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Community participation in landslide risk reduction: a case history from Central Andes, Peru

Abstract This article describes the intertwined history of scientific research and landslide disaster risk reduction efforts in a small peasant community in the Rampac Grande of the Peruvian Andes. It was struck by a catastrophic landslide in 2009, claiming five fatalities and challenging local knowledge about landslide occurrence and mitigation practices. This article describes collaboration between a team of scientists, comprising both foreign and Peruvian experts and the local community, which started after the 2009 landslide and culminated during the disaster risk reduction (DRR) project which ran from 2016 to 2017. It illustrates the shift from refusing outside intervention to acceptance of the proposed measures and active community participation in their application and maintenance. This was achieved by rethinking the role of local and scientific knowledge during the process of DRR through enhanced communication and the appropriate use of the participative methods. Emphasis is placed on the crucial role played by community representative participation during formulation of the expected outcomes of the DRR, which leads to hazard reduction through the preparation of hazard maps and of the monitoring of landslide movement. Enhanced community development can also be evidenced by the construction of water tanks in the year following termination of the project. Despite the documented short-term success in landslide DRR, defining long-term exit strategy allowing the community to continue applying the measures with necessity of the minimum input from the outside actors is intrinsically difficult and still needs to be resolved.

Keywords Community-based risk reduction · Risk perceptions · Landslides · Participative methods · Local knowledge · Peru

Introduction

Community-based landslide risk reduction

Disaster risk reduction (DRR) necessitates existence and enforcement of regional or state-wide legal norms (Schuster and Hihgland 2007) as it often requires expensive structural measures or involves land development regulations. Thus, formulation and acceptance of landslide DRR strategies by governmental or regional authorities is a necessary precondition for successful risk reduction of landslides or other natural hazards. At the same time, an increasing number of studies accentuates the importance of participation in DRR by people whose well-being and assets are directly at risk, thus calling for the multilevel risk reduction where governmental strategies are complemented with public participation in order to mobilize different sources of resilience (Adger et al. 2005; Djalante et al. 2011). This can be illustrated with community-based projects to reduce risk from rainfall-triggered landslides in poor rural communities (Anderson et al. 2011), the use of local knowledge to assess community vulnerability to landslides (Ahmed and Kelman 2018), or the preparation of international landslide early warning (EW) standard which includes commitment of local authorities and communities to secure and maintain the EW system (Fathani et al. 2016). However, within these efforts, some authors also emphasize that more critical stance should be taken to consider different meanings of the community concept across space and time, (e.g., Cannon and Schipper 2014; Raška 2018).[11]

Further, authors are even arguing that when population at risk is not engaged in DRR (herein understood as the entire process from conception through implementation and long-term result maintenance), they might see the suggested measures as imposition, causing them to resist the preventive actions (Carey et al. 2012a). Several authors assess such attitude of people at risk as related to contradicting risk perceptions and distrust among public and experts (Sjöberg 1999; Slovic et al. 2000; Carey 2010) or to contradicting perceptions of coping appraisals of natural hazard phenomena (e.g., landslide occurrence, Klimeš and Vilímek 2011; retreat of mountain glaciers, Jurt et al. 2015). An important range of studies suggests to overcome the analytic categories of experts and lay people and to focus rather on different actors (e.g., populations at risks, scientific and technical staff), whose knowledge is relevant for developing robust coping strategies (Lupton 1999; Jurt 2009). In addition, following Berkes in Naess (2013) local knowledge needs to be seen rather as a process than as content only.

Hazard zoning applied for land development planning is one of the preferred mitigation measures by scientists arguing it is the safest and most economic option (Schuster and Highland 2007), but at the same time, it has often been resisted by local communities or private owners (e.g., outburst floods and rock avalanches, Carey 2010 or debris flows, Vilímek et al. 2006). Apart from the absence of participation considerations, the reason for the opposition may be embedded in different expectations of stakeholders and decision-makers contesting social, economic, or environmental priorities for the area under risk and eventually resulting in land use conflicts (Banba and Shaw 2017). The opposition may also be caused by insensitivity to local cultural contexts, i.e., specific culturally based understandings to the risk processes and the risk reduction measures (Cannon and Schipper 2014; Krüger et al. 2015). Finally, expectation towards economic development may increase the acceptable risk (Finlay and Fell 1997) among local communities. But also, long-time delay between disaster and termination of the zoning study may cause the study results to be useless, since the re-building process started meanwhile (e.g., recovery after the 1970 Ancash earthquake, Peru, in Maskrey (1989).

Setting the study context

Historical examples of successful community engagement in reducing high mountain disasters in Peru as early as in the 1980s were described in Maskrey (1989). He argues that community-centered DRR better identifies needs of the affected people, and due to detailed knowledge of local environmental and socio-cultural conditions, it provides constraints for acceptable and effective mitigation measures. Most importantly, responsibility of the local community for DRR projects reduces the community vulnerability in a long-term by strengthening its internal organization and increasing its confidence in negotiating with outside (e.g., governmental) institutions. This has been applied in recent years when the Peruvian government recognizes the importance of the local perspective for formulation of national wide adaptation measures to climate change, although much work is still needed in terms of local impact and vulnerability assessment (Huggel et al. 2015). Another example of community engagement in DRR is an EW designed to reduced risk of glacial lake outburst floods (GLOFs) for town of Carhuaz (Ancash, Peru), which paid large attention to engagement of town authorities as well as local communities in all steps of the project implementation (Muñoz et al. 2016). A variety of activities (e.g., workshops with local authorities and community members, school educational projects, simulation training) were executed to explain the prepared mitigation measures to different stakeholders possibly affected by GLOFs.

This article describes intertwined history of scientific research and landslide DRR effort at small, peasant community in the Peruvian Andes (Rampac Grande, Ancash Region), which was struck by catastrophic landslide in 2009. Using the process tracing framework (Alexander and Bennett 2005; Crasnow 2017), the main aim of the paper is to document a good practice case and its challenges deciphering the shift of the community attitude to the landslide DRR effort. In particular, the paper illustrates the shift from refusing an outside intervention to an acceptance of the proposed measures and active participation on their application and maintenance. Crucial thereby was to rethink the role of local and scientific knowledge for the process of DRR through enhanced communication. Studies illustrate the complex roles that knowledge plays for risk perceptions and so for the development of risk reduction measures. In our paper, we consider local knowledge not necessarily as merely culturally and place-based as was suggested in earlier studies (see Agrawal 1995 for discussion), but we concentrate on approaches that conceptualize it as a dynamic process of social learning (Zent 2013) based on daily experiences and practices resulting from people's activities in their environment (Adger et al. 2005; Dekens 2007; Mercer et al. 2009).

Furthermore, the paper shows the crucial role that participation of the community representatives plays during formulation of the expected outcomes of the DRR. In summary, the case study provides a detailed narrative for a framework suggested by Mercer et al. (2010) to integrate local and scientific knowledge, while avoiding disrespectful imposement of scientific results to local communities, on the one hand, and overvalorization of local knowledge, on the other. By this approach, the study tries to trace the efforts to overcome the often-noted shortcomings of scientific–indigenous division (Agrawal 1995) as well as of the simplistic top–down identification of proper and effective mitigation measures of the DRR (Gaillard and Mercer 2013).

[1] Despite this criticism, we will use the term "community" in this paper, because the case study of Rampac Grande constitutes part of the Ecash peasant community, a term officially coined by government.

Study area

Environmental characteristics

Rampac Grande community is located on the NE slopes of the Santa River in Central Peru (Fig. 1) at the altitude of about 2900 masl. The valley is wide, graben-like structure bordered by Cordillera Negra (5181 masl) on the SW, where the village is situated, and by Cordillera Blanca (6768 masl) on the NE. The valley is filled with Mesozoic and Tertiary sedimentary and volcanic rocks extensively covered by fluvial and glacial sediments. The latter originates from the Cordillera Blanca, which is tropical mountain range with the largest glacier cover (Ames and Francou 1995). Favorable geological conditions enabled extraction of precious metals in underground mines run mainly by international companies as well as operation of limestone quarries and coal mines. Two large mines are about 12 km SW (San Luis) and 17 km SSE (Pierina) from the Rampac Grande. The climate is warm with low annual temperature variations and pronounced rainy season (October to April) with precipitation totals between 500 and 1000 mm (Kasser et al. 1990). In the case of the Cordillera Negra, rainfalls are the only water source for agriculture and domestic use. Due to the sparse vegetation cover and absence of glaciers in the mountain range, the water availability is important issue for the local agriculture, which production is focused on fruits and grains. Precipitations and water saturation are also frequent landslide triggers (Table 1) especially during rainy seasons affected by the El Niño effect (Vilímek et al. 2013). Nevertheless, strong earthquakes are capable of triggering extreme number of landslides exceeding number of cases triggered by precipitation during several decades. Plafker et al. (1971) identified several thousands of landslides triggered by the 31 May 1970 earthquake while during 38 years (1971–2009) precipitations, including five El Niño events, triggered only about 369 reported landslides (Vilímek et al. 2013) within the Ancash Region.

Economic, cultural, and political background

Rampac Grande community is a part of the Carhuaz District (population of about 15 thousand in 2017, with roughly 33% of rural population; INEI 2018), being part of the higher administrative unit of the Carhuaz Province (Fig. 1). Carhuaz Province Municipality (PM) represented by mayor and council is seated in the city of Carhuaz and has specific administrative powers over the Carhuaz City, District, and Province as well as Rampac Grande community. The Carhuaz PM has large autonomy, but also coordinates the district and province administration with the regional (Ancash Region) and the central government authorities. Rampac Grande represents one of the 34 parts ("sectores"), which form the Ecash peasant community ("comunidades campesinas"), which spatial extension does not respect the Carhuaz and Yungay Province division (Fig. 1). Peasant communities are legal entities recognized by Peruvian law (Ley de Comunidades Campesinas—Law of Peasant Communities, no. 24656) which are conceptualized by

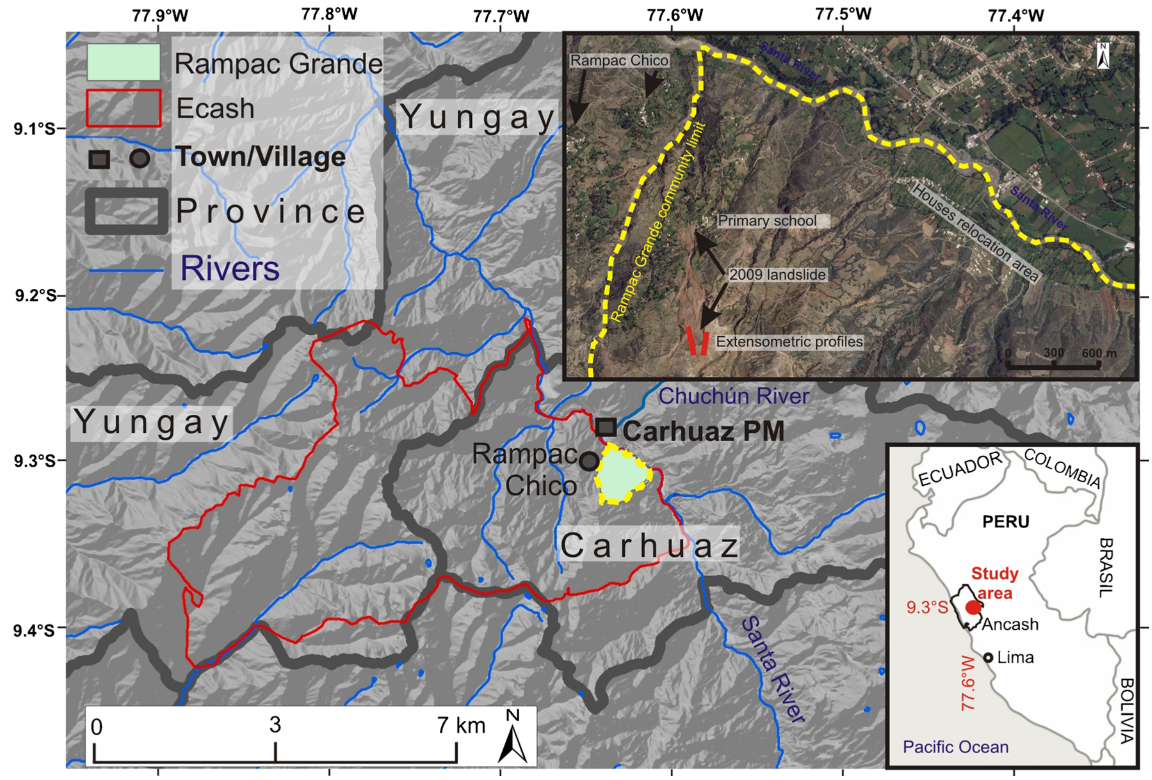

Fig. 1 Location of the study area represented by the Rampac Grande community territory (delimited based on interviews with its members) and its position within the Ecash peasant community (data source COFOPRI) and the Carhuaz and Yungay Provinces. PM provincial municipality

common territory delimited by historical usage, inhabitants of this territory which identifies themselves as a group and process of recognition by neighbors, state, and other agencies (PUCP 2012). The Ecash community, with significant share of Ancash Quechua descendants, was formally recognized in 1947 (SICCAM 2016). Nevertheless, its real formation and history reaches much further back in time. Similar to other communities, and despite the cultural influences following the European settlement, the communities are characterized by strong ties to local land, traditions based on reciprocal and joint work as well as other traditional agricultural practices (Vincent 2018; Steele and Allen 2004). Certain role in preservation of their largely unique properties (e.g., social, ethnic, linguistic) could be attributed even to the colonial legislation and administration which protected native and peasant communities for economic reasons further strengthening their segregation from Spanish dominated towns (Roedl 1998).

Table 1 Overview of historical landslides around the Rampac Grande community (*G.* Grande, *C.* Chico) collected from unpublished reports and interviews with local inhabitants (in italic). A very large number of destroyed houses and deaths during the 1870 event are probably not realistic as the local inhabitants doubt existence of such a large number of houses in the community

Date	Description (causes, occurrence conditions)	Damage
6 March 1870	Probably debris flow, Rampac C. (precipitations or water infiltration from artificial pond)	99 houses destroyed, 400 dead[1]
1942	*Rockfall or rockslide*	*1 destroyed house*
28 February 1966	Landslide, Rampac C.	25 houses destroyed[2]
31 May 1970	Several landslides, Rampac G. (earthquake)	Unknown[3]
7 December 1977	Landslide (water saturation)	4 houses destroyed, 1 dead[4]
10 December 1977	Landslide (water saturation)	2 houses destroyed[4]
1982/1983	*Slowly moving, short run-out landslide*	*Not reported*
2002	*Landslide*	*Not reported*
25 April 2009	Compound landslide, Rampac G. (water saturation)	8 houses destroyed, 5 dead

[1] Gutierrez et al. (2004), Zapata (2002), [2] Zamora (1966), [3] Plafker et al. (1971), [4] Zapata (1972)

The Ecash community and its elected representatives oversee topics which involve at least several parts of the community. These include proper compliance with property rights over the community land and its regulations towards outside entities. The community negotiates and signs agreements about social development projects (e.g., with Silver Standard Mining Company; Mining.com 2012) or resolves disputes which occasionally results into conflicts and protests, which is typical for the recent years when pressure on community land and adoption of new roles increase (Diez 2012). An example of such a conflict was a dispute between the Ecash community and private company operating local Ancash airport over land property rights (CR Noticias 2016). Another conflict involved a mining company, which car attempted to pass the community land without the community permission. The community seized the car and attacked a group of policemen who tried to reclaim it, arguing that the police action was unofficial. When several community members were charged by the Carhuaz Prosecution Office, hundreds of the Ecash community members protested asking acquit on the charges (Huaraz Noticias 2015).

Although Rampac Grande forms part of the Ecash peasant community, it remains independent and sovereign with respect to the majority of decisions made over its territory. Its inhabitants elect representatives who manage economic activities and decide on the use of collective resources (e.g., water, soil, manual labor) and development or maintenance of communal infrastructure (e.g., irrigation channels). The main governing body of the Rampac Grande community is represented by executive council ("junta directiva") led by the president and vice-president and containing five other members (cf. secretary, treasurer, auditor, and two assessors) and seven more plenary members. This executive council is elected every 2 years and represents the community towards the outside entities (e.g., Carhuaz PM, which is the main partner for negotiation over government-funded investments) and leads regular community meetings ("asambleas"), which have the maximum decision-making authority over all important matters of the community. Decisions adopted (by voting) during these meetings are obligatory. In addition, the Rampac Grande community forms thematic commissions which are responsible, e.g., for water management, electrifying households.

Methods

The selected methods and performed works constrained by the scope of the small-scale development project followed previous research activities of foreign expert team and technical reports done for the Carhuaz PM (Fig. 2). The development project was funded by the Czech Embassy in Lima and was conducted by the Peruvian research institute INAIGEM (Instituto Nacional de Investigación en Glaciares y Ecosistemas de Montaña) in collaboration with the experts from the Czech Academy of Sciences. The applied methods (Tables 3 and 4) focused on participative techniques aiming to bring community acceptance and active involvement to the landslide DRR, while geomorphological and geological research served to collect base information for DRR measures and therefore is only shortly characterized in Table 4.

The participative techniques included semi-structured interviews with selected community members (one member of each household was interviewed, in total 253 community members—men and women—responded; the interviews were conducted during 18 days in September 2016 and 2017 and November 2017), focus group meetings (with members of the Rampac Grande executive council and community commissions, Carhuaz PM mayor and commission, each of the eleven meetings attended between 5 and 30 persons), and presentations at the entire community meetings (four "asambleas" with participation between 63 and 180 community members, see Online Resource 1). The interview outline was developed based on previous experiences working with the Quechua-speaking communities in the Cordillera Blanca, and the communication was partly done in the Quechua language. These interviews were used to obtain information about the main regular community events (festivals, meetings) and agricultural practices to understand its life and functions directly not related with the natural hazards (see Online Resource 2). The interviews with the household members were used to acquire local knowledge related to landslide hazard: its mitigation and perception (see Online Resource 1). In particular, we focused on experiences with past landslide events to reveal the perception of their impacts, rationalization of their causes (beliefs), and recovery efforts (Table 1, Fig. 2). During the dissemination project phase, explanation of the final landslide hazard map was done during the interviews with household members in the region assigned as "houses relocation area" on Fig. 1 and also at the community meetings, which were used to (i) understand the community expectations of the DRR project, (ii) introduce and explain the scope of the project and basic benefits for the community, (iii) obtain the community agreement and commitment to collaborate on the project, and (iv) present the gained results. Also here, the talks were explained to the Quechua-speaking part of the community in their local dialect, which was often done directly by the president of the community, who therefore actively participated as the interpreter. The community agreement with the DRR project was gained during "asamblea" where the Ambassador of the Czech Republic (Fig. 2) participated, representing financial donor of the project, the director of the INAIGEM research institute, and the Carhuaz PM representatives (project phase 1 in Table 3).

All field work was closely coordinated with the community (Table 3) by telephonic contact with the community president. During all mapping campaigns, community member joined the research group serving as a guide and informant on the one hand and as community observer on the other hand. These persons were selected by the members of the community executive council and provided additional information about the landslide occurrence and reactivations (e.g., dates, magnitude, caused damages) as well as their perceptions and understanding to the landslide-related processes and community responses. We could also use the results of the land surface motion map derived from InSAR (satellite interferometric synthetic aperture radar) analysis which were interpreted into landslide movement maps and were provided by Strozzi et al. (2018). Results of the landslide mapping and their activity assessment based on morphological evidences, information from the community members, and InSAR data interpretation were used to define landslide hazard classes in the zoning map. Results of the extensometric measurements were used for landslide hazard communication to the community members, illustrating annual movement pattern of the monitored landslide parts and provide basic information about the state of the activity of the monitored landslides which could be applied for description of regular annual movement patterns which unusual changes

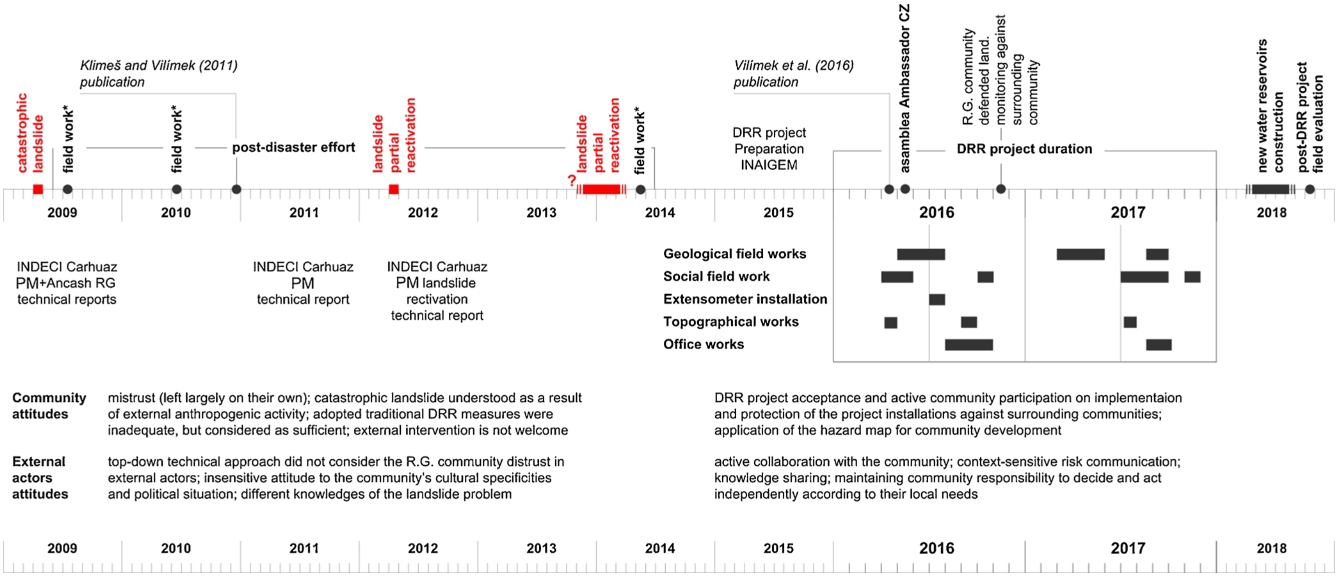

Fig. 2 Landslide research and DRR activities carried out in the Rampac Grande community since the April 25, 2009 landslide. *Activities performed by the foreign research team without INAIGEM participation. At the bottom of the figure, the main community and external research group attitudes towards the landslide DRR are described. comm. community, CZ Czech Republic, land. landslide, RG regional government, R.G. Rampac Grande, PM provincial municipality, INDECI National Institute of Civil Defense

could precede possible catastrophic movements. The technique was never intended for fully functioning the early warning system. Community members selected by the executive council also participated in the construction works of warning signs and measurement poles of the extensometric profiles providing certain income for workers who were paid by the development project. The participation also allowed the community members to get a direct insight in what was done and was a crucial element in trust building.

Results

The 2009 landslide event and emergency response

The catastrophic 2009 landslide developed in weathered sedimentary and volcanic rocks and caused extreme water accumulation during the 2008/2009 rainy season, which received most rainfalls since 1955 (Klimeš and Vilímek 2011). It represented mostly reactivation of previous, freshly looking (cf. active) landslide (identified on the 2003 Google Earth image, Klimeš and Vilímek 2011) as well as older, temporarily inactive one located around its crown part (see Strozzi et al. 2018). No active landslides were detected on archive aerial photographs (16.8.1948, library of ANA, Huaráz, Peru), and no continuous surface movements around the 2009 landslide were identified through InSAR analysis on ALOS-1 PALSAR-1 and Sentinel-1 radar data (Strozzi et al. 2018). The main scarp of the 2009 landslide was firstly observed by local inhabitants around 8:00 am on April 25, 2009, disrupting frequent path above the settlement. The sliding turned into a fast moving flow around 9:40 am killing a local woman transecting its transport path and buried a house with four persons at the edge of its accumulation. Another seven houses (Table 1) were damaged. This tragedy left one orphan girl and traumatized the community.

Local authorities were alarmed immediately after the event. First to arrive on the site were medics from a Carhuaz hospital followed by police (arrived 1.5 h after the event) and heavy bulldozers provided by the Carhuaz Municipality and one international mining company. The Carhuaz PM put a lot of effort in the relief measures supplying families from destroyed houses with basic needs and supporting the orphan girl.

Community needs and resources mobilized for the post-DRR

After the emergency relief, the Rampac Grande community and Carhuaz PM began to look for long-term landslide DRR measures. The community agreed with the suggestion of the National Institute of Civil Defense (INDECI) to relocate inhabitants from the area of the 2009 landslide on flat, presumably safe zone near the Santa River (inset in Fig. 1) where the community owned properties suitable for house construction. Part of the relocated families decided to return as they assumed that their houses are located outside the zone of the major hazard while others continued to cultivate crops on their properties around the 2009 landslide site. This solution was supported by risk assessment report prepared for the Ancash Regional Government (Salazar 2009). Another concern was safety of the newly constructed medical post, which was flooded by water and mud drained from the landslide accumulation as well as safety of the primary school located 150 m east of the edge of the landslide accumulation. The Carhuaz PM appointed an architect, working for the municipality civil protection department to oversee the landslide risk mitigation measures. The architect was identified as a key person for participatory action during the first period of field research (2009–2010, Klimeš and Vilímek 2011, Fig. 2). The implemented measures were restricted to prevention of water infiltration from a conduct channel crossing the landslide. Such insufficient solution was probably caused by the lack of landslide-related knowledge and awareness about governmental institutions which may provide help in such situations or by low ability of the local government to get the proper assistance from them. As the event gained large attention in local as well as national media, several groups of geologists and engineers from state institutions inspected the site, but did not return to provide official and relevant information to the local community or to Carhuaz PM. These aspects have further worsened the credibility of "outside" experts within the Rampac Grande community. In 2010, results of the detailed site investigations done by foreign research group were shared with the representatives of the Carhuaz PM civil protection department assuming they will use it to communicate the results with the community (Klimeš and Vilímek 2011). A poster describing landslide occurrence and triggering conditions as well as the most endangered houses was based on a priori scientific expert assumption about the community needs and without in-depth analysis of the stakeholder roles in the DRR and their institutional vulnerability (e.g., weakness to protect against disaster risk, Lassa 2010). Unfortunately, the selected key person (architect) left the municipality office due to the political changes after the national presidential elections in 2011 without ensuring continuity of the DRR mitigation effort. This development resulted into significant reduction of financial support from the governmental institutions as they become less willing to invest money into development of the site considered as high risk area by the INDECI. The general reduction of financial subsidies limited the infrastructural recovery (roads, educational facilities), finally affecting re-development of social capacities necessary to improve the community resilience.

The 2009 landslide risk reduction measures adopted by the community

The scientific knowledge generated during the post-DRR effort (Fig. 2) was developed independently without participation of the community nor was it properly shared with it. Also, no acceptable measures were suggested to minimize future landslide risk; thus, the community made its own explanation of the landslide event and defined DRR measures based mostly on their knowledge and economical abilities.

As there was significant period without precipitation (10 days) before the landslide failure, the community concluded that the landslide was triggered by explosion during illegal prospection of precious metals (Klimeš and Vilímek 2011). Such explanation was supported by the reported observations of "lights" (compare with the 2002 landslide event, Table 1) in the landslide depletion area interpreted as "people digging gold and other minerals". Another, but far less mentioned hypothesis identified noise of passing airplane to trigger the landslide. This explanation has already been reported as suggested triggering mechanism of the 1962 rock avalanche from Mt. Huascarán (personal communication). Both discourses blamed people from outside the community (e.g., metal prospectors most likely working for foreign "gringo" company; airlines operators) for the disaster and set-up forming conditions for the adopted DRR measures. Apart from the already-mentioned water infiltration prevention to the landslide body and relocation of the most affected households, the community decided to close itself to any external intervention. In this way, the community hoped to prevent any possible dangerous activity by outsiders. This action addresses two aspects: outsider can be a rather high risk themselves and their knowledge is not necessarily considered to be trustworthy or the knowledge for mitigating the hazard at stake. Traditional concepts to mitigate the landslide risk were applied among them the need to wait long enough (no specific time horizon was provided), so the mountain can "heal itself" lowering its hazard to the level enabling return to the pre-event land use and settlement. Other traditional ways of landslide hazard mitigation used in previous landslide events are described in the "Implementation of the joint landslide risk reduction project" section suggesting development of the traditional practices or their selection based on specific cases.

Joint landslide risk reduction project

In 2014, field verification of the Rampac Grande landslide showed that no effective long-term mitigation measures were done to reduce the community vulnerability or landslide hazard (Vilímek et al. 2016). Some parts of the landslide described as potentially hazardous after 2009–2010 research failed as predicted (Klimeš and Vilímek 2011) or were found in even less stable conditions. Therefore in 2016, INAIGEM research institute implemented a 2-year landslide DRR project (Fig. 2) in order to increase the community resilience by preparing landslide hazard map and building up a system of warning signs and initiation of landslide movement monitoring. The total cost of the DRR project was about 34,000 USD from which about 9500 USD was spent on monitoring equipment and related field installation works (placement of the warning signs, extensometric profiles and information panels with hazard map). The project team is comprised of seven core members (including one from Europe) and other collaborators who were assigned mainly technical tasks (e.g., topographic measurements, map preparation).

Success of the project depended largely on the Rampac Grande community acceptance and collaboration. The original motivations of the community to participate in the project consisted in getting the hazard zoning in order to obtain governmental subsidies for construction (which reduction may also have purely political reasons, "Community needs and resources mobilized for the post-DRR" section) rather than to increase the safety, which was generally believed to be sufficiently ensured with cultural measures, natural forces, and over time ("The 2009 landslide risk reduction measures adopted by the community" section). To ensure an effective participation, it was necessary to identify and define the roles of the involved stakeholders in the DRR process and to apply sensitive approaches to change largely disapproving attitude of the Rampac Grande community to external intervention mainly due to former experiences as outlined earlier (project phase 1 in Table 2). The first step was to contact the mayor of the Carhuaz PM gaining his support for the project. He arranged the contact with the community executive committee, whose members, along with representatives of others community commissions, help to prepare the project presentation (e.g., project aims, methods) to the entire community during the "asamblea" meetings. Also during all project phases, the executive committee—a crucial player in the actual power relations in the community—was considered as the main stakeholder for managing and coordinating of all project works. During all project phases, major decisions or results were first discussed with the executive committee members during the focus group meetings and then presented to the community approval at the "asambleas" (Online Resource 1).

Table 2 Participative methods applied for the DRR mitigation project. *CC* community commissions, *CZ* Czech Republic, *PM* provincial municipality, *R.G.* Rampac Grande

Project phase		Applied methods	Involved actors	Outcomes/products
1	Social agreement	Focus group and entire community meetings during "asambleas"	R.G. Carhuaz PM Mayor and council; R.G. executive council, director, and researchers of INAIGEM; R.G. community members; Ambassador of CZ	Formal contract between INAIGEM/R.G./Carhuaz PM; socialized work plans; feedback with participation of all actors
2	Diagnosis	Workshops, structured interviews	R.G. executive council and representatives of CC; community members—household representatives	Calendar of regular community events; detailed housing map of the community; local perceptions of the landslide hazard; past landslide response and prevention actions
3	Implementation	Field mapping; site selection and installation of extensometric profiles and warning signs; presentation of interim project results during field excursions, talks in local school, or "asambleas" and Carhuaz Municipality	R.G. executive council and representatives of CC and community members, Carhuaz PM officials	Installation of warning signs (Fig. 4); landslide hazard map (Fig. 5); extensometric profile measurements
4	Dissemination	Talks to the entire community during "asambleas"; semi-structured interviews; landslide hazard map display on selected places within the community; talks at Carhuaz Municipality	R.G. executive council and community members, Carhuaz PM officials	Socialized landslide hazard map accepted by the community; agreement on the future actions; landslide hazard perception change

Prioritization and role identification of local stakeholders

The Peruvian legislation states that the local governments led by the mayor are responsible for risk management at district and provincial levels. Therefore, Muñoz et al. (2016) assigned the highest priority to the Carhuaz PM and the Platform Civil Defense when conducting a GLOF early warning project for the Chucchún River basin (Fig. 1). Nevertheless, our previous experiences from the study region indicated on the one hand high institutional vulnerability of local governments limiting their governing role and on the other hand high ability of individual peasant communities to enforce their regulations and policies over their territories. The latter may be illustrated by number of cases when peasant communities opposed research or business activities conducted on their lands by external, officially acknowledged stakeholders (e.g., institutions of the central government or from outside Peru). In 1960, local community blamed precipitation gauge to disrupt the mountain gods and removed it from the installation site. When group of Peruvian engineers came to collect data, they were seized and released only after the intervention of high local police officer accompanied by strong troop (personal communication). In 2003, dilatometer monitoring of the Cordillera Blanca fault movement located 33 km ESE from Carhuaz (Košťák et al. 2002) was destroyed, as it was blamed for causing extended dry season resulting into a crop damage. The instrument was destroyed despite the fact that it was installed underground and secured by locked iron door and operated 7 years before its damage by the Huaráz-based office which at that time belonged to the INRENA (Instituto Nacional de Recursos Naturales) state agency. Well documented is decadal dispute of the local groups coalition from the district of Caraz (its capital city is located 32 km NW from Carhuaz) with the private multinational corporation over the water management of the Parón Lake (Carey et al. 2012b). The community coalition seized control over the reservoir in 2008 enforcing their views of proper water management which resulted in considerable outburst flood hazard increase (Carey et al. 2012b).

Personal fluctuations and related discontinuities of the civil service—resulting in disruption of established participatory networks—represent a major factor of institutional vulnerability of the local governments. It proved to seriously disrupt not only the Rampac Grande DRR institutional efforts (see "Community needs and resources mobilized for the post-DRR" section), but also caused loss of results of extensive geological project (Rajchl et al. 2011) done for the regional government of Piura (personal communication).

The above-described experiences suggested that agreement and collaboration between local governments and communities is the limiting condition, and both should be assigned as the priority stakeholders. The Carhuaz PM is very often the authority to legally approve and assign financial support to DRR measures, while the community has to reach agreement to approve/disapprove the proposed action that is intended to be realized on its territory. Such decisions are then respected by other parts as well as central executive committee of the entire Ecash community.

Sensitization of the Rampac Grande community towards the 2016–2017 landslide DRR project

Sensitization of the community was considered to be one of the key aspects for the success of the project. The community was supposed to undergo a process of sensitization during phase 1 of the project that culminated in the formal agreement signed during the visit of the Czech Ambassador in 31 May 2016 (Fig. 2). During this process, a respectful relationship to the political representatives of the community was built up. Joint field work always coordinated with the community and Carhuaz PM representatives for a recognition of the time for the project spent by the community members as "in-kind" contribution of the community in a form of a small payment or building up personal relationship between the outside experts and the community members contributed to this trust building process.

The use of the Quechua language and effort to collect local terms used for specific processes and search for the proper vocabulary to explain highly technical content of the project was very difficult and required active participation of the community members, but proved to be an important part of the sensitization process as well as the trust building. Since their direct involvement, they shared responsibility and credits for the research results on this topic. The importance of the comprehensible explanation of the project using the appropriate language was further supported by the community member statement related to other projects: "the technical, incomprehensible terms are used to manipulate the community members."

This sensitization process can be considered as a process of knowledge sharing (Fig. 3). Different types of knowledge (scientific knowledge as well as local knowledge of community members and also municipality members and politicians) have been shared in a process of mutual understanding and trust building. The different kinds of knowledge shaped the final result as well as the strategy of the implementation of the project (project phases 2 and 3 in Table 2). As an example, the community event calendar was used to better understand the community dynamics during the year (Online Resource 2) and also proved to be important step in the trust building process. Additionally, otherwise, unavailable information about occurrence, movement activity, and magnitude of landslides and damages they caused was used to improve the landslide hazard map. The community was also a source of important information about recent settlement distribution applicable for the exposure assessment as well as local knowledge and landslide mitigation praxis ("Implementation of the joint landslide risk reduction project" section).

Increasingly, the commitment of the community had been growing and resulted in an active participation in the process of DRR as, e.g., in terms of sharing its facilities for project purposes and—particularly important—of guarding the installations against damage.

Without such specific commitments, the community would not share responsibility along the other project actors (e.g., INAIGEM, Carhuaz PM), while the shared responsibility made it part of the project.

Implementation of the joint landslide risk reduction project

After the Rampac Grande community approval, the DRR project team begun with collection and generation of knowledge related to the landslide hazard with respect to the environmental conditions of landslide occurrence (Table 3) and community practices of dealing with it

The traditional local landslide hazard knowledge of the Rampac Grande community includes the already-mentioned process of "mountain healing" which is probably related to the appearance of landslides which are increasingly less visible with time passing from their last reactivation. This assumption follows the geomorphological definition of landslide activity assuming that the landslide with well visible and freshly looking morphology may be more active than the one with surface features masked by vegetation and erosion processes (Table 4, McCalpin 1984; Wieczorek 1984). It may provide the scientifically incorrect perception of a decreasing hazard of only temporarily inactive landslides, which reactivation probability is actually increasing by the time passing from the previous reactivation event. At this point, we need to clarify that local knowledge and scientific knowledge cannot be directly compared as the contexts in which they are produced differ considerably from each other (Klenk et al. 2017). Local knowledge might address landslides as only one challenge among others which might be considered as even more dangerous under the same time horizon by different actor groups. This might have different implications in terms of the development of local measures against landslides: other risks might be more urgent to respond to as for instance deteriorating respect to the mountains, and their disturbance by outsiders, as has been showed by Jurt et al. (2015). In this sense, the measures developed by local actors address the distrust they have experienced in the past and reflect the risks they see in the process of cultural change that is closely intertwined with environmental, political, social, and economic changes.

Coming back to the specific risks of landslides, other traditional landslide hazard mitigation measures were applied for the 1982/1983 reported event (Table 1). The mitigation measures follow oral myth which explains landslide as an action of a "bull" pushing the earth downslope. To "mitigate" this process, they make quinoa (*Chenopodium quinoa* used as a grain) offerings placed into head parts of the streams. More recent practice involves catholic mass held near the landslide site, which—according to the local beliefs—results into calming the landslide movement activity. Considering available historical landslide record for the Rampac Grande community (Table 1), we suggest that such practices were usually used for the most common landslide activity style within the community area. It is represented by apparent sudden movement usually at meter scale causing land and house fracturing, with diminishing activity which is not observable for the inhabitants within several days after the landslide first recognition. This may also explain why nobody was alarmed when developing landslide scarp was observed tens of minutes before catastrophic movement phase of the 2009 landslide. This landslide activity perception and observation stresses importance of placing the warning signs to inform the inhabitants that are entering or crossing high landslide hazard areas and also providing clear indication of evacuation routes in the case of dangerous event occurrence. The exact placement of the warning signs was chosen during field visits and discussions with community (Fig. 4). This involvement ensured better community understanding and acceptance (e.g., the warning signs were actually placed by the community members who could share their experiences from joint work with other members) of the mitigation measures.

The traditional perception about most frequent landslide movement activity style also points to the importance of the extensometric monitoring of the two selected areas considered as highly dangerous (Vilímek et al. 2016). As the monitoring begun in July 2016 and the measurements are taken at irregular time steps under very difficult environmental conditions (e.g., direct sun light, occasional strong winds), so far no clear conclusions about the movement dynamics can be made. Nevertheless, the obtained results clearly show that the method is capable of capturing

Fig. 3 Important part of the community sensitization was sharing the landslide DRR project outcomes and advances with entire community during their regular "asambleas" (left) or with the community representatives (e.g., executive council members, local school representatives) during field excursion (right), explaining extensometric monitoring of the potentially dangerous landslide parts

gravitationally induced slope movements with clear annual cycle of mostly reversible deformations governed by seasonal precipitation pattern. Nevertheless, small irreversible component of the movements (at scale of few mm y^{-1}) was identified suggesting landslide creep which requires permanent attention to spot signs (e.g., unusual accelerations) of any possible future, potentially catastrophic movement.

A scientific assessment of the landslide activity as a measure of hazard was crucial for the preparation of the landslide hazard zonation map (Fig. 5). Combination of field work with the InSAR data interpretation (Strozzi et al. 2018) and information from the community members considerably increased reliability of landslide activity assessment and therefore also of the resulting hazard map. It assigned the majority of the community land to the moderate hazard class where no evidences of previous landslide occurrence were identified, but future landslide initiation cannot be excluded as the areas are on slopes with sufficient inclination (Table 4). Safe zones (low hazard class, Fig. 5 and Table 4) comprise regions with gentle slopes either near the Santa River or on flat platforms near the ridge divides. The final hazard zonation map was prepared and presented to the community during the last project phase making sure that the community members understand the meaning of the colors representing hazard zones. During this phase, the fear from decreasing property value or further limitations of the governmental investments within the very high hazard zone expressed by the community members was overcome—the community finally obtained reliable information about safe and low hazard regions which will facilitate negotiation with the Carhuaz PM over infrastructure investments as the hazard map was presented and explained to the Carhuaz PM representatives as well. The majority of the community members understand the necessity to respect the very high hazard zones when considering, e.g., the housing development. Three copies of the map accompanied with photographs and explanation of the map meaning (Online Resource 3) were placed within the community territory (hazard map information panels on Fig. 5).

Presentation of the 2-year results of the extensometric measurements was done during the community meeting (Fig. 3). It was performed by the foreign member of the INAIGEM research group using beam projector and laptop in the community center

Table 3 Geomorphological and geological research methods applied

Aim	Methods	Technical results	Execution	Benefits for community
Landslide hazard zoning	Geomorphological mapping, satellite image interpretation, InSAR analysis[1], interviews with local inhabitants	Landslide spatial distribution and movement activity	Field campaigns in 2016 and 2017; joint work of INAIGEM and foreign experts	Tool possibly used for community development
Landslide movement monitoring	Portable tape extensometer (accuracy ± 0.1 mm) measurements of two profiles (inset on Fig. 1)	Annual pattern of landslide surface movements potentially detecting extreme behavior which may in future serve for landslide reactivation warning	INAIGEM experts, irregular time intervals with about five measurements per year	Information allowing timely preparation of the community to possible important landslide reactivation movements
Warning/evacuation sign placement	Site selection based on hazard zoning and interview results with the community members	Information about the most hazardous parts of the community land and evacuation indication	INAIGEM with the help of the community members	Salary for limited number of community workers; increasing community safety during rainy seasons

[1] Results provided by Strozzi et al. (2018)

Table 4 Definition and explanation of the landslide hazard classes as they appear on the landslide hazard map information panels placed within the Rampac Grande community (Fig. 5)

Hazard level	Hazard definition	Land use recommendations
Very high	Active landslides possibly causing soil and house cracking; gullies with side sliding and possible debris flow occurrences; active dejection cones with possible debris flow occurrences which may threaten people, houses, and crops	Avoid excessive water infiltration (e.g., irrigation), and presence of people during rainy season, house construction, or agricultural use is not recommended
High	Temporarily inactive landslides with possible reactivation and damaging houses; small landslides and debris flows which may cover with debris roads, irrigation channels, and fields and which occur mainly during high-intensity precipitations; inactive dejection cones where debris flows may occur and threaten people, houses, and crops	Avoid additional water infiltration (e.g., irrigation), and presence of people during rainy season and house construction is not recommended; agricultural use with restrictions
Medium	High or medium slopes where landslides may occur during intensive or prolonged precipitations; possibly affected by landslides and debris flows of high intensity	No restriction for people presence with precautions during rainy season, no restriction for agricultural use; it is recommended to perform detailed geological study before house constructions
Low	Flat areas with very low probability of landslides or debris flow occurrences	No land use restrictions with respect to landslides and debris flows

connected to the electricity only for this occasion. The talk was translated into the Quechua by the community president who participated in the field excursion aimed on explanation of the extensometric measurement technique and was able to explain the results in comprehensible way to the community members. They showed their concern requiring clear statements about the hazard degree of the monitored landslide parts, but were able to accept explanation that more time and measurements are needed before alarm levels may be established.

Discussion

Current efforts aiming to establish community-centered DRR strategies revealed various barriers hindering the development and implementation of widely accepted risk reduction measures at the local level, such as insufficient knowledge sharing (e.g., knowledge of the historical events and their location; Raška et al. 2015), lack of mutual recognition of knowledge of the different knowledge systems under current environmental and social conditions (e.g., the role of traditional mental models and cultural specificities; Wagner 2007; Krüger et al. 2015), and inadequate risk communication strategies (e.g., strategies that do not consider specificities of responsibilities among stakeholders and of local perceptions of expert opinions; Sjöberg 1999).

In the described example of the Rampac Grande community, contradicting effects of the different knowledge systems (i.e., strong ties with the local environment, but biased explanation of the landslide triggers) were not a major constraint on the implementation of the proper DRR measures. It was rather the inadequate strategy of risk communication (i.e., top–down technical approach that did not take into account community lived experience including the distrust in different actors—governmental and non-governmental), insensitive attitude to the community cultural specificities and political situation, different knowledge of the landslide problem, and partly inadequate mitigation measures (both at the community and government levels), which prevented the engagement of experts with relevant experiences to ensure implementation of effective DRR measures.

The relevant scientific knowledge of the landslide process and possible mitigation options was known since 2010 (Klimeš and Vilímek 2011), but it took 6 years to develop a project which would in a comprehensible and appropriate form address the community. Reason for the delay (apart from the technical and financial constraints) was the necessity to overcome serious cultural, historical (e.g., Roedl 1998), and political barriers (mainly distrust to the experts from outside the community, impression of abandonment of the local community) between the community and external research group. Importance and role of the barriers in successful DRR project implementation would be worth of further research. Overcoming them required experience and time which were not available at the moment of the scientific knowledge generation (2009–2010, Fig. 2). The technical aspects of the knowledge generation are increasingly facilitated through rapidly developing Earth observing technologies and sharing of the best practice research methodologies through international governmental as well as non-governmental organizations (GAPHAZ 2017; Sassa et al. 2018a, b). At the same time, we argue that these advancements do not substitute the on-site participative methods necessary for successful implementation of effective landslide DRR measures at the community level. Therefore, more research is needed that brings the fields of DRR, risk perceptions, and knowledge sharing together. Only the engagement of professionals with relevant social training, experiences, and skills (e.g., researchers from institutions with deep knowledge going beyond the Quechua language, but including knowledge about the social, cultural, political, and historical framework of the concerned) and dedication of appropriate time and financial resources could result in DRR projects which are build on community participation and so are more likely to develop mitigation strategies in a process of joint knowledge production that are accepted on-site.

Distinct shift of the Rampac Grande community from refusing of the external intervention to the commitment to participate on the project implementation can be documented by an event from November 2016, which is considered as a short-term success indicator. At that time, the onset of the rainy season was seriously

Fig. 4 Locations of the warning and evacuation signs were selected in collaboration with the executive council and performed under assistance of the Rampac Grande community members

delayed causing damage to the local agriculture within the broader surrounding of the Rampac Grande and Carhuaz. The peasant communities asked the government to declare a state of emergency and to subsidize their losses. As the central government was reluctant in its answer, they decided to take a prevention action based on their reality of the climatic system. Large number of the communities (including majority of the Ecash peasant community) claimed that antennas and meteorological stations located throughout the region are causing the weather irregularities (e.g., "casting out the rains", Jurt et al. 2015). Community members and their leaders declared their intention to remove all meteorological stations on their community lands, during public meeting in Carhuaz, which involved 400 people. Appeals and explanations of the Carhuaz PM officials and number of experts from local university, civil defense agency (INDECI), and research institutes (INAIGEM, ANA) did not convince them about ineffectiveness of their decision. Moreover, the crowd destroyed meteorological station at the Pampa Shonquil which formed part of the GLOF early warning system (Muñoz et al. 2016). During this period, representatives of the Ecash community approached also the Rampac Grande leaders asking them to destroy the extensometric measurement posts, claiming that also these strange installations are responsible for precipitation delay. The Rampac Grande leaders refused it arguing that the posts are part of their landslide mitigation project and defended the installations from any damage. This represented the majority opinion within the Rampac Grande community, and it illustrates the importance of acceptance and awareness about the implemented mitigation measures achieved through participation of the community members on the post installation and on-site explanations of the measurements as well as their results. This event shows complexity, partly still not well described, of the sustainability of the DRR projects where the community collaborative actions and context-sensitive risk communication are the main success conditions. Another indicator of the short-term success of the 2016–2017 DRR project is a construction of two new water reservoirs in 2018 (Online Resource 4) with the total cost of approximately 26,000 USD involving Carhuaz PM collaboration. Selection of the construction sites respected the landslide hazard map (Fig. 5), although originally, other sites were preferred by the community, which opinion was changed by the community executive council and Carhuaz PM officials. These short-term successes raise questions about the long-term sustainability. They show that the communities' perceptions and decisions are framed by a diverse range of ongoing cultural, social, political, and economic processes including processes like facing different opinions of surrounding communities or municipalities with other experiences with outside experts. The example shows that so-called "cultural hindering" has to be understood in the context of relationships with the social and natural environment.

Such appropriate DRR context for the landslide hazard was seriously lacking before the joint DRR project at the Rampac Grande, despite the fact that the Carhuaz PM formally fulfilled its legal obligation of risk management. The community was left without relevant input from outside, which would set a scientific frame (e.g., relevant understanding of the landslide trigger and its possible future movement activity), and only very limited resources were provided for successful landslide risk mitigation. Therefore, the community was forced to act on un-aided self-help base (Maskrey 1989), relying on their local knowledge and adopting only very limited, provisional mitigation measures. This situation has changed dramatically with the implementation of the local landslide DRR project which was conducted collectively with the Rampac Grande community, Carhuaz PM, INAIGEM, and foreign experts. This case supports the opinion that effective landslide risk reduction project could be defined and contribute to a decreasing community vulnerability only through well-organized collaboration of several stakeholders, knowledge sharing, and trust building processes. Similarly, the multi-stakeholders' well-coordinated participation is among the main challenges of successful landslide EW system implementation (Fathani et al. 2016). These aspects related to the community-based resilience are underlined in the ISDR-ICL Sendai Partnerships 2015–2025 for Global Promotion of Understanding and Reducing Landslide Disaster Risk which significantly contributes to the proper attention of the international research community (Sassa 2017).

Participation of the external experts on the DRR measure implementations is an important condition for its effective and efficient realization as some examples show that communities may fail in proper implementation and maintenance of medium to long-term mitigation measures without the external supervision

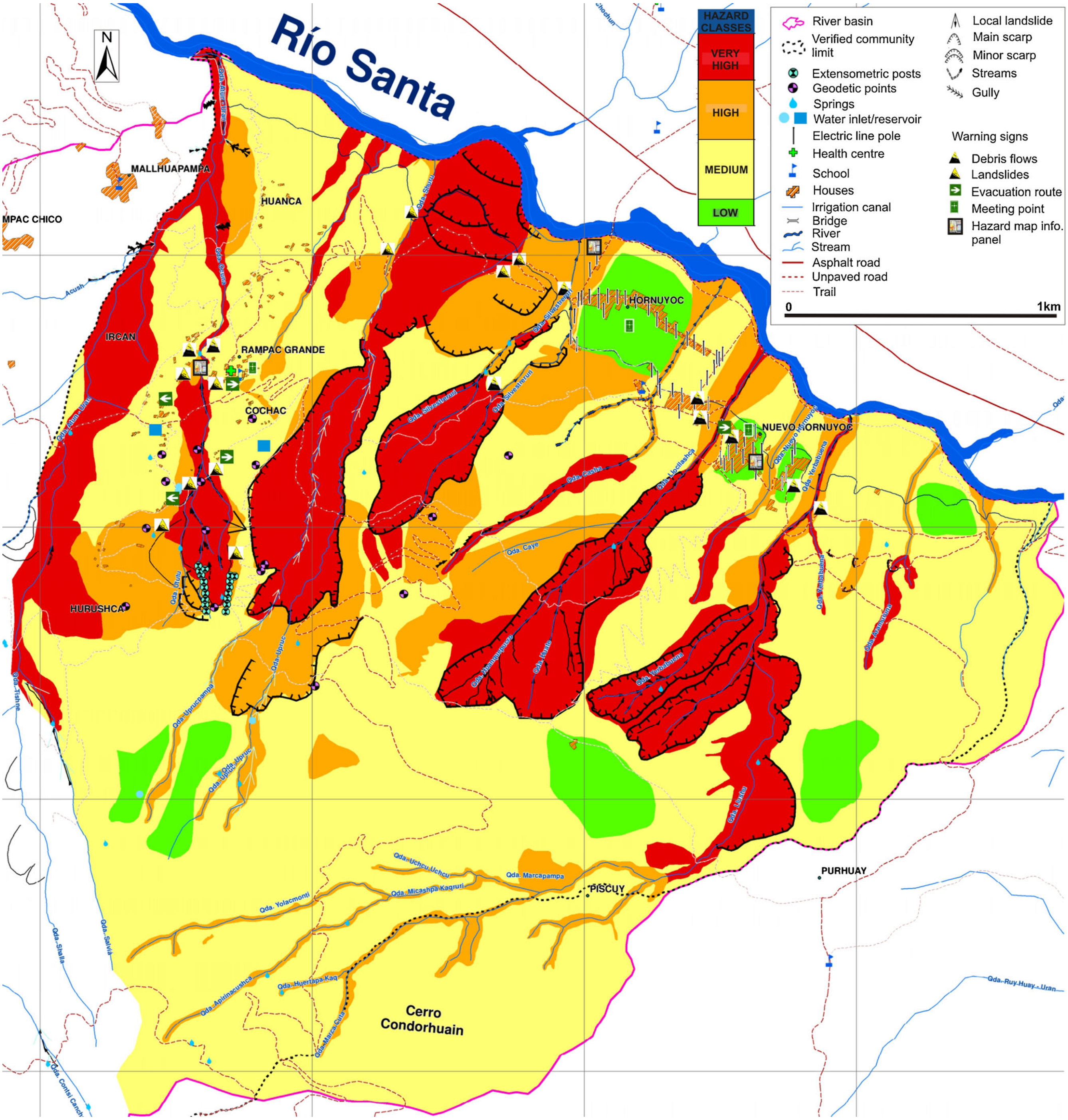

Fig. 5 Landslide hazard zonation map of the Rampac Grande community (info. information)

(e.g., Cuyocuyo community in Maskrey 1989). However, there is a need for setting up a process in which the external as well as the local and national stakeholders participate in a way that mutual trust can be built up. Thereby, the communities' autonomy and local knowledge should be respected in the process of the development of the mitigation measures without imposing specific political or economic interests. This underlines how difficult it is to define the proper "exit strategy" by external stakeholders which involvement is limited by available time and economic resources. Since the INAIGEM as well as foreign researchers involvement at the Rampac Grande community continues (Online Resource 4), no exit strategy has been defined yet. Nevertheless, the performed mitigation measures require minimum maintenance costs represented mainly by regular monthly extensometric readings with estimated annual cost of 2300 USD, which is an affordable amount for the INAIGEM. It is also important to carefully consider the high complexity of the landslide hazard assessment and implementation of the effective mitigation measures, which requires collaboration with highly trained and experienced supervisor personnel.

In the case of Peru, recent advances in Earth observing capabilities applying InSAR technology (Strozzi et al. 2018) or using the optical satellite data (Fiorucci et al. 2011; Lacroix et al. 2015) for landslide hazard description may significantly contribute to objective and reliable landslide hazard assessment for local DRR measures, as the data may be processed and interpreted by national, highly specialized agency ensuring standard output data quality for the entire Peru applicable at a local scale. There is also continuous lowering of the institutional vulnerability of the major national wide agencies dealing with the landslide phenomena in terms of capacity building, available technology, and practical experiences. When combined with large community interest and priority which is placed on the safety with respect to the natural hazards, it forms suitable conditions for growing community resilience.

When performing landslide DRR at the peasant community level, inequality in benefit distribution (e.g., personal income related to the construction of mitigation measures, accessibility of early warnings) within the community members or neighboring communities has to be carefully considered as they may represent a source of serious conflicts. In the Rampac Grande case, the hazard map covers the entire community land, and the warning signs are distributed in the most densely populated areas with the highest hazard ensuring equal benefits to the entire community. On the other hand, it was not possible to equally involve all households into the mitigation measure implementation (e.g., field construction works, guiding the research teams during field works), and also the extensometric monitoring is located only around the 2009 landslide. Therefore, community members who do not feel threatened by its possible future reactivation may feel that they do not benefit equally from the DRR project. Such feelings may cause an internal opposition to the DRR project, which may negatively affect the long-term implementation of the DRR project in the case when the community leaders (or the involved institutions) will change and people with contradicting opinions will take responsibility for the community leadership.

Another potential future threat for the DRR effort may be perceived lack of respect to traditional beliefs (including religious views of Christians and non-Christians) of the community which may be often perceived by scientists as at least partly in contradiction to the scientific concepts underlying the implemented DRR measures. In such cases, context and solutions where both concepts may exist next to each other and preferably contribute to the common goal of DRR should be envisaged. In addition to that, other important local actors—also non-human actors represented by entities of the physical environment (e.g., a mountain or a lake, compare with Jurt et al. 2015)—could be overlooked or handled without corresponding care. That may cause partial or total rejection of the implemented DRR measures if new community leaders should stress this aspect. The dynamic (repeated or long-term) studies of complex social and power structures of local communities (Vincent 2018) and their perceptions as well as economic preferences are suggested as the main way to prevent resistance and conflict in solving disaster as well as climate change risk reduction (compare with Carey et al. 2012b).

Conclusions

In the present paper, we described a shift in the Rampac Grande community attitudes, from refusing the external intervention to the acceptance and the commitment to participate on the landslide DRR project. At the beginning of the DRR effort, the inadequate assumptions about the community needs, inadequate communication between external experts and the community, and limited resources mobilized for community involvement in the landslide DRR resulted into the un-aided self-help-based community action, relying solely on their local knowledge and adopting only very limited, provisional mitigation measures. It is shown how this approach changed during the 2016–2017 landslide DRR project when a proper communication and sharing of scientific and local knowledge resulted into the community acceptance and active participation on the DRR project and implementation of the mitigation measures.

The landslide DRR project illustrates how important it is to correctly describe stakeholder's roles and set the adequate risk communication strategy within the DRR considering both the legal and informal authorities involved in the management process. The Rampac Grande executive council with the thematic community commissions and the Carhuaz Provincial Municipality were identified as equally important main stakeholders, while the community leaders (e.g., executive council and the thematic community commission members) were crucial in communicating community needs, opinions, and research results between the external expert group (cf. INAIGEM and foreign researchers) and the entire community. In addition, considerations about different worldviews including physical world entities (e.g., mountains) which are not conventionally part of the stakeholder prioritization performed within Western culture need to be included in knowledge sharing processes.

Deriving from a cultural paradigm in DRR, the article suggests a knowledge-sharing process that allows the understanding of the local as well as scientific basis of knowledge and simultaneously contributing to the building of trust among the involved stakeholders and improving scientific bases of the project. While collection, analysis, and joint production of knowledge are still a challenging task, availability of timely and high-quality scientific data for reliable and proper DRR including relevant experience is increasingly available thanks to rapidly developing Earth observing technologies and sharing best practice methodologies through international governmental as well as non-governmental organizations. The Rampac Grande landslide DRR history illustrates that knowledge needs to be properly communicated to the relevant stakeholders, which is a difficult, time-consuming, individual process which can hardly be replaced by remote or standardized solutions. Approaches to effectively connect the available scientific data with local knowledge and needs represent one of the major challenges for future research also considering the environmental change related with the recent climate developments. Although this study clearly showed that the community collaborative actions and context-sensitive risk communication are the main success conditions for long-term sustainability of the community-centered DRR projects, complexity of this process is still not well understood calling for further research.

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References

Adger N, Hughes T, Folke C, Carpenter S, Rockstrom J (2005) Social-ecological resilience to coastal disasters. Science 309:1036–1042

Agrawal A (1995) Dismantling the divide between indigenous and scientific knowledge. Dev Chang 26:413–439

Ahmed B, Kelman I (2018) Measuring community vulnerability to environmental hazards: a method for combining quantitative and qualitative data. Nat Hazard Rev 19(3):04018008

Alexander GL, Bennett A (2005) Case studies and theory development in the social sciences. MIT Press, Cambridge

Ames AM, Francou B (1995) Cordillera Blanca—glaciares en la historia. B Inst Etud Andines 24:37–64

Anderson MG, Holcombe E, Blake JR, Ghesquire F, Holm-Nielsen N, Fisseha T (2011) Reducing landslide risk in communities: evidence from the Eastern Caribbean. Appl Geogr 31:590–599

Banba M, Shaw R (2017) Land use management in disaster risk reduction. Springer, New York

Cannon T, Schipper L (eds) (2014) World Disasters Report 2014: focus on culture and risk. International Federation of Red Cross and Red Crescent Societies, Geneva

Carey M (2010) In the shadow of melting glaciers—climate change and Andean society. Oxford University Press, Oxford

Carey M, Huggel C, Bury J, Portocarrero C, Haeberli W (2012a) An integrated socio-environmental framework for climate change adaptation and glacier hazard management: lessons from Lake 513, Cordillera Blanca, Peru. Clim Chang 112:733–767

Carey M, French A, O'Brian E (2012b) Unintended effects of technology on climate change adaptation: an historical analysis of water conflicts below Andean glaciers. J Hist Geogr 38:181–191

COFOPRI (Comisión de Formalización de la Propiedad Informal) (n.d.) https://www.arcgis.com/home/item.html?id=b42b332a9b1f486c90621487ca1a5beb. Accessed August 2018

CR Noticias (2016) http://crnoticiascarhuaz.com.pe/2016-04-04-comunidad-campesina-de-ecash-exige-respeto-a-corpac-s-a/. Accessed August 2018

Crasnow S (2017) Process tracing in political science: what's the story? Stud Hist Philos Sci Part A 62:6–13

Dekens J (2007) Local knowledge for disaster preparedness: a literature review. International Centre for Integrated Mountain Development, Kathmandu

Diez A (2012) Introdución—Las comunidades campesinas como procesos. In: Diez A (ed) Tensiones y transformaciones en comunidades campesinas. Pontifíca Universidad Católica del Perú, Lima, 2012 ISBN: 978-612-45732-55

Djalante R, Holley C, Thomalla F (2011) Adaptive governance and managing resilience to natural hazards. Int J Disaster Risk Sci 2:1–14

Engdahl E, Lidskog R (2014) Risk, communication and trust: towards an emotional understanding of trust. Public Underst Sci 23:703–717

Fathani TF, Karnawati D, Wilopo W (2016) An integrated methodology to develop a standard for landslide early warning systems. Nat Hazards Earth Syst Sci 16:2123–2135. https://doi.org/10.5194/nhess-16-2123-2016

Finlay PJ, Fell R (1997) Landslides: risk perception and acceptance. Can Geotech J 34:169–188

Fiorucci F, Cardinali M, Carlà R, Rossi M, Mondini AC, Santurri L, Ardizzone F, Guzzetti F (2011) Seasonal landslide mapping and estimation of landslide mobilization rates using aerial and satellite images. Geomorphology 129:59–70

Gaillard JC, Mercer J (2013) From knowledge to action. Bridging gaps in disaster risk reduction. Prog Hum Geogr 37:93–114

GAPHAZ 2017 Assessment of glacier and permafrost hazards in mountain regions—technical guidance document. Prepared by Allen, S., Frey, H., Huggel, C. et al. Standing Group on Glacier and Permafrost Hazards in Mountains (GAPHAZ) of the International Association of Cryospheric Sciences (IACS) and the International Permafrost Association (IPA). Zurich, Switzerland / Lima, Peru, p. 72

Gutierrez FM et al (2004) Mapa de peligro, plan de usos del suelo y medidas de mitigacion ante desastres, ciudad de Carhuaz. Proyecto INDECI PNUD PER/02/051, Carhuaz, p 222

Huaraz Noticias (2015) http://www.huaraznoticias.com/titulares/comuneros-de-ecash-protestan-contra-fiscalia-provincial-de-carhuaz. Accessed August 2018

Huggel CMS, Albrecht F, Andres N, Calanca P, Jurt C, Khabarov N, Mira-Salama D, Rohrer M, Salzmann N, Silva Y, Silvestre E, Vicuña L, Zappa M (2015) A framework for the science contribution in climate adaptation: experiences from science-policy processes in the Andes. Environ Sci Pol 47:80–94 ISSN 1462-9011

INEI (2018) Instituto Nacional de Estadistica e Informatica. Lima, Peru. http://censos2017.inei.gob.pe/redatam/. Accessed 14th June 2019

Jurt C (2009) Perceptions of natural hazards in the context of social, cultural, economic, and political risks: a case study in South Tyrol. Dissertation. University of Bern

Jurt C, Burga MD, Vicuña L, Huggel C, Orlove B (2015) Local perceptions in climate change debates: insights from case studies in the Alps and the Andes. Clim Chang 133:511–523. https://doi.org/10.1007/s10584-015-1529-5

Kasser GA, Ames A, Zamora M (1990) Glacier fluctuations and climate in the Cordillera Blanca, Peru. Ann Glaciol 14:136–140

Klenk N, Fiume A, Meehan K, Gibbes C (2017) Local knowledge in climate adaptation research: moving knowledge frameworks from extraction to co-production. WIREs Clim Change 2017(8):e475. https://doi.org/10.1002/wcc.475

Klimeš J, Vilímek V (2011) A catastrophic landslide near Rampac Grande in the Cordillera Negra, northern Peru. Landslides 8:309–320

Košťák B, Vilímek V, Zapata L (2002) Registration of microdisplacements at a Cordillera Blanca fault scarp. Acta Montana IRSM AS CR 19:61–74

Krüger F, Bankoff G, Cannon T, Orlowski B, Schipper ELF e (2015) Cultures and disasters: understanding cultural framings in disaster risk reduction. Routledge, London

Lacroix P, Berthier E, Maquerhua ET (2015) Earthquake-driven acceleration of slow-moving landslides in the Colca valley, Peru, detected from Pléiades images. Remote Sens Environ 165:148–158. https://doi.org/10.1016/j.rse.2015.05.010

Lassa JA (2010) Institutional vulnerability and governance of disaster risk reduction: macro, meso and micro scale assessment (with case studies from Indonesia). Doctoral dissertation, Bonn University, Germany

Lupton D (1999) Risk and sociocultural theory: new directions and perspectives. Cambridge University Press, Cambridge

Maskrey A (1989) Disaster mitigation: a community based approach. (development guidelines). Oxfam, Oxford, p. 100

McCalpin J (1984) Preliminary age classification of landslides for inventory mapping. Proceedings 21st annual Engineering Geology and Soils Engineering Symposium, University of Idaho, Moscow, Idaho, 5-6 April 1984, pp. 99–111

Mercer J, Kelman I, Dekens J (2009) Integrating indigenous and scientific knowledge for disaster risk reduction. In: Shaw R, Sharma A, Takeuchi Y (eds) Indigenous knowledge and disaster risk reduction. Nova Science Publishers, Inc, New York, pp 115–131

Mercer J, Kelman I, Taranis L, Suchet-Pearson S (2010) Framework for integrating indigenous and scientific knowledge for disaster risk reduction. Disasters 34:214–239

Mining.com (2012) http://noticiasmineras.mining.com/2012/08/21/proyecto-san-luis-y-la-comunidad-de-ecash-firman-importante-acuerdo/. Accessed August 2018

Muñoz AR, Gonzales C, Price K, Rosario A, Huggel C, Frey H, García J, Cochachin A, Portocarrero C, Mesa L (2016) Managing glacier related risks disaster in the Chucchún catchment, Cordillera Blanca, Peru. In: Salzmann N, Huggel C, Nussbaumer S, Ziervogel G (eds.) Climate change adaptation strategies—an upstream-downstream perspective, Springer, Cham, pp. 59–78. https://doi.org/10.1007/978-3-319-40773-9_4

Naess LO (2013) The role of local knowledge in climate change adaptation. WIREs Clim Change 4:99–106. https://doi.org/10.1002/wcc.204

Plafker G, Ericksen GE, Concha JF (1971) Geological aspects of the May 31, 1970, Perú earthquake. Bull Seismol Soc Am 61:543–578

PUCP (2012) http://puntoedu.pucp.edu.pe/noticias/cinco-claves-para-entender-que-son-las-comunidades-campesinas/. Accessed August 2018

Rajchl M, Hroch T, Nývlt D, Šebesta J, Vít J, Kopáčková V (2011) Exogenic natural hazards affecting middle and lower catchements of Piura and Chira rivers (Region Piura, Northern Peru, in Czech). Geosci Res Rep 44:218–222

Raška P (2018) Community-based landslide risk reduction: an evolutionary perspective. Landslides. https://doi.org/10.1007/s10346-018-1099-5

Raška P, Klimeš J, Dubišar J (2015) Using local archive sources to reconstruct historical landslide occurrence in selected urban regions of the Czech Republic: examples from regions with different historical development. Land Degrad Dev 26:142–157

Roedl B (1998) In the name of Inca Túpac Amaru (in Czech). Scriptorium, Prague

Salazar HFS (2009) Estimación de riesgo del centro poblado rural de Rampac Grande. Gobierno Regional de Ancash, Sub Gerencia de Defensa Civil, Huaráz, p 50

Sassa K (2017) The 2017 Ljubljana Declaration on landslide risk reduction and the Kyoto 2020 Commitment for global promotion of understanding and reducing landslide disaster risk. Landslides 14(4):1289–1296. https://doi.org/10.1007/s10346-017-0857-0

Sassa K, Guzzetti F, Yamagishi H, Arbanas Ž, Casagli N, McSaveney M, Dang K eds (2018a) Landslide dynamics: ISDR-ICL landslide interactive teaching tools: Volume 1: Fundamentals, mapping and monitoring. Springer International Publishing, p 604

Sassa K, Tiwari B, Liu KF, McSaveney M, Strom A, Setiawan H eds (2018b) Landslide dynamics: ISDR-ICL landslide interactive teaching tools: Volume 2: Testing, risk management and country practices. Springer International Publishing, p 836

Schuster RL, Hihgland LM (2007) The third Hans Cloos lecture. Urban landslides: socioeconomic impacts and overview of mitigative strategies. Bull Eng Geol Environ 66:1–27. https://doi.org/10.1007/s10064-006-0080-z

SICCAM (2016) Directorio de comunidades campesinas del Perú. Instituto del Bien Común, CEPES, Lima

Sjöberg L (1999) Risk perception by the public and by experts: a dilemma in risk management. Hum Ecol Rev 6:1–9

Slovic P, Fischhoff B, Lichtenstein S (2000) Rating the risks. In: Slovic P (ed) Risk perception. Earthscan, London, pp 104–120

Steele PR, Allen CJ (2004) Handbook of Inca mythology. ABC-CLIO, Santa Barbara

Strozzi T, Klimeš J, Frey H, Caduff R, Huggel C, Wegmüller U, Rapre AC (2018): Satellite SAR interferometry for the improved assessment of the state of activity of landslides: a case study from the cordilleras of Peru. Remote Sens Env

Vilímek V, Klimeš J, Vlčko J, Carreño R (2006) Catastrophic debris flows near Machu Picchu village (Aguas Calientes), Peru. Environ Geol 50:1041–1052

Vilímek V, Hanzlík J, Sládek I, Šandov M, Santillán N (2013) The share of landslides in the occurrence of natural hazards and the significance of El Niño in the Cordillera Blanca and Cordillera Negra Mountains, Peru. In: Sassa K, Rouhban B, Briceño S, McSaveney M, He B (eds) Landslides: global risk preparedness. Springer, Berlin, pp 133–148

Vilímek V, Klimeš J, Torres MZ (2016) Reassessment of the development and hazard of the Rampac Grande landslide, Cordillera Negra, Peru. Geoenviron Disaster 3:5. https://doi.org/10.1186/s40677-016-0039-8

Vincent S (2018) Transformations of collectivism and individualism in the Peruvian Central Andes: a comunidad over three decades. Ethnography 19:63–83

Wagner K (2007) Mental models of flash floods and landslides. Risk Anal 27:671–682

Wieczorek GF (1984) Preparing a detailed landslide-inventory map for hazard evaluation and reduction. Bull Assoc Eng Geol 21:337–342

Zamora MC (1966) Deslizamento de tierras en Rampac Chico (Carhuaz). Unpublished report Electroperu S.A., Glaciology y Seguridad Lagunas, Huarás, Ancash, Peru, p. 4

Zapata ML (1972) Deslizamentos de tierrasen Rampac Chico, provincia de Carhuaz. Unpublished report Electroperu S.A., Glaciology y Seguridad Lagunas, Huarás, Ancash, Peru. I-Geotec-007, p. 3

Zapata ML (2002) La dinamica glaciar en lagunas de la Cordillera Blanca. Acta Montana IRSM AS CR, Ser A 19:37–60

Zent S (2013) Processual perspectives on traditional environmental knowledge: continuity, erosion, transformation, innovation. Understanding cultural transmission in anthropology: a critical synthesis. Berghahn Books, New York and Oxford

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