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Multi-stakeholder cost-benefit analysis of climate change adaptation measures and options

The case of urban water provision in the context of melting glaciers in Bolivia

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Multi-stakeholder cost-benefit analysis of climate change adaptation measures and options: the case of urban water provision in the context of melting glaciers in Bolivia.

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1 Introduction

Climate change research in the tropical Andes on the effects of climate change on glacier melting and on the hydrology of the La Paz Valley extensively describes the possible impact of climate change on water resources in the metropolitan area of La Paz and El Alto, and thus on water provision for urban domestic uses. Eighty per cent of the glaciers in the Bolivian tropical Andes are melting, much has already disappeared and the Tuni-Condoriri system, important for water provision in the cities of La Paz and El Alto will disappear towards 2025 and 2045. These studies also provide information related to the water balance (precipitation, consumption, water losses) in the water systems of La Paz and El Alto.

Other climate trends are increased water evaporation reducing soil moisture due to increased temperatures, the climate becoming more erratic, changes in rain patterns, extreme events, flash floods and more frequent droughts. For this study, the principal stakeholders related to water provision and its sustainable use in the region were interviewed to understand their needs and perspectives in relation to water uses. These included the Ministry of Environment and Water, the water company EPSAS (Empresa Pública Social del Agua y Saneamiento), water user organisations in neighbourhood associations in La Paz and El Alto, municipal authorities in La Paz and El Alto, farmer's associations, researchers, local NGOs and projects.

2 Objectives of the study and outline

This study applies the stakeholder focused cost benefit analysis methodological framework developed by IIED to the climate change adaptation option for the La Paz and El Alto cities, given the current increased demands and reduced water flows due to the melting of the glaciers in the Andes. The research will contribute mostly to the generation of evidence on the actual costs and benefits of adaptation accruing to different stakeholders in in this urban-rural water user setting.

3 Project strategy and methodology

Glacier melting in the Altiplano is not a new concern in the context of climate change discussions in Bolivia. In the last two decades much has been published in relation to the hydrology of glacier basins and on the potential impacts of glacier retreat on the availability and sustainability of water resources. The Bolivian government, with the support of multilateral banks and international co-operation agencies, has initiated various pilot activities to address the issue of potential glacier retreat in this region and it has also applied for international funding to implement urgent infrastructure investment needed to reduce the potential risk and enhance the reliability of the water systems. Even though many research questions remain open and need to be addressed, the main constraint is not lack of information; there are enough sources, including scientific papers and project reports, to have a good picture of what is happening and what might be the main issues.

In spite of water resources already becoming depleted, there has not been enough action within Bolivian society to be effective in addressing the need for adaptation. There is still a lack of stakeholder participation and dialogue and the region urgently needs to construct a broader adaptation agenda.

Nur University is not one of the principal stakeholders in this area, but it has the experience in participatory processes to understand and try to integrate the different perceptions and point of views of the different stakeholders. Its collaboration with IIED has served to initiate stakeholder consultations in the context of a multi-stakeholder cost-benefit analysis of adaptation measures. The methodology has four main steps.

(1) Gathering relevant information from different sources (scientific papers, project reports, reportages and interviews) to understand the complexity of the issues related to glacier retreat and water provision in the greater La Paz / El Alto area.
(2) Approaching relevant stakeholders to understand their perspectives and demands and gain an overview of the range of adaptation measures suggested.
(3) With decision makers, focusing on one particular adaptation option where a multi-stakeholder analysis is needed.
(4) Bring the stakeholders together to talk about their different points of view and initiate the construction of a common agenda.

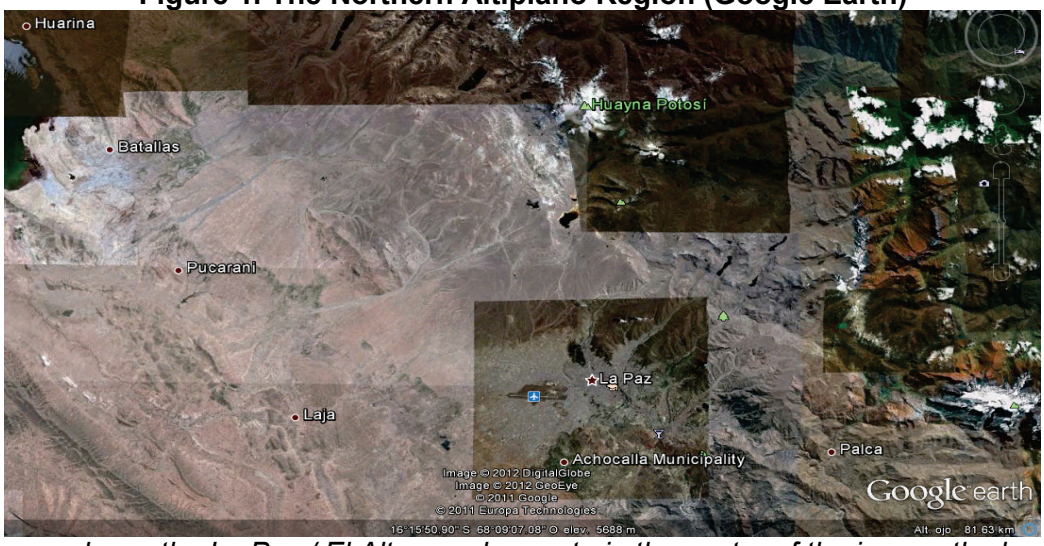
4 Project site, geography, demographics and climate change

The Bolivian Altiplano lies 3500 metres above sea level (m.a.s.l.) and comprises around one-third of the Bolivian land area. It is located within the Andes and enclosed by two mountain chains or ranges. To the west, the Cordillera Occidental runs along Bolivia's western borders, and to the east lie the ranges of Apolobamba, Real and Tres Cruces. Most of Bolivia's glaciers (which is 20 per cent of glaciers on Andes Mountains) are situated along this mountain range and together with Lake Titicaca they constitute the principal geographic features of the northern part of the Bolivian Altiplano.

The climate is driven by the seasonal oscillation of the Intertropical Convergence Zone (ITCZ). During the year, the oscillation defines the temporary dry seasons of April to September and the wet or rainy seasons of December to March. This oscillation is due to other atmospheric thermodynamics described by Vuille and Bradley (2000) and Ribstein *et al.* (1995).

The annual temperature variation on the Altiplano does not exceed 8°C with the diurnal and annual range of temperature being almost equal (Wagnon *et al.*, 1999).

Figure 1. The Northern Altiplano Region (Google Earth)



The image shows the La Paz / El Alto conglomerate in the centre of the image, the localities of Batallas and Huraina close to the Titicaca lake (upper left), the Huayna Potosi (centre top) and the Mururata Mountains and Palca locality (right)

The Northern Altiplano has an annual avarege temperature of 12°C and a total annual rainfall of about 800mm in the area around Lake Titicaca.

About one-quarter of the Bolivian population is concentrated in the greater La Paz and El Alto area. The capital city, La Paz, is situated in a valley in the eastern rim of the Altiplano between 3250 and 4100 m.a.s.l. making it the highest large city in the world. It is the seat of

government in Bolivia. The irregular landscape of the valley of La Paz determines the pattern of settlements; the lower parts of the valley are inhabited by wealthy residents, while the eastern slopes and surrounding areas are settled by medium and low-income populations. The neighbouring city of El Alto, located entirely in the Altiplano, has recently surpassed La Paz in population and is now the second largest city in Bolivia with a population of 960,767 (Table 1). It is also one of the fastest growing cities in the world with a growth rate of 4.95 per cent a year. Half of the population are younger than 19 years and the poverty rate of 70 per cent is the highest of any urban settlement in Bolivia.

Table 1. Population of the metropolitan area of La Paz/El Alto

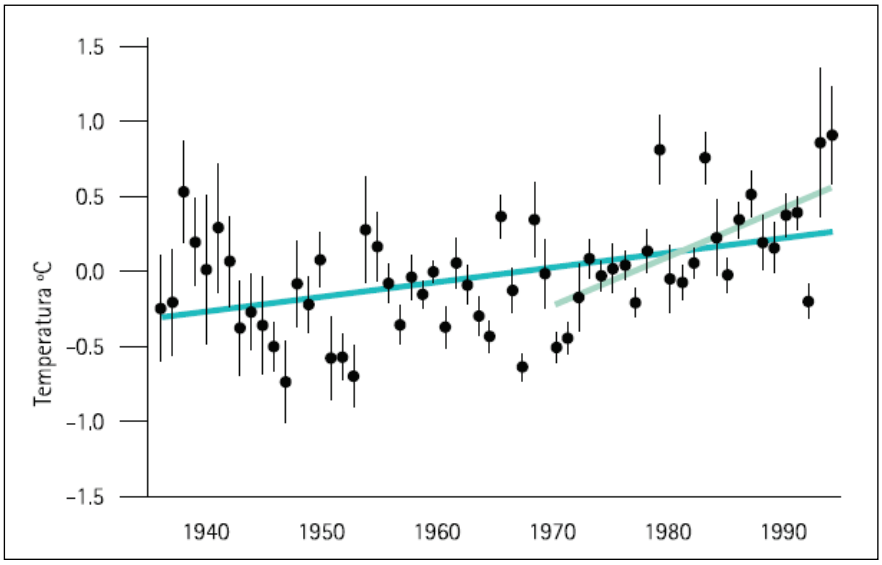
Municipality	Total	Percentage	Urban	Rural
La Paz	840,209	42.6	836,282	3,927
El Alto	960,767	48.7	956,912	3,855
Viacha	77,668	3.9	43,494	34,174
Achocalla	16,481	0.8	11,310	5,171
Palca	15,411	0.8	3,082	12,329
Mecapaca	13,688	0.7	7,802	5,886
Laja	17,716	0.9	768	16,948
Pucarani	30,656	1.6	987	29,669
Total	1,972,596	100	1,860,637	111,959

Source: INE (2008)

4.1 What are the current and potential future climate change scenarios?

Temperature trends and expected changes: glaciological studies have shown that the temperature in the Tropical Andean Cordillera has risen by between 0.10° and 0.11° C per decade since 1939 and the pace of warming increased between 0.32° and 0.34° C per decade from 1975 to 2000 (Figure 2) (Vuille and Bradley, 2000). Seiler (2009), based on the PRECIS regional climate model and scenario A2, states that temperatures are expected to rise in the Andean region (both the valleys and the Altiplano). According to the IPCC emission scenarios, temperatures are likely to increase in the range of 1.3 to 1.6° C by the year 2030 and between 4.8 to 6° C by the year 2100 compared with the average temperatures for the period 1961-1990.

Figure 2: Temperature trends in the tropical mountain range of Bolivia



Source: Vuille & Bradley (2000)

Precipitation trends and expected changes: Jaffrain (2007) observes an increasing trend in precipitation in the Altiplano in recent years, but others, such as Vuille *et al.* (2003) and PRAA (2008) have found the opposite. A compendium of results from the IPCC models have been ambiguous about this. Vuille et al (2003) shows a cycle of more intense rainfall during the rainy season (December, January, February) and less rain during the dry season (June, July and August) with larger decreases in rainfall in the month of August.

Seth *et al*. (2010), using the results of the multi-model in the A2 scenario, observes a decrease in precipitation during the spring (September-November) between latitudes 10 and 20ºS. During the high rainy season (December to March) the rains are more abundant and the increase continues until April. This trend is consistent with other observations (PNCC, 2000) based on the Normalized Difference Vegetation Index(NDVI) and the National Oceanic and Atmospheric Administration NOAA image showing a decrease of rain in October and September and an increase in November, which suggests a shortening of the wet phase.

Table 2. Temperature (ΔT) and precipitation (ΔP) changes in the Bolivian Altiplano 2001-2030 and 2071-2100 (Scenario A2)

ECHAM4 (25 km) A2	**2001-2030**		**2071-2100**	
Altiplano	ΔT: 1.6° C	ΔP: 26%	ΔT: 6.0° C	ΔP: 37%-59%

Source: (Seiler, 2009)

4.2 What are the expected climate change impacts in the region?

Climate change will have a serious impact on water resources. Bolivia has 20 per cent of the Andes' glaciers and they form important water reservoirs not just for the provision of water for the cities of La Paz and El Alto but also for irrigation. Even though climate trends and future scenarios are not well understood, changes in rain patterns, a clear delay in the start of the rainy season in many parts of the country and increasingly frequent extreme rain events are stressing water provision systems, increasing the levels of sediments in dams, and damaging infrastructure, pipelines, drainage and sanitation systems and reducing the life span and effectiveness of infrastructure projects.

The major concern among water practitioners is the perception that the climate is becoming more erratic. More uncertainty is putting additional burden on the design of systems, projects are becoming more expensive and the expected success of infrastructure projects reduced. As an article in The Economist reported in July 2007:

> A report by a team from the World Bank published last month in the bulletin of the American Geophysical Union (AGU), a scientific association based in Washington, DC, confirms most of the major's fears. It predicts that many of the lower glaciers in the Andes will be gone in the next decade or so, and that glacial runoff may dry up altogether within 20 years. It also paints a troubling picture of the future impact on water and power supplies. One danger is that as the ice melts, newly formed lakes may send water cascading down mountainsides, triggering mudslides that are potentially lethal for the villages below. Another is that if there are no glaciers to regulate water flow, flood will alternate with drought.... The Bolivian Mountain Institute, an NGO, reckons that glacial melting threatens water supplies to La Paz and its satellite city, El Alto, and will aggravate existing conflicts between farmers and miners over use of the water from the marshes of the Altiplano, the high intermontane plain, (The Economist, 2007).

The population in the Altiplano and its major cities depend on surface water sources. The metropolitan water systems of La Paz and El Alto are currently supplied by water from rain,

ice and groundwater. How much each contributes to the urban supply system varies annually according to the inherent seasonality of each source, often complementing each other. In some micro-basins, glacier melting becomes an important water source during the dry season. This complementarity between the available sources of water makes these systems individually and collectively vulnerable to climate change.

El Alto and La Paz get 80 per cent of their drinking water supplies from the Tuni-Condoriri, Choqueyapu and Hampaturi basins and a range of 15 glaciers east of La Paz. Glaciers contribute an estimated 30-40 per cent of the annual water supply of the La Paz / El Alto systems (World Bank, 2007). Caballero (2001), who analysed the contribution of the nivo-pluvio-ice Llaullani basin based on an Interaction Soil Biosphere and Atmosphere model, found that the glaciers contributed almost 15 per cent of the total water resource of the basin. Olmos (2010) estimated for the purpose of water management in the cities of La Paz and El Alto that the contribution of glaciers in the basins that feed the Tuni Condoriri dam was between 8 to 11 per cent for the period 2000-09. Olmos also predicts a decrease in this contribution of between 30 to 70 per cent by 2026, depending on the different IPCC scenarios (Olmos, 2010).

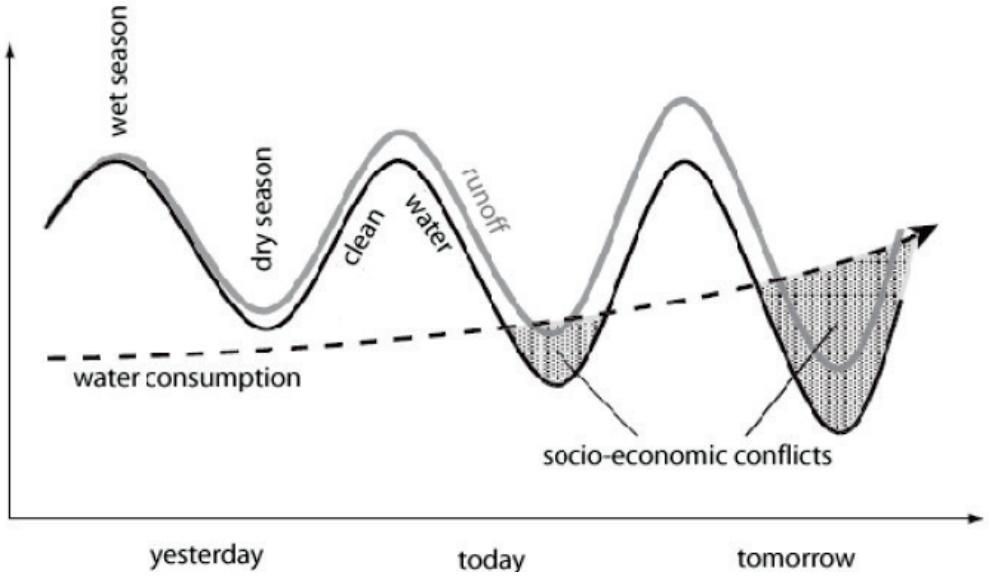
Photo 1. Current Puna Landscape with the glacier almost gone

Source: Instituto Boliviano de la Montaña

There is concern that the melting of glaciers may lead to additional water shortages and sustainability problems of the main drinking water systems in the Bolivian Altiplano (for example Ramirez, 2008; SPCR, 2011).

The expected growing demand due to population increases is expected to surpass water supply, especially during seasonal dry periods, when there will no longer be water stored in glaciers being released gradually. As there is currently insufficient storage capacity to save the rainy season's excess precipitation and balance these losses, the potential for further disturbances of socio-economic systems are expected (see Figure 3)

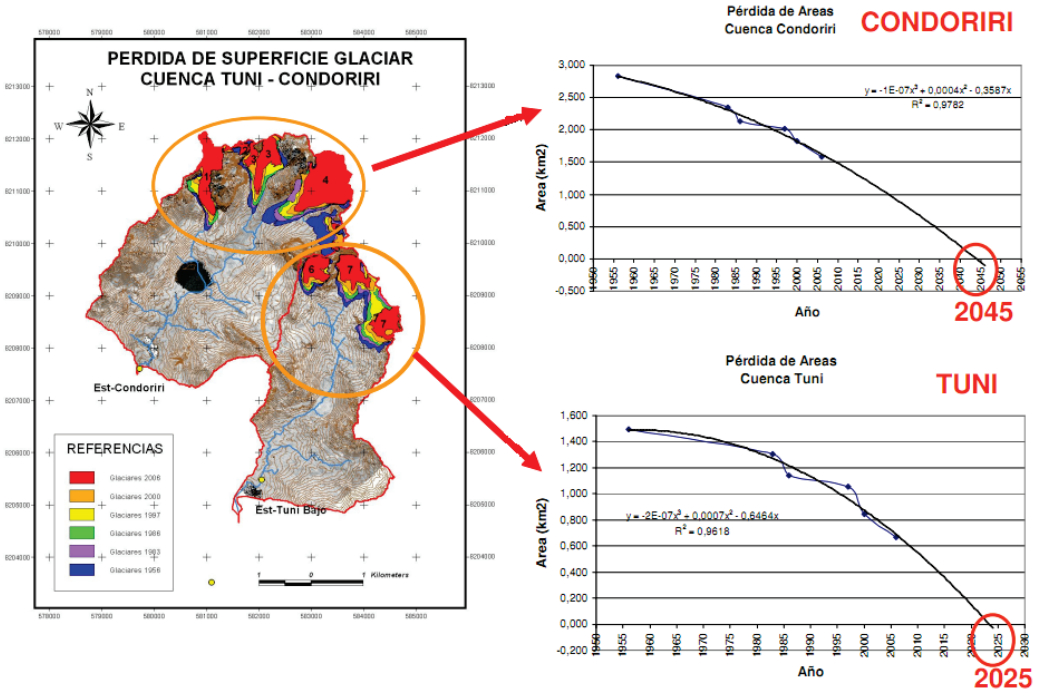
Figure 3. Opposing trends in future water demand and availability



Source: Vuille (2007) in Painter (2007)

Given the high rate of population growth in El Alto, and the need to increase the water coverage, (80 per cent) even the resources currently available are not expected to be enough to provide water of sufficient quantity and quality to the population in the future.[1] Ramirez (2008) suggests that critical glaciers for the El Alto system will disappear towards 2025 and 2045 making the El Alto system highly vulnerable (Figure 4).

Figure 4. Trends in glacier surface in the Tuni and Condoriri watersheds



Source: IHH-UMSA, IRD

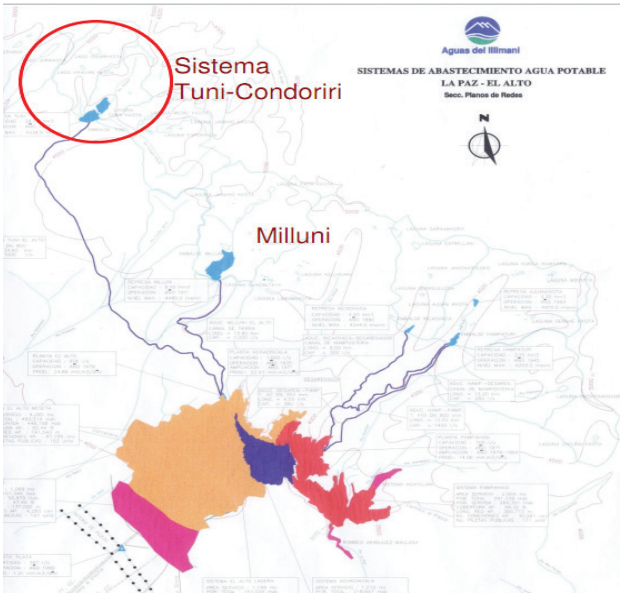
[1] personal conversation with Marcial Berdeja, Vice minister of Water and Sanitation

The Ministry of Environment and Water is in charge of the sector with two divisions in charge of Water and Sanitation (VAS) and Watersheds and Irrigation (VRHR Spanish acronym). The new administration of President Morales has been changing Bolivia's institutional framework with the issue of a new constitution. Since then many laws have been issued, but two in particular will have a strong impact over the environment sector: 1) The Law of the Mother Earth and 2) The Law of Decentralization and Autonomies which gave local authorities more responsibilities. A major constraint on the water sector in Bolivia has been the difficulty of agreeing on a new Water Law: at the moment more than 20 versions are under discussion and supported by different stakeholders. As a result, many of the existing institutions are run based on local *ad hoc* agreements. Many areas have established water commissions and basic rules to deal with all the aspects of a particular watershed, but these arrangements are not legally supported. It is expected that the new Autonomies Law will provide the platform for local authorities and regional institutions to enhance their constituencies.

Water is major priority of the Bolivian government. The new constitution recognises water as a human right and thus it has emphasised establishing major programmes to meet the unmet demands of broad sectors of the population concerning water for irrigation and drinking.

Despite relatively high investment in the basic sanitation sector in Bolivia, the proportions of people with access to drinking water and waste water disposal are very low, even by Latin American standards. On the Altiplano and in El Alto, access to drinking water is even lower than the average (70 per cent). The Bolivian SPCR (2011) estimate that by 2018 the current water supply systems for La Paz and El Alto will face difficulties meeting the incremental demand from projected population growth. Climate change will also have a significant impact on the water sources that supply the metropolitan areas of La Paz and El Alto. Specifically, seasonal climate variations of rain patterns are expected to occur in the Altiplano (Seth *et al*.,2010) coupled with the fact that, of the country's three main basins, the Altiplano is the one that receives the least annual rainfall (about 61 million cubic meters).

Box 1. Water system of La Paz / El Alto *(Source:* Empresa Pública Social del Agua y Saneamiento *(EPSAS)*



The greater La Paz / El Alto drinking water system comprises the following subsystems:

(1) Achachicala System. This system provides for the central part of the city and is fed by following sources:

Milluni basin: The 58.2 km^2 basin is located approximately 15 km northwest of La Paz. Pata Lagoon (Pata Khota) and Janko Lagoon (Janko Khota) are in the upper basin. The Milluni river is also fed from the Charquini basin which crosses the abandoned Milluni mine, receiving waters contaminated with iron, manganese, sulfates and other metals. In 1920 a 10.8 million m^3 dam was built to store drinking water

Janko Khota lagoon is 6 km upstream of the Milluni dam.

Choqueyapu Basin: A 70 km^2 basin approximately 15 km northwest of La Paz. Glacier meltwater from this watershed is used during the dry season.

(2) Panpahasi System: Provides water to the southern part of the city. Its current sources are the Incachaca and Hampaturi basins. This system comprises three dams, one in the Incachaca basin and two in the Hampaturi basin.

(3) System El Alto (gravity-fed): This system provides water to the city of El Alto. Its current sources are the Tumi Basin, with a 21.5 million m^3 reservoir which became operational in 1977 and the Condoriri basin with a 230,000 m^3 reservoir built in 1999.

(4) El Alto - Tilata System (groundwater): The system is supplied with groundwater wells by two lines, each with 15 25cm diameter wells 90 to 105 m deep.

4.3 Impacts of glacier retreat on rural livelihoods

CNN described the situation of rural communities in areas affected by glacier melting in November 2009:

> 'There is less water now' says Leucadia Quispe, a 60-year-old mother, grandmother and farmer. Seven of her eight children have left the region, she says, because there is no way for them to make a living. Most of the men of the village have also gone, heading to the conjoined urban sprawl of nearby La Paz and El Alto in search of work, returning just once or twice a month to see their wives and families. Jaime Nadal, the United Nations Population Fund's (UNFPA) representative in Bolivia, said that Quispe's situation was far from unusual. 'Young people tend to leave these areas. Old women are typically left in the community having to perform harder and harder tasks to keep up the household. We already see mostly old women in many of these communities'. (Hooper, 2009)

Glaciers are melting and climate is becoming more erratic, affecting the sustainability of agricultural systems and rural livelihoods (see Table 3).

Table 3. Climate change perceptions of rural farmers in the Altiplano (UNDP, 2011)

GENERAL WEATHER	The weather is unpredictable and severe. Periods of drought and intense heat are followed by torrential rains that generate floods. Also, other extreme events such as hailstorms, windstorms and heat waves have become more intense and frequent.
RAINS	The seasons are less stable, the rains come later and the time between the first and the last rain has shortened. Rainfall is stronger and shorter, the gaps between one precipitation and the other are longer.
TEMPERATURE	The weather is hotter and does not allow the soil to retain moisture, although some communities benefit from the increased heat.
HAIL	Hailstorms have been frequent in the Puna region. They are unpredictable, with larger hailstones, and affect crop growth
FROST	Increased frequency of frost with more catastrophic consequences. It occurs out of the traditional season, which affects crop growth and flowering.
WINDS	More 'crazy' winds
SNOW	Where once it snowed a lot, this phenomenon has now diminished. The snow helps control pests.

5 Prioritised adaptation options by principal stakeholders

Traditional systems in the Andes are perceived as highly resilient due to the diversity of coping strategies, but the predicted effects, rates and variability of climate change may push local systems beyond their range of adaptability (Halloy *et al.*, 2005). Agricultural systems in the region are affected by environmental changes like temperature rises, delayed rainfall and water shortages. These changes are pushing farmers to adopt new coping strategies. In a study in the Palca region, McDowell and Hess (2010) concluded that 'The farmers of Palca have historically employed a wide array of strategies to deal with climate variability, but in recent decades have shifted some practices to respond to changing social and economic stressors, which may make them more vulnerable to future climate change.'

A local leader, Mr Aruquipa, interviewed about glacier melting by the BBC said:

> 'For the past two decades, we, the people from the Andean regions have been suffering because of the greenhouse emissions from the developed countries. If they don't stop our glaciers will disappear soon,' Mr Aruquipa says. 'We want those countries to compensate us for all the damage they have done to nature,' he says. Schipani (2010)

Principal stakeholders are aware of the trends of climate change and the main issues and they are changing their views, expectations and demands in relation to water resources.

Table 4. Changing stakeholder demands

Stakeholder	Baseline demands	Climate change-linked demands
Neighbourhood association (El Alto)	Water to satisfy domestic demands in the right quantity and quality, tariffs should remain low.	Water to satisfy domestic demands in the right quantity and quality, tariffs should remain low. Might be open to contribute to public awareness campaigns to reduce water consumption.
Vulnerable urban populations	To obtain access to water resources.	To obtain access to water resources. Might be open to participate in public awareness campaigns.
Water company (EPSAS)	To maintain the service and grow the business, ensure system reliability.	Reduce or keep water demand low by increasing efficiency. Pressured to seriously consider climate change adaptation by international funders (CAN, World Bank, IADB, other sources)
Vice-minister of Water and Sanitation	To keep commitments to principal constituencies in particular the demands of "social vulnerable" groups.	New opportunities to maintain commitments due to additional climate money becoming available.
Vice-minister of Environment	To ensure the sustainability of water resources.	To ensure the sustainability of water resources. To claim just compensation from big emitters
Environmental activists	To ensure the wellbeing of ecosystem and the quality of environmental services.	To ensure critical environmental services like grasslands (*bofedales*). Support climate justice campaigns.
Local communities in Palca valley.	To ensure the access to water resources	Climate change is affecting basic human rights. Address climate justice.
Local communities in the Altiplano (Batallas, Pucarani)	To gain access to water for irrigation.	They see the need to enhance water reservoirs and make more efficient use of water resources.
Industry (milk production, farms)	To maintain water amounts and tariffs.	More pressure to use other water resources like ground water. Enhanced pressure to keep water clean

Source: interviews

Based on a comprehensive study of the Zongo basin, Jeschke (2009) classifies the following adaptation measures for the northern Altiplano:

a) **Climate proofing:** in order to strengthen the resilience of local populations, ecosystems and economies to the impacts of glacier retreat.
b) **Water storage in the wet season**: rainwater harvesting and storage systems to replace the depleting natural regulation capacities of the glaciers.

c) **Water management and water conservation:** to secure the sustainable and efficient use of water in the tropical Andes and thus to reduce demand.
d) **Research, monitoring and risk management:** the likelihood of natural disasters in the topical Andes is expected to increase considerably due to glacier retreat and the intensification of the hydrological cycle (see for example, Painter, 2007).

Other environmentally driven proposals include the sustainable use of ground water and enhanced infiltration levels by afforestation measures;[2] the conservation of grass and peatlands, ensuring sound management, reducing cattle pressure and avoiding exploitation of peatlands;[3] and the cleaning of the Cohana Bay in Lake Titicaca.

Three major projects shape the climate change agenda in the Bolivian Altiplano.

1) The Andean Adaptation Project (PRAA) started in 2006 with support of the World Bank to address the different impacts of rapid glacier melting in the Andean region.
2) A project helping local communities adapt to climate change in the Palca district, carried out by local communities and the local NGOs Agua Sustainable and Ayni Tambo with the support of the Danish Cooperation. This project explores adaptation measures in rural communities affected by rapid glacier retreat.
3) The Pilot Project on Climate Resilience (PPCR) which is intended to support Bolivia´s efforts to deal with climate change in its principal watersheds. The project is funded by the Climate Investment Fund through the World Bank and the Inter-American Development Bank (IADB). One of the sites selected by the Bolivian government is the metropolitan area of La Paz and El Alto affected by glacier withdrawal. The project will focus on the climate resilience of the La Paz / El Alto water system and is programmed to build a dam to increase water storage capacity for El Alto. Section 6 analyses this project option in more detail.

6 Multi-stakeholder cost-benefit analysis

Based on discussions with decision makers in the Vice ministry of Environment project PRAA and the results of the workshop carried out in February 2012, the project team selected two options to be evaluated in more detail using the multi-stakeholder cost-benefit analysis (MCBA) methodology: the construction of a new dam and efficiency measures in the La Paz / El Alto water delivery system.

1) **The construction of a new dam:** the Bolivian government needs to evaluate this option to satisfy increasing water demand and increasing water shortages due to climate change. As a case study, we have chosen the construction of a new dam in the Batallas district (Peñas Dam) 60km from La Paz / El Alto. The construction of the dam has two major implications:
    a. The construction of a new dam in a rural district where two principal livelihoods (dairy and agriculture) compete for water.
    b. Meeting the unsatisfied water demands in the Batallas locality.

The dam has a proposed size of 15 million m^3 and is principally designed to complement the current water system of La Paz / El Alto and provide water for El Alto. The additional amount of water will maintain and if possible increase the current water coverage in El Alto in the face of rapid population growth.

Besides providing water to El Alto, which is the political priority, and meeting the water demands of the municipality of Batallas, the actual owners of the watershed, the project needs to evaluate the cost/benefit of complementary projects for livelihood generation in the area. For the purpose of this case study we have chosen an alternative tested in neighbouring municipalities where the emphasis is put in recovering the productivity of the

[2] Conversation with Hugo Bohero, Programa de Fortalecimiento Integral (PFI)
[3] Conversation with Stephan Beck, Ecology Institute

ecosystem, reducing soil erosion and enhancing soil fertility, recovering native pastures and enhancing dairy livestock (SID, 1999).

Table 5. MCBA of the Peñas Dam

Stakeholders	COST Monetary	COST Non-monetary	BENEFITS Monetary	BENEFITS Non-Monetary
Building the Peñas dam				
Ministry of Environment and Water	US$ 50 – 60 million (Source: SPCR)	More co-ordination, negotiation with other stakeholders	Increase in water availability: 16-000-20,000 new connections	More visibility
Public water companies (EPSAS) / co-operatives				More reliable system
Municipal government of La Paz				Less pressure on the current water system of La Paz
Municipal government of El Alto	Up to 25% of the total investment.			
Municipal government of Batallas	25% of the total investment.			
Neighbours of El Alto	Water tariff	Labour hours	Enhanced economic opportunities and less time consuming obligations for family members estimated at US$ 300 / year	Access to water
Farmer families in Batallas	US$1.5 million	Labour hours (estimated US$ 0.5million)	Increase in family income of US$ 1171	
Milk producers in Batallas	Not estimated	Not estimated		Water available for crops, time availability Possibility of tourism and gastronomy
Rural socially vulnerable groups, subsistence farmers		Incidence to guarantee their participation. Open to contributing labour hours	If access is guaranteed, increase in family income of US$ 1171	
Urban poor		Open to contributing with labour hours	Enhanced economic opportunities and less time consuming obligations for family members estimated at US$ 300 / year	Access to water, better sanitation
Environment			Increased income from rural livelihoods. Soil and water conservation.	Water regulation, Reduced soil erosion.

2) Efficiency measures in the La Paz / El Alto pipe water System:

The water system itself could generate better water availability and sustainability by reducing water losses (unmetered water) and reducing water pollution. The local water company, EPSAS, estimates that water losses can be reduced from almost 40 per cent to 26 per cent with low incremental costs, making 4 to 5 million m^3 of additional water available.

Table 6. MCBA of reducing pipeline water losses

Stakeholders	COST Monetary	COST Non-monetary	BENEFITS Monetary	BENEFITS Non-monetary
Ministry of Environment and Water.	US$ 8 million (Source: EPSAS)	More co-ordination, negotiation with other stakeholders	Increase in water availability and 2000 new connections / year	More visibility
Public water companies (EPSAS) / co-operatives				More reliable system
Municipal government of La Paz				Less pressure on the current water system of La Paz
Municipal government of El Alto	Up to 25% of the global investment.			Less social pressure upon the current administration.
Neighbours of El Alto			Enhanced economic opportunities and less time consuming obligations for family members estimated at US$ 300 / year	Less risk of disease
Urban poor				Less risk of disease
Environment	Not estimated			

7 Discussion

Despite high levels of uncertainty and complexity, and the need for more research and investigation, glacier melting is already taking place and the potential impact on water provision for the cities of La Paz and El Alto are well understood in qualitative terms. This is a priority for the Bolivian government and an important issue for many of the stakeholders dealing with water resources in urban areas who have competing demands for the use and distribution of water resources.

A multi-stakeholder cost-benefit analysis approach helps to clarify the broad range of possible adaptation options and how important these might be for the different stakeholder groups. It can also help clarify possible means of implementing 'out of the box' measures and help clarifies a communication strategy and dialogue among them.

The two options assessed do have a positive net present value (NPV) in financial, social and environmental terms. Building the new dam to satisfy water demands in El Alto may have more benefits resulting from providing water to the mainly poor population. The trade off with the rural municipality of Batallas is to initiate a programme of recovery and the enhancement of traditional livelihood systems which can keep water demands low and enhance family income. The investment needed to carry out this measures is relatively low, at US$ 1.5 million for 1000 families, compared to irrigation systems, which can cost in the range of US$ 3000-5000 per hectare, and the general investment needed to build the dam at US$ 60 million. The benefit in terms of income is higher at US$ 1171 per family) (SID, 1999) in comparison with the estimated average income increase of irrigation projects, at US$ 579 per family (PRONAR) and the use of water can be reduced drastically.

In the case of the second option, reducing water losses, an estimated investment of US$ 8 million would net the water system of La Paz / El Alto an additional 4 million m^3 of water to satisfy current demands. The main net benefits resulting from additional water provision can be expressed in monetary terms by estimating the increased family time available for work and education. The benefits in terms of improved system reliability and reduced social pressure are also relevant.

Bibliography

Caballero, Y. 2001. Modélisation des ecoulements d'origine pluvio – nivo – glacière en contexte de haute montagne tropicale: Application à la haute vallée du Zongo (Bolivie). Thesis. Montpellier University.

Economist, The. 2007. When ice turns to water: Glacial melting poses potentially costly problems for Peru and Bolivia. 12 July.

Gonzales, J. and Zalles, H. 2010. *Climate change vulnerability reduction in Bolivia: MDG 7, target: achieve significant improvement in lives of at least half million slum dwellers in Bolivia by 2020*, The Netherlands Climate Assistance Programme, La Paz.

Hala Abou, Ali. 2003. *Water and health in Egypt: an empirical analysis*. Department of Economics, Göteborg University, Sweden.

Hindman Persson, T. 2002. Household choice of drinking-water source in the Philippines. *Asian Economic Journal*, Vol. 16 No. 4.

Hensher, D., Shore, N., and Kenneth T. 2005. Household willingness to pay for water service attributes, *Environmental & Resource Economics*, 32(4):509-531.

Hooper, S. 2009. Women 'bearing brunt' of climate change. *CNN*, 22 November.

Jaffrain J. 2007. Les extrêmes de migration de la Zone de la Zone de Convergence Intertropicale en Amerique du Sud, Étude de la variabilité spatio-temporelle des précipitations en Amerique du Sud tropicale sur les dérnières decennies. Report. Montpellier University.

Jeschke, M.L. 2009. Glacier retreat in the Bolivian Andes as a consequence of global climate change: Impacts on regional water supply according to the simulation of future runoff from Zongo glacier. Thesis. Potsdam University.

Jordan, E. 1998. Glaciers of Bolivia. In: *Satellite Image Atlas of Glaciers of the World: Glaciers of South America*. U.S. Geological Survey.

Halloy, S.R.P., Ortega Dueñas, R., Yager, K. and Seimon, A., 2005a. Traditional Andean cultivation systems and Implications for sustainable land use. Acta Horticulturae, 670, 31-55.

INE (Instituto Nacional de Estadística) 2008. *Bolivia: Proyecciones de población departamental según Provincia y Municipio. 2000-2010*. INE.

IPCC, 2007. Working Group II Contribution to the Intergovernmental Panel on Climate Change Fourth Assessment Report. Climate Change 2007: Climate Change Impacts, Adaptation and Vulnerability - Summary for Policymakers, 23 pp.

McDowell, J. and Hess, J. 2010. Vulnerability to competing social and climatic stressors in the Bolivian highlands. 2nd International Conference: Climate, Sustainability and Development in Semi-arid Regions, Fortaleza - Ceará, Brazil.

Olmos, C. 2010. Gestion des ressources hydriques des villes de La Paz et El Alto (Bolivie): Modélisation des apports glaciaires et analyse des enjeux (In revision). Doctoral thesis. Université Libre de Bruxelles.

Painter, J. 2007. *Deglaciation in the Andean Region.* Human Development Report Office Occasional Paper. UNDP, New York.

PNCC. 2000. *Escenarios climáticos: estudio de impactosy opciones de adaptación al cambio climático*, La Paz, Bolivia.

Proyecto PRAA (Proyecto Regional Andino de Adaptación) 2008. *Proyecto Regional Andino de adaptación al cambio climático-Bolivia*. Ministerio de Planificación Territorial y Ambiental - Programa Nacional de Cambios Climáticos.

Proyecto PRAA 2009. Adaptación al impacto del acelerado retroceso glaciar en los Andes Tropicales. PRAA, PPP, Buenos Aires.

Ramirez, E. 2008. Impactos del cambio climático y gestión del agua sobre la disponibilidad de recursos hídricos para las ciudades de La Paz y El Alto. *Revista Virtual REDESMA.* Vol. 2(3).

Ribstein, P., Tiriau, E., Francou, B., and Saravia, R. 1995. `Tropical climate and glacier hydrology: a case study in Bolivia', J. Hydrol., 165, 221±234.

Schipani, A. 2010. Bolivian villagers want compensation as glaciers melt. *BBC News*, 19 April.

Seiler, C. 2009. *Implementation and validation of a regional climate model for Bolivia*. Fundación Amigos de la Naturaleza (FAN-Bolivia). http://precis.metoffice.com/docs/PRECIS Christian Seiler FAN Bolivia v1 2.pdf.

Seth, A., J. Thibeault, M. Garcia, and C. Valdivia, 2010: Making sense of twenty-first-century climate change in the Altiplano: Observed trends and CMIP3 projections. Ann. Assoc. Amer. Geogr., 100, 835–847.

Shukman, S. 2009. Glacier threat to Bolivia capital. *BBC News,* 4 December.

SID (Strategies for International Development) 1999. Estrategias para recuperar el Altiplano "Achamamam Ukrupa Qhantawi" en los Municipios de Patacamaya Y Umala de La Paz Bolivia, SID.

SPCR (Strategic Program for Climate Resilience) 2011. *Pilot Program for Climate Resilience – Climate Investment Fund*, La Paz – Bolivia.

UNDP 2011. Tras las Huellas del Cambio Climático en Bolivia. 2011 Publicaciones, Energía y medio ambiente

UNFCCC (United Nations Framework Convention on Climate Change) 2011. *Assessing the costs and benefits of adaptation options: an overview of approaches.* UNFCC, Bonn, Germany.

Vuille, M., and R. Bradley. 2000. Mean annual temperature trends and their vertical structure in the tropical Andes. *Geophysical Research Letters* 27:3885-3888.

Vuille, M., R.S. Bradley, R. Healy, M. Werner, D.R. Hardy, L.G. Thompson, and F. Keimig, 2003: Modeling in precipitation over the tropical Americas: 1. Interannual variability and climatic controls. *J. Geophys. Res.*, 108, 4174, doi:101029/2001JD002038.

Wagnon P., P Ribstein, G Kaser et al.1999. Energy balance and runoff seasonality of a Bolivian glacier, Global and planetary change.

World Bank. 2007. *Making services work for poor people.* World Development Report. Washington DC.

ANNEX I: Qualitative approach to cost and benefit of different adaptation options

Potential adaptation measure Costs / benefits	Stakeholder groups				
	Government, including local governments	Water company EPSAS / water co-operatives / irrigation associations	Industry	Social groups (urban, rural)	Environment
Water reservoirs (dams, presses)	Benefit: Gain from keeping promises and ensuring policies. Cost: high risk that climate change will mean they do not ensure coverage and high cost.	Benefit: improved water availability to run their businesses Cost: responsibility to ensure the feasibility of the project, High risk of unexpected higher costs due to climate change	Benefit: improved water reliability, Potential for tourism and gastronomy Cost: trade offs with mining, sands and aggregates to maintain clean water.	Benefit increased access to drinking water and irrigation. Cost: potential increase in tariff .	Benefit: potential regulation of run off and reduced soil erosion Cattle raising and tourism might be encouraged. Costs: impact on landscape and potential reduction of water for the ecosystem.
Reduction of water losses in the pipelines	Cost: more effort to regulate and fund.	Benefit: increased reliability of the system. More water coverage and better tariffin.	Benefit: increased reliability of the system.	Benefit: better and more reliable service Cost: potential increase in tariff .	
Changes in domestic appliances	Benefit: enhanced visibility.	Benefit: better tariffing and coverage.	Benefit: increased reliability of the system.	Benefit: better and more reliable service Cost: potential increase in tariff (m3/ household).	Benefit: the measure can have a positive impact if it is widespread enough.
Efficient irrigation	Benefit: enhanced visibility.	Benefit: ensure the sustainability of the business.	Benefit: some water intensive sectors benefit.	Benefit: more water available for valuable crops .	Cost: potential reduction of greenwater for the ecosystem.

Potential adaptation measure Costs / benefits	Stakeholder groups				
	Government, including local governments	Water company EPSAS / water co-operatives / irrigation associations	Industry	Social groups (urban, rural)	Environment
Grassland conservation	Cost: more effort and bureaucracy to understand real benefits in political and economic terms.	Benefit: sound watershed management means more recharge, less soil erosion, less maintenance costs and enhanced life span of infrastructure projects. Cost: increased work with the local communities More administrative costs to understand benefits in economic terms .	Benefit: better recharge of groundwater enhances the sustainability of water resources. Costs for community entrepreneurs hips (such as tuff producers, sands, agriculture).	Benefit: improved rural livelihoods such as cattle raising. More reliability of rural livelihoods. Cost: direct impact on income opportunities.	Benefit: environment will benefit from sound management, maintenance of water resources, vegetation, native flora and fauna and groundwater recharge.
Reforestation	Cost: more effort and bureaucracy to understand real benefits in political and economic terms.	Benefit: better recharge of ground water resources. Cost: need to work and negotiate with local communities Increased costs in the shorter term.	Benefit: better recharge of groundwater enhances the sustainability of water resources. Cost: money and labour in the shorter term.	Benefits: economic benefits from wood in the longer term. Costs: money and labour in the shorter term.	Benefit: environment will benefit from sound management (native species), maintenance of water resources, vegetation, native flora and fauna and groundwater recharge.
Purification of used water	Cost: cost of new regulation.	Benefit: sustainability of water resources. Cost: cost of dealing with difficult sectors.	Cost: increase in water tariffs due to polluters pays principle.	Benefit: better sanitation, mitigation of potential health issues.	Benefit: less pollution
Establishment of a watershed commission	Benefit: better negotiation platform Cost: need to co-ordinate among different stakeholders.	Benefit: possible negotiation and consensus-building platform. Cost: cost of accountability.	Cost: cost of accountability.	Benefit: better advocacy.	Benefit: better communication of economic and social benefits of environmental measures.

Potential adaptation measure Costs / benefits	Stakeholder groups				
	Government, including local governments	Water company EPSAS / water co-operatives / irrigation associations	Industry	Social groups (urban, rural)	Environment
Other structural measures aimed at reducing rural-urban migrations by enhancing opportunities in rural areas and intermediate cities, providing public services like water and sanitation, cheap energy, tax benefits.	Benefit: enhanced visibility with social vulnerable populations. Costs: more co-ordination needed.	Benefit: less pressure on resources due to slower urban growth.	Benefit: new investment opportunities.	Benefit: new jobs and improved quality of life.	Benefit: less transport, less energy demands, less impact on the environment.

ANNEX II: Persons and institutions interviewed

Institution	Contact	Stakeholder opinion
Viceministro de Agua y Saneamiento Básico	Marcial Verdeja	Construction of Dam: Peñas or Jampaturi or Milluni or Choqueyapu There are 4 alternatives for water: - Measures to mitigate climate change - 25% are expected to lose the melting - Install low-flow devices from now on - Offer incentives to substitute for existing appliances
Programa Nacional de Cambios Climáticos (PNCC), Proyecto de Adaptación Andina (PRAA)	Consuelo Luna	In rural and urban areas your goal is to have: - Efficient use of water - Integrated pest management - Management of micro watersheds (master plan)
Programa de Fortalecimiento Integral (PFI)	Hugo Boero	There are many problems with the Andes, with gaps and Tuni Condoriri, Milluni
Empresa Publica Social de Agua y Saneamiento (EPSAS)	Iván Enrique Revollo Pizarroso (Jefe Departamento Planificación) Ivette Arias Irusta	EPSAS's main objective is the construction of dams to provide water to the city of La Paz and El Alto. It also aims to build a water purification centre
Herbario Nacional-Instituto de Ecología	Stephan Beck	
Instituto de Geología	Jaime Argollo	They say that climate change is not significant in the mountain ecosystems yet then there is no rainfall and precipitation. The biggest problem has not changed in recent years
CARE	Silvia Aguilar Responsable del Programa de Cambio Climático.	In his experience working with communities, and especially the issue of water, the most important thing is to respect their customs and traditions. They focus on techniques and adaptive capacities, contributing to human capital within their recommendations is to work in the Management of Water and display programmes in their entirety. Moreover, communities are already adapting spontaneously; it is not always adequate for future needs, but the interest and concern to work on it is very high, because they perceive a lack of water in the near future. The damages the community are seeing are unpredictable rainfall and freezing hail in addition to loss of biodiversity and some varieties of crops. Also claim that several interventions may be beneficial for some but very expensive for others and therefore appropriate support strategies should be considered. Also there will be high costs in the future that are not being taken into account at present and the emigration sized and water supply for communities in addition to the growth of cities.

Institution	Contact	Stakeholder opinion
Agua Sustentable	Paola Pacheco Directora de Agua Sustentable Matilde Averguera Responsable proyectos	Mainly emphasise the work zone for their absolute dependence glaciers thaw, where the key point is the preservation of their customs, they use the mapping methodology rights, gambling wetlands conservation and water sources for the impact of the measure. Project that communities convey water conflicts, since they are very close to the cities and say that is not enough.
Instituto de Hidráulica e Hidrología (IHH)	Edson Ramírez Responsable del IHH	The Institute has conducted studies for nearly five decades which warns of the retreat of glaciers and their impact on water availability for human consumption. * La Paz and El Alto will obviously have problems from decreased rainfall to fill the dams providing drinking water. It is important to supply and demand for water in the basin. * Efficient use of water is one of the most important issues to address. in El Alto there are losses of up to 50 per cent, something not necessarily related to climate change, but important for the management of water resources. * The information on which they work covers the whole system involving precipitation, glaciers, subsurface water runoff, water quality and water erosion.
FEJUVE Asociación de las laderas de El Alto	Claudio Luna Francisco Manzaneda Rubén Benito Pongo (Junta Vecinal)	FEJUVE supports Peñas dam because this dam will benefit the city of El Alto. They also say that there are water co-operatives, but not many. These water co-operatives are paid a fixed price by EPSAS instead of paying for what is consumed
Asociación de Instituciones de Promoción y Educación (AIPE), Local NGOs which work with vulnerable groups in El Alto		Groups of people with whom we have worked believe that there is not enough water, because they have water 24 hours a day and 7 days a week, in certain places and peri-urban water rationing were drastically.
Asociación de Lecheros de Batallas (Peñas)	Basilio Calisaya	There are social problems; they do not want to supply water to the city of El Alto, because they suffer from lack of water for their animals, crops and for their own consumption
Asociación de Regantes de Batallas (Peñas)	Juan Vilca Mamani Ramiro Prudencio Flores	Water user associations are not well informed about the proposed Peñas dam. There are many emerging issues such as land rights, competition for water among various social groups and much corruption among the communities themselves. Some communities are very close to the dam and suffer from water shortages because there is not sufficient means so that water reaches them. They also say that the government makes promises to help with the issue of water and then does not meet them