sociedade & natureza

DOI: http://dx.doi.org/10.14393/SN-v31-2019-45623

Perceptions of and adaptation to climate change in the Cordillera Blanca, Peru

Anderson R. De Figueiredo[1]
Jefferson C. Simões[1]
Rualdo Menegat[2]
Sarah Strauss[3]
Bruna B. Rodrigues[2]

Abstract
Climate change and glacial disasters directly affect the Andean periglacial populations in the environmental, social, economic and cultural spheres. Regional atmospheric warming is causing an increasing retreat of glaciers in the Cordillera Blanca, Peru. The melting of these glaciers causes, among other consequences, the formation of new glacial lagoons and an increase in volume of the pre-existing lagoons; both phenomena increase the possibility of glacial disasters. Thus, this paper reports an investigation of perceptions and adaptations to climatic change and glacial disasters in the Cordillera Blanca, Department of Ancash, Peru, through the ethnographic method with the campesino communities of Vicos and Humacchuco; this method included observations and semi-structured interviews with managers and campesinos. The measures adopted by the managers are, predominantly, engineering to reduce disasters, such as increasing of dike sizes and lagoon drainages. The retreat of the glaciers, as noted by the campesino communities themselves, is the main perception of the impacts of climate change. We suggest that the choice of safe places to live in campesino communities is the main strategy of adaptation and is related to an ancestral ethnoknowledge. The reterritorialization of sites susceptible to glacial disasters is not only due to the need to have a place (to plant, to live), but is also due to the topophilic feelings formed by the affective link between a person and a place. There is a central and structural issue that adds to these problems: the development model prevailing in Peruvian postcolonial society tends to complicate possible strategies for adapting to climate change in the Andes.
Keywords: Tropical glaciers. Glacier-related disasters. Ethnography. Campesino communities.

[1] Centro Polar e Climático, Instituto de Geociências, Universidade Federal do Rio Grande do Sul (UFRGS), Porto Alegre, RS, Brasil. anderson.figueredo@ufrgs.br
[2] Departamento de Paleontologia e Estratigrafia, Instituto de Geociências, Universidade Federal do Rio Grande do Sul (UFRGS), Porto Alegre, RS, Brasil.
[3] Interdisciplinary and Global Studies, Worcester Polytechnic Institute (WPI), Worcester, MA, USA.
Received: Oct 22, 2018. Accepted: Oct 10, 2019.

Introduction

Scientific evidence of the impacts of human activities on the Earth's system (GOUDIE, 2000; MANNION, 1991; MEADOWS; RANDERS; MEADOWS, 2007; RYABCHIKOV, 1975) shows the instability caused by anthropic activities on ecosystems and climate (STEFFEN; CRUTZEN; MECNEILL, 2007), with global warming having the greatest impact (MENEGAT, 2006). The main environmental changes caused by global warming in the tropical Andes are: increases in temperature, consequent reductions in glaciers, seasonal changes in runoff and increased insect-borne diseases (IPCC, 2014a); additionally, researchers have observed an increase in the risk of glacier-related disasters (FIGUEIREDO, 2017), such as avalanches, landslides and glacial lake outburst floods – GLOFs (CASASSA et al., 2007; HARRIMAN, 2013).

Tropical glaciers are essential for the subsistence of Andean populations, as they encompass water supplies used as a resource for domestic, agricultural, and industrial uses in drought conditions or when precipitation is reduced (CASASSA et al., 2007; KASER; OSMASTON, 2002; VUILLE et al., 2008).

The melting of these glaciers causes, among other consequences, the formation of new glacial lagoons – due to the melt water held by terminal moraines – and volume increases in the pre-existing lagoons. Eventually, these natural and artificial dikes break, releasing water and debris forcefully and destructively into a stream. The increased glacial meltwater, associated with the intensity of earthquakes, detaches blocks from glaciers over adjacent lagoons. This dynamic increases the incidence of dike disruptions, and also increases the susceptibility of cities in the Santa Valley to GLOFs.

The relevance of tropical glaciers is evident, and not just as an economic resource. Glaciers represent, for some campesino communities, icons from ancient stories, spiritual beliefs, and places to enjoy the landscape

and recreational activities (CAREY, 2014; JURT et al., 2015). Thus, glaciers are immersed in the cultural field of Andean populations and reinforce their sense of belonging.

In the last decade, increased attention has been paid to research on culture and climate change (CRATE; NUTTALL, 2016). However, these studies are still minimal compared to physical studies of climate change. Given that culture plays a key role in the way people respond to environmental changes, the field of climate research must be broadened by the study of cultures and societies where these changes occur (CAREY, 2010). This research investigates existing and possible ways of adapting to climatic changes; specifically, how environmental managers and campesino communities perceived the glaciers of the Cordillera Blanca, and respond to their demise.

Perceptions: glaciers and climate change

The notion of perception has been studied by the geographer Yi-Fu Tuan (1974, 1983), who understands the concept as "[…] both the response of the senses to external stimuli and purposeful activity in which certain phenomena are clearly registered while others recede in the shade or are blocked out" (TUAN, 1974, p. 4).

The senses can be regarded as the common means of perception among humans. However, people can perceive the same reality in different ways, and "no two social groups make precisely the same evaluation of the environment" (TUAN, 1974, p. 5). Thus, examinig the culture of each population studied is essential for understanding their perceptions, as culture influences environmental perception, attitudes, and worldview.

In considering environmental perception, the sense that we have as a central reference is vision (OLIVEIRA; MACHADO, 2004; TUAN, 1974). In this perspective, "two attributes of glaciers shape the ways in which humans

perceive them: they are visible and they are subject to cultural framing" (ORLOVE et al., 2008, p. 5).

In the research area and elsewhere, studies have shown that local communities reconigze the increase in retreating glaciers in recent decades (GAGNÉ et al., 2014). This perception comes of their own observations of the environment they inhabit, and is "more the product of local epistemologies, it does not seem to be mediated by the global discourse on climate change" (GAGNÉ et al., 2014, p. 795).

The knowledge that campesinos have of their own environment was recognized by the Peruvian geographer Pulgar Vidal (1981, p. 14), who argued that "there is an indigenous geographical knowledge" in Peru. Notably, campesino communities are composed primarly of indigenous people who work as farmers. Thus, the term campesino, which is used commonly by Peruvians themselves, can be seen as a way of masking Peruvian indigenous ethnic groups (SPALDING, 2016; STOCKS, 1981).

In the Santa Valley, indigenous knowledge was recognized by Mark Carey (2010, p. 13), who argued that "local inhabitants, of course, had their own glacier expertise and knowledge about the Cordillera Blanca." In this perspective, the "farmers in mountain communities whose crops depend on irrigation are sensitive observers of changes in streams and in the flow of water" (GAGNÉ et al., 2014, p. 795). The disappearance of glaciers as well as the decreases in precipitation and differences in drainage patterns (YOUNG; LIPTON, 2006) have had a significant impact the ways that campesino communities perceive their available options for adapting.

Adaptations to climate change and glacier-related disasters

The relevance of adaptations in the current scenario of climate change in the Andean environment requires further exploration of this theme. First, we must discuss adaptation as a concept. For this purpose, we use the

definition of adaptation proposed by the Intergovernmental Panel on Climate Change (IPCC, 2014b):

> The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects. (IPCC, 2014b, p. 5).

Adaptation, therefore, can be verified within both societies and natural systems. However, when dealing with societies, the interpretation of climate change adaptations can be ambiguous, thereby revealing the complexity of addressing this issue (STONE et al., 2013). The different social groups of the Cordillera Blanca, for instance, have different perceptions about the risks of glacier-related disasters. In relation to disaster adaptation strategies, there are similar proposals among the different groups, such as the drainage of glacial lakes (CAREY, 2008). The impacts of glacier-related disasters in this region are different according to the geographical location of the population (CAREY, 2010), and the most affected inhabitants are the riverside populations of the Santa river and their tributaries that extend to the glaciers (CAREY, 2010).

It is necessary to recognize that the strategies presented by IPCC to deal with climate change, such as mitigation and adaptation, do not alter the territory's conditions (GAGNOL; SOBEYRAN, 2012). The hegemonic economic structure that emerged in the colonial period continues to be reproduced at different scales, and the predatory effects that this system has on territories continues to expand. Thus, reducing the causes and effects of climate change is not helpful if the economic development model that produced it remains untouched. It is, therefore, not possible to deal with climate change, and to reduce the emission of greenhouse gases, without changing the current development model (GAGNOL; SOBEYRAN, 2012).

McDowell et al. (2019) identified 690 discrete adaptations initiatives documented for mountain glaciers regions. Among these initiatives, 78% have some level of information about adaptation action, and most are concentrated in the Himalayas and Andes. In general, stimuli for the development of adaptation measures arise from hydrological changes in the glacial region (71% of strategies) (McDOWELL et al., 2019). Despite the considerable number of initiatives, the authors highlighted that the measures are developed as reactions to the problems that arise with social and environmental changes, and are not based on a formal adaptation plan.

In the context of Latin America, three categories of adaptation can be highlighted: agriculture, water, and community (FORERO et al., 2014). The strategies that are usually adopted from these categories are: recovery of ancestral knowledge in crops and traditional medicine; conservation agriculture and agroforestry systems; and irrigation systems and reforestation of watersheds (FORERO et al., 2014).

The State of Peru developed a series of public policies that includes adaptation plans in relation to climate change and related disasters. On a national scale, there is the Water Resources Law nº 29.338/2009 that regulates the use and management of water resources. On a regional scale, there are a series of climate change adaptation measures combined into a plan called the *Plan de acción de adaptación y mitigación frente al cambio climático* [Climate change adaptation and mitigation action plan] by the Ministry of Environment (*Ministerio del Ambiente* – MINAM, 2010). An action plan is important for proposing measures to address socioenvironmental changes.

However, adaptation projects in the Peruvian territory have sectorial propositions that do not consider the territorial context in which they have developed (GLAVE; VERGARA, 2016). In this view, the Peruvian government produces public policies in response to the effects of climatic changes from a fragmented view of the territory, instead of from a holistic view that considers

territory as a totality, with all the actors involved in the process of adaptation (GLAVE; VERGARA, 2016). In this sense, recent research suggests that only interdisciplinary perspectives can provide potentially effective adaptive strategies (CAREY et al., 2017; McDOWELL et al., 2019; YOUNG; LIPTON, 2006).

Methodology

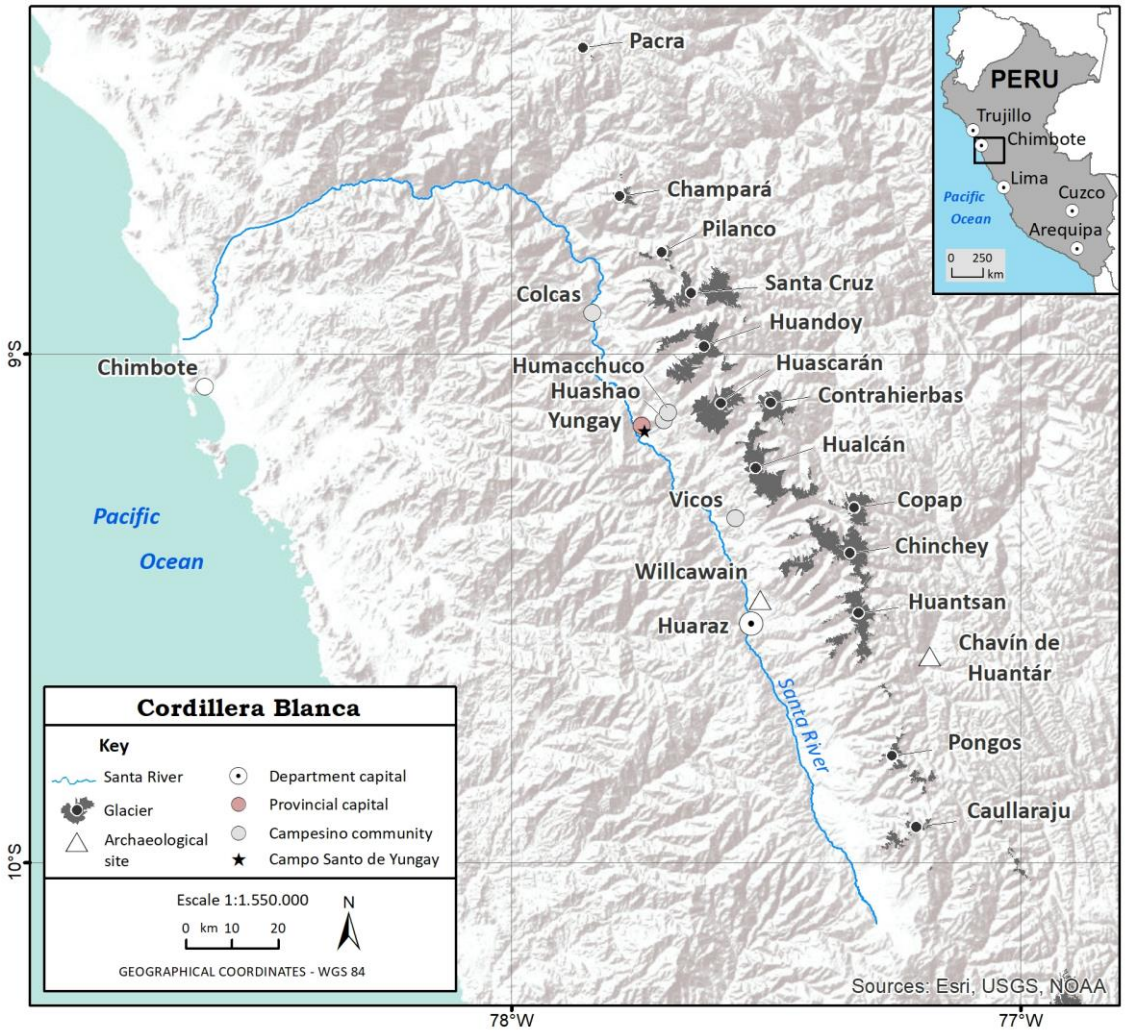
Study area

The glaciers of the Cordillera Blanca (Department of Ancash, Peru – Map 1) comprise fourteen glacier systems that have retreated severely in recent decades (RABATEL et al., 2013). A previous study estimated that over 27% of the ice covered area was lost in 33 years – between 1970 and 2003 (ANA, 2014).

The elevation in the Cordillera Branca region ranges from 1900 m asl (on the river plains of the northern portion) to 6701 m asl (at the peak of Huascaran glacier). The most populated cities are at an average altitude of 3000 m asl, i.e., Huaraz, usually on the river plains of the Santa river.

The annual average temperatures in Callejón de Huaylas are between 16° and 20 °C (maximum) and between 0 and 4 °C (minimum), according to data from the *Servicio Nacional de Metereología e Hidrología del Perú* [National Service of Meteorology and Hydrology of Peru] (SENAMHI).

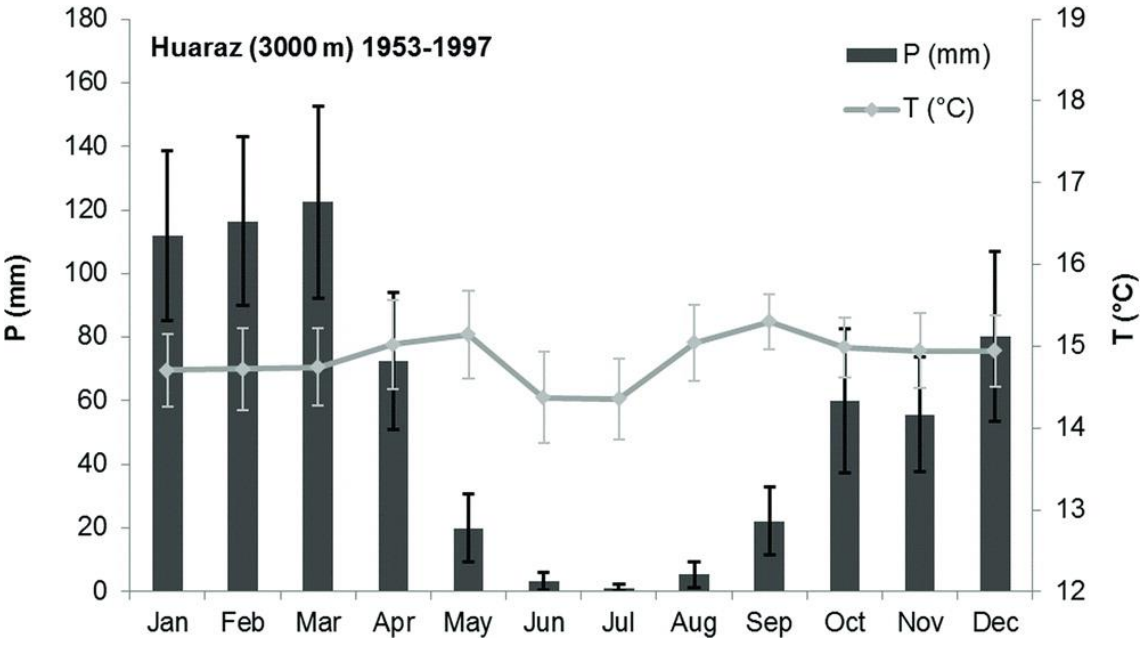
Map 1 – Glaciers systems of Cordillera Blanca and the cities and campesino communities of Callejón de Huayllas investigated during in field work.



Source: base image from ESRI; NOAA; USGS. Org.: cartography of the authors, 2018.

The historical monthly (1953–1997) precipitation (P) and temperature (T) for the departmental capital of Ancash, Huaraz, are presented in Figure 1. In general, average temperatures do not vary substantially throughout the year. However, precipitation shows a marked seasonal variation during the year, with the total highest rainfall in summer and the lowest in winter.

Figure 1 – Historical record averages for precipitation (P) and temperature (T) for Huaraz between 1953 and 1997.



Source: Bury et al., 2013.

Mark and Seltzer (2005), Mathias Vuille et al. (2008), and Racoviteanu et al. (2008) reported changes in the average annual temperature in the Cordillera Blanca and adjacent regions in past decades, as shown in Table 1; an increase in the annual average temperature change, at +2.79° C (0.9°C / decade) is observed.

Table 1 – Annual average temperature changes in Cordillera Blanca and adjacent regions in past decades.

Region / metereological station	Observation period	Temperature change cumulative; rate	Reference
Tropical Andes, 1°N-23°S	1939-2006	+0,68°C; 0,1°C/decade	Vuille et al. (2008); 279 stations
Peru (9°-11°S), including Cordillera Blanca	1951-1999	+1,95°C; 0,39°C/decade	Mark and Seltzer (2005); 29 stations
	1962-1999	+1,01°C; 0,26°C/decade	
Huaraz, 3038 m asl	1970-1999	+2,79°C; 0,9°C/decade	Racoviteanu et al. (2008)
Recuay, 3394 m asl	1970-1999	+1,55°C; 0,5°C/decade	

Source: Carey et al., 2012.

Methodological considerations

An analysis of existing and possible climate change adaptations, and of the perceptions of managers and campesinos regarding the dynamics of the Cordillera Blanca glaciers, was carried out through fieldwork, in August 2016, February 2018 and June and July 2019. The ethnographic method was adopted as an investigative guideline for the Vicos and Humacchuco campesino communities (Map 1).

In addition, 20 semi-structured interviews were conducted with environmental managers, leaders, and inhabitants of campesino communities from Callejón de Huaylas. Thus, this qualitative research prioritized interviewing people who were politically and culturally engaged in the socioenvironmental context of the study area. For reasons of confidentiality, pseudonyms for all interviwees are used in this work.

The semi-structured interview was organized using a script of questions. However, according to the respondents' answers, the interviewer could raise different questions from the standard script.

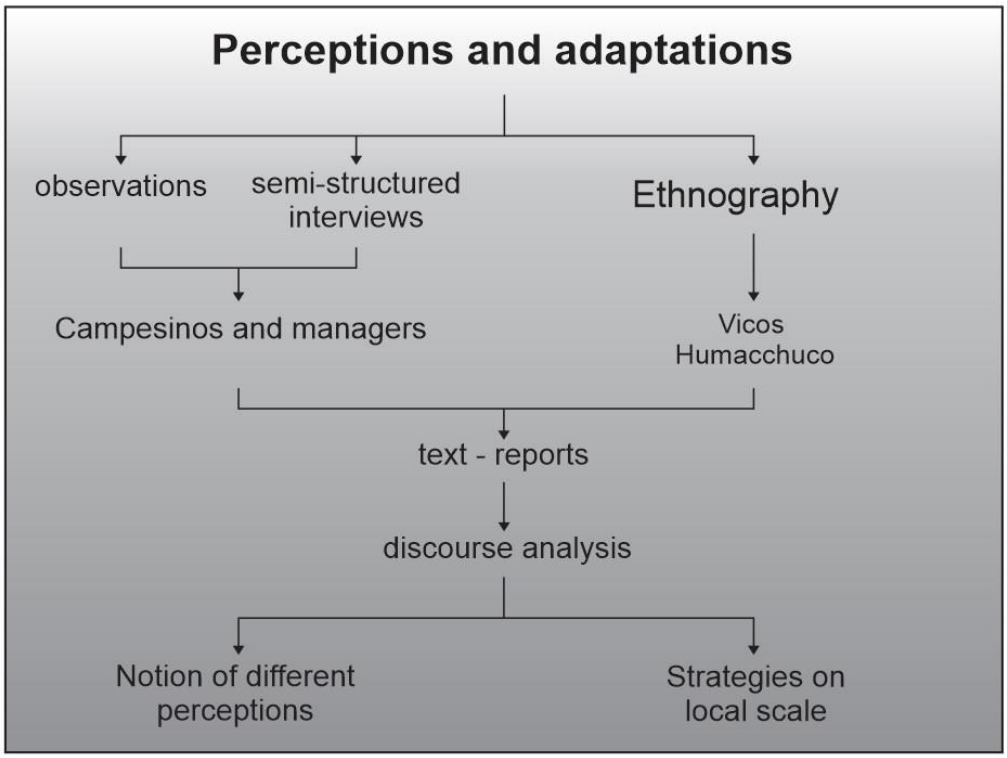
In addition, the interviewees had the opportunity to report their observations of phenomena that they considered relevant. The analysis of the interviews considered the reading keys proposed by Heidrich (2016),

> (1) contents generated by the starting considerations and the research objectives; (2) surprise contents, which can be stored as gems that [...] highlight the units of meaning (MICHELAT, 1982); and the other (3), the content of geographic object-concepts within (in the soul) of the speeches. (HEIDRICH, 2016, p. 28).

Interpretation of the interviews used discourse analysis tools in which the *corpus* of the study was selected from the interview. The corpus expresses "a gathering, above all, of facts (meanings in process in the production of discourse), not just of data" (SILVA, 2009, p. 112). This analysis made it possible to cut fragments and reconstitute discursive regularities.

The systematization of the methodologial procedures used to understand perceptions and adaptations to climate change is presented in Figure 2.

Figure 2 - Systematization of the methodological procedures used to study perceptions and adaptations.



Org.: Authors, 2018.

Glacier-related disasters and climate change: perceptions and adaptations

Semi-structured interviews with campesinos, residents and managers of Callejón de Huaylas provided a general reading of the perceptions and adaptations of the communities that inhabit the Santa Valley. Discussions concerned glacier-related disasters, their impacts and the representation of glaciers. As the interviews retained a conversational style, the interviewees related other topics, such as disaster prevention measures, social and

environmental changes, tourism, migration, mining impacts, identity, and topophilia.

Historically, there have been several glacier-related disasters that have occurred in the Callejón de Huaylas region. Among them, the disaster that had the greatest social and environmental impact was that triggered by the 7.7 Richter scale magnitude earthquake event on May 31, 1970, which was followed by ice avalanches and debris originating from Huascarán glacier. This disaster killed about 18,000 people in Yungay village.

The reports of the campesinos and residents of Yungay (Map 1) showed that they do not believe in the possibility of another glacier-related disaster from Huascarán. The Yungay tourist guide and survivor of the 1970 disaster, Jorge, stated that "no, no, sometimes we think that on the other hand, by Huandoy (...) a strong earthquake may cause an avalanche in Huandoy".

Luis, a Huashao community leader who experienced the 1970 disaster, reported that he was six years old at the time. According to him, some people were saved from the large alluvium by climbing the hill adjacent to their community. However, two years later, the residents of Huashao returned to occupy the same place. He also said that his community does not fear the risk of another alluvium debris flow, because "people forget".

We suggest that this forgetfulness reported by Luis is due glacier-related disasters not displaying an obvious periodicity; specifically, they happen on an acyclic time scale. In addition, there are the issues raised by a member of the Huascarán National Park (*Parque Nacional Huascarán* – PNH), Simón, who reported that the "lastest disasters on Callejón de Huaylas have not caused much damage, only on crops and on few roads".

However, there is a group of people who recognize that they live in a high-risk area of glacier-related disasters. Huaraz community leader Carmen reported that, when she talks to people who occupy high-risk areas, these villagers say that "it doesn't matter if I die, it's my poverty." Therefore,

villagers in high-risk areas experience issues that refers to the need to have a place to live, to plant, and to survive.

In Huashao's case, the residents feel topophilia about the place that they inhabit; more specifically, the "affective bond between people and place or setting" (TUAN, 1974, p. 4). This relationship was observed in the Luis's report:

> I like the countryside, the verdancy, it is more open, freer, it has fewer cars, less bus. For me it is calmer to live here in the country. In the city there is a lot of violence. (Report from Luis, obtained in fieldwork in August 2016).

Geographer Haller (2010) analyzed 47 Yungaines' perception of risk zones through mental maps. The survey found that 75% of respondents who were at least 39 years old, recognized that Yungay is in a potentially dangerous area. However, 45% of the group of respondents aged 15 to 39 years (i.e., born after the 1970 disaster), did not recognize the city as a potential danger zone (HALLER, 2010). Therefore, the analysis of groups with different age groups showed that most of the younger generations did not recognize the possibility of another disaster in the region. Thus, this portion of inhabitants is not perceived as an integral part of the socio-cryosphere.

Haller (2010) reconigzed that residents live in risk zones as a consequence of their socioeconomic conditions; this is because they have no other alternatives, thereby corroborating the report of Carmen, the community leader of Huaraz. There is an increase in the occupation of risk areas in Yungay (such as the Acobamba and Cochahuain sectors) stimulated by both inactions and actions by the Peruvian state. For example, Haller (2010) considered that the Santo Domingo de Guzmán School was built by the federal government over the alluvial deposit area of 1970. On the other hand, Haller (2010) did not attribute the occupation of danger zones to the lack of knowledge of the campesinos.

Our research revealed that glaciers represent a source of water for the campesinos and residents of Callejón de Huaylas. Luis reported that “glaciers are important because we have water, we have visitors, tourists, without glaciers we would not have water.” Jorge stated that "the Cordillera Blanca glaciers are important for the water, thank God." The President of the Yungay House of Culture, Antonio, a survivor of the 1970 disaster, elaborated a critique by comparing modern civilizations with pre-Columbian civilizations, which follows:

> Well, that is hardly taken into account. The ancient Peruvians, yes, the mountains, the lagoons, all the geographical objects were taken as if they were species of gods, the *apus*, in Quechua, was called, and the Huascarán, which is a big mountain glacier, had an importance, if it can be said quite deep, the veneration, the worship of geographical accidents. (Antonio’s report, obtained from fieldwork in August 2016).

In this symbolic perspective, Miguel, a Chavín de Huantar resident and spiritual representative of the Chavín culture, shares the local belief that there is a (hidden) guardian protector of glaciers. The symbolic dimension of the Amerindian peoples was explained by anthropologist Catafesto de Souza:

> […] generally the originary groups are respectful to the cosmological principles of their existence, where the beings of the world are alterities (minerals, plants, animals, shamans, deads, demiurges and gods), as if subjects considered in their spirituality and ability to establish communication with the others human beings (in the style of “Amerindian perspectivism” formulated by Viveiros de Castro, 2002). (CATAFESTO DE SOUZA, 2010, p. 98).

This study revealed that the main disaster prevention measures adopted are engineering solutions, according to reports from interviews with environmental managers at Callejón de Huaylas, which is corroborated by Mark Carey (2010). The interviewees included a member of the PNH, Simón, and an member of the Glaciology and Water Resources Unit [*Unidad de*

Glaciología y Recursos Hídricos – UGRH] from Huaraz, Javier. These engineering works are restricted to the construction of dikes and discharge channels in glacial lagoons.

These measures require public funding and labor to maintain. The last security work on Palcacocha lagoon (with volume of 17,325,206 m^3 – ANA, 2014), upstream of Huaraz, was in 1970. The UGRH member acknowledged that this system, built 49 years ago, is no longer efficient; therefore, "UGRH's proposals for Palcacocha lagoon are to discharge water and build a 25 m high dam".

Social and environmental changes are perceived by both managers and campesinos. The member of the PNH reported:

> We are perceiving in a obvious way the reduce in lack of water and changes in hydrological cycles […] There is interdisciplinary work with the community. Campesinos say there is a need for damming (and we at the National Park also consider it important in the medium and long term). In the Cordillera Negra the issue is very serious, because there is no water recharge, it is not done. This year there was a water crisis in both mountain ranges. (Simón's report, obtained in field work in August 2016).

Maria, a campesino from the Colcas community (Map 1), reported that there is enough water in her community for crops, but stated that there is water scarcity in Mato District, Huaylas Province (Cordillera Negra district, to the west and parallel to the Cordillera Blanca). The strategy of this village is to cultivate only during the rainy season. In the dry season, when there is no harvest, the campesinos engage in other occupations that guarantee their subsistence.

The semi-structured interviews showed that the campesinos perceive, above all, the shrinkage of the glaciers adjacent to their communities. The campesino and tourist guide of Humacchuco reported the changes that he noticed in the landscape:

> In the past climate was different, for example, like the heat, when I was a child. Now it is much, much, much hotter. And as the glaciers, every year there is more retreat of glaciers. In the past it was more covered by snow, more than all ice. Right now every year more there is retreat, because of that heat, no. Everything has changed. (Enrique's report, obtained in the fieldwork in February 2018).

The perceptions and strategies used to adapt to climate change in the Vicos and Humacchuco campesino communities are presented in Chart 1.

Chart 1 – Perceptions and adaptations to climatic changes by Vicos and Humacchuco campesino communities in the Cordillera Blanca, Peru.

	Perceptions	Consequences	Adaptations
Vicos	Glacier retreat	Short term: ↑ supply of melting glacier water ↑ disaster risk	Choice of safe places to live
	Changing patterns of rainfall - decrease in rainy season and increase in precipitation intensity	↓ supply of rainwater to crops	Increased use of water for irrigation of crops, including in the rainy season
	Decrease and/or extinction of species of flora and fauna of the region	↓ biodiversity	Not identified
Humacchuco	Glacier retreat	Short term: ↑ supply of melting glacier water ↑ disaster risk	Choice of safe places to live
	Suface temperature increase	↑ burning of flower cultivation	Increased use of water for irrigation of crops, including in the rainy season Need to build greenhouses

Org.: Authors, 2018.

In Vicos, residents have noticed the retreat of glaciers, and a decrease in the total amount of precipitation during the rainy season, but increased individual intensity precipitation events, as well as the decrease and/or extinction of species of flora and fauna. The campesinos of Humacchuco

recognized the retreat of glaciers along with an increase in atmospheric temperature.

However, the main problems perceived by the interviewees refer to the mining activities that exist in large numbers in the Callejón de Huaylas region. Martín, a resident of Huaraz, who is a taxi driver during the high season (from June to August) and a freight transporter in several villages in the low season, associated mining activities with the large migratory movements taking place in the region. This is why, according to Martín, the commencement of mining activities had effects on the increase of violence, environmental contamination and the spoilage of regional wealth.

According to the Martín's observations, the residents of Paira (a village about 7 km from Huaraz), for example, first migrated to Huaraz (capital of Ancash department) in search of a better life. When they could not find an occupation to support them, or better economic conditions, they migrated onward to Lima. However, many residents preferred to stay in Paira, as they have affection for the place and pride in their village, according to the Martín's report.

One of the main measures of adaptation to social and environmental change is migration. Therefore, we can consider that deterritorialization processes are caused not only by glacial disasters, but also by the consequences of regional environmental changes, such as regional changes in microclimate (MARK; SELTZER, 2005; RACOVITEANU et al., 2008; VUILLE et al., 2008). In this sense, Wrathall et al. (2014, p. 294) showed that glacier melting in Peru is a factor that "also alters access to these essential resources, undermining the bases of rural livelihoods and motivating migration," thus corroborating the Martín's report.

Final considerations

The populations that inhabit urban areas in high-risk zones do so mostly with the knowledge that they are occupying the course of eventual

alluvium (CAREY, 2014; HALLER, 2010). Notably, the occupation of these areas results from the need to have a place to live and, sometimes, from topophilic feelings about the place; namely, the affective link that connects the person to the place. Carey (2014) argued that we should also consider that most populations occupy high-risk areas on the assumption that state agencies will carry out engineering works to prevent disasters (such as increasing dike size and draining glacial lagoons), and that such works will make high-risk areas become "safe" places.

We suggest that choosing safe places to live in campesino communities is the main strategy of adaptation to environmental changes and is more a practice linked to an ancestral heritage of pre-Columbian civilizations than a modern sense of concern about high-risk areas (FIGUEIREDO, 2017; PULGAR VIDAL, 1981). However, this only demonstrates that there is a preservation of ancestral knowledge (at least in rural communities) that does not diminish the relevance of this ethnoknowledge, which is essential to identity and to surviving in this region.

Migration is the second main strategy of adaptation to climate change (WRATHALL et al., 2014). The glaciers of the Cordillera Blanca are important to campesinos as they represent the water that is essential for their subsistence. In addition, glaciers reinforce identity bonds with the region's inhabitants. There is a concern about the lack of water and measures such as glacial meltwater damming constitute a medium- and long-term adaptation strategy, as demonstrated by interview reports. However, the atmospheric warming comes from global structural conditions, which include economic, political, and technological factors that communities alone cannot reverse.

The current agroindustrial and extractivist economic system (agroindustry, intensive agroindustrial agriculture, which predominates in the region) tends to complicate adaptations to climate change (GAGNOL; SOBEYRAN, 2012). This system implies a mode of production that depletes existing resources, either through intensive land use or mining activities;

these activities can harm small producers in the Callejón de Huaylas region. Therefore, understanding the perceptions that these populations have of their environment should be a basis for the development of regional plans for adaptations to climate change.

Acknowledgments

This work was supported by the Brazilian National Council for Scientific and Technological Development (CNPq – Process 573720/2008); the Foundation for Research Support of the State of Rio Grande do Sul (FAPERGS – Process 17/2551-0000518-0); and the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brasil (CAPES) – Finance Code 001.

References

ANA – AUTORIDAD NACIONAL DEL AGUA. **Inventario Nacional de Glaciares y Lagunas**. Peru: ANA, 2014. Available in: < https://www.ana.gob.pe/sites/default/files/normatividad/files/inventario_de_lagunas_del_peru_parte1.pdf>. Acessed: June 14, 2015.

BURY, J. *et al.* New geographies of water and climate change in Peru: coupled natural and social transformations in the Santa river watershed. **Annals of the Association of American Geographers**, v. 103, n. 2, p. 363–374, 2013. https://doi.org/10.1080/00045608.2013.754665

CAREY, M. Disaster, development, and glacial lake control in twentieth-century Peru. In: WIEGANDT, E. (ed.). **Mountains:** sources of water, sources of knowledge. Rotterdam: Springer Netherlands, 2008. p. 181–196. https://doi.org/10.1007/978-1-4020-6748-8_11

_____. **In the shadow of melting glaciers:** climate change and Andean society. New York: Oxford University Press, 2010.

_____. **Glaciares, cambio climático y desastres naturales:** ciencia y sociedad en el Perú. Trad. Jorge Bayona. Lima: IFEA/IEP, 2014.

CAREY, M.; HUGGEL, C.; BURY, J.; PORTOCARRERO, C.; HAEBERLI, W. An integrated socio-environmental framework for glacier hazard management and climate change adaptation: lessons from Lake 513, Cordillera Blanca, Peru. **Climatic Change**, v. 112, n. 3, p. 733–767, 2012. https://doi.org/10.1007/s10584-011-0249-8

CAREY, M.; MOLDEN, O. C.; RASMUSSEN, M. B.; JACKSON, M.; NOLIN, A. W.; MARK, B. G. Impacts of glacier recession and declining melt water on mountain societies. **Annals of the American Association of Geographers**, v. 107, n. 2, p. 350–359, 2017. https://doi.org/10.1080/24694452.2016.1243039

CASASSA, G. *et al.* Editorial: current status of Andean glaciers. **Global and Planetary Change**, v. 59. p. 1–9, 2007. https://doi.org/10.1016/j.gloplacha.2006.11.013

CATAFESTO DE SOUZA, J. O. Etnografia e situação de perícia envolvendo comunidades originárias: o caso do sul do Brasil. In: SCHUCH, P.; VIEIRA, M. S.; PETERS, R. (orgs.). **Experiências e desafios do fazer etnográfico contemporâneo**. Porto Alegre: Ed. da UFRGS, 2010. p. 89–107.

CRATE, S. A.; NUTTALL, M. (Eds.). **Anthropology & Climate Change:** from encounters to actions. New York, 2016.

FIGUEIREDO, A. R. **A sociocriosfera nos Andes Centrais:** percepções, adaptações e impactos dos desastres glaciais no Callejón de Huaylas, Peru. Dissertação (Mestrado em Geografia). Porto Alegre: POSGea/UFRGS, 2017. Available in: <https://lume.ufrgs.br/handle/10183/156775>. Acessed: October 30, 2017.

FORERO, E. L.; HERNÁNDEZ, Y. T.; ZAFRA, C. A. Percepción latino-americana de cambio climático: metodologias, herramientas y estrategias de adaptación en comunidades locales. Una revisión. **Rev. U.D.C.A. Act. & Div. Cient.**, v. 17, n. 1., p. 73–85, 2014.

GAGNÉ, K.; RASMUSSEN, M.B.; ORLOVE, B. Glaciers and society: attributions, perceptions and valuations. **WIREs Clim Change**, v. 5, n. 6, pp. 793–808, 2014. https://doi.org/10.1002/wcc.315

GAGNOL, L.; SOBEYRAN, O. S'adapter a l'adaptation: la condition sahélienne à l'épreuve de l'injonction au changement climatique. **Géographie et cultures**, v. 81, 2012. https://doi.org/10.4000/gc.200

GLAVE, M.; VERGARA, K. Cambio global, alta montaña y adaptación: uma aproximación social y geográfica. In: GRADE (GRUPO DE ANÁLISIS PARA EL DESAROLLO). **Investigación para el desarollo en el Perú.** Once balances. Lima: GRADE. p. 445–507, 2016.

GOUDIE, A. **The human impact on the natural environment**. 5ed. Cambridge: MIT Press, 2000.

HALLER, A. Yungay: recent tendencies and spatial perceptions in an Andean risk zone. **Espacio y Desarrollo**, n. 22, p. 65–75, 2010.

HARRIMAN, L. Where will the water go? Impacts of accelerated melt in the Tropical Andes. 2013. Available in: <https://na.unep.net/geas/archive/pdfs/GEAS_Sep2013_Andes.pdf>. Acessed: March 10, 2015.

HEIDRICH, A. L. Método e metodologias na pesquisa das geografias com cultura e sociedade. In: HEIDRICH, A. L. & PIRES, C. L. Z. (orgs.). **Abordagens e práticas da pesquisa qualitativa em Geografia e saberes sobre espaço e cultura**. Porto Alegre: Editora Letra 1. p. 15–33, 2016.

IPCC (Intergovernmental Panel on Climate Change). **Climate Change 2014:** impacts, adaptation, and vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [BARROS, V. R. *et al.*]. Cambridge: Cambridge University Press, 2014a. https://doi.org/10.1017/CBO9781107415386

_____. 2014: Summary for policymakers. *In:* **Climate Change 2014:** Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B. *et al.*]. Cambridge: Cambridge University Press, 2014b. p. 1–32. https://doi.org/10.1017/CBO9781107415379.003

JURT, C.; BRUGGER, J.; DUNBAR, K. W.; MILCH, K.; ORLOVE, B. Cultural values of glaciers. In: HUGGEL, C.; CAREY, M.; CLAGUE, J. J.; KÄÄB, A. (Eds.). **The high-**

mountain cryosphere: environmental changes and human risks. Cambridge: Cambridge University Press, 2015. p. 90-106. https://doi.org/10.1017/CBO9781107588653.006

KASER, G.; OSMASTON, H. **Tropical Glaciers**. Cambridge: Cambridge University Press, 2002.

MANNION, A. M. **Global Environmental Change**: a natural and cultural environmental history. Harlow: Longman, 1991.

MARK, B. G.; SELTZER, G. O. Evaluation of recent glacier recession in the Cordillera Blanca, Peru (AD 1962–1999): spatial distribution of mass loss and climatic forcing. **Quaternary Science Reviews**, v. 24, p. 2265–2280, 2005. https://doi.org/10.1016/j.quascirev.2005.01.003

McDOWELL, G.; HUGGEL, C.; FREY, H.; WANG, F. M.; CRAMER, K.; RICCIARDI, V. Adaptation action and research in glaciated mountain systems: Are they enough to meet the challenge of climate change? **Global Environment Change**, v. 54, p. 19–30, 2019. https://doi.org/10.1016/j.gloenvcha.2018.10.012

MEADOWS, D. RANDERS, J. MEADOWS, D. **Limits to growth:** the 30-year update. Vermont: Chelsea Green Publishing Company, 2007.

MENEGAT, R. **A matriz do lugar na interpretação das cidades Incas de Machu Picchu e Ollantaytambo:** um estudo de ecologia de paisagem e a reconstrução dos processos civilizatórios. Tese (Doutorado em Biociências). Porto Alegre: IB/UFRGS, 2006.

MINAM (MINISTERIO DEL AMBIENTE). Resolución Ministerial nº 238 de 2010 – MINAM. **Diário Oficial El Peruano**, Separata Especial, Lima, 2 de dezembro de 2010. p. 430162.

OLIVEIRA, L.; MACHADO, L. M. C. P. Percepção, cognição, dimensão ambiental e desenvolvimento com sustentabilidade. In: VITTE, A. C.; GUERRA, A. J. T. (eds.). **Reflexões sobre a Geografia Física no Brasil**. Rio de Janeiro: Bertrand Brasil, 2004. p. 129–152.

ORLOVE, B. S.; WIEGANDT, E. B.; LUCKMAN, B. H. The place of glaciers in natural and cultural landscapes. In: **Darkening peaks:** glacier retreat, science, and society. Berkeley: University of California Press, 2008. p. 3–19.

PULGAR VIDAL, J. P. **Geografia del Perú;** las ocho regiones naturales del Perú. 8 ed. Lima: Editorial Universo, 1981.

RABATEL, A. *et. al*. Current state of glaciers in the tropical Andes: a multi-century perspective on glacier evolution and climate change. **The Cryosphere**, v. 7, p. 81–102, 2013. https://doi.org/10.5194/tc-7-81-2013

RACOVITEANU, A. E.; ARNAUD, Y.; WILLIAMS, M. W.; ORDOÑEZ, J. Decadal changes in glacier parameters in the Cordillera Blanca, Peru, derived from remote sensing. **Journal of Glaciology**, v. 54, n. 186, p. 499–510, 2008. https://doi.org/10.3189/002214308785836922

RYABCHIKOV, A. **The changing face of the Earth**; The structure and dymanics of the geosphere, its natural development and the changes caused by man. Moscou: Progress Pub., 1975.

SILVA, J. M. Análise do discurso e pesquisa qualitativa em Geografia. In: RAMIRES, J. C. L.; PESSOA, V. L. S. (Orgs.). **Geografia e pesquisa qualitativa:** nas trilhas da investigação. Uberlândia: Assis, 2009. p. 91–122.

SPALDING, K. **De indio a campesino**. Cambios de la estructura social del Perú colonial. 2 ed. Lima: IEP, 2016.

STEFFEN, W.; CRUTZEN, P. J.; MECNEILL, J. R. The Antrophropocene: are humans now overwhelming the great forces of nature? **Ambio**, n. 36, p. 614-621, 2007. https://doi.org/10.1579/0044-7447(2007)36[614:TAAHNO]2.0.CO;2

STOCKS, A. W. **Los nativos invisibles:** notas sobre la historia y realidad actual de los cocamilla del Río Huallaga, Perú. Lima: Centro Amazónico de Antropología y Aplicación Práctica, 1981.

STONE, D. *et al.* The challenge to detect and attribute effects of climate change on human and natural systems. **Climatic Change**, v. 121, n. 2, p. 381–395, 2013. https://doi.org/10.1007/s10584-013-0873-6

TUAN, Y. F. **Topophilia:** a study of environamental, perception, attitudes, and values. New York: Columbia University Press, 1974.

TUAN, Y. F. **Espaço e Lugar:** a perspectiva da experiência. Trad. de Lívia de Oliveira. São Paulo: DIFEL, 1983.

VUILLE, M.; FRANCOU, B.; WAGNON, P.; JUEN, I.; KASER, G.; MARK, B. G.; BRADLEY, R.S. Climate change and tropical Andean glaciers: past, present and future. **Earth-Science Reviews**, v. 89, p. 79–96, 2008. https://doi.org/10.1016/j.earscirev.2008.04.002

YOUNG, K. R.; LIPTON, J. K. Adaptive governance and climate change in the tropical highlands of Western South America. **Climatic Change**, v. 18, n. 1, p. 63–102, 2006. https://doi.org/10.1007/s10584-006-9091-9

WRATHALL, D. J.; BURY, J.; CAREY, M.; MARK, B.; MCKENZIE, J.; YOUNG, K.; BARAER, M.; FRENCH, A.; RAMPINI, C. Migration amidst climate rigidity traps: resource politics and social–ecological possibilism in Honduras and Peru. **Annals of the Association of American Geographers**, v. 104, n. 2, p. 292–304, 2014. https://doi.org/10.1080/00045608.2013.873326