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ORIGINAL ARTICLE

Development, local livelihoods, and vulnerabilities to global environmental change in the South American Dry Andes

Elma Montaña[1] · **Harry Polo Diaz**[2] · **Margot Hurlbert**[3,4]

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Abstract Climate change will increasingly impact large areas of South America, affecting important natural resources and people's livelihoods. These impacts will make rural people disproportionately more vulnerable, given their dependency on ecosystem services and their exposure to other stressors, such as new rules imposed by agribusiness and trends toward the commodification of natural resources. This paper focuses on the vulnerability of rural communities in Andean drylands of Argentina, Bolivia, and Chile, showing how different economic and political pathways lead to different levels of vulnerability. The paper begins with a brief discussion of the methodological and theoretical concept of vulnerability, which framed the research. Starting from the premise that global environmental change impacts are strongly linked to styles of development, the discussion explores the diverse institutional capital and governance schemes as well as different development styles in the case studies and their role in increasing or reducing local vulnerability to climate and water scarcity. Using a comparative perspective, the exposures and adaptive capacities of rural actors in three river basins are discussed, emphasizing situations that speak for the ways in which development styles counteract or magnify conditions of vulnerability. The analysis considers irrigated and non-irrigated agriculture, water property interests, different productive structures (viticulture, horticulture, etc.), producer typologies (large/small, export, etc.), and geographical location. Finally, the paper offers some insights about development style and adaptive capacities of rural people to overcome those vulnerabilities.

Keywords Global environmental change · Vulnerability · Development styles · South America · Andes · Drylands

✉ Elma Montaña
elmamontana@gmail.com; emontana@dir.iai.int

Harry Polo Diaz
harry.diaz@uregina.ca

Margot Hurlbert
Margot.Hurlbert@uregina.ca

[1] Science Programs, Inter-American Institute for Global Change Research, Av. Italia 6201. LATU, Ed. Los Tilos, Of.102/103, CP 11500 Montevideo, Uruguay

[2] Sociology, University of Regina, 3737 Wascana Parkway, Regina, SK S4S 0A2, Canada

[3] Sociology and Justice Studies, University of Regina, 3737 Wascana Parkway, Regina, SK S4S 0A2, Canada

[4] Governance and Inclusive Development, Amsterdam Institute for Social Science Research, University of Amsterdam, Amsterdam, The Netherlands

Introduction

The Latin America chapter of the Intergovernmental Panel on Climate Change (IPCC) (Magrin et al. 2014) indicates that changes in precipitation and temperature have already been observed in South America, as well as a number on unusual extreme climate events. These changes are projected to continue in the future. Water scarcity is one of these expected impacts, especially in areas that are already facing increasing aridity. The IPCC expects that by 2020, several million people in the central and southern Andes of South America will experience water stress due to climate change, and face critical problems with drinking water supply and sanitation (Magrin et al. 2007; see also WGCCD 2006), mainly as a result of a reduction in existing glaciers, snowpack, and precipitation, as well as

seasonal changes in streamflows. The livelihoods of many poor rural people will be disproportionately affected, given their dependency on natural resources and the extent to which they are already exposed to other stressors, such as globalization and restricted fiscal policies. The IPCC 2014 Report calls for a reduction in the vulnerability to present climate to reduce this social deficit and improve future resilience of rural people, calling our attention to the role that non-climatic factors and uneven development processes play in the determination of differences in people's vulnerability to climate (Magrin et al. 2014; IPCC 2014a). There is an increasing need for an appropriate understanding of existing climate vulnerabilities and adaptive capacities of local rural populations that addresses both climatic and social systems in the context of global change (O'Brien 2013). Expanding our knowledge about present and past climate impacts and vulnerabilities is essential not only for an effective management of present risks but also for the development of adaptive capacities able to deal with the future challenges of climate change and sustainability.

This paper examines and compares the vulnerabilities of rural actors in three Andean watersheds: Mendoza in Western Argentina, Pucara in Cochabamba, Bolivia, and Elqui in the Coquimbo Region, Chile (Fig. 1). All these watersheds are part of the Dry Andes, an area characterized by semiarid conditions, seasonal precipitation, and where water streams are essential to agricultural production. Expected impacts in the dryland Andean basins such as increasing temperatures (especially in the highlands), melting glaciers, reduced snowcover, river streamflow reductions, and extreme events such as droughts constitute serious problems in areas where a dynamic agriculture is only possible through irrigation and where groundwater is used as a reserve to cover for deficits. Adding to these potential impacts of climate change, water demands (agricultural, human, mining, and others) are expected to continue rising. The Andes are a diverse and complex region where geomorphology, climate, soils, water availability, and especially altitudinal zonation determine local variations, but in all three dryland basins, hydroclimatology contributes to the vulnerability of rural communities. The basins also share other vulnerability-creating mechanisms prevalent in drylands, which determine sensitivity and ability to cope with or adapt to changes (Sietz et al. 2011). Poverty production mechanisms are present (Montaña 2012), as outcomes and drivers of vulnerability. Frequently related to poverty-induced practices, soil degradation is also observed, especially in the lowlands, adding to the natural agroconstraints present in the basins.

The watersheds differ in terms of their development styles and economic and political institutional systems. These differences add some degree of complexity but also

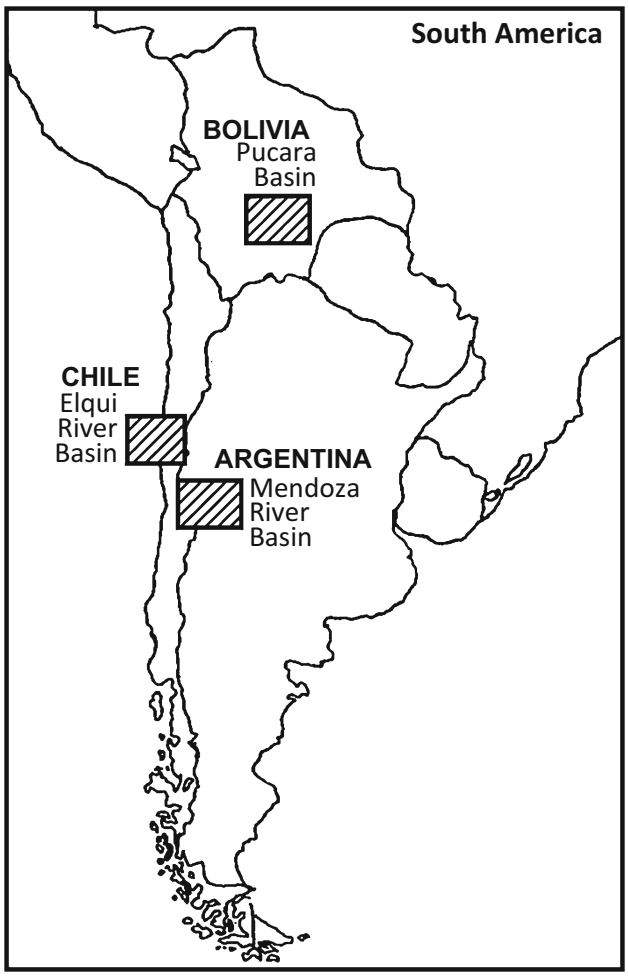

Fig. 1 Three Andean basins

the possibility to isolate the social components of these complex natural social couplings that characterize the regions. This paper focuses on the role of existing styles of development in shaping climate vulnerabilities, an issue that emerges from our reflection on the results of our research. The paper begins with a brief discussion of the concept of vulnerability, which framed the methodological and theoretical approach. A brief description of the three basins follows, with special consideration given to rural actors and the climate and productive conditions that they face. The next section focuses on a comparison of the different styles of development that prevail in the three regions. This is followed by a discussion of the sensitivities and adaptive capacities of rural actors in the three basins, emphasizing the ways in which development styles counteract or magnify conditions of vulnerability. Finally, the paper offers some insights about the importance of development choices and the role of institutional conditions (of which water governance is a key component) in determining the adaptive capacities of local people.

Theoretical framework and the literature review

Vulnerability to climate, in this definition, is a function of the exposure/sensitivity and the capacity of a community to adapt to climate stress (Liverman 1994; Wisner et al. 2004; Handmer et al. 1999) and is the degree to which a system (such as a rural community or a farm) is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes (IPCC 2001; Adger 2006; Füssel and Klein 2006; Fritzsche et al. 2014; Polsky and Eakin 2011). Exposure, in this context, refers to the character, magnitude, and rate of change and variation in the climate (Fritzsche et al. 2014). Exposure, however, is not limited to climate but also to other general processes—economic, social, and political—that have the capacity to generate risks to the community. Sensitivity and adaptive capacity are characteristics of the social system that is exposed to climate and other stimuli. Sensitivities refer to the interaction with both the characteristics of the system and a stimulus. They reflect the manner in which a system is adversely or beneficially affected by climate conditions to which it is exposed (Smit and Wandel 2006; IPCC 2001) and they are shaped by the attributes of the system, which include multiple social conditions. An example is differentiated access to water resources. The actions taken to adjust to climate events in order to reduce risks and capitalize on opportunities are considered adaptive strategies. The system's ability to employ a variety of adaptive strategies reflects its adaptive capacity. In this context, the most vulnerable systems are those most likely to be exposed to climate change impacts and are more sensitive to perturbation, with a limited capacity for adaptation (Adger and Kelly 1999).

In this context, the vulnerability of a rural community or a farm is not a function of climate alone, but rather it is the result of the access and control by social actors of a multiplicity of social, economic, and political resources, as well as of access to the natural capital defined by the existing environmental conditions of the locality, such as topography, quantity and quality of water resources, and quality of soil. These multiple resources (listed on the right side of Fig. 2) are not only interlaced with the dynamics of community vulnerability and the consequent development of adaptive strategies to reduce vulnerability (Smit and Wandel 2006) but also link local vulnerabilities with the power structures that characterize the specific style of development of the country. The model in Fig. 2 guided the research approach, including the configuration of the interviews and their coding and analysis, facilitating the comparison among the different cases within each basin and among the countries.

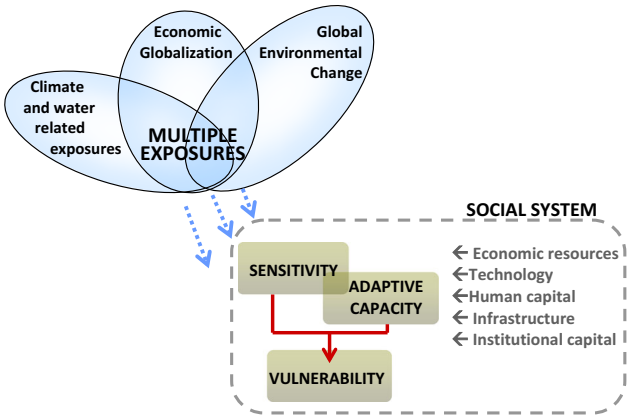

Fig. 2 Vulnerability to global environmental change

In these terms, local vulnerabilities are built around the confluence of a multiplicity of exposures. Leichenko and O'Brien (2008) label this *double exposures* resulting from the synergisms between the impacts of climate change and economic globalization, as well as other structural conditions such as policies.

Determinants of adaptive capacity are defined as resources that "influence the occurrence and nature of adaptation and thereby circumscribe the vulnerability of systems and their residual impacts" (IPCC 2001) and include the existence of economic resources, technology, information and skills (including human capital), infrastructure, equitable social relations, and well-developed institutions such as government bodies. A limited access or the improper capacity to manage them will contribute to increasing the sensitivity of the actor.

The IPCC considers that established institutional conditions, such as the existence and availability of insurance mechanisms or water conservation programs, facilitate the management of climate-related risks reinforcing the adaptive capacity of the population (IPCC 2001). Formal and informal institutions coexist and interact. Regional and local governments, religious organizations, and forms of social capital such as networks for mutual support become structured into complex sets of relationships that contribute or disrupt the stability, viability, and, in our case, the adaptive capacity of rural people (Adger 2003; Halpern 2005; Dale and Onyx 2005). As well, rural localities, like any other locality, function within larger institutional political systems of governance, which link them with the development style that characterizes the larger society. Governance, which is central to adaptive capacity given its mandates, permanency, social acceptance, and legal basis, pervades the lives of the community members by imposing a body of regulations, rules, processes, and resources on communities. It refers to the patterns by which public

power is exercised in a given context (Jenkins 2002), and accordingly, it is an expression of a style of development. Relevant to our research approach, water governance is a key component of the rural agricultural producer case studies and important for reducing vulnerability of rural agricultural producers and their communities (Diaz et al. 2012). Water governance assumes a diversity of forms, ranging from a highly centralized system to one that encompasses a diversity of public and non-public organizations (Hurlbert et al. 2009a, b). This emphasis on governance informs our discussion of the role that formal institutions play in influencing vulnerability to climate and climate-related water stress of the rural population.

We have emphasized the idea of style of development as an important aspect that shapes the prevailing modality of governance or institutional capital. *Style of development* is defined as the specific ways in which human and material resources are organized and assigned within a particular system with the object of solving such questions as what goods and services to produce, how, and for whom (Pinto 2008). These ways of organizing the assets of a society define the organizational distributional parameters in which the resources listed in Fig. 2—the determinants of adaptive capacity—are found in a region and its localities, conditioning the choice of possible adaptation strategies. Following the arguments from Wisner et al. (2004), styles of development are part of the root causes that shape governance and its impacts of local people. The forms assumed by capitalism in Argentina, Bolivia, and Chile are different styles of development, with distinct emphases on the distribution of roles, responsibilities, and resources.

Rural vulnerability in the Andes is a field to be further developed. The Latin America chapters of the IPCC reports (Magrin et al. 2014) remain key references in the field. Most literature refers to the tropical Andes (Stadel 2008, 2009; Carrascal et al. 2012) and the Colombian *paramos* (Angel and Sandino 2010) and focuses on national actions or policies (Buenfil 2013; DAPA-CIAT 2013; González et al. 2011; Jarvis et al. 2010; Lampis 2012; Mendoza Vereau 2012). Postigo et al. (2012) analyze the vulnerability of small Tropical Andean producers focusing on the links between climate change and productive systems, while social processes are introduced secondarily. Feola et al. (2014) adopt the multiple exposures framework to examine the ways in which economic and governance stressors such as trade liberalization and violent conflict add to climate change in impacting Colombian agriculture, drawing the attention on the interplay among these issues. Sietz et al. (2012) studied the case of the Peruvian Altiplano, relevant to the Pucara basin case because of the existence of ancient cultures that evolved based on a sophisticated management of natural resources, but whose current inhabitants are poor and rely on overused water resources, frequently in combination with degraded soils. They examined smallholders' vulnerability to weather extremes with regard to food security at the household level, informing on the consequences of resource scarcity, diversification of activities, and income restrictions. Risks to food security linked to traditional crops due to market pressures associated with globalization are analyzed by Hellin and Higman (2005) for Bolivia, Peru, and Ecuador. Especially scarce are comparative case studies. This paper addresses this gap in knowledge.

Methodology

The article is based on three research projects carried out in these regions between 2004 and 2012. The first project was an SSHRC (Social Science Research Council of Canada) funded collaborative project between Canadian and Chilean researchers focused on institutional adaptations to climate change in the context of semiarid watersheds (see Diaz et al. 2009; Cepeda et al. 2009; Fiebig-Wittmaack et al. 2009). The second project—a comparative two-year interdisciplinary effort funded by the Inter-American Institute for Global Change Research (IAI)[1]—sought to identify and characterize the vulnerabilities of rural actors to climate variability and climate-induced water problems in the basins of the Mendoza, Choquecota, and Elqui rivers (see Salas et al. 2012; McDowell and Hess 2012; Diaz et al. 2012; Montaña 2008). The last project, carried out by Dr. Montaña with funding from CLACSO-CROP (Comparative Research on Poverty program, supported by the ISSC and the University of Bergen), was focused on the links between poverty and climate vulnerability in the three study areas (Montaña 2012, 2013).

All these projects focused on present and past vulnerabilities to climate to understand adaptive gaps in the context of regional climate change scenarios and involved mixed methodological designs. Climatic exposures at the regional level were appraised based on the IPCC (IPCC 2007, 2014b, c; Parry et al. 2007; Bates et al. 2008), PNCC (2007, 2009), the Geophysics Department of the University of Chile (www.dgf.uchile.cl/ACT19/html/bases.html), OXFAM (2009a, b), Quiroga et al. (2008), Villalba and Boninsegna (2009), and Masiokas et al. (2008). In these projects, the local effects of climate exposures were explored through qualitative vulnerability assessments. Two hundred and fifteen interviews were conducted in the three basins between 2004 and 2012: 55 in the Argentinean basin, 27 in Bolivia, and 133 in Chile. Exploratory qualitative interviews to key informants were followed by semistructured interviews applied to agricultural producers

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(70 % of interviews aprox.) and representatives of different governance organizations (30 % of interviews). Representative samples of local producers were selected using as criteria the typology of producers (from peasants to capitalized units), the type of agricultural activity (livestock or agriculture, and viticulture or vegetable crops within agriculture), as well as of their upstream/downstream position in the basin. Governance representatives were selected from a number of organizations relevant to the study (productive sectors and agriculture, environment, water) and operating at different levels (local, subnational, and national). Our research questions explored the climate vulnerability of the producers, the role of other stressors in shaping local vulnerabilities, and the role of governance in the reduction of vulnerability. Qualitative data were coded according to categories associated with the concepts of vulnerability and adaptive capacity (Fig. 2 below) and analyzed with the help of NVivo software.

The watersheds

The three watersheds are mainly agricultural regions (although the Mendoza and the Elqui basins have a more complex economic base where mining, industry, and services complement a very dynamic agricultural industry). They share, however, a long-standing coexistence with water scarcity that has informed social structures along with the deliberate management of water, shaping nature-society regional systems that can be identified as *hydraulic societies* (Worster 1985).

In Chile and Argentina, agriculture is only possible through irrigation and the existence of dams. Grape-growing accounts for about half of the cultivated area of the Mendoza river basin, followed by horticulture (23 %) (CNA Argentine National Census 2002). Agriculture in the basin is highly integrated with the industrial sector since 99 % of grape production is destined for winemaking. Twenty-three thousand irrigators in the basin account for 89 % of surface water use (DGI General Department of Irrigation 2007). In the basin, only 45 % of the farmers irrigate with surface water; 27 % irrigate with groundwater only (CNA 2002), and 28 % use both surface water and groundwater. In the non-irrigated downstream basin area, the rest of the agricultural sector consists largely of goat husbandry performed by *puesteros* (peasant families)—mostly of indigenous origin—and always lacking formal water rights.

In Chile, water drawn from the Elqui river and two dams makes agriculture possible. There are three main economic activities: agriculture (within the irrigated area), mining, and tourism. The main crops are fruit trees (citrus, avocado, papaya, and cherimoya), which account for 39 % of the irrigated area (Young et al. 2010). Vegetables, which rank second in cultivated area (29 % of the total surface), are grown in the lowlands of the basin, where water is also obtained from springs near the city of La Serena. Pulse and root vegetables rank third in area (13 %), followed by vines and vine arbors, which account for almost 10 % of the total (Dattwyler Cancino 2008). Table and wine grape vineyards (mainly for the production of *pisco*, a type of brandy) in the upper reaches of the valley are highly profitable for capitalized firms. Mining competes for water and labor but is located up in the mountains. Just as in Argentina, the only ranching in the Elqui river basin is goat breeding by small-scale subsistence farmers (*crianceros*) in the non-irrigated areas of the basin.

Finally, the Pucara Basin is located in the department of Cochabamba, in the geographical center of Bolivia, and agriculture is also dependent on irrigation and the existence of dams. There is a relative homogeneity in the typology of producers, especially when compared to Argentina and Chile. In the three Pucara areas studied, there are diversified smallholders growing the mix of crops that better fits their location (Sevenhuijsen et al. 1988; Ampuero 2007; Ampuero and Salazar 2009; Saldías et al. 2014). In the highlands of K'aspi kancha, most agricultural production is oriented toward Andean root vegetables, mainly potato, and broadbeans, both of them for self-consumption and sale. Most households raise animals: oxen for ploughing (tractors are rare), some horses, pigs, poultry, or other farm animals that are either integrated into agricultural production or that supplement the family diet. At a lower altitude, in Huaña kahua, the main economic activities are agricultural production (fruit trees—mainly peach—corn, and various vegetables) and artisanal activities (mostly *chicha* production) complemented with jobs in construction and services. In the south of Municipio de Punata, Chirusi, the third area under study in Bolivia, the main agricultural activities are agriculture (corn, both for seed and self-consumption) and small-scale dairy farming associated with the growing of alfalfa as cattle fodder.

In contrast to the Argentinean and Chilean cases, the rural life in the Punata watershed is mostly based in informal institutions and relies in community-based decision-making systems in which the state is a very marginal actor. Community social organization is strong, and so are family bonds. The nuclear family, the extended family, and family associations also play a role in the organization of production. Family bonds and contribution to household support is a long tradition in the region, and they are maintained even by those who have emigrated. Salaried work is rare; the concept of *ayni*, however, remains strong. *Ayni* is a system of reciprocity, mutual work or assistance between two or more families in sowing, harvesting, home building, and even in exchanging water turns (Zamora 2012).

Governance and styles of development

Local dynamics developed in the context of three very different styles of development express themselves in distinctive governance schemes impacting the adaptive capacity of the producers. Chile is a country with a clearly stratified society in which a neoliberal economic policy inspired in economic liberalization, privatization, fiscal austerity, deregulation, agent's competition, and free trade favors a primary export-oriented economy ruled by competition (Carruthers 2001). In Chile, social actors are valued according to their success in the formal economy. The water market is an example of a common good turned into a commodity. In addition to the market rules, the decision-making system is quite centralized in the formal federal administration and based on economic and technical rationales (Hurlbert and Diaz 2013).

The Argentine model is a special case. Animated by principles of equality of opportunity and equitable distribution of wealth, the Argentinean state takes responsibility for those unable to avail themselves of the minimal provisions for well-being and plays an active role in the protection of vulnerable groups (Cortes and Kessler 2006; Barrientos and Hinojosa-Valencia 2009). However, owing money to international funding agencies and always with more expenses than incomes, the state fulfills that role partially, often addressing the most serious situations by welfare interventions not integrated into a planning scheme. It is a welfare state providing assistance to vulnerable people, but with very little resources; these pervasive but weak formal institutions are always overwhelmed by demands. Prioritization is always an issue of political nature, and rules and criterion for decision making are neither always explicit nor consistent with practices. It is a volatile and not always transparent system that has subsidized the weaker social and economic players.

These schemes impact the situation of the most vulnerable actors facing the challenges of climate and water. For instance, only a few Chilean *crianceros* (goat ranchers), practically with little access to water, are able to maintain their small orchards. It is an aging population that needs external contributions to survive (Salas et al. 2012). These goat producers are almost the only subsistence producers in the Elqui Basin since the competitive Chilean economy has expelled most of the weaker farmers and smallholders, with the exemption of some small-scale agricultural producers engaged in horticulture near the city of La Serena or spread in the most marginal areas of the basin. In contrast, the subsistence of the Argentinean goat breeders in dry years is facilitated by water tankers provided by the local government, which contribute to mitigate emergency situations. Recently, a small aqueduct was built to provide a minimum endowment of water.

While the Argentinean state has been more protective of those small farmers increasingly cornered by the advances of agribusiness, the neoliberal Chilean system has been harsh. The capitalized sector has been monopolized by export companies using a strict business logic. There are almost no smallholders integrated into the more dynamic agricultural circuits: as producers, they have been expelled from this sector by the big players under the strict rules of competition and reintegrated as labor force (Berdegué and Fuentealba 2011). As one fruit exporter put it, "They can't meet our quality standards and to teach them would be complicated and expensive. We prefer to do it ourselves." (Montaña, fieldwork 2012). The styles of development of Argentina and Chile are aligned with traditional concepts of development which favor economic growth and integration of economic sectors into a global marketplace. The Chilean case is more structured and technocratic and the Argentinean more unpredictable and fractious. In both, ecosystem conservation objectives are mostly sacrificed in favor of economic development, conceived in terms of plain economic performance.

The situation is quite different in Bolivia, where indigenous roots are much stronger and customary institutions and laws are in force in parallel with modern institutional arrangements (Berg and Vargas 2009; Hoffmann 2005; Garrigue 2004). The election of Evo Morales, the *cocalero* activist from indigenous roots, as president in 2005 legitimized the indigenous worldview into formal power. The Bolivian *Constitución Política del Estado* (State of Bolivia 2009, Articles 306 and 311) adopts the plural economy as a balance between an economy of development and the traditional communitarian economy. The official Bolivian policies have formally adopted the premises of the good living (*buen vivir* in Spanish) setting aside the restricted visions of development exclusively based on economic growth and proposing an alternative model in which humans must embrace being an integral part of nature. This worldview includes the right to not develop (Agostino 2004) and the right to difference (Merkel 1998), a development pathway closer to sustainability objectives. This model works best at the local levels and not so well in macroscales, where tensions between community-based traditional decision making and the forces of the globalized economy coexist in official decision making, not without contradictions (Mansilla et al. 2014).

These three different styles of development have shaped processes of differentiation among agricultural producers. The Bolivian basin is characterized by a high degree of homogeneity among producers, which is the result of the predominance of an ethnic culture where community—as

an institutional form—is central to the lives of the producers. The cases of Argentina and Chile, in opposition, represent a process of modernization characterized by an increasing bipolar process of differentiation of the agricultural units: on one side, modern, large units that orient their production to highly profitable crops and, on the other hand, a precarious, marginal agriculture characterized by small units of production.

There are also significant differences among the institutional systems that exist in the three countries. In comparison with the other two countries, Bolivia is perhaps the weakest in terms of the presence of its public institutional system in the rural areas. Few central government institutions are active in these areas, and municipal governments lack the technical and institutional capacity to provide substantive assistance to agricultural producers. There are also some differences between Chile and Argentina. While Argentina is a federal country in which provincial public organizations have some degree of autonomy from the central government, Chile is characterized by a centralized government and by regional institutions dependent on a central decision-making government. Despite this difference, both countries have more developed and established institutional systems than Bolivia, with strong presence at the level of the basin. In both cases, water governance institutions have played a strong role in shaping the existing adaptive capacity in the basins, although with some limitations. Table 1 summarizes shared characteristics as well as differential situations.

Results and discussion

The case studies provide a differentiated perspective on vulnerability as the result of a complex interplay of a variety of factors, including the incidence of the development styles—and of governance schemes in particular—in the adaptive capacity of different productive actors. This section provides those projects' results that highlight the impacts of the styles of development (within the context of institutional capital and governance) on the vulnerability of agricultural producers. The findings relate to irrigated and non-irrigated agriculture, water property interests, different productive structures (viticulture, horticulture) and producer typologies (large/small, export, etc.), and geographical location within the basin. A discussion of how these styles impact vulnerability follows.

Producers from the irrigated lands in the three basins studied proved to be sensitive to reduced snow precipitation in the Andes headwaters and diminishing river runoffs, as they displayed different sensitivities than those of the non-irrigated drylands (goat husbandry production). Lacking social power, excluded from the formal water governance system, non-irrigated land producers were extremely sensitive to diminishing rainfall. Reduced precipitation in the foothills deepened the desertification processes already occurring, putting rural people at their livelihood survival limits. Horticultural producers had adaptive advantage in their ability to change annually the choice or location of crops. Most common in the Bolivian basin, polyculture

Table 1 Shared biophysical characteristics and differences in social, political, and institutional factors

	Mendoza river basin Mendoza, Argentina	Elqui river basin Coquimbo, Chile	Pucara river basin Cochabamba, Bolivia
Physical characteristics	Semiaridity/aridity. Altitudinal zonation. Nivo-glacial regime rivers		
Expected climatic changes	Climate extremes. More severe droughts. Increasing temperatures		
Water availability	Water scarcity—regulated surface waters—partial access to groundwater		
	Gradual depletion of water sources, groundwater overexploitation/pollution		
Agriculture	Export agriculture	Export agriculture	Prevalence of multifunctional traditional small farms most of them fitting the peasant profile
	Small traditional farmers	Small traditional farmers	
	Desert goat breeders	Desert goat breeders	
		Mining	
Water governance	Democratic distribution of surface water (just among holders of water rights)	Water market	Water management tied to community social organization
Institutional arrangements	Overlapping/disconnected formal institutions	Structured/organized and centralized formal institutions	Customary laws. Social/family networks and strategies based on relations of reciprocity
Political system	Welfare state supporting poor	Economic growth and trade liberalization paradigm	Indigenous power in formal institutions

showed less sensitivity, especially when annual and perennial crops were combined.

Characteristics of producers

The impact of a particular climatic exposure varied according to the organization of the agricultural subsector in which the producer participates, and the relative position he holds within that structure. In the Argentinean and Chilean cases, horticulture was an atomized agricultural sector formed by a great number of small and heterogeneous producers, mostly integrated into a semiformal economy producing for regional urban centers. The complicated and unstable decision-making process faced by horticultural farmers did not encourage big investments for reducing exposures. The migratory dynamics of producers, the interannual variability of market prices, and activities developed within the informal economy without state regulation or protection created barriers for (formal) institutional measures for vulnerability reduction. In contrast, dynamic agriculture of viticulture and fruticulture showed a strong participation in the agribusiness system, with horizontal and vertical integration and regulations set by formal institutional arrangements (Hill 2013). Adaptive measures for this last sector could be fostered not only with the direct support from the state but also by the existing farmers' organizations that bring together these producers and facilitate access to technical advice and financial resources and support in marketing and commercial activities that are fundamental for adaptive capacity. But as integrated and organized as this productive structure of viticulture and fruticulture production is in both the Argentinean and Chilean cases, the farmers' universe was quite polarized between producers that participate in the industrial chain of the commercial circuits (winemaking, canned fruit, or vegetables) and directly involved in the export circuits, and those small and medium farmers whose weak participation in the chain put them in a subordinate position (Salas et al. 2012; Hill 2013).

The research showed that the position of producers within farmer's typologies (big/small, capital intensive/traditional, export/domestic, or any other dual power categories) influenced directly their degree of vulnerability, from the marginal goat husbandry producer to the highly integrated agricultural producer which was channeled through water governance practices. For instance, the economic wealth of large farmers allowed them to overcome reduced surface water allocations by pumping from aquifers. In the context of the loosely regulated groundwater management of the Argentinean basin, they could even become independent from the democratic but tedious water governance rules and the control of water users' organizations. They could just pump whenever it is required according to their irrigation needs, obtaining water volumes only restricted by affordable (and subsidized) energy prices. In the same way, they were in a better position to adopt other vulnerability-reducing measures. These measures included actions such as pressurized irrigation (for more efficient water use) and hail net protection. Unlike the more disadvantaged farmers, they could move to a better location, an adaptive strategy of horticulture farmers renting the land for their annual crops that was being adopted by large winemakers, who buy land and build wineries in upstream foothill locations.

The situation was different in the Pucara basin, as there was less social and economic distance between large and small producers and production tended to be more diversified (Ton et al. 2007). Local productive chains were interconnected. The reduced presence of the state translated into greater flexibility. The community-based decision-making system benefited from centuries of indigenous adaptive learning, which included decisions related to climate variability and change: what crops to choose, how to balance subsistence crops with cash crops, how to combine double or multiple crops, when to plant, when to harvest, etc. The shortcoming, however, was the limited capacity to organize the water resources at the level of the basin. When water was scarce, communities of large basins found it more difficult to agree on how to share scarcity, making the downstream farmers—farther from water sources—more vulnerable.

Geographic location

Vulnerability was also linked to location within the basin. In the Argentinean and Chilean cases, the more successful agricultural farmers (especially those integrated to the industry or export chain) gradually climbed the foothills to settle in the upper lands, looking for lower temperatures, proximity to water sources, better water quality, and less pollution, and in some cases a better standard of water rights (less likely to be cut back in a drought situation). The process pushed the agricultural border upstream by means of groundwater pumping. These were capital-intensive properties relatively protected against climate and water risks. The higher elevation the agricultural border reached, the greater and easier was the access to the benefits of irrigation, and the worst the quality of soil and water at the tail end of the irrigation schemes, as Chambuleyron studied for the Argentinean case (2002). So those farmers without the resources to afford these prime geographical locations had to resign themselves to the less attractive locations, which add to fewer resources to reduce their exposure. This last group of producers was in greater need of institutional support to cope with the expected effects of global environmental change, a support that was not easy to obtain as

they were trapped in a spiral of agroecological degradation and poverty.

In the case of the Pucara basin, access to land and water was more closely linked to community and family networks, and the socio-spatial segregation of farmers is much lower than the Argentinean and Chilean cases. In the Pucara Basin, during periods of water scarcity, communities downstream have to agree water allocation and schedules with upstream communities. However, as the mismatch between supply and demand intensified in the Pucara Basin during periods of water scarcity, water tended to "be territorialized" as the locals say (Montaña, fieldwork 2012), meaning that those who lived at the beginning of the basin became increasingly reluctant to share it with irrigators downstream.

Water governance

The various water governance schemes determined differences in vulnerabilities. In Chile, the private water right created by the Water Code favored water use efficiency since the irrigator could derive benefits from market exchanges of surplus water. Though the water market was—at a basin level—an incentive for an efficient water use, an analysis at the level of the actors showed that it is a very competitive mechanism in which water rights were concentrated in the hands of the more powerful producers which made small-scale producers more vulnerable to water scarcities. The water market complemented both the land and the labor markets, combining asymmetrical powers that turned against the interests of small farmers and peasants, and forced them to search for other sources of income (Salas et al. 2011a, b). Even the capitalized, dynamic export agriculture sector found it difficult to compete with mining in accessing water and labor resources (Montaña 2012). In the Chilean economic development and trade liberalization style, the economically powerful were able to take advantage of this system, aggravating climate and water vulnerabilities for the poor who were without state support.

Water distribution in Mendoza was quite the opposite: Irrigation water supply was proportional to the land area (regardless of the type of crop), and water was inherent to the land, so it could not be used in other farms. This system prevented a more efficient water use in the sense that the supply hardly matched the real demand. Some farmers needed more water, and other farmers had surplus water, but there was no way to balance these differences within the existing law (Diaz and Bertranou 2004). In this context, it was unlikely that a farmer would sell his water rights—as it may be in the Chilean case—in order to overcome a critical situation. Even in the case of unprofitable agricultural activities, small farmers tended to keep living in their irrigated plots attached to their rural or peri-urban lives, supplementing household income with salaried work. Water institutional arrangements here protected only those who had water rights; downstream *puesteros* with no formal water rights had no protection. Moreover, their marginality in accessing adaptive resources was so high that even their struggles in drought periods were invisible to those who occupied positions more relevant in a hydraulic oasis society (Kubik et al. 2010).

In the Bolivian case, water rights were ruled by customary laws. In case of drought, priorities were decided by bottom-up decision-making processes that involved most of the agricultural producers in the basin: negotiations occurred among uphill and downhill communities, assemblies in each community, and included extended family decisions (Del Callejo et al. 2007; Cruz 2009; Zambrana 2009; Saldías et al. 2012). Producers also identified the *ayni* as a resource for overcoming water and climate emergencies (Soliz et al. 2007:114). Here, a problem shared is a problem halved. But the system showed its limits when the drought was severe and prolonged: This was when the communities in the headwaters of the Pucara basin tended to impose their own traditional rights upon downstream communities, an imposition that was possible given their immediate and first access to water in the river. At that moment, the principles of solidarity that normally prevail during non-critical periods tended to get diffuse and there was potential for significant conflicts within the basin as the weak national water governance institutions were absent or too weak to mediate.

Adaptive capacity

As adaptive capacity contributes to vulnerability reduction, our studies focused not only on the amount of resources devoted to adaptation—a determinants of adaptive capacity IPCC (2001)—but also on the type of and manner of management of resources (which is closely related to the style of development). Chile's economic growth and trade liberalization style favored a private sector that is constantly searching for and implementing modern technology increasing efficiency. The Argentinean welfare development style faced the challenge of dwindling, insufficient government subsidies. It is these differences that explained why most producers of the Elqui river basin used modern irrigation technology, contrasting with the Mendoza basin, where a minority—only 6 %—of the producers did. On the other hand, the Bolivian development pathway (more traditional and with a special emphasis on the local) showed a relative lack of material resources for implementing adaptive strategies, but deployed capacities to use the organizational resources of communities. Drought emergency measures resulting from community-based decision-

making processes included distributing water shortages equitably, temporarily giving water or irrigated land to the most affected producers, and seeking particular solutions that help compensate losses.

How much of these adaptive capacities were related to individual responses and how much were a social construction, where the state or some social entity is the leading actor? The Chilean economic development model supported producers according to their degree of modernization where modernization was defined as efficiency and their capacity to do well in the market. Accordingly, this model expected them to develop their own adaptive capacity (water saving technology, water wells). The situation was different in Argentina and Bolivia, where the social component of the adaptive measures was greater. However, the institutional capital in each case was different. In the Argentina welfare case, the first reaction of the producers was to request state aid, and the state did provide (financial support to cope with climate damages—crops lost), although usually in a limited and insufficient way. In the Bolivian case, the state support was just one among other less formal institutional resources, including family and social networks or mutual aid as the *ayni*.

Adaptation decisions became complex systemic problems when producers were no longer considered as a homogenous block and instead a set of stratified groups that included at the lowest level peasant producers. Adaptive measures that worked well for some groups resulted in aggravated exposures and increasing vulnerabilities for others. In the regulated basin, such as Mendoza and Elqui, dams were considered to be suitable adaptations, so that the water flows could be managed to adjust to crop needs. But if the dam operation did not guarantee ecological or some kind of minimal flows, the efficiency of this adaptive practice could entail an additional drought factor for those who were not formally entitled to use the water of the dam. The more the *Potrerillos* dam favored water consumption in the Mendoza oasis, the less probable was that a water surplus would reach the downstream area, which was the only way in which the downstream goat breeders (having no formal water rights) could use the river water. The subordinate position of these groups in the Mendoza river *hydraulic society* explained to a large extent their huge vulnerabilities vis-à-vis those of the capitalized producers. No different is the case in Chile, where an emphasis on the private market—a suitable adaptation in the neoliberal perspective—favored large producers (Hill 2013). Small producers did not have the resources needed to perform in agribusiness, nor the social power to fight their claims and negotiate changes in water governance (ibid.).

This was an example on how adaptation, in the context of an unequal society, could turn into new exposures and increased vulnerability for some. The vulnerability of the dryland communities in the downstream Mendoza river was not just associated with climate and water-related exposures but also with a social distribution of power corresponding to a worldview that prioritized agricultural productivity and saw no point in allocating water to communities considered worthless. The oases-centered social representations made them invisibilized subaltern actors (Montaña et al. 2005; Imache et al. 2009) adding to the climatic exposures in building their vulnerability. There was also a social construction of drought (Mehta 2003, 2005, 2007) in the Elqui basin, although here it was more serious when related to mining (Salas et al. 2012). A portion of the water used by a farmer upstream in the Elqui valley would infiltrate and percolate to finally emerge at some point downstream, where it would be reused. In the case of mining, the water was contaminated and could not be reused. However, the dominant paradigm in Chile did not make it easy to question the use of water, as mining was the most profitable activity. A relative homogeneity of the farmers in the Pucara basin combined with strong community-based governance prevented such situations in the Pucara basin. However, an emerging issue was that some communities leverage their geographical proximity to water sources, over the principles of solidarity that normally prevail.

Conclusions

Comparative research on social vulnerability to global environmental change in dryland basins of different regions in the Central Andes disclosed the different styles of development that add to exposures, magnify or reduce sensitivities, and increase or diminish adaptive capacity, shaping and reshaping vulnerability to climate and water stressors. The study of dryland basin cases in Argentina, Chile, and Bolivia showed the ways in which three economic and political pathways lead to different levels of vulnerability to drought for diverse rural actors.

People, in a modern society, are not a homogeneous collective. Rather they were a heterogeneous collection of actors, with distinct livelihoods, different amounts of resources, and diverse possibilities in life. This paper has shown that various actors from South American rural drylands had different possibilities for coping with challenges of global environmental change and that their different situations of vulnerability were molded by development styles. The cases analyzed showed the limitations of development pathways that rely on simplistic, technocratic, and econometric approaches that promote adaptive measures focused almost exclusively on maintaining the *status quo* of the path that led us into global

environmental change. These approaches disregard the complexities of an increasingly risky situation ignoring the multiple dimensions of vulnerability, especially that of the weakest actors. The water governance systems of Bolivia and Argentina protect the smaller more vulnerable producers, while the Chilean does not. The characteristics of the producers that are important determinants of vulnerability are their size and ability to access capital, export markets, and prime geographical location in Argentina and Chile; in Bolivia, there is less social and economic distance between producers and producers are more stationary.

Leichenko and O'Brien (2008) examined simultaneous impact of climate change and economic globalization, concluding that certain regions, sectors, ecosystems, and social groups suffer double exposure to the impacts of climate change and consequences of economic globalization (see also Benko and Lipietz 1992). This research confirmed that the large economically powerful producers in Chile and Argentina were the double winners with the development pathways and the smaller poorer producers the double losers. However, these large producers may be vulnerable to global market risk, while the smaller producers were not subject to this risk and did have an ability to sell their labor seasonally to reduce their risk (Salas et al. 2012). This is why interdisciplinary studies focusing on more than climate change, but global environmental change is of value (O'Brien 2013; Mosser et al. 2013).

The research findings are useful for building people's capacity to respond to natural and social stressors prioritizing with the most vulnerable social groups and working on strengthening social and natural systems to—at least—cope with negative situations and, if possible, to embrace sustainability. Assessing the development style associated with the context is an important factor for consideration. Chile's economic development and trade liberalization market style requires measures counteracting this to protect its most vulnerable; Bolivia's situation requires focus on geographical vulnerability caused by the weakness of the state and powerful local organizations. Finally, Argentina's principle of inherence needs to be addressed in combination with its impecunious state. It is not only technology or infrastructure (a hail net or a dam) that will reduce vulnerability, but also investing in more broad resilience-building factors related to capacity building, education and health, and promoting access to equal opportunities, and personal freedom. Adding aspects of development style deepens recommendations. It is not just about taking care of the more vulnerable or the poorest. If poverty and vulnerability are considered the other side of the coin of extreme wealth, the forces of economic and political pathways should be moderated toward social equity, in addition to ecosystem conservation objectives and economic efficiency.

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