystem Assessment (2005) **Ecosystems and Human Well-being: Synthesis.** Island Press, Washington D.C., USA

Moore JL, Manne L, Brooks T, Burgess ND, Davies R, Rahbek C, Willams P, Balmford A (2003) **The distribution of cultural and biological Diversity in Africa.** *Proceedings of the Royal Society B.* 269:1645-1653

Muller-Dombois D, Ellenberg H (1974) **Aims and Methods of Vegetation Ecology.** John Wiley & Sons, New York/London/Syndey/Toronto

Nabhan G, Pynes P, Joe T (2002) **Safeguarding Species, Languages, and Cultures in the Time of Diversity Loss: From the Colorado Plateau to Global Hotspots.** *Annals of the Missouri Botanical Garden* 89(2):164-175

Navarro G, Maldonado M (2002) **Geografía ecológica de Bolivia, vegetación y ambientes acuáticos.** Centro de Ecología Simón I. Patiño, Santa Cruz de la Sierra, Bolivia

Noss RF (1996) **Ecosystems as conservation targets.** *Trends in Ecology and Evolution* 11:351

Oviedo G, Maffi L, Larsen PB (2000) **Indigenous and Traditional Peoples of the World and Ecoregion Conservation. An integrated approach to conserving the world's biological and cultural diversity.** WWF-Terralingua, Gland, Switzerland

Perfecto I, Vandermeer J, Wright A (2009) **Nature's Matrix: Linking Agriculture, Conservation And Food Sovereignty**. Earthscan, London, UK

Persha L, Fischer H, Chhatre A, Agrawal A, Benson C (2010). **Biodiversity conservation and livelihoods in human-dominated landscapes: forest commons in South Asia.** *Biological conservation* 143:2918-2925

Pestalozzi HUA (1999) **Traditionelle Zelgenwirtschaft an der Obergrenze des Ackerbaus in den bolivianischen Anden (Dept. Cochabamba) und ihr Einfluss auf Vegetation und Nährstoffdynamik.** PhD Thesis, University of Bern, Bern, Switzerland

Platt T (1992) **The Sound of Light. Speech, Script and Metaphor in the Southern Andes.** In: Arze S (ed) Etnicidad, economía y simbolismo en los Andes. Hisbol-IFEA-SBH-ASOR, La Paz, pp. 439-466

Ponce D (2003) **Previsión del clima y recreación del conocimiento indígena en los Andes bolivianos. El caso de la comunidad de Chorojo, Prov. Quillacollo, Dep. Cochabamba.** MSc dissertation, Universidad Mayor de San Simón, Cochabamba, Bolivia

Posey DA (1999) **Introduction: culture and nature – the inextricable link.** In: Posey DA (ed) Cultural and Spiritual Values of Biodiversity. A Complementary Contribution to the Global Biodiversity Assessment. UNEP, Intermediate Technology Publications, London, pp. 1-18

Pretty J (2002) **Agri-culture: Reconnecting people, land and nature.** Earthscan, Oxford, UK

Pretty J (2007) **The earth only endures: On reconnecting with nature and our place in it.** Earthscan, Oxford, UK

Pretty J, Adams B, Berkes F, Ferreira de Athayde S, Dudley N, Hunn E, Maffi L, Milton K, Rapport D, Robbins P, Sterling E, Stolton S, Tsing A, Vintinner E, Pilgrim S (2009) **The Intersections of Biological Diversity and Cultural Diversity: Towards Integration.** *Conservation and Society* 7(2):100-112

Quinlan M (2005) **Considerations for collecting freelists in the field: examples from ethnobotany.** *Field Methods* 17(3):1-16

Rafiqpoor D, Ibisch P (2004) **The physical environment of Bolivia.** In: Ibisch P, Mérida G (eds) Biodiversity: The richness of Bolivia. State of knowledge and conservation. Editorial Fundacíon Amigos de la Naturaleza, Santa Cruz de la Sierra, pp. 4-45

Rist S, Dahdouh-Guebas F (2006) **Ethnosciences - A step towards the integration of scientific and indigenous forms of knowledge in the management of natural resources for the future.** *Environment, Development and Sustainability* 8(4):467-493

Robson JP, Berkes F (2011) **Exploring some of the myths of land use change: Can rural to urban migration drive declines in biodiversity?** *Global Environmental Change* 21:844-854

Rodriguez C (1994) **Sistema de pastoreo en la comunidad de Chorojo, Prov. Quillacollo, Dep. Cochabamba.** Undergraduate thesis, Universidad Mayor de San Simón, Cochabamba, Bolivia

Rozzi R, Massardo F, Anderson CB, Heidinger K, Silander JA Jr. (2006) **Ten Principles for Biocultural Conservation at the Southern Tip Americas: the Approach of the Omora Ethnobotanical Park.** *Ecology and Society* 11(1):43

Serrano E (2003) **Influencia de las Relaciones Sociales de Reciprocidad y Parentesco en la Reproducción de los Sistemas de Producción Indígenas para una Agricultura Sostenible. El caso de la Comunidad de Chorojo, Prov. Quillacollo, Dep. Cochambamba.** MSc dissertation, Universidad Mayor de San Simón, Cochabamba, Bolivia

Serrano E, Boillat S, Rist S (2006) **Incorporating Gender in Research on Indigenous Environmental Knowledge in the Tunari National Park in the Bolivian Andes.** In: Premchander S, Müller C (eds) Gender and Sustainable Development: Case Studies from NCCR North-South. Geographica Bernensia, Bern, pp. 305-327

Smith EA (2001) **On the coevolution of cultural, linguistic and biological diversity.** In: Maffi L (ed) On biocultural Diversity, linking language, knowledge and the environment. Smithsonian Institution Press, Washington D.C., pp. 95-117

Stoian D (2005) **Making the Best of Two Worlds: Rural and Peri-Urban Livelihood Options Sustained by Nontimber Forest Products from the Bolivian Amazon.** *World Development* 33(9):1473-1490

Strauss AL, Corbin JM (1998) **Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory**. Sage, Los Angeles, USA

Torri MC (2011) **Conservation, Relocation and the Social Consequences of Conservation Policies in Protected Areas: Case Study of the Sariska Tiger Reserve, India.** *Conservation and Society* 9(1):54-64

Tryzna T (2007) **Global urbanization and protected areas.** California Institute of Public Affairs, Sacramento, USA

Van den Berg H (1990) **La Tierra no da así nomás. Los ritos agrícolas en la religión de los aymara-cristianos.** Hisbol, La Paz, Bolivia

Wachtel N (1981) **Los Mitimaes del Valle de Cochabamba: la Política de Colonización de Wayna Capac**. *Historia Boliviana* 1(1). Cochabamba, Bolivia

Wieser A, Lepofsky D (2009) **Ancient Land Use and Management of Ebey's Prairie, Whidbey Island, Washington.** *Journal of Ethnobiology* 29(2):184-212

Wildi O, Orloci L (1996) **Numerical exploration of community patterns. A guide to the use of MULVA-5.** SPB Academic Publishing, The Hague, Netherlands

World Health Organization (2001) **World Medical Association Declaration of Helsinki. Ethical Principles for Medical Research Involving Human Subjects**. *Bulletin of the World Health Organization* 79:4

Wyndham FS (2009) **Spheres of Relations, Lines of Interaction: Subtle Ecologies of the Rarámuri Landscape in Northern Mexico.** *Journal of Ethnobiology* 29(2):271-295

Zent S (2009) **Traditional Ecological Knowledge (TEK) and Biocultural Diversity: A Close-up Look at Linkages, Delearning Trends & Changing Patterns of Transmission.** In: Bates P, Chiba M, Kube S, Nakashima D (eds) Learning and Knowing in Indigenous Societies Today. UNESCO, Paris, pp. 39-58

Zimmerer K (1993) **Soil Erosion and Labor Shortages in the Andes With Special Reference to Bolivia, 1953-1991: Implications for "Conservation-With Development".** *World Development* 21(10):1659-75