Chapter 35
Water Resources Management in the Peruvian Andes: Participatory Adaptive Measures to Climate Change

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Abstract Glacial retreat caused by global climate change is creating uncertain conditions for the rural farming communities of Yungay province in the Peruvian Andes. Peru's glacial mass has been reduced by an average of 22% over the last 30 years, leading to a reduction in water supplies vital for local farming and agricultural activities. Local water management practices are inefficient and are increasing pressure on already strained supplies. In 2006, Practical Action Peru initiated a four-year capacity-building project in sustainable water management in 12 rural communities. Participatory approaches shaped project design and implementation, including experimental plots and community training programmes. Consequently, five adaptation measures were prioritized for implementation: improved irrigation techniques, plague management, crop rotation, recovery of local knowledge about water management, improved dissemination of water management knowledge and technology, and strengthening the organization of Water User Boards. The introduction of improved technologies saved up to one-fifth of the water being used for farming. Community awareness of links between climate change impacts, improved technologies and reduced vulnerability were improved. By providing a focal point for community decision-making on water distribution and use, User Boards reduced the potential for social conflict and led to increased preventative measures implementation.

Keywords Climate change · Glacial retreat · Adaptation measures · Rural vulnerability · Water use · Improved technologies · Participatory methods

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Introduction

Global warming is central to climate change: one of the world's most worrying and pressing topics on the current agenda. This phenomenon is apparent from observations of increased atmospheric and ocean temperatures, widespread melting of snow and ice, and rising sea levels Intergovernmental Panel on Climate Change: fourth Assessment Report (AR4) (2010a). The scientific community and leading environmental protection agencies collectively accept that anthropogenic greenhouse gas (GHG) emissions play a fundamental role in global warming Intergovernmental Panel on Climate Change: fourth Assessment Report (AR4) (2010b). Consequently, the reduction of GHG emissions is considered to be a key strategy in slowing global warming, and is the driving force behind a series of international agreements, most notably the Kyoto Protocol.

Despite its globalized effect, the chain of reactions linked to climate change also affects diverse ecosystems on a local scale. Populations most directly impacted are those which are vulnerable to increased climatic variability, such as the occurrence of extremes events and desertification, often suffered by rural dwelling, farming/agriculture communities already enduring poverty-related hardships. Therefore, in addition to the development of global strategies and solutions to climate change, local answers are necessary in response to the uncertainties caused by microclimate change. In other words, local agenda must focus on investigating and generating situation-appropriate adaptation and mitigation measures. Under this conceptual framework, the Practical Action's Peruvian office designed and implemented the project Water Management and Climate Change in 2006, as part of a nationwide initiative entitled Climate Change Adaptation and Mitigation Technologies.

Climate change is producing both negative and positive effects at a local level, and adaptation methods should seek to simultaneously reduce the negative effects and enhance the positive. On the basis of this premise, the objective of this project was to reduce the vulnerability of local populations to climate change through participatory capacity building in watershed management practices amongst rural communities living in the Yungay province, specifically in the San Toribio subbasin and upper reaches of the Santa river. Ultimately, participatory strategies and results obtained in this project have great potential for implementation in similar contexts, namely rural farming communities based in tropical Andean ecosystems.

Yungay Province and Climate Change

The province of Yungay extends over the Cordillera Negra and the western flank of the Cordillera Blanca, within Ancash, a department located on the western side of the central Andes. Areas in this region of Peru have been noticeably affected by climate change over the past 30 years, with the strongest repercussions being felt by the rural farming majority of approximately 8 million inhabitants. Ancash is the

Table 1 Vulnerability factors in Yungay

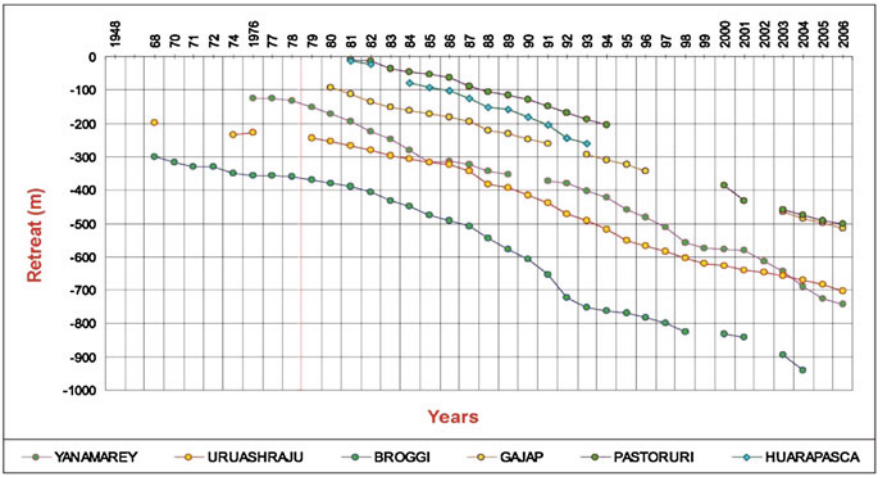
Component	Vulnerability
Geomorphic	Surrounding snow-capped mountains and high, steep slopes lead to detached ice-flows, lake overflows, flooding and avalanches
Environmental	Contaminated and depleted water reserves
	Contaminated and unproductive soils
	Deforestation
	Pollution
Physical–Infrastructural	Precarious and dangerous construction: canals, highways, housing and medical clinics
	Insufficient service infrastructure: reservoirs, canals, etc.
	Dangerous infrastructure location
	Poor technical knowledge of safe housing construction
Technological	Inadequate crop production technologies (fertilization and irrigation), yet high cost
	Low-quality fertilizers
	Little or no unbiased technical information regarding fertilizing techniques (merchants consulted)
	Undernourished and unvaccinated livestock
	Water loss during irrigation
	Inadequate disease and pest treatment
	Weak crops susceptible to plagues and disease
	Unplanned and unorganized crop cultivation, based on habit or highest immediate profit
	Ignorance of soil quality classification for housing construction
Sociocultural	Weak organization
	Limited sense of control over risks
	Poor access to information about risks
	Food insecurity (malnutrition) and poor sanitation
Economic–Financial	Low income and poverty
	Lack of participation and consultation mechanisms
	High cost of fertilizers
	Produce sold for very little
Political–Institutional	Little support from authorities
	Authorities unaware of climate change issues and the impacts suffered by the general population

most vulnerable of Peru's 24 departments, and Yungay is the province with the most vulnerability factors, as described in Table 1.

Yungay has seen climate change manifested in rainfall pattern changes: advance or delay in the onset of rainy seasons, increased rain intensity characterized by shorter duration and prolonged absence; as well as the presence of increasingly damaging frosts yet higher daily temperatures. Agriculture represents at least 80% of the region's economy, and therefore climate change directly affects local economic activity as well as daily life itself.

Other impacts attributed to local climate change commonly reported by regional farming communities are the increased presence of crop plagues, pests

Table 2 Glacial retreat in the Cordillera Blanca until 2006



The table illustrates the accumulative annual retreat (in metres) of six Cordillera Blanca glaciers until 2006.

and associated diseases carried by these vectors. But while there is consensus about the problems experienced as a result of climate change, there is a distinct lack of management strategies organized by communities in order to better face them, with the exception of a series of spontaneous adaptive measures such as the construction of irrigation canals and adjustments to the agricultural calendar. This characteristic lack of organized management within and between communities is worsened by the prevalence of misinformation with respect to the real causes of climate change-related problems.

Yungay is an important province in Peru's seismic history, most notably for the immensely destructive earthquake suffered in 1970. The devastation caused by the quake and the resultant landslide was such that much of the population now attributes many of the regional-wide climatic changes to the event itself.

Climate Change and Glacier Retreat in the Cordillera

While glaciers have been absent from the Cordillera Negra for several centuries, they are still present in the Cordillera Blanca. This is illustrated in translation of their Spanish names, the *Black Ranges* and *White Ranges*, respectively. However, the accelerated retreat of these glaciers is well known throughout the region, and perhaps one of the best documented, as demonstrated in Table 2. Of the 723 km^2 of Cordillera Blanca present at the end of the 1970s, only 536 km^2 remained in 2003 (Zapata 2008).

From this data it is evident that glacial mass has been in steady decline since the 1970s. Approximately 30% of the glacial mass in the Cordillera Blanca region has been lost over the past 30 years, which implies a very significant loss to additional water reservoirs that are so vital to local agricultural needs during the summer months.

Agricultural water stress is already experienced regularly in areas within the Cordillera Negra, and while adaptation efforts consisting of water storage and regulation do exist, these are spontaneous and isolated, and therefore there is a heavy dependence on rainfall.

Problems in Yungay

The five districts within Yungay that were chosen for the Practical Action capacity building project represent the range of socioeconomic conditions and variety of ecosystems found within the province. Perpetual poverty, as indicated by a low human development index of 0.487 UNDP 2010, and strong economic dependence on small-scale agricultural activities is characteristic of this region. Staple foods such as maize, potatoes, wheat, barley, garden vegetables and other grains make up the bulk of crops grown. Upon consultation throughout the project, farmers commonly expressed that their principle concern was inefficient water use, rather than a severe shortage of water.

A number of factors have led to the ever-increasing vulnerability faced by the population of Yungay today: poor water management, unsustainable and outdated farming and crop cultivation practices; and detrimental climate changes and associated effects. Increased migration and cross-culturalism amongst younger generations has led to the progressive collective loss of traditional agricultural know-how, and this is exacerbated by a general lack of modern crop management technologies. The various components of this problem are summarized in Fig. 1.

Project Methodology

Project implementation consisted of a series of stages: social approach, introduction of locally appropriate technologies, definition and validation of adaptation measures, and influence on social, institutional and political aspects.

Social Approach

Potential intervention areas were identified through a workshop attended by local government representatives and community leaders from all Yungay districts, who each proposed intervention areas based on the water availability problems their

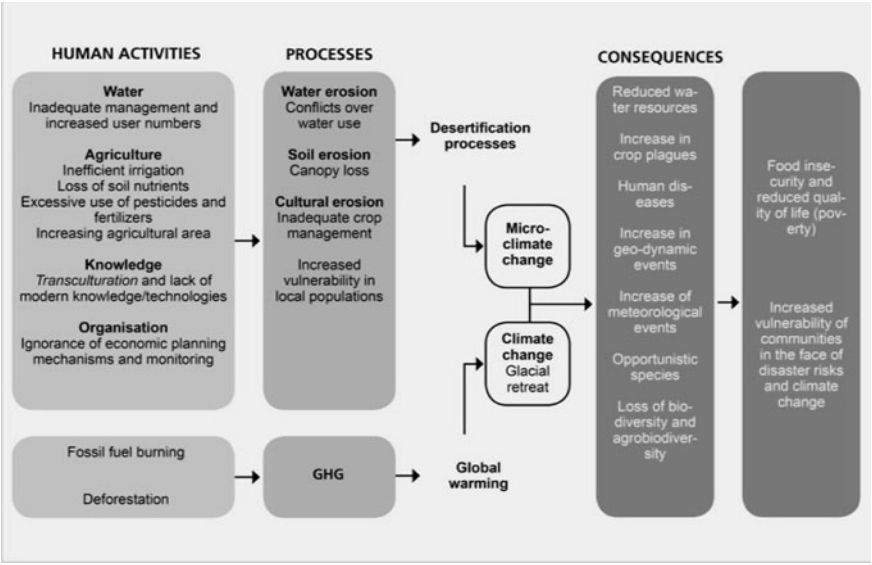


Fig. 1 Problem components

communities were experiencing. Subsequent one-day workshops were held within each of the selected districts–Yungay, Mancos, Ranrahirca, Shupluy-Cascapara and Yanama–in order to gain a first-hand understanding of community perceptions of climate change, and to identify the most vulnerable elements in local social organizations. Eleven project sites were selected from the original five districts, and a participative Adaptation Action Plan was formulated.

Introduction of Adaptation Technologies

The results obtained during the first stage of the project were instrumental in identifying the demands and technological deficiencies in current farming practices, as well as water usage concerns in the Yungay province. This phase called for the implementation of test plots in order to introduce good practice techniques such as pressure irrigation and disease monitoring. Plot areas and crops were selected in consultation with community leaders and farmers themselves.

Key steps taken during this phase were the participative formulation of an agricultural Adaptation Action Plan, via two planning and leadership workshops; the cataloguing of current local knowledge and techniques through a planning session between agricultural specialists and local farmers; the establishment of test plots sown with potato, maize, avocado, peach and alfalfa, where pressure irrigation and disease monitoring was applied; implementation of a knowledge

transfer course from specialists to farmers during field sessions, emphasizing proper water and crop management; an evaluation of current potato production processes via interviews with farmers; and studies into the impacts of climate change on crop diversity and water resources.

Adaptation Measures

Four priority components to be addressed during the project were defined and validated during the planning phase: water, farming, knowledge and social organization.

Water

Water is a key element in agricultural development, and it is the resource that is most directly affected by climate change in the region. Water supply to the province is declining due to the gradual disappearance of the glacial mass in the Cordillera Blanca, and the general misuse of water through inappropriate irrigation techniques in particular. It is estimated that irrigation in common highland farming practice is less than 15% efficient, and that approximately 80–85% of current water resources is being consumed by agricultural activity, according to local information.

Diminished water supply is a continual source of conflict within and between communities, and therefore improved water management is critical to climate change adaptation efforts.

Farming

Temperature increases leading to more frequent incidences of crop disease and plagues have resulted in indiscriminate use of chemical fertilizers, insecticides and pesticides by farmers ill-informed about the detrimental effects these practices have. Often crop plague and disease management are heavily influenced by the biased recommendations of commercial merchants motivated purely by short-term economic gain. Local farmers mentioned the following commonly witnessed diseases and plagues during the initial workshops:

- Increased presence of the so-called white fly (Aleiroridos) with the El Niño phenomenon.
- Increased citrus rust mite presence during periods of high humidity.
- The development of scale insects, favoured by drought.

- High occurrence of water mould, or blight, during periods of high humidity.
- Increased fruit-fly presence.
- Presence of sand flies (Phlebotomus) in cold areas (Huaraz).
- Increased plague presence in grains and stored produce.
- Increased rodent presence.

In collaboration with the National Service of Agrarian Health (SENASA), the Centre for Development and Participation Studies (CEDEP) and the National University of Ancash, Practical Action held workshops and field sessions to train farmers in ecological pest management techniques.

Knowledge

Although over recent years farmers have indeed been adapting their practices to changing weather conditions, there is a clear need to improve and adapt their basic farming techniques, including water flow measurement, pest management technology and adequate housing and infrastructure construction in the face of climate change. Small meteorological stations were set up at project sites, and community members were then able to quantitatively monitor daily parameters such as rainfall and temperature. The information collected from these community-managed stations allowed for a more comprehensive understanding of local climate variability.

Social Organization

Community water management is currently either inefficient or unprepared for increasing climate variability in both the Cordillera Negra and Cordillera Blanca. The organization of communities into committees is a key strategy to inclusive water management, as it enables water users to make unified decisions and exercise greater influence on local government with regard to demand for and use of water supplies. While communities in the Cordillera Negra are already organized into water boards, given their common water shortage, this level of organization and planning is not found in the Cordillera Blanca. However, in both cases, water management is simply adapted to current circumstances and is ill-prepared for the water shortages projected for the future.

Influence on Social, Institutional and Political Aspects

In order for project results and experiences to have an effective and long-term impact, local governments were lobbied to incorporate the adaptation strategies into local development plans.

Table 3 Significant climatic events

Gender	Event	Year	Perceived effect	Areas Affected
Men	Torrential rain and hailstones	1965	Sowing season adversely affected	Poncos, Ocshpachán
	Freezing weather conditions	1997	Crops burnt	Bellavista, Primorpampa
	Heavy rains from January to March	1997	Roads, schools and farmland destroyed	Casacapara, Shupluy
	Rain shortage	2004–2005	Sowing season adversely affected	Entire sub-basin
	Plagues of rats and mosquitoes	2004	Crops destroyed	Entire sub-basin
Women	Prolonged drought	Pre-1970	Water shortage	Entire Cordillera Negra
	Drought from November to March	1989	Poor harvest and no sowing	Entire Cordillera Negra
	Heavy rains and hailstones	1995	Transport made impossible	Steep slopes
	Severe drought	2004	Disappearance of springs and streams	Spring-fed farmland

Project Outcomes

Popular Perception of Climate Change-Associated Risks

In order to gauge local population perceptions of climate change impacts and associated risks, information was compiled from interviews, testimonies and workshops that took place in the eleven project sites. Testimonial information on significant climatic events in the past (summarized in Table 3) reflects the variability of weather conditions and patterns in this area of the Peruvian Andes, and confirms that the people are aware of the increasingly unpredictable and often destructive nature of the region's climate, with some anecdotes dating back to the 1960s.

Rainfall seasonality and intensity is the most common weather indicator used by locals. Surveys revealed that the population has perceived a gradual change in rainfall characteristics. Whereas previously the rainy season was well defined and regulated the crop cultivation calendar, now seasonality is far less defined and varies greatly from year to year. Similarly, rain intensity is no longer predictable given the month, and rains are said to be shorter yet more intense, occur out of season–interrupting the growth cycle of important crops–and are often punctuated by atypical droughts or summer-like spells.

Perceptions of temperature related variations in local weather were also investigated. Daily temperature extremes were commonly reported: hotter by day yet colder by night. Increased daily temperatures have a positive effect on evapotranspiration, which requires more frequent crop irrigation. However,

increasingly limited water availability means farmers have diminished irrigation capacity, and crops may go up to 28 days between watering. While frosts previously occurred between July and December once every 2–4 years, now they are endured annually between June and January. Frost occurrence in atypical periods of the year has serious consequences for agriculture, most commonly resulting in great losses in production.

The two sectors most vulnerable to climate change impacts were identified as agriculture and livestock. Severe climatic events such as those previously mentioned have direct negative effects on the health of crops and livestock, whether as a result of disease or physical damage. As a consequence, the population suffers impacts such as insufficient production of food for household consumption, diminished income, increased cultivation costs, land contamination due to increased use of agrochemicals and plague proliferation.

Significant and widespread impacts on infrastructure, housing and health were also recognized. Heavy rains primarily damage roads and highways, irrigation systems and canals, and sewerage systems, and weaken already unstable housing construction. Elevated lead content in stored drinking water is attributed to drought, and locals perceive frosts as influential in the development or exacerbation of respiratory illness and rheumatism.

Findings and Recommendations

Local adaptation efforts in response to climate change were largely limited to alterations to the farming calendar and the gradual construction of irrigation canals with institutional support. More technical adaptation responses, such as drip irrigation and specific plague management, were isolated efforts carried out at the level of families or groups of families. As a result of the surveys, Practical Action proposed a number of adaptation measures to assist communities in climate change adaptation and help them to reduce their vulnerability to associated risks.

Water and Improved Irrigation

Through the various training workshops with existing water boards, community members acquired basic knowledge of efficient water use practices, including the construction of irrigation canals, improvement of existing systems and the development of sustainable technology alternatives such as overhead irrigation. Six test plots featuring pressurized irrigation systems were implemented, in order to illustrate the benefits of water-saving practices, where between one-fifth and one-tenth of the volume of water usually used was saved. To date, potatoes, maize and avocado are successfully being grown on these test plots, demonstrating to

farmers that with less water than traditionally used they can obtain equal or greater harvests.

Given the inevitable decline in water supply in the Yungay province, future projects should prioritize water management practices by minimizing leakage and evaporation of water resources. To this end, it is recommended that water from the reservoirs be channelled through pipes rather than canals. In order to maximize benefits to local populations, priority should be placed on installing irrigation systems on communal land, systems should be affordable, and concerted action research efforts are required in order to achieve the technological innovations still necessary.

Adaptive Agricultural Practices

The community training programme offered in collaboration with the National Service of Agrarian Health (SENASA), the Centre for Development and Participation Studies (CEDEP), and the National University of Ancash offered local farmers the chance to learn on-site improved agricultural practices grounded in environmental conservation principles. Emphasis was placed on basic soil and water analysis before initiating sowing, the importance of investigating their markets so as to better select which crops to cultivate, the use of fertilizers that are appropriate to soil characteristics, integral pest management, and basic techniques in the installation, operation and maintenance of irrigation systems. A key recommendation of the project is that a territorial farming system be established for the entire Santa river basin.

Encouraged Knowledge Sharing

One of the key objectives of the project was to salvage traditional adaptation methods in response to microclimate irregularity, and to disseminate this information through community workshops and field training sessions.

Innovative agricultural initiatives, noteworthy for their creative simplicity, include the use of ground *rocoto* (native chilli pepper) as a natural pest deterrent, and the nightly removal of egg-bearing weevils from crops. Together with novel techniques demonstrated by project specialists, improved methodological farming practices were proposed consensually within communities, simultaneously reinforcing successful, locally produced solutions, and introducing new techniques as a way of adapting to ever-changing conditions.

While the population already senses the gradual reduction of water resources in the region, there is a general lack of organized local initiatives and responses to the problem. The project's capacity-building process for the introduction and acceptance of improved irrigation systems consisted of a series of logical stages: raise

awareness of the need to save water, stimulate ideas for improved water use, jointly produce water-saving methods and the implementation of test plots featuring improved irrigation systems.

Water management techniques were introduced and implemented in all five intervention districts. Nevertheless, promotion of research efforts applied to agriculture and water management in Ancash, as well as the rest of the region, is necessary if local communities are to continue improving their understanding of climate change impacts and viable adaptation methods.

Social Organization

Ancestral water usage was based on the colloquially termed "rule of the third", whereby each user has the right to a third of a waterway's flow, without regard to farming area or crop type. Currently, in water usage schemes in place throughout the Cordillera Negra, where water resources are scarce, this traditional scheme has been replaced by one based on categories, dependent on territory size and crop type. Water usage schemes in the still water-abundant region of the Cordillera Blanca, in contrast, are much more incipient, and are very wasteful of water.

As a result of the numerous workshops and training sessions, consensus of climate change and impact perceptions was reached between local authorities, farmers and other community members. Subsequently, a participative climate change Adaptation Plan that linked into local and regional development plans was put forth to local authorities.

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