Building Adaptive Capacity in Two Vulnerable Semi-arid Mountainous Regions in Bolivia

**Javier Gonzales, Marylin Aparicio, Jorge Cusicanqui,
William Dougherty, Tahia Devisscher**

1. Introduction

Since the Rio Summit in 1992 different actions have been promoted and implemented to improve the capacity of countries to combat and adapt to climate change. Mitigation strategies to reduce greenhouse gas emissions are currently implemented under the Kyoto Protocol framework. Along with mitigation, adaptation to climate change effects is gaining importance in the international agenda due to increasing intensity and frequency of climatic hazards that are impacting natural and socio-economic systems worldwide. Both mitigation and adaptation will be needed to reduce climate change effects while contributing to human development. This challenge is substantial, particularly in developing countries where human development is dependent on the state of the natural systems and is therefore more vulnerable to climate change effects. In developing countries, the achievement of the Millennium Development Goals (MDGs) is currently jeopardized by climatic hazards and this situation will worsen over time if these countries do not build adaptive capacity to prevent and adapt to climate change effects.

Climatic hazards in Bolivia have become an additional challenge to achieving poverty reduction objectives. The costs of the “El Niño” event in 1997/98 represented about 6% of the GDP and the flooding of the Mamore River in 2006/07 exceeded 400 million US$. In urban areas, the effects of climatic events have caused infrastructure loss and in rural areas agricultural activities have been seriously affected, threatening the sustainability of local livelihoods and causing massive migrations to the country’s main cities. The negative social indicators and the high poverty incidence in Bolivia, as well as a narrow economy mainly based on agricultural production and primary resource extraction, increase the country’s vulnerability to climatic hazards resulting in large impacts on the productive sectors and human development.

Recognizing the importance of building capacity in the country to cope with potential climate change effects, the Bolivian government agreed to cooperate with the government of the Netherlands to implement the Netherlands Climate Change Studies Assistance Program (NCCSAP) in 1998. After successfully completing the first phase of this initiative, Bolivia started the second phase of the NCCSAP (NCAP II) in 2004. Acknowledging that protecting local communities from climate change related risks based on a top-down approach can alienate and in some circumstances negatively affect communities, this second phase adopts a local-level approach to build adaptive capacity in the country. On this basis, the NCAP focuses on assessing the vulnerability and developing adaptive capacity in local communities of two vulnerable semi-arid mountainous regions in Bolivia. The scope of the study includes the vulnerability of local human subsistence systems through assessing the potential impacts caused by climate change effects on food security and human health in the selected study areas. Adaptation strategies are then identified and implemented at the local level contributing to the development of the national adaptation capacity by serving as pilot studies for the design of the National Adaptation Plan (NAP) and the Global Change Strategy of the National Development Plan.

2. Rationale, Objectives and Methods

2.1 Rationale

The mountainous regions provide important ecosystems services, particularly as a source and storage of high quality water that can be used for domestic purposes and agricultural activities. The conservation of these ecosystems is therefore fundamental for the development of socio-economic systems and for the support of life in general.

Because of high quality water resources, the mountainous regions in Bolivia sustain the highest rural population densities in the country. In these regions the level of poverty is high – more than 70% of the local population lives in poverty conditions – and even though poverty reduction measures are being implemented, poverty conditions and vulnerability of these human settlements may be enhanced by climate change. The population settled in these regions depends largely on the ecosystems' services for their productive activities and subsistence based mainly on agriculture. Their production systems are particularly vulnerable due to the low level of technology, insecure land tenure, limited size of land property and poor economic diversification. Hence, climate change effects on ecosystems of mountainous regions can have serious consequences on the local livelihoods in these regions which affect human development conditions. Climate change effects can not only negatively impact their livelihoods (particularly food security), but also provoke an emergence and expansion of vector transmissible diseases such as Malaria and Chagas increasing the pressure on human health in these regions.

The situation described above is particularly sensitive in semi-arid mountainous regions where scarcity of water resources can be exacerbated by climate change. In these regions water availability can decrease up to 50% of the potential resources due to temperature rise and precipitation decrease. According to future climate projections in Bolivia, the inter-Andean xeric valleys will be one of the most vulnerable regions due to its xeric climate and orographic isolation. Other highly vulnerable ecosystems to climate change are the ecotones of the sub-Andean valleys that have periodic rainfall.

Figure 1. Pilot Regions Selected as Case Studies for the NCAP Project in Bolivia

To evaluate this situation and find possible preventive measures, two vulnerable semi-arid mountainous regions in Bolivia have been selected as the scope of the study: the region of the Lake Titicaca and the region of Vallegrande[1] (see figure 1). These regions were selected as pilot studies based on physiographic criteria, watershed management considerations and political division. The project focuses mainly on human

1 The Titicaca region was selected as a study area because it is highly sensitive to hydrological changes due to glacier withdrawal. Furthermore, it is delimited by the Northern Altiplano Basin which is an international watershed area shared by Peru and Bolivia and is currently regulated by both countries. The Vallegrande region is located in the middle basin of the Grande River and has been selected because it is the upstream watershed area of the Santa Cruz Provinces that have demonstrated interest in reducing the environmental impacts upstream that are causing sedimentation and floods downstream and have given special attention to risk and disaster prevention.

subsistence systems by assessing food security and human health in both regions. Although the focus is placed on those two sectors, water resources play a fundamental role in the assessment, mainly due to the potential direct impacts of climate change on the local hydrology and the effects this may cause on local livelihoods.

2.2 Objectives

The objectives of the project are (see table 1): 1) to improve the understanding of climate change risks, the vulnerability and adaptive capacity of local communities in semi-arid mountainous regions in Bolivia, 2) to develop a cost effective methodology for rapid appraisal and monitoring of climate change vulnerability and 3) to build adaptive capacity in these regions using a participatory approach to identify preventive adaptation measures focusing on food security and human health. The results of the study will complement policies and measures implemented at the local and national levels.

Table 1. NCAP Project Objectives

Objective 1	Assess the local vulnerability and adaptive capacity of the two study areas
Objective 2	Identify suitable adaptation strategies to implement at the local level
Objective 3	Assess current policies and develop preventive adaptation strategies to climate change, focusing on food security and human health

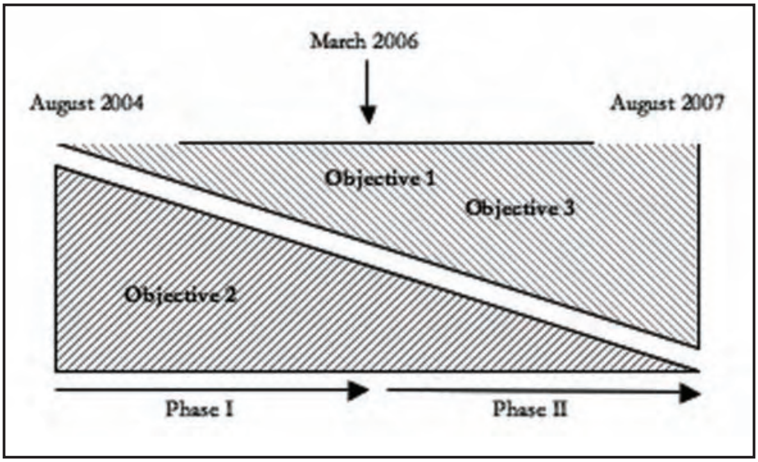

Figure 2. NCAP Project Phase I and Phase II

The project was implemented in two phases (see figure 2). Phase I involves a vulnerability assessment of climate change effects mainly evaluating food security and human health vulnerability. This phase included diverse studies: a climatology evaluation; a diagnosis of the ecosystem; an analysis of the production and socio-economic systems; an assessment of possible bio-indicators for climate change; a retrospective assessment of the Malaria outbreak in the Lake Titicaca region; an analysis of the traditional knowledge to estimate local climatic conditions; and the identification of potential adaptation measures for each study area. Parallel to the local-scale evaluation, a national-scale assessment was conducted in phase I to determine the potential impacts of climate change on the different sectors in the country. Phase II focuses on completing the vulnerability assessment and evaluating the identified options to develop strategies for adaptation to climate change – with particular focus on local livelihoods (food security) and human health. This is to be incorporated into the development plans of each study region and implemented by the local governments and communities, and considered as pilot studies in the development of the National Adaptation Plan and the Global Change Strategy under the National Development Plan[2].

2.3 Methodology

The NCAP-Bolivia followed the principles suggested in UNDP/GEF Adaptation Policy Framework:

- Adaptation to short-term climate variability and extreme events were used as a basis for reducing vulnerability to longer-term climate change
- Adaptation policy and measures were assessed in a developmental context
- Adaptation occurs at different levels in society, including the local level
- The adaptation strategy and the process by which it is implemented are equally important

As previously mentioned, the study focuses on: 1) two semi-arid mountainous regions: the region of the Lake Titicaca and the region of Vallegrande; and 2) two sectors to assess the vulnerability of human subsistence systems to climate change: food security and human health. Under this framework, water resources are assessed as a cross cutting issue.

The project has adopted both a participatory and an integrated approach. The vulnerability assessment and the identification and design of possible adaptation measures have included the active participation of local stakeholders in the process through consultation, questionnaires, interviews, workshops and focus groups. In the region of the Lake Titicaca, 12 communities were selected to carry out the participative assessment, 6 communities were involved in the assessment of the productive systems (food security) and 6 communities were involved in the evaluation of the local public health system (human health). In the Vallegrande region the participative assessment was carried out with 14 communities. The participative approach is important 1) to validate and triangulate information obtained during the assessment, 2) to gain a better and more objective understanding of the local reality and needs, 3) to understand the local perceptions of climate change effects, and 4) to identify local knowledge that can be used to build adaptive capacity at the local and national levels. The stakeholders involved in the process were local authorities, farming organizations and independent farmers, local institutes, and staff working in health centers located in the study regions.

In addition, the integrated vulnerability assessment of both regions encompasses different disciplines to evaluate ecosystem vulnerability, the hydrologic system, climatic variability, productive systems, traditional knowledge and current policies influencing production systems and human health. An integrated approach is also used for the development of adaptation strategies. Different tools and methods are used for the integrated assessment: GIS tools for multi-criteria analysis; participatory tools for evaluation and planning; questionnaires, rapid appraisal methods and web-based tools to exchange information and promote communication on climate change related risks.

Finally, the project complements the top-down planning process with a bottom-up process of capacity building. While the study contributes towards developing national adaptation policies and strategies working with national authorities and departmental centers of the health system, the participatory approach used to build adaptive capacity in the two selected regions allows designing and implementing adaptation measures from the bottom-up that can serve as case studies in the

2 The Global Change Strategy puts emphasis on enhancing adaptive capacity in strategic sectors of the country.

development of national policies. The project also explores creating synergies with current policies and measures implemented at the local and national levels in the context of rural development, watershed management, public health and education.

The following sections present the key results obtained in the different studies carried out for phase I, as well as the local perceptions of climate change effects and the associated risks for local production systems and human health. The key results for the Lake Titicaca region are described first, followed by the Vallegrande region. The next section presents the adaptation strategies developed for each study region and some activities carried out to build adaptive capacity in different municipalities. The last section summarizes the lessons learned and gives strategic recommendations.

3. Key Results and Findings

3.1 Description of the Lake Titicaca Region

This study region is located in the dry inter-Andean valleys of Bolivia and covers the municipalities of Batallas, Ancoraimes and Carabuco. These municipalities are located in the northern area of the Bolivian Altiplano. The northern Bolivian Altiplano is an 800km long and 200km wide flat region in the Andean highlands and is highly sensitive to hydrologic changes caused by glacier withdrawal. In general terms, the North Altiplano Basin is divided into 3 altitudinal ecological zones: the region of the Andean mountain range (4,300 to 6,500m above sea level), the foot of the hill (4,300 to 4,000m above sea level) and the flat land (3,850 to 4,000m above sea level). Almost 75% of the North Altiplano Basin is between 3,600 and 4,300m above sea level.

Although the climatic conditions in this region are not favorable for the production of many crops, 65% of the economically active population is dedicated to agriculture. Potatoes and quinoa are the main crops produced under dry conditions in this region. Drought and low temperatures combined with low soil fertility and a lack of access to external productive factors to intensify the production have resulted in very low productivity levels in the Lake Titicaca region.

3.1.1 Climate in the Lake Titicaca Region

The climate of this region is influenced by its altitude. Given the altitude and the geographic location, this region faces significant climatic variations: it receives high sun radiation during the day (reaching 533cal/cm^2/day) and it has low temperatures during the night. The maximum average temperature in the northern Altiplano ranges from 15 to 17 °C during the day and a minimum average temperature of 0.5 °C in summer and -10 °C in winter during the night. The average temperature in the region varies between 7 and 8 °C. Moreover, the average velocity of wind in the region is 3m/s with a predominant direction coming from west-southwest.

The climatic conditions of the region are also determined by low levels of humidity. Average precipitation in the Altiplano is 550mm/year. Almost 72% of the rainfall occurs from November to February. The cold weather, high daily temperature variation and low humidity levels of the highlands limit the growth rate and density of vegetation in this region, resulting in low levels of organic matter in the soil and consequently in poor soil fertility.

Moreover, Lake Titicaca has a thermo-regulator effect on the region. The level of humidity in the area surrounding the lake is higher due to the evaporation process of the water reaching an average precipitation of 600mm/year that favors the climatic conditions of the area it influences.

Finally, the region of the Lake Titicaca is greatly influenced by the "South Oscillation El Niño" (ENSO) also known as the "El Niño" that causes serious droughts in the area. This event does not have a fixed cycle and is currently being researched, however it is estimated that its frequency of occurrence is around 4 years. The “El Niño” event is part of the rainfall pattern of the northern Bolivian Altiplano.

3.1.2 Ecosystem Diagnosis

The objective of the ecosystem diagnosis is to assess the state of conservation of the ecosystem in the study region and to identify (using bio-indicators) changes in the ecosystem due to climate change and subsequently assess the potential implications on food security and human health. The area selected for the ecosystem diagnosis in the Lake Titicaca region is the Caldera zone in the municipality of Ambana, the municipality of Combaya and the municipality of Batallas. The study of the fauna and flora in this area was carried out in coordination with the Bolivian Collection of Fauna (CBF) and the National Herbarium of Bolivia in La Paz. The most relevant findings of the study are described in this section.

Changes in the State of Conservation of the Ecosystem and the Implications for Human Health and Food Security

The flora in the study area is mainly threatened by the expansion of agriculture and cattle production. The areas covered by native vegetation are few and are generally located in areas with difficult access along water streams and in fragmented forest patches, as well as in rocky ravines that are not suitable for crop production. The areas with easy access are generally covered with introduced crop species and also opportunistic species with low requirements for water and nutrients. These species compete with native species that have the potential to provide higher value as forage and which are more important for the conservation of the ecosystem.

One of the main threats to the fauna in the study area is the introduction of invasive species such as the *Mus musculus* (domestic mouse). The relative abundance of this species in the zone of Caldera is surprisingly higher to that of any native species. Several studies have shown that the presence of this species can cause an emergence of tropical diseases due to its constant contact with vectors. Therefore, it is important to monitor the population of *Mus musculus* in the area, because it is a potential threat to both human health and food security.

The main pressure placed on bird populations is the destruction or modification of their habitat. The depositing of sediments and drainage are affecting the Andean wetlands and rivers, as are the mining activities and the disposal of heavy metals. The forest relicts are threatened by wood extraction for fuel affecting the birds that live in these ecosystems and the birds that live in the Lake Titicaca are endangered by the nets that local fishermen use to catch fish in this habitat.

Finally, although in general terms the entomofauna is affected by the fragmentation of forests and the over-exploitation of natural resources in the study area, some species of insects may be favored if climatic extremes have greater intensity and frequency in the area. The presence of *Anopheles pseudopunctipennis* (vector of Malaria disease) in the area – a vector that is not typical for areas higher than 2600m above sea level – already represents a threat for human health in the community of Caldera and its surroundings. This threat can become even more severe if temperature and rain intensity increase causing the migration of more vector species from lower strata to the study area. The species *Triatoma sp.* (vector of Chagas disease) has not been identified in the study area. Among the insect species that could be favored by climatic variability and could represent a threat to food security are *Acromyrmex spp.*, *Phthorimaea operculella*, *Aphis gossypii*, and *Premnotrypes spp.*, all plagues that can affect the quality and availability of the main crops produced in this region.

Potential Bio-Indicators for Climate Change

Flora species that have been suggested as bio-indicators for climate change in this region are: dominant species of forest relicts such as *Schinus andinus*, *Polylepis racemosa*, *Myrsine pubescens*; less dominant species such as *Escallonia myrtilloides*, *E. paniculata*, *E. resinosa*, *Mutisia lanata*, *Duranta spp.* and some climbing species such as *Fuchsia apetala* and *Passiflora inca*.

Other species that have been identified as potential bio-indicators for climate change are good indicators of humidity and depend on water for at least one stage of their life cycle. Species with these characteristics in the region are bryophytes such as *Radula voluta*, *Porella sp*., *Leptodontium longicaule*, and *Thuidium sp*. Other important bio-indicators of climatic variability are ferns, in particular epiphyte ferns of the families Gramitidaceae and Hymenophylaceae.

Fauna species that could be potential bio-indicators for climate change are small mammals that play an important role due to their ecological functions within ecosystems and their sensitivity to temperature changes, availability of natural resources and the quality of ecosystems in general. The study has identified species of chiroptera that belong to the Vespertilionidae and Molossidae families in the study area although these are typical of lower ecological strata. The altitudinal migration and presence of these species in the study area suggest that monitoring their population over a longer time period may be a good way of identifying and evaluating climate change. Also, species of rodents of the *Phyllotis* genus that are typical of inter-Andean valleys can be good bio-indicators for climate change, as well as species of the *Akodon* and *Oligoryzomys* genus that are typical species of lower ecological strata.

There are a total of 21 bird species with migration patterns (austral, altitudinal or other type) that have been identified in the study area. Given that their migration is related to climatic conditions, it is suggested that monitoring the population of these species will help to assess climate change. Bird species that are present outside their altitudinal range or life zone can be particularly important in evaluating climate changes. In the area of Caldera, a total of 30 bird species were identified. Although the majority of these species were typical of the area, 5 species were over their altitudinal range. For sedentary species, population behavior during their reproduction stage or their nesting stage can be assessed to evaluate climatic variations.

Lastly, to identify and validate the bio-indicators for climate change proposed in this section, a monitoring system needs to be implemented. This system should include the modeling of ecological niches encompassing the relationship between abundance and distribution of populations. Rare species and species with limited distribution should be given a higher status.

3.2 Livelihoods Vulnerability and Risk Perceptions in the Lake Titicaca Region

3.2.1 Production Systems Vulnerability

Production systems play a fundamental role in the human subsistence in the Lake Titicaca region. In general, the production systems in this region are for personal consumption. These systems are generally precarious and therefore highly vulnerable to climate change effects. To prevent the potential impacts of climate change effects on food security and increase the resilience of these subsistence production systems by implementing suitable adaptation measures, an assessment of climatic hazards on the local production systems was conducted.

This section first presents the results obtained in the agro-climatology assessment. This information is useful in determining the most suitable production and risk prevention strategies in the area. Secondly, the main findings of the agricultural systems assessment are described. Thirdly, the local perceptions of climate change and the effects on the production systems are presented, as well as suggestions for possible adaptation measures that were identified with the local stakeholders. Finally, a short description of the state and vulnerability of the water resources in the region and the associated implications for the production systems is given.

Agro-climatology Assessment

The temperature in the Lake Titicaca region follows a typical tendency for a tropical region located at high altitude: while the thermal difference during the day is high, the annual range is short. During a year, the period that presents the lowest temperature variation/difference (10 to 14ºC as opposed to 15 to 19ºC) is between October and April. Within this time range, there is a period of 160 days (November to March) that is considered to be free of frost occurrence (< 50% of probability/day). This period that is frost free, coincides with the occurrence of rain fall in the region. As a result, the agricultural activities are concentrated mainly between the months of October and April and the selection of crops is reduced to those that have a short productive cycle and good adaptive capacity to daily temperature variations of 10 to 15 ºC.

In the northern Bolivian Altiplano, the agriculture systems face two main climatic hazards: droughts and frosts. The geographical location and altitude of this region result in a period with a high risk of frost occurrence between April and mid-October. The rain variability in the arid regions is very high and therefore a drought period is difficult to determine in these regions. However, by assessing the distribution of very dry, dry, normal, and wet years, it is possible to estimate that the risk of years with drought occurrence is high (40%), where 3 out of 10 years the occurrence of drought is considered to be normal. Moreover, a period of 160 days with a high rainfall has been identified between the end of October and the end of March, with 70% of the annual precipitation falling between December and March as well as a high correlation between the start date and the length of the rainy season. If the rainy season starts at an early date it lasts longer. For instance, if the rainy season starts the third week of October, it lasts for about 6 months. However, if the rainy season starts in mid December, it only lasts for 3 months. This means that a late start of the rainy season will cause a water deficit, reducing the productivity of crops that need at least 5 months to develop. This in turn will negatively impact the production systems and therefore food security in the region.

In addition, the Lake Titicaca region faces two short dry periods within the rainy season, generally one at the beginning or at the end of the rainy season and another during the rainiest months (December to March). Under these conditions, it is very probable for the crops that have been introduced in October to face a dry period of two weeks in February. Considering that at this time of the year these crops are generally flowering or developing grains, a drop in productivity due to a shortage of water can be expected. This situation is aggravated when the short dry periods during the rainy season last longer. These droughts disturb the agricultural production planning in the region, delay the sowing and/or make it necessary to repeat the sowing due to failure in the first round.

Finally, the aridity index in the Lake Titicaca region classifies it as a semi-arid region because only 34% of the atmospheric water demand is covered by precipitation[13]. During the rainy season this index increases to 65%, reducing the stress on the crops cultivated in the region. Figure 3 shows that the monthly surplus precipitation calculated for 25%, 50% and 75% probability is lower than the level of evapotranspiration. However in the month of January the precipitation calculated at 25% probability exceeds the absolute evapotranspiration. This means that the water deficit in the area over the year is severe and consequently agriculture without irrigation is considered under constant stress, even during the rainy season.

To conclude, it is possible to state that the production systems in the Lake Titicaca region face significant climatic hazards that determine their successful development and consequently the food security in the area. The probability and frequency of frosts and droughts is high and they would jeopardize the production systems in the region. This is aggravated by high rainfall variability. In particular, when the start of the rainy season is delayed, crop production can be seriously affected due to water shortage. The low temperatures and water availability in the region over the year slow down the physiological activity of plants extending their productive cycle and making them even more vulnerable to the effects of frosts and droughts, in particular during the last stage of the

3 Aridity index calculated using the UNESCO methodology.

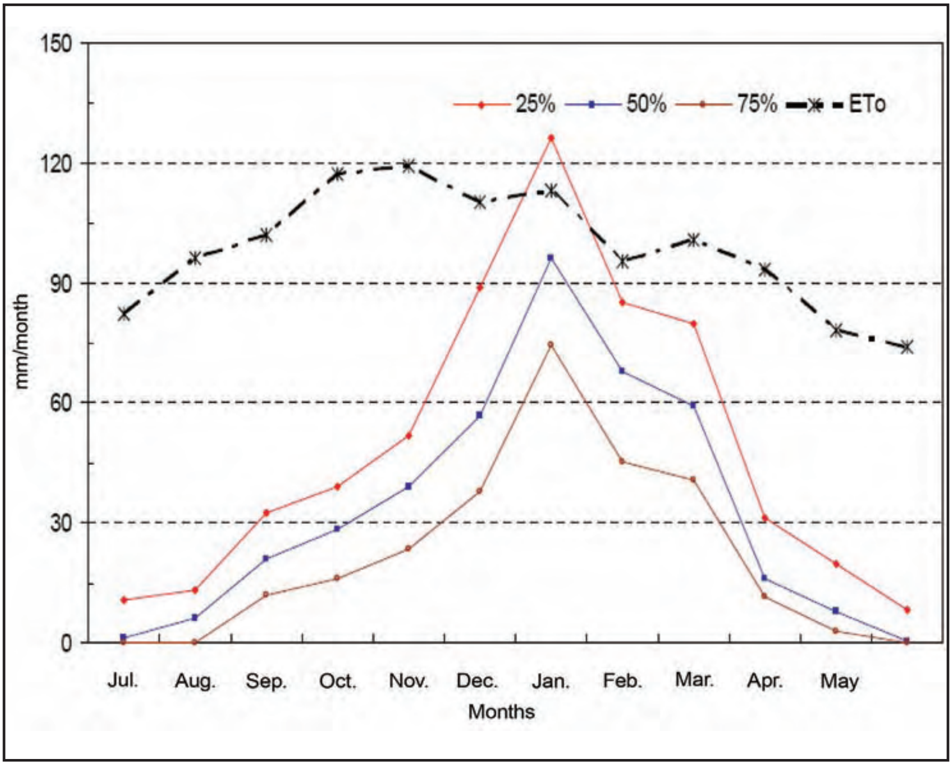

Figure 3. Monthly Levels of Rainfall at Different Probabilities of Evapotranspiration

rainy season. As a result, it is very important to select crops that are resistant to climatic variability and have short productive cycles. It is also necessary to consider that the implementation of an irrigation system, at least during the critical stages of the crops' development, could significantly increase the productivity and adaptive capacity of the production systems in the region, contributing to food security and the sustainability of livelihoods.

Production Systems Assessment

The agricultural production in the Lake Titicaca region is mainly for personal consumption due to the limited land property size and the low means that each family has to produce in this area. About 34% of the local population has stated that the potato is the main crop produced in the study area, followed by quinoa (25%) and broad bean (23%). Besides the important role these crops play for food security, these crops also have significant value for the local economy due to their profitability and high demand in the local, national and international markets. In addition, other crops are cultivated in the region such as cereals (tarwi and cañahua), vegetables (peas), and tubers (oca and papaliza).

In general, the production area per family in the region is smaller compared to two decades ago. The decrease in the size of land property for agricultural use is due to the distribution of inherited land from generation to generation within a family. As a result, current farmers have a small area of land property (sometimes no larger than a furrow) because over time the family plot has been shared out among all the family descendants. This limits the amount and diversity of crops that a family can produce in this region.

In addition to crop production, the local communities in the region, in particular those located on the flat land, diversify their production with cattle breeding. Dairy production is important for these communities and the families that have cattle use their agricultural land to produce forage for the livestock, such as oats and alfalfa. Dairy production is generally complemented with the breeding of sheep and pigs for personal consumption. Another important production activity for the communities located near the lake is fishing. The fish that are caught in the Lake Titicaca are mainly for commerce, contributing to the economic resources of the families in this area.

In summary, the production systems in the Lake Titicaca region are mainly based on the production of crops such as potatoes, quinoa and broad bean and cattle breeding mainly for dairy production. Fisheries are an additional economic activity for the communities located near the lake. Generally, production in the region is not only for commerce but also for personal consumption, which is important for local food security. Unfortunately, the poor conditions in the region and the limited size of available land for agricultural use shape the productivity and vulnerability of the production systems affecting their capacity to cope with climatic hazards such as droughts and frosts. In this sense, an increase in intensity and frequency of climatic extremes places the food security and the socio-economic system of the local population at risk.

Local Perceptions: Climate Change Effects on the Production Systems and Possible Adaptation Measures

Local perceptions of climate change were collected through questionnaires and workshops. Among the local population that answered the questionnaires[4], more than half viewed drought to be the most important climatic hazard affecting production systems, followed by frost and hail. Around 77% of the people interviewed stated that droughts have become more frequent and have increased in intensity, 76% pointed out that frosts occur more frequently, 66% affirmed that frosts now occur "out of season" and have become unpredictable, 74% believed that the temperature in the region has increased over time, and 88% stated that precipitation has decreased and is now concentrated within a few months of more intense rain instead of a more uniform distribution throughout the rainy season.

Table 2 summarizes local perceptions of climate change and the effects on production systems and food security collected during workshops with local stakeholders including local authorities and leaders, farmers, and community members. It also presents proposed adaptation measures. Box 1 presents the traditional knowledge system used to estimate/predict the annual climatic conditions and subsequent planning of agricultural activities. It is suggested that traditional knowledge can complement the current systems used to evaluate weather and climatic variations and can contribute towards developing adaptive capacity in the region.

During the workshops local stakeholders recognized the necessity to prioritize strategic agricultural fields that have better adaptive capacity to climate change effects. Based on a multi-criteria analysis that considers several factors such as productivity, nutrition level, prices, hand labor and fertilizers requirement, soil requirement and potential risks, the following production fields were prioritized for the flat areas: alfalfa, oats, pastures and barley. For the areas located at the foot of the hills the prioritized production fields were: quinoa, alfalfa, cattle, dairy production and barley

Water Resources Vulnerability

Rain water resources are limited in the northern Bolivian Altiplano. Only a few communities have irrigation systems, particularly in the higher areas. Among the communities that have permanent access to water, only a few implement an improved irrigation system. However, these systems are deteriorating due to lack of maintenance. The main rivers in the region contain water for the majority of the year and are used by the communities for irrigation. There are two main sources

4 A total number of 90 questionnaires were carried out per municipality, equivalent to 180 questionnaires for the study region.

Box 1. Case Study: Traditional knowledge that can be used for Climate Change Adaptation

Traditional knowledge based on the observation of nature to predict weather and take decisions on crop production is widespread in the country and its systematization has begun to attract the interest of scientists and society. The objective of this case study is not only to understand the mechanisms of traditional systems to assess climatic conditions, but also to evaluate the relevance of these systems from a vulnerability and climate change adaptation point of view.

Traditional systems that assess climatic conditions are based mainly on systematic observation of indicators and analysis. For this reason, it is possible to state that this type of knowledge is compatible with the current scientific knowledge. Farmers take important decisions about their production at critical points of the year based on the analysis of observations, and use festivities as reference points in the solar calendar (currently the Gregorian calendar). Observations of indicators and analysis allow for understanding and "predicting" the climate characteristics in the productive year and how to plan production activities to obtain a good harvest.

Specific plants are used as indicators to prepare and carry out agricultural activities. Animals and animal behavior are also used as indicators to predict whether a year will have droughts or a long rainy season. In past years, local farmers in the region have noticed a change in the climate and affirm that it has become more unpredictable and complex to predict.

Traditional knowledge is becoming lost as a result of migration to the cities by younger generations, secularization, and the introduction of technology and modernization into the region. However, recent interest in traditional knowledge is attempting to re-value this system recognizing it as an integrated analysis system complementary to the weather and climate assessment methodologies currently used.

of water in the Lake Titicaca region: glaciers and rain. In past years, glaciers in the region have been melting and problems associated with a lack of available water resources have become more severe. This situation is expected to worsen in coming years due to climate change.

The coverage of drinking water services in the communities in the study area is deficient. Only 35% of communities have easy access to drinking water services. A potable water system is under construction for 12% of the communities and the remaining 53% of the population does not have access to drinking water. The quality of the system is deficient, some communities need an extension of the system and several communities need an improvement in infrastructure. Also, some communities do not have sanitary systems with the exception of some households and educational centers.

In several areas surrounding the Lake Titicaca, drinking water is obtained from both rivers and groundwater wells built with stones or cement. About 40% of drinking water in the region comes from these wells. Water in these wells is generally extracted with water pumps or manually. In general, water from rivers and wells is not boiled before being consumed resulting in parasitic infections.

With regards to local perceptions, more than half of the people interviewed (79%) believed that 10 years ago water for irrigation was sufficient; however 76% believed that current water resources are scarce in the region and are not sufficient for human and cattle consumption or for crop irrigation. Table 3 summarizes local perceptions of the risks affecting water resources in the region and the associated effects on production systems, as well as some suggested preventive measures.

Table 2. Local Perceptions of Climate Change and the Associated Effects on the Production Systems and Food Security, and Suggested Adaptation Measures

Local Perceptions	Adaptation Measures
The rainfall season has changed; rain is starting later delaying the sowing. Because the rainy season is shorter, the suitable period for production has also shortened. Due to water scarcity and drought some crops such as broad beans cannot be cultivated.	New resistant crops have to be developed for the area.
Frosts are “out of season” and have become unpredictable affecting crops such as potatoes.	New varieties of potatoes that are resistant to frosts need to be introduced into the region.
Frosts and hail have increased in intensity sometimes causing the loss of entire production fields.	Crops have to be cultivated again in the hills. Community fires have to be organized to prevent the impacts of frosts.
Droughts are more intense and frequent than previous years and the soil dries faster.	Suitable irrigation systems and crop varieties that are resistant to drought should be introduced.
Higher temperature and rain intensity (within a few months) increase the risk of plagues. Plagues have become more aggressive affecting crops, in particular potato production.	
Lower productivity does not allow for surplus production to be commercialized, affecting the monetary income for local families.	
Crops used for personal consumption have been replaced by commercial crops.	Re-introduce crops that were used for personal consumption to ensure food security.
Higher rain intensity (within a few months) affects the pastures and crops cultivated on the flat areas.	Drainage systems have to be developed.
Temperature rise is affecting the cattle, increasing their susceptibility to diseases.	Introduce new cattle that are tolerant to temperature variability and improve control of animal diseases. Introduce new forage varieties resistant to drought.

Table 3. Local Perceptions of Risks Affecting Water Resources and Suggested Adaptation Measures

Local Perceptions	Adaptation Measures
Rainfall is more concentrated within a few months, particularly in February.	It is important to find new water sources.
Water resource scarcity is affecting the production of crops such as potatoes and barley and forage such as alfalfa and pasture.	More wells are needed and more water pumps need to be installed. Productivity needs to be improved with the introduction of improved crop varieties and animal breeds, as well as improved technology.
Conflicts over water resources between communities have increased.	It is necessary to improve the irrigation systems and their maintenance.
Rivers are starting to dry and do not always contain water throughout the year affecting human and animal consumption and also the production systems in the area.	
Irrigation systems are not properly maintained, current infrastructure is deficient and the administration of irrigation systems lacks capacity.	The administration capacity needs to be strengthened and the construction of more reservoirs and irrigation channels is necessary.
There is a lack of knowledge about the importance of vegetation for water storage and the proper use of irrigation systems.	
The contamination of the Lake Titicaca is affecting the fisheries.	Organizational capacity of the fishing communities needs to be strengthened.

3.2.2 Human Health Vulnerability

The correlation between health and climate is highly complex due to the multi-causal origin of the former and the multi-systemic influence of the latter as a determining factor. Moreover, impacts on human health caused by climate change effects greatly depend on the socio-economic development and organizational capacity of a community and the state of the natural system in the area. In this sense, human health vulnerability to climate change effects of a community is influenced by the state of the ecosystems it depends on and by its social, institutional and technological adaptive capacity, as well as by its level of awareness on climate change risks.

Climate change may increase the emergence of diseases that were previously under control or had already disappeared, and also the geographic and altitudinal expansion of disease endemic areas. This is particularly true in the case of vector transmissible diseases, since vectors are highly sensitive to climatic variations. As a result, the incidence and prevalence of vector transmissible diseases is increasing.

In countries like Bolivia that have a high epidemiologic profile of contagious diseases transmissible by vectors, the human health vulnerability level to climate change is very high.

Box 2. Case Study: Malaria outbreak in the Lake Titicaca Region

To assess the vulnerability of human health to climatic variability and extremes in a high semi-arid mountainous region, the cases of Malaria outbreaks in the municipalities of Mocomoco, Ancoraimes, Batallas and Carabuco were studied. In 1998 the disease impacted communities in this area that were not endemic of Malaria.

This study focuses on a retrospective assessment carried out for the period 1998 to 2006 in the communities of Tuntunani, Mollebamba, Caldera and Sehuenquera (see figure 4).

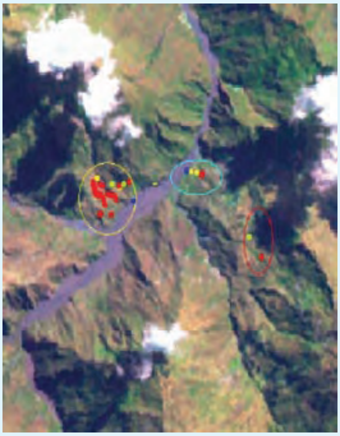

Figure 4. LANDSAT image that shows the location of Tuntunani (center in yellow), Mollebamba (blue) and Sehuenquera (red). The access to these communities is difficult.

During the rainy season in 1998 (between January and May) the Malaria outbreak affected 83 people (figure 5). The epidemic outbreak was caused by Plasmodium vivax reaching 8 communities in the area situated between 2,600 and 3,800m above sea level and about 50km away from the Lake Titicaca. Given the altitude, low temperature and the ecosystems in the area, neither Malaria nor other vector transmissible disease antecedents were previously recorded in the area. The majority of Malaria cases (52) were registered in the community of Tuntunani, representing about 20% of the total population of this community (250 inhabitants). However, data provided by the Andean Rural Health Council show that 93% of the population in Tuntunani had symptoms of the disease during the 1998 outbreak. The staff of the health centers that entered the community during that time confirmed that almost the entire population was suffering from the disease. According to the local authorities, 5 people died from Malaria in Tuntunani that year.

During the Malaria outbreak the local authorities and communities communicated the situation to the health centers in the area. The centers lacked the capacity and equipment to respond to this type of emergency, however, three medical campaigns were carried out in Tuntunani to evaluate and treat people suffering from the disease. Blood samples were sent to the Epidemiological Centre in La Paz to confirm the diagnosis (P. Vivax was positive).*

Surveys conducted in 2006 revealed that 71.4% of the population in the area knew about the Malaria disease locally called “Chujchu”. The local population identified the mosquitoes as vectors of the disease, however they believed that “Chujchu” was originally brought to the region by a person who died of the disease in 1998 and became infected with it in Alto Beni – a lowland area located in the northeast of the country and recognized as a Malaria endemic area.

According to the locals, mosquitoes in the area locally called “zancudos” appeared between 1990 and 1998. Studies conducted in the area from 1998 to 2006 suggest that the outbreak had a local character transmission because the infected people did not travel abroad in the year before the outbreak and because some of the people had two or more Malaria episodes during 1998. Moreover, the possibility of a local transmission is supported by the fact that the period when mosquitoes are typically present in the region (January to June) coincides with the period of the outbreak and the rainfall season (January to May).

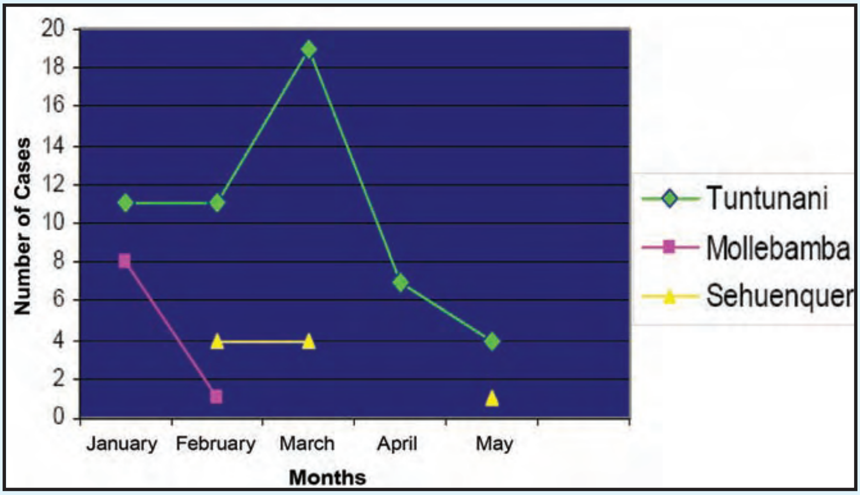

Figure 5. Malaria Cases in the Study Area between January and May 1998

The entomological monitoring carried out in the region recorded *Anopheles pseudopuntipennis* in communities within the area. Anopheline mosquitoes were identified in all their life stages and in both indoor and outdoor environments. According to the study, the local population is exposed to vectors when they are close to water bodies and wells but also when they are at home because the housing material and poor infrastructure is not suitable to protect the indoor environment from the vectors. Another factor that contributes towards the exposure of humans to vectors is the coexistence with animals that live near the houses or in some cases inside them.

The increase in temperature and rain intensity (within a few months) in the Lake Titicaca region could increase the vulnerability of the local population to vector transmissible diseases such as Malaria. The year 1998 coincided with the "El Niño" event 1997/98 that strongly impacted the region, causing an increase of the temperature and the rainfall concentrated within a few months. The outbreak of Malaria during the rain season is attributable to the climatic events of that year. This relationship has also been perceived by the locals involved in the assessment.

Between 1998 and 2006 new Malaria cases appeared sporadically in the area: 10 cases in 1999, 1 case in 2001, 2 in 2002 and 3 cases in 2005. These cases suggest an altitudinal and geographical expansion of the disease associated with climate change in the area that is modifying the ecosystems and creating suitable conditions for the development of vectors. As a result, areas in the high semi-arid mountainous region of Bolivia are becoming endemic for vector transmissible diseases.

* The use of medicinal plants and the services of traditional doctors (Callahuayas) is also part of the culture in the Lake Titicaca region. Nevertheless, an expansion of health centers in the area is facilitating access to "occidental" medicine in the region. Even so, the local population tends to mainly use traditional medicine. By consulting the population that suffered from Malaria in 1998 about the medicine used, 30.8% indicated that they used medicine provided by the health centers, and 69.2% stated that they used traditional medicine based on different plants.

In the specific case of Bolivia, this vulnerability is exacerbated by the existence of multiple ecosystems and microclimates with suitable conditions for the development of vectors in the country, as well as by the migration processes of people between disease endemic areas and areas that are not endemic. A preliminary evaluation at the national level estimated that climate change contributes to the development of 27.4% of Malaria cases (11.3% produced by *P. vivax* and 43.6% by *P. falciparum*). The assessment also established an increase in Malaria cases caused by *P. falciparum* since 1993 and in cases produced by *P. vivax* since 1994. The study estimated that Malaria will increase its endemic area between 12 and 20% over the next decade. As a preventive measure, the country has established a health network system with institutions working on vector transmissible diseases at national and local levels.

Table 4. Perceptions of the Effects of Climate Change on Human Health

Local Perceptions of the Effects of Climate Change on Human Health
Staff working in the local health centers have noticed that climatic variations (droughts, frosts and rain) are related to thermo oscillations that favor the development of respiratory infections.
The incidences of respiratory diseases have increased (acute respiratory infections, tuberculosis) and vector transmissible diseases have emerged.
The increase in temperature is causing problems with the skin and eyes of the population.
There is an increase of acute diarrheic diseases due to hygienic/dietary conditions. The main cause of these problems is the water scarcity in the region, which has become more severe over the past years, affecting water sources but also the agricultural production in the area.
Sporadic Malaria cases have occurred in the area.
People have died of Malaria in the area due to late recognition and diagnosis of the disease. This is because this area is not considered endemic of Malaria and the health centers and local population are not prepared to deal with this disease.
The health team stated that there is a presence of probable vectors that transmit Malaria in the area.
Lack of employment opportunities in the area oblige people to temporarily migrate to Malaria and Chagas endemic areas looking for work opportunities. Migrations can contribute to the transport of vectors that adapt to the conditions in the study area, particularly because climatic conditions have been changing and may now be suitable for their development.
The Malaria and Chagas monitoring system in the area is insufficient and only covers the areas that have presented epidemic cases of Malaria over the past decade.

Over the past decade, the combination of climate change, migration patterns and other previously mentioned factors has resulted in the outbreaks of local vector transmissible diseases in areas that have never had these diseases before and are not considered endemic areas. Such is the case of Malaria outbreaks in the Lake Titicaca region (see box 2). The impacts of such epidemics are significant given the precarious health system in the area, high poverty incidence, difficult access to communities, deficient building materials and housing infrastructure, and exposure to a new disease that is not typical of the region and for which the population has not yet acquired immunity. As a result, the human health vulnerability of the communities in this region to this type of diseases is very high and can result in death if preventive measures are not implemented in time. The health network system established in the country contributed to the human health vulnerability assessment of the local population in the study area, and will play a central role in the implementation of adaptation measures to reduce risks that climate change effects have on human health. Table 4 summarizes the perceptions of the staff working in the local health centers of the effects of climate change on the human health of the communities in the region.

3.3 Description of the Vallegrande Region

This region covers three provinces, the province of Vallegrande, the province of Manuel Maria Caballero and the province of Florida, as well as 11 municipalities. The study was carried out mainly in three municipalities: Moro Moro, Vallegrande and Saipina. The physiology of the study area comprises different altitudinal ecological zones: the head of valleys or high dry valleys located between 2,200 and 3,300m above sea level; the low dry valleys between 1,500 and 2,200m above sea level; the flat plains between 1,100 and 1,500m above sea level; and the sub-tropical humid zones between 460 and 1,100m above sea level. The physiographic characteristics of the region correspond to varied landscapes that expand without any sequential geographic order forming alluvial plains, terraces, hillsides, highlands, slopes, hills and mountains with different geological fragility. In hydrographic terms, the study area is part of the Amazonian Basin and the Grande River Sub-basin that is a tributary of the Mamore River.

3.3.1 Climate in the Vallegrande Region

The meso-thermal sub-humid dry climate is predominant in the region with low levels of water in the rainy season and water shortages during the dry season. Due to the different geographic characteristics of the region, the climate varies for the different localities within the area. In general terms, the average minimum temperature ranges between 6.8 and 15.5°C and extends from April to August (winter). The maximum temperature average ranges between 21.1 and 26.2°C and is applicable from October to March (summer)[5].

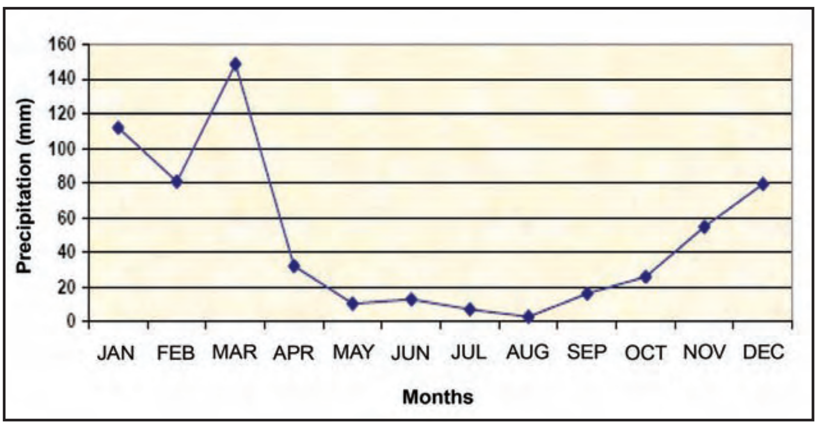

Figure 6. Monthly Precipitation Average in the Vallegrande Region (1971-2001)

The rainy season in the Vallegrande region begins in October and can last until April. During this period, and in particular between January and March in the past two decades, some areas such as Postervalle and Masicuri present occasional flooding problems. The average monthly precipitation

5 Data provided by the Research Center for Tropical Agriculture (CIAT) Meteorological Station in Vallegrande.

(1997 to 2001) is presented in figure 6. The relative humidity average in the region varies between 60 and 70%, presenting significant differences between the months of winter (low level of humidity) and summer (high level of humidity).

The predominant winds in the region come from the north with an average velocity that ranges between 5 and 15km/h. During the dry season (winter) wind can come from the south for short periods and with high velocities reaching 50km/h. This wind is cold and causes a decrease in temperature in the region. This event is locally known as "surazo" and can cause drought or drizzle. The latter benefits the crops cultivated during that period.

3.3.2 Ecosystem Diagnosis

The objective of ecosystem diagnosis is to assess the state of conservation of the ecosystems in the region and to identify elements that can contribute towards the monitoring and generation of information associated with climate change and the potential implications on socio-economic systems and human health in the area. To carry out the diagnosis, an area with ecotonal features within the study region was selected because these areas are considered to be the most sensitive to climatic variability. Consequently, the study focuses on two provinces of the region and 4 localities: the province of Manual Maria Caballero and the locality of San Rafael; and the province of Vallegrande and the localities of Alto Seco, Piraymiri and Chañara.

Changes in the State of Conservation of the Ecosystem and the Implications for Human Health and Food Security

The study area is located in the low sub-Andean dry valley altitudinal ecological zone (below 2,000m above sea level) and the vegetation in it can be divided in two main groups: 1) vegetation of the xeric inter-Andean valleys and 2) vegetation of the mountainous areas with periodic rain. The vegetation of the first group growing on soils with poor drainage is composed of riverside vegetation currently threatened by agricultural expansion and cattle breeding. The vegetation growing on well drained soils is composed of semi-arid inter-Andean forests currently threatened by the expansion of cattle farming. The vegetation of the second group includes mainly humid forests, sub-humid forests and riverside vegetation. The humid forests are currently exploited for wood extraction and agricultural expansion. The sub-humid forests are generally in a good state of conservation but are occasionally affected by fire that comes from adjacent areas. The riverside vegetation in narrow valleys is in a relatively good state of conservation, while in broad valleys it is threatened by agricultural expansion.

Potential Bio-Indicators for Climate Change

It is recognized that climate change will affect aquatic ecosystems transforming them from permanent into seasonal systems, thus impacting biodiversity and biogeochemical cycles. The magnitude of these impacts cannot yet be estimated with precision. The most affected ecosystems will be lakes, lagoons, rivers and streams in mountainous regions (1,600 to 2,500m above sea level), coastal wetlands and ecosystems that depend heavily on the underground water. In this study, different species of flora and fauna that depend on aquatic ecosystems were identified in the region. Based on the observations obtained in the field, the considerations mentioned above and the sensitivity level of the identified species to climatic variability and water availability, some of the species are suggested as potential bio-indicators to be included in a long term (> 15 years) climate change monitoring system.

As part of the group of fauna species that have potential as bio-indicators for climate change, a total of 47 species are suggested. The most important species groups for the study area are the lepidopteron, the macro-benthonic, amphibians and aquatic birds. Although one way of carrying out the monitoring is assessing the effects of climate change on each species, the study suggests evaluating the effects by assessing the biological interactions, not of one species but of a group of species. The following outlines the species that the study suggests as bio-indicators of climate change.

In the study area a total of 164 species of insects were identified corresponding to 3 orders (Lepidoptera, Coleoptera and Hymenoptera), 40 families, and 140 genuses. The presence and relative abundance of the insects identified in the area does not allow for defining their quality as biological indicators, with the exception of the lepidopteron (Nymphalidae, Papilionidae, Morphidae and Ithomidae). Indeed, to state that these species are good bio-indicators for climate change it is necessary to observe these species for a longer period of time. With this in mind, and based on the results obtained from field observations, the study suggests two species of the family Nymphalidae: *Anartia jatrophae* for high localities such as San Rafael and Chañara, and *Doxocopa cyane boliviana* for localities such as Alto Seco.

Among the macro-benthonic communities in water bodies, the study identified in both the humid and dry seasons 17 orders and 46 families in the phylum Nematodo, Annelida and Arthropoda. The macro-benthonic are typical organisms of aquatic substrates; they are sedentary, of broad distribution, and highly sensitive to physical and chemical changes in water. Moreover, they have long aquatic life stages, their taxonomy is well known and stable, and they are easy to capture. These characteristics make these organisms ideal bio-indicators of water bodies with a high sensitivity to environmental changes. In some circumstances, the assessment of these organisms exceeds the quality obtained from chemical evaluations because it integrates the effects caused by environmental variations in the past and therefore considers cumulative effects. Moreover, the monitoring of these organisms provides a high level of reliability. For these reasons, this study suggests the assessment of these species as bio-indicators for climate change. It also recommends assessing them using the tropic index. This means monitoring the proportion of the macro-benthonic species at each tropic level and the taxonomical composition of the community to evaluate the effects produced by climate change.

Fish communities in the study area are distributed in a heterogenic manner. As a result, each river has its characteristic species measured in terms of abundance or restriction in the distribution area. One of the most diverse fish in the region is the Characidae. They are predators and detritus in the trophic chain, which gives them an important place for the stability of aquatic ecosystems. Therefore this study suggests monitoring the composition and abundance of the Characidae as a possible bio-indicator of climate change.

In the study area a total of 15 species of amphibians and 16 species of reptiles were recorded. The identified reptiles represent species of dry environments, while amphibians represent typical species of semi-humid dry environments. The amphibians identified in the study are restricted to humid environments such as rivers, streams and lagoons, which determine their distribution. These environments are currently the most threatened ecosystems in the study area due to deforestation, expansion of agricultural activities and use of agrochemicals and industrial waste disposal. As a result, amphibians are one of the most vulnerable species in the area. In addition to the pressures placed on their habitats, amphibians are threatened by a new infection not yet intensively studied that is produced by a fungus and causes their death by asphyxia. Given the high sensitivity of amphibians to climatic factors, the study suggests some species as potential bio-indicators of climate change in the area: *Bufo arenarum* and *Hypsiboas andinus* for San Rafael; *Bufo arenarum* and *Hypsiboas andinus* for Chañara; *Dendropsophus minutus*, *Hypsiboas andinus*, *Hypsiboas marianitae* and *Odontophrynus americanus* for Alto Seco. Besides their sensitivity, these species are easy to sample and identify facilitating the monitoring process.

The bird observations carried out in the study area identified a total of 240 species of which 40 are included in the Convention on International Trade in Endangered Species (CITES). Climate change can reduce plankton and fish availability in water bodies affecting the food sources of aquatic bird species and reducing their success of reproduction and the number of eggs as well as affecting the survival of chicks and reproductive adults. Therefore, the study suggests monitoring the behavioral and population changes of 17 aquatic bird species identified in the area considered potentially good bio-indicators to assess climatic variability and change.

For mammals, the study recorded 31 species distributed in 18 families and 8 orders. This number of species does not represent the real biodiversity in the region, since chiropterans and rodents were not included in the sampling. The focus is placed on large mammals (generally carnivores) because these contribute towards determining the state of conservation of the studied areas[6]. Among the 31 registered species, the *Procyon cancrivorus* (karamaki) was selected as a potential bio-indicator for climate change monitoring due to its high dependence on humid environments and water bodies.

For the flora in the area, several bio-indicators were selected. In relation to the vegetation in the xeric valleys, characteristic species for each vegetation unit were proposed. In several cases, these represent the dominant species in each unit. The proposed species are: *Schinopsis haenkeana* (soto), *Neocardenasia herzogiana* (karapari), *Loxopterigium grisebachii* (cuchimara), *Cochlospermum tetrapterum* (paper tree), *Prosopis alba* (thako), *P. kuntzei* (lanza lanza), *Ceiba boliviana* (toborochi) and *Pseudobombax andicola*.

With regards to the sub-humid and humid mountainous regions, species were selected based on their abundance and for being characteristic of a vegetation unit. The following species were suggested: *Phoebe porphyria* (laurel), *Juglans australis* (nogal), *Nectandra angusta* (laurel), *Cedrela lilloi* (cedro), *Myrcianthes mato* (mato), *Myrcianthes pseudomato*, *Siphoneugena occidentales* (guayabilla), *Tabebuia lapacho* (lapacho), *Blepharocalyx salicifolius* (palo barroso), *Parapiptadenia excelsa* (chare), *Tipuana tipu* (tipa) and *Erythrina falcata* (ceibo).

The monitoring system of the species suggested above also has to consider the following requirements: 1) the data collection of the physical environment, including the aquatic environment, and 2) the establishment of meteorological stations to record the climatic events. By including these requirements, an integrated analysis of the climatic variability and change and the obtained field data can be conducted. This in turn will contribute towards the development of suitable preventive measures to reduce the associated risks and potential negative impacts of climatic extremes. The list provided above is not definitive, but is a group of proposed species that are characteristic of the area and sensitive to climatic variations. Indeed, the bio-indicators to be included in the monitoring system can be modified according to the conditions of the localities selected for the assessment and their capacity to carry out the monitoring activities.

3.4 Livelihoods Vulnerability and Risk Perceptions in the Vallegrande Region

3.4.1 Production Systems Vulnerability

The soils in the Vallegrande region have alluvial origin. In general terms, the study reveals that a great portion of the land in the area is not suitable for agriculture. This is due to the soil capability classes in the region (see table 5 and annex 1), and soil erosion caused by unsustainable land use and management. Nevertheless, the production systems in the area can be improved by introducing more sustainable production practices complemented with a suitable irrigation system. This region also presents an area rich in flora and fauna diversity located in the zone near the Amboro National Park.

Table 5 indicates that soils with capability class I are absent in the area and only 5% of the land in the region presents suitable soils for intensive agriculture (Class II to IV). Moreover, pastures represent only 6% of the area. The soil classification suggests that a great part of the area is mountainous and more suitable for wildlife and watershed protection.

6 The felines identified in the area, in particular Puma yaguarondi and Oncifelis geoffroyi that were recorded in the four localities (San Rafael, Chañara, Alto seco and Piraimirí) are important indicators of a relatively good state of ecosystem conservation.

Table 5. Land Use Capability in the Vallegrande Region

Class	Ha	%	Recommended Use
II to IV	31,113	5%	Annual and perennial crops
V to VI	37,792	6%	Pastures and perennial crops
VII to VIII	604,387	89%	Wildlife and watershed protection
Total	673,292	100%	

The Vallegrande region not only has poor soils for agriculture, but also experiences problems related to erosion. On the flat plains where boundaries are well defined, the arable layer of the soil ranges from 20 to 40cm. The arable soils in the hills and mountains are even more superficial ranging from 15 to 20cm in depth despite having well developed profiles with soil horizons A, B and C well defined. Moreover, several localities in the Vallegrande region experience serious erosion problems. The municipalities have introduced few practices to recover and conserve degraded soils. One of the most common practices is reforestation with exotic species, often ending in poor results. Although there are institutions in the area working on this situation, local farmers do not commonly implement soil conservation practices. This problem is aggravated by the poor economy and the scarcity of suitable land available for agriculture in this area where production is mainly for personal consumption. The highly degraded soils are generally abandoned and used for pastures. Over-grazing is another problem in the region.

The conditions described above shape the vulnerability of the production systems in this region. The following section presents the results of the agro-climatology assessment, describes the production systems in the region and presents the local perceptions of the effects of climate change on the production systems and water resources, as well as some locally proposed adaptation measures.

Agro-climatology Assessment

In the Vallegrande region there are six main climatic hazards that affect the production systems including: winds, snow (once a year in the Municipality of Pucara), frosts, hail, drought and flooding (Municipal Development Plan Mancommunity Vallegrande 2002). The municipalities in high elevation areas such as Moro Moro have a cold climate influenced by the high altitude, soil type, and the scarce vegetation cover. In the municipality of Vallegrande the climate is temperate, while in the municipality of Saipina the climate is dry. The lower humidity in the valley plains cause a reduction in the vegetation growth rate and density, resulting in low levels of organic matter in the soil. The slow vegetation growth is exacerbated by the temperature differences between day and night. Given the physiographic and climatic characteristics of the region, the production systems in the region are highly vulnerable to climatic variability and extremes.

The winds in the region are predominantly from the north with an average velocity ranging between 5 and 15km/h. In the winter season the crops receive winds for short periods from the south. These winds locally called “surazos” can reach a velocity of 50km/h and can bring drizzle. Although these winds can contribute towards crops’ growth by increasing humidity, they can also damage the production if they are too strong. Surazos and other winds influencing the region can also be dry. This can accelerate evapotranspiration increasing aridity and water demand. Due to the small size of agricultural property in the region, production systems have not included tree plantations that could serve as natural barriers against the wind and protect crops.

The average precipitation in the region is 580mm concentrated between November and March. In the last 3 years rain intensity has been concentrated between January and February causing soil saturation. Rain has been scarce between March and April drying the soils and contributing to the proliferation of plagues with negative impacts on cultivated crops. In general terms, the region has a very high climactic variability: The period 1995/96 was dry and was affected by the “El Niño” event; the period 1996/97 was rainy and very humid; the period 1997/98 was dry and was affected again by the “El Niño” event; the period 1998/99 was semi-dry; the period 1999/2000 was semi-dry with frosts and hail; 2000/01 was rainy with floods; the periods 2001/02 and 2004/05 were semi-dry and were affected by the delay of the rain season, frosts and hail; and the period 2005/06 was rainy with favorable conditions for the production of corn in the region.

Among the above mentioned climatic hazards that affect the region, drought is considered to be the most significant by the local farmers. The soil is prepared for cultivation between March and June in Saipina and October and December in Moro Moro and Vallegrande. If the soils are not humid by then, the organic matter that contributes towards soil fertilization will not be sufficiently decomposed thus negatively affecting productivity. Moreover, if the soils are dry during sowing, the seeds will dry and germination will also be negatively affected. If drought affects the first development stage of the crops, this will reduce the resilience of crops to cope with frosts or plagues. If water is not ensured for crops at least until the flowering and grain building stages, then production is highly vulnerable and the probability of a good harvest is very low.

In summary, the production systems in the Vallegrande region are influenced by high climatic variability and threatened by several climatic hazards. Successful crop production in the study area is mainly determined by water availability. The scarcity of water resources increases the vulnerability of crops to climatic hazards such as frost, hail, drought and flooding. The lack of preventive measures implemented to reduce the impacts caused by climatic events results in a decrease in the productivity negatively affecting the local population.

Production Systems Assessment

To assess the production systems in the region and define different levels of vulnerability to climatic hazards, the area has been divided into 3 productive zones: the highlands, the areas at the foot of the hills, and the valleys. Each of these zones has a different production system.

Zone 1 (Highlands): In the highlands the production system is based mainly on agriculture. The most produced crops are potatoes, wheat, barley and oats. Production is based on traditional extensive agriculture and is mainly for personal consumption. The predominant crop in this zone is the potato due to its adaptability to the physiographic and climatic conditions.

Zone 2 (Foot of hills): The production systems in this zone are semi-intensive and can combine crops such as corn and vegetables with cattle breeding. Households in this zone have larger areas of land property and can therefore raise cattle for both dairy and meat production.

Zone 3 (Valley plains): Due to better soil characteristics and water accessibility in this zone, production systems in this area are intensive. The main crops are vegetables (especially tomatoes and carrots), potatoes, sugar cane, peanuts and others.

In general terms, the main crops cultivated in the Vallegrande region are corn, potatoes, oats, wheat, barley, peanuts and vegetables. Fruit such as peaches, prunes and apples are also produced in this area. On the flat plains, sugar cane is a very important crop due to its profitability. According to data provided by the local authorities, 95% of families cultivate corn, followed by potatoes (85%), vegetables (42%) and sugar cane (90% in the zone 3).

The main threats currently affecting the crops in the study area are plagues and plant diseases that have arisen due to an increase in climatic variability. Known plagues and plant diseases in the region have spread and new ones have appeared. On the one hand, higher temperatures and lower precipitation have contributed towards an increase of plagues. For instance, new climatic conditions in the area are contributing towards the development of "polilla" and "mosca blanca" that affect potato crops and vegetables. Although these plagues are more characteristic in the valleys, climatic variations in the region are causing their migration to higher areas. Farmers in these areas do not know about control measures for these plagues. Although Integrated Pest Management (IPM) techniques exist to control these plagues, these techniques are not developed for different environments and have to be adapted for the conditions in new areas. Moreover, the difficult economic conditions of farmers in higher areas complicate the implementation of control measures in the short term. On the other hand, higher rain intensity within a few months has contributed towards the development of pathogen agents that cause plant diseases. This is particularly serious on the flat plains where the occurrence of floods has increased problems with plant diseases negatively affecting production.

These regional problems caused by climatic hazards, such as plagues and plant diseases are exacerbated by deforestation and agricultural expansion in upstream areas of the micro-basins and riparian areas. Deforestation in these areas (see box 3) increases water runoff causing severe soil erosion. While soils in these upstream areas are losing their water retention capacity and fertility, the downstream areas are affected by flooding during the rainy season.

To conclude, over past decades the agricultural production systems in Vallegrande region have been affected by climatic and social changes. On the one hand, more intense and frequent climatic hazards have impacted production directly (e.g. droughts that restrict water availability for plant development) and indirectly (e.g. contribution to the emergence of plagues and pathogen agents). On the other hand, farmers have expanded and intensified production systems without considering the sustainability of ecosystem services and land use suitability. The combination of these factors increases the vulnerability of production systems in the area and puts the food security and socio-economic systems of local communities at risk.

Box 3. Deforestation for "Chancaca" Production

The use of firewood as fuel is the main factor causing ecological degradation in the region. To produce "chancaca", a product made out of sugar cane, wood is used as a combustion fuel. Five trucks of six cubic meters of wood are necessary to process one hectare of sugar cane. As a result, in the area of Saipina (zone 3 - Valley plains) the average annual deforestation for firewood extraction used in the "chancaca" production is equivalent of 360 to 400ha.

Local Perceptions:
Climate Change Effects on the Production Systems and Possible Adaptation Measures

Local farmers indicate that climatic variability and extremes are the main hazards affecting their production. They recognize that climate has become more unpredictable and that some indicators used locally to estimate climatic variations are not reliable any more. Plagues and plant diseases are identified as the second most important hazard affecting local production. Farmers state that although control measures are implemented, new plagues and diseases have appeared in the area.

Moreover, the local population acknowledges that unsustainable production practices and over-exploitation of natural resources are disturbing the local ecosystems and climate. They believe that water, forests and soil resources are used indiscriminately, and agrochemicals are used on the crop fields without proper restrictions. Deforestation, forest fires, and the over-exploitation of pastures are contributing towards the changes in the climate. Local farmers have noted that drought periods have become longer, rain is less frequent and the rainy season is delayed.

According to local farmers, the consequence of all these factors is a decrease in the productivity or the loss of the entire production. This in turn impacts on the local economy, food security of the families, and the health of humans and animals. Table 6 below summarizes local perceptions[7] of climate change and the associated effects on production systems and food security. It also lists some of the locally proposed adaptation measures.

Table 6. Local Perceptions of Climate Change and the Associated Effects on the Production Systems and Food Security, and Suggested Adaptation Measures

Local Perceptions	Adaptation Measures
Climate conditions have changed and are affecting crop production.	New crops with shorter growth period have to be introduced.
The climate conditions are suitable for the development of plagues in new areas which affects the crop production.	Integrated measures have to be developed in cooperation with the municipal authorities. Technical assistance is necessary especially for the production of resistant vegetables.
Changes in climate dry the soil faster and contribute towards water scarcity. As a result, there is not enough water availability to irrigate the crops.	New seeds can be introduced to improve the quality and resistance of crops.
Heat is more intense and drought periods are longer affecting dairy cattle.	Resistant breeds need to be introduced into the area.
The heat is also affecting pig production by increasing diseases and complicating breeding.	New feeding techniques and diets are necessary, in particular for the periods of food scarcity.
The rain is "out of season" disturbing agricultural planning. The rainy season starts in December and sometimes even in January affecting sowing and crop production.	Information networks and technological capacity to predict/estimate climate conditions are necessary in the area.
Sudden temperature changes are affecting the crops, in particular more frequent frosts. Frosts are not predictable anymore.	New varieties of crops that are resistant to climatic variations are needed. Information networks to alert farmers are needed.
Hail is more frequent in the area affecting the crops.	Varieties with shorter growth period have to be introduced.
Winds have become stronger and more frequent.	Farmers need to be trained in climate change related risk prevention.
Increase in water scarcity is affecting the production and causing migration to the cities.	Projects to improve the local production systems are necessary.

Water Resources Vulnerability

Given its physiographic characteristics, the study area is an important source of water resources. Available water resources are used by the local population for domestic purposes, cattle breeding and crop irrigation.

7 Local perceptions were gathered in workshops carried out with local stakeholders including local authorities and leaders, farmers and community members.

Table 7. Local Perceptions of Risks Affecting the Water Resources and Suggested Adaptation Measures

Local Perceptions	Adaptation Measures
Rain distribution has changed and rain water is insufficient for human and animal consumption, as well as for crop irrigation.	Funds are needed for the construction of small-scale reservoirs and irrigation systems.
Water quality is low due to dissolved solids and agrochemicals among others.	Proper systems for drinking water need to be developed in the area.
The number of water springs is decreasing and some water springs are now shared by humans and animals.	
Rivers used to have water throughout the year, but are now dry two months a year causing problems for cattle and crop production.	Policies to protect water sources have to be developed and measures such as reforestation need to be implemented.
Less available water for irrigation is affecting crop production, in particular potatoes and vegetables.	Community projects to collect water are necessary.
Conflicts for water resources are increasing among users and communities.	Implement rules and regulations to improve the distribution system and irrigation schedule.
Water scarcity is causing a reduction in the production (crops and cattle) affecting local food availability and monetary incomes.	Varieties and breeding that are more resilient to climatic variations need to be introduced into the area.
Production and food scarcity is causing the migration of families and increasing the vulnerability of children and animals to local diseases.	Systems to store grains have to be improved and varieties with shorter growth periods are needed.

The main sources of water are reservoirs in high areas, the rivers that cross several communities and water springs located near the hills. Among the most important rivers in the region are the Saipina River and the Chilon River. The main water sources for human consumption are water springs (60%), followed by streams (18%), rivers (9%), water reservoirs (7%), wells (3%), and others (1%). Water is brought from the water springs to the communities using a cement storage tank and underground pipelines that distribute water to the different households. Currently, all the communities covered by the study use this system, except for the community of La Tranca that has an open system. In general, the Water Committees in the communities do not properly treat the water with chloride. As a result, water resources can be contaminated with solid residues and agrochemicals, particularly if the water distribution system is open. Moreover, water used for consumption is generally not boiled causing parasitic infections among the population.

In the area, 95% of the communities do not have a sanitary system. Only the capitals of the Moro Moro and Vallegrande municipalities have sanitary systems, while in the capital of Saipina a feasibility assessment for such a system is currently being carried out. Also, none of the communities covered by this study have a sewage system, only some households and education centers have latrines.

The water used for crop irrigation generally comes from rivers and reservoirs. In Saipina, irrigation water comes from the Comarapa and Chillon Rivers where a water reservoir has been built. The water is transported from this reservoir to the crop fields using cement channels. The water supply is organized in shifts: each farmer has the right to 4 to 8 hours a day according to the size of their land and the distance to the reservoir. The further away, the fewer hours a farmer has to irrigate. The municipality of Vallegrande lacks a system for irrigation; however, a reservoir is currently under construction to ensure food security for the communities Tucumancillo and El Bello. While the municipality of Moro Moro also lacks an irrigation system, drip irrigation is being implemented in fruit tree plantations and water is collected in 180 small reservoirs constructed in this municipality.

Over the past two decades, some areas have flooded during the rainy season making access to the crop fields difficult, while during the winter season, river flows have reduced considerably drying over a period of two months. These events are relatively new in the area and have caused negative impacts on local livelihoods, especially in terms of food security. According to local stakeholders, some families that were not able to adapt have decided to migrate. Local communities feel vulnerable to water scarcity and urgently demand the introduction of measures to reduce associated impacts. They recognize the importance of strengthening the capacity to manage water resources and of improving local awareness of the sustainable use and protection of water sources.

Local authorities have demonstrated interest in implementing measures to protect water resources by facilitating reforestation and the development of irrigation systems to ensure food security in the region. Table 7 below presents the local perceptions of the climatic hazards threatening water resources and the associated effects on production systems and food security.

3.4.2 Human Health Vulnerability

Climate change effects disturb the hydrologic dynamics of the continental water systems causing dry periods with lower precipitation and wet periods with higher rain intensity. On the one hand, these alterations have negative effects on the native fauna and flora that depend heavily on aquatic systems and are highly sensitive to climatic variability. On the other hand, these climate changes can favor the colonization of species that are highly competitive and have a high environmental tolerance level. These species can become dominant after an environmental change and displace other species. Species that have these characteristics and are of particular interest to this study due to their biomedical importance are the ones that belong to the Anophelinae subfamily, considered vectors of diseases such Malaria, Dengue and Yellow Fever.

The Anopheline mosquitoes have a broad distribution and high adaptability to environmental stress. Larvae of these species can be found in rivers, lagoons, wells and any other places that can store water, for instance Bromelia leaves. The Anopheline mosquitoes also have a preference for lentic bodies that contain detritus and aquatic vegetation. Moreover, these mosquitoes have the capacity to colonize ephemeral environments, displacing competitors and predators.

Given the ecological characteristics of the Anopheline larvae and the effects of the climatic extremes presented above, a growth in the population of these species can be expected, as well as a widening of their distribution. These species may colonize rivers with low flows and high concentrations of dissolved solids in the dry periods, in addition to water wells and pools that appear in the rainy season. An increase in available habitats will contribute towards their reproduction and the abundance of adult individuals. As a result, the possibility of Malaria, Dengue and Yellow Fever cases may increase, as well as the emergence of new infectious diseases.

Another important biomedical species that could favor climatic extremes is the Triatomine bug. The Triatomines are vectors of the Chagas disease. Around 60% of the Bolivian territory is endemic of Triatomines. The endemic areas are generally located in geographic zones between 300 and 3,500 m above sea level. Approximately 3.7 million of the inhabitants in the country are at risk of infection and about 1.8 million are already considered infected. A change in the climate could cause a broader distribution of the vector and cause an increase in the risk of infection at the local and national levels.

Due to the situation described above, this study focuses on estimating the population variations of Malaria and Chagas vectors due to climate change in the study area. To do so, the vectors are identified over a year in the households located in the selected localities[8]. The results show that Triatoma infestans are present in all the localities, while Anophelines are less present.

According to the local population, the incidence of Malaria in the evaluated localities has decreased significantly over the past 5 to 6 years. Among the main reasons for this reduction are the fumigation programs in the area and local campaigns to prevent Malaria disease such as posters, messages on the radio and TV, and workshops. The establishment of local health centers, the reduction of medical treatment costs and easier access to information on vector transmissible diseases have also contributed to the control of Malaria incidence.

As a result of the local campaigns, local farmers in the evaluated localities fumigate their homes using the residual agrochemicals that were used in the field. It has been confirmed that the dose they use follows the recommendations provided by the campaigns. Given that the products used for household fumigation are the same as the ones used in the field, fumigations are carried out according to the agricultural planning of the area and follow the preventive control for the cultivated crops. Apparently, the fumigations have been effective for mosquitoes but not for Triatomine bugs.

Lastly, the study suggests that although it was possible to identify Triatomines and to a lesser extent Anophelines in the area, it is necessary to establish a long-term monitoring program to determine population variations of Malaria and Chagas vectors due to climatic variability and change.

3.5 Municipal-level Adaptation Strategies

In the first phase of the project the vulnerability to climate change effects of each study region was assessed and the most critical aspects affecting their subsistence systems were determined. With this information, baseline scenarios have been established that will serve to evaluate climate and biological changes over time as well as adaptive capacity in the pilot regions. Besides contributing towards the understanding of the bio-climatic systems in the study areas, the first phase identified organizations and institutions that can contribute towards building adaptive capacity in changing scenarios and vulnerable environments.

Based on the results obtained in the first phase of the study and using a participatory and integrated approach, adaptation strategies are proposed for each study region. Cause-effect diagrams (“fish bone” diagrams) were used to involve local stakeholders in the development of adaptation strategies. This graphic technique allows the defining of clear relationships between the problems identified in the first phase for each sector (production systems and human health) and the causes of these problems. Using this technique in different workshops[9], municipal-level adaptation strategies were constructed for each region.

In both study regions water resources are identified as the central theme around which to develop adaptation strategies. Water resource management integrates the identified climate change impacts, particularly in relation to the sustainability of livelihoods (food security). Additionally, production systems adaptation strategies involve land use planning, capacity building and organizational development, while human health adaptation strategies consider the improvement of health services, prevention of effects caused by environmental degradation/change of human health, awareness creation, and the integration of health policies into other sectoral policies. In general terms, the proposed adaptation strategies for production systems correspond (see figure 7):

---

8 The study area covers 2 provinces and 5 localities: the province of Manueal Maria Caballero with the locality of San Rafael; and the province of Vallegrande with the localities of Alto Seco, Masicuri, Piraymiri and Chañara.

9 A workshop to conduct this activity was carried out in the Vallegrande region in December 2006 and in the Lake Titicaca region in February 2007.

Figure 7. Categories for Production Systems Adaptation Strategies

Figure 8. Categories for Human Health Adaptation Strategies

Land use planning: refers to the identification of vulnerable and risk zones such as water recharge zones and wetlands and their protection through the establishment of Municipal Protected Areas.

Water security: refers to the preservation of water resources such as lakes, lagoons, water springs, rivers, wells, and wetlands. To do so, wetland areas have to be properly managed, recharge zones have to be protected and water has to be used more efficiently.

Production system robustness: refers to the production of resistant crops; the use of improved seeds better adapted to current climatic variability; the development of organic fertilizers; the implementation of integrated pest management systems; the introduction of sustainable production practices; the improvement of animal health management and the recovery of pastures.

Organizational development: refers to the development of community enterprises; engagement of entrepreneurs; community banking; agricultural insurance; micro-credit; and capacity development. The proposed adaptation strategies for human health systems involvPIe the following categories (see figure 8):

Proactive health system management: refers to a preventive epidemiological approach, it is aimed at strengthening the capacity of health centers and networks to successfully cope with the diagnosis and treatment of diseases that are sensitive to climatic variability and change. It also considers research capacity building; epidemiologic monitoring; the introduction of vector transmissible diseases as a presumed diagnosis even if these diseases are not in the traditional epidemiologic profile of the area; and the improvement of private and public housing infrastructure to reduce vulnerability to potential climate change related hazards on human health.

Environmental prevention and protection in the health sector: refers to environmental health projects and programs that improve sanitary aspects in all environmental systems.

Public participation and organization: refers to a well informed and educated population with the capacity to reduce their vulnerability to climate change effects and better adapt by reducing associated risks and preventing potential impacts on their health.

Moreover, to successfully implement the adaptation strategies, the study suggests incorporating climate change adaptation and risk management programs and projects into municipal government planning. Mechanisms to implement the proposed adaptation strategies include: Annual Operative Plans; Municipal Development Plans; Municipal Land Use Plans; and Municipal Climate Change Programs. Although the project supports the development of these strategies, they have to be implemented through the establishment of programs and projects approved by the Municipal

Councils through regulations to be executed by the Municipal Executives. Financial mechanisms and agricultural insurance systems can also serve as mechanisms to implement the proposed strategies. Finally, the municipal-level adaptation strategies described for each region in the following sections will contribute towards the development of the National Adaptation Plan and the Global Change Strategy under the National Development Plan.

3.5.1 Adaptation Strategies for the Lake Titicaca Region

Adaptation strategies suggested for the Lake Titicaca region are in line with the categories presented in the section above and focus on sustainable management of natural resources (particularly water resources) to prevent impacts caused by climate change on production systems (livelihoods) and human health. Table 8 presents the strategies proposed to help build adaptive capacity in this region.

Table 8. Adaptation Strategies for the Lake Titicaca Region

Land Use Planning
Mechanisms to support the development of Municipal Land Use Plans are assessed to establish a normative framework to use the land according to the soil capability, introducing sustainable practices, and incorporating risk prevention management.
Strengthening of Socio-economic Organizations
Strengthening the capacity of social and economic organizations includes: primary production diversification with introduction of improved technology; seed management and phytosanitary measures improvement; introduction of new breeds of flora and fauna; water, soil and forest resources management and conservation; support from micro-credit systems; and promoting community participation to implement adaptation strategies.
Ecological Production
Support is given for the development and consolidation of organizations that adopt eco-friendly production practices. To conserve and reduce the pressures placed on natural resources, capacity building, training and technology is provided to local farmers. Moreover, local production is enhanced to reduce food security vulnerability.
Conserve Water Springs, Water Courses, Wetlands, Pastures and Soil
The local population is trained in conservation of water resources and is aware of the importance of improving the management system of these resources and ensuring their equal distribution. Water supply systems are improved for human consumption (coverage and quality). Synergies with other programs and projects working on soil and wetland conservation are achieved. Wetlands and pastures are used according to their carrying capacity.
Proactive Health Systems Management
Local prevention strategies to reduce climate change impacts on human health are developed. Epidemiologic vigilance systems are established for diseases that are sensitive to climatic variability. Staff working in local health centers are trained to implement measures that improve the environmental health in the area and to develop research into this topic.

3.5.2 Adaptation Strategies for the Vallegrande Region

Adaptation strategies suggested for the Vallegrande region relate to the categories presented in the section above and focus mainly on natural resources conservation (in particular water resources) as the central theme to creating adaptive capacity in the region. On this basis, the following adaptation strategies are suggested (see table 9).

Table 9. Adaptation Strategies for the Vallegrande Region

Training and Awareness Raising
Local population is trained about the current and potential impacts caused by climate change on human health, water resources and production systems, as well as about the appropriate ways to react to, and prevent these impacts.
Land Use Planning
Mechanisms to support Municipal Land Use Plans and risk maps are developed and implemented.
Pesticides Management
Synergies with the Persistent Organic Compounds Program and other organizations working with pesticides in the area are achieved. Experiences and information on Integrated Pest Management (IPM) are shared and IPM practices are incorporated into the Municipal Development Plans.
Endemic Diseases
The national program on Malaria and Chagas supports the development of adaptive capacity in the region reducing human health vulnerability to these diseases. Moreover, other mechanisms to improve water quality and solid waste management are developed.
Environmental Education
The local population is educated on climate change and the associated impacts on human health.
Forest Resources Protection
The forests in the region are conserved and ecosystem services used sustainably. By conserving the forests, water springs are protected, floods are prevented, food security and human health are improved and biodiversity is conserved.
Capacity Strengthening
Municipalities are provided with better meteorological equipment, laboratory material, and geographical information systems and improved technical capacity.
Research and Management
Research institutes are involved in the development of adaptive capacity in the Vallegrande region.

3.5.3 Activities to Help Build Adaptive Capacity

Different activities have been planned for the six municipalities that compose both study regions. The activities are framed within the adaptation strategies explained above. Table 10 lists the 14 activities prioritized by the local authorities to help build adaptive capacity in the municipalities.

Table 10. Prioritized Activities to Help Build Adaptive Capacity in the Municipalities

No.	Activity	Municipality	No. of Families benefited
1	Introduction of improved potato varieties	Ancoraimes	120
2	Revitalization of broad bean production systems in the areas surrounding the Lake Titicaca	Carabuco	70
3	Capacity building by 70 promoters and environmental leaders	Carabuco	70
4	Capacity building in soil and water resources management and conservation	Batallas	120
5	Biomass production in wetlands cultivating white clover	Batallas	120
6	Capacity building by the staff working in health centers in the identification of epidemiologic indicators related to climate change	Ancoraimes	50
7	Implementation of social vigilance networks in charge of monitoring vector transmissible diseases that are sensitive to climate change	Carabuco	25
8	Promotion of organic vegetable production to reduce the use of pesticides	Vallegrande	10
9	Capacity development of Chagas disease prevention activities	Vallegrande	176
10	Capacity development and implementation of preventive measures to control and create awareness of Chagas disease	Saipina	250
11	Promotion and construction of ecological ovens	Moro Moro	210
12	Capacity building in and implementation of preventive measures to control and create awareness of Chagas disease	Moro Moro	881
13	Pilot project development to promote ecological ovens	Moro Moro	320
14	Strengthening in community organizational capacity	In all the Municipalities	

Activities to Help Build Adaptive Capacity in the Human Health Sector

The process to help build adaptive capacity in the health sector of both study regions started with the identification of institutions that could play a key role in the implementation of adaptation measures. After establishing inter-institutional agreements with these institutions that included local health centers, adaptation strategies and activities were developed with the active participation of local stakeholders and these institutions. The following describes the activities conducted under the categories that encompass the strategies to develop adaptive capacity in the human health sector:

Proactive Health System Management

Through workshops and seminars carried out in both regions local perceptions of climate change effects on human health are first collected. Once this stage is completed, local stakeholders, staff working in local health centers and Vector Information Points (VIPs), as well as local authorities and managers of the health network system covering the study areas are trained in the potential climate change impacts on human health and climate change related epidemiologic diagnosis and monitoring. This initiates a social process that enables a better understanding of the topic, the identification of the main impacts and causes in each region and the development of local adaptation strategies to reduce negative climate change effects on human health in each region.

Environmental Prevention and Protection

To reduce the impacts of environmental change on human health, monitoring activities of the natural systems are conducted with the local communities. The focus of the monitoring activities is to identify Malaria and Chagas vectors in the study regions. To do so, local staff working in the health centers and VIPs are trained in entomological monitoring. The different monitoring activities confirm that vectors are expanding their distribution area and pose a threat in new areas that were not considered endemic. For example, Malaria vectors are identified over 3,700m above sea level in the Lake Titicaca region. The local climatic variability suggests that this trend may continue over time and that Malaria vectors may reach the central area of the Bolivian Altiplano. Monitoring activities are complemented with questionnaires[10] to collect information of local perceptions and potential human exposure to vectors in the local communities.

In addition to monitoring activities, local communities receive training on vector control measures. Moreover, a proposal for a new regulation on “healthy housing” is developed using better material and infrastructure for the construction of housing in both regions. New housing models are designed based on the characteristics of each region, diagnosis of current housing conditions and the requirements needed to prevent indoor vector intrusion. This proposal is shared with staff working in local health centers and municipal authorities. To create awareness of this topic among the local population, questionnaires are conducted on the relation between housing, vectors and Malaria and Chagas cases in the communities.

Finally, another activity under this category is raising awareness among the communities of the importance of protecting natural systems as a preventive measure to reduce hazards threatening human health. To do so, topics such as the use of pesticides, mining contamination, waste disposal and hazardous waste management and the effects these activities have on human health are discussed with local stakeholders.

Public Participation and Organization

The adaptation activities conducted in line with this category aim at developing, in collaboration with the local stakeholders, a social change in the communities to restrain the propagation of diseases that are sensitive to climatic variability. Workshops are carried out to create awareness among the locals about climate change impacts on human health. Some communities have developed “Epidemiologic Vigilance Committees” aimed at monitoring climate change impacts upon sanitation. For the successful development and functioning of these committees and local information sharing on the topic, the support provided by the VIPs and health centers is fundamental.

---

10 A total of 150 people in the Vallegrande region and 100 people in the Lake Titicaca region participated in the questionnaires.

Activities to Help Build Adaptive Capacity in the Production Sector (Food Security)

To help build adaptive capacity in the production systems in the Lake Titicaca and Vallegrande regions, different activities are prioritized and conducted by the municipalities (see table 10). While the municipalities in the Vallegrande region focus on developing ecological ovens, the municipalities in the Lake Titicaca Region focus on increasing the resilience of productive systems and improving the management of natural resources. The activities are developed based on a "Learning by Doing" philosophy, where beneficiaries become involved in a cyclic learning process by carrying out the activities and then reflecting on the results to improve and continue with the process of increasing the production and improving the production systems' resilience to climate change. The following summarizes the activities carried out to help build adaptive capacity in the production sector in the Lake Titicaca region.

Revitalization of Broad Bean Production Systems in the Areas Surrounding the Lake Titicaca

As mentioned above, the production systems in the Lake Titicaca region are vulnerable to climatic hazards such as droughts, frosts, hails, etc. The impacts of climatic variability and change on these systems affect the food security and income generation of local communities. To prevent these impacts and build adaptive capacity to climate change, the communities that surround the Lake Titicaca in the municipality of Carabuco decided to increase the resilience of their production systems by improving the broad bean production in the area. Broad beans are a suitable crop for these communities, because the lake contributes towards generating a micro-climate that provides the optimal conditions required by this crop to develop.

To improve the production, the broad bean variety "Gigante de Copacabana" is used and local knowledge of this crop's management is strengthened. Firstly, farmers and farming associations establish productive agreements. Secondly, soil is prepared in plots selected using traditional technology. Thirdly, workshops are carried out to train farmers in seed selection and management, improved production techniques, and phytosanitary control, and technical assistance is provided during crop development. Fourthly, meetings to share experience are organized among the farmers participating in the project and between these farmers and farmer associations located in other areas of the region that have extensive experience in the production of this crop, as well as in its post-harvest processing. Finally, training is given in business development, micro-enterprise management and accountability, marketing and commercialization.

Among the main results and lessons gained from the activity are: a more broad and open vision of different production options; the strengthening of farmer organizations and the establishment of productive agreements; the better understanding of market dynamics and product quality; the knowledge of techniques that can accelerate the crop development cycle and shorten the exposure to climatic hazards; and knowledge of processing and commercialization of the product that contributes to food security but also to income generation.

Introduction of Improved Potato Crops

Potatoes are the main crop produced in the municipality of Ancoraimes. As in other areas of the region, the production of this crop is threatened by climatic hazards and soil degradation. To increase the robustness of their potato production systems, the communities in this municipality have decided to introduce a new and improved potato seed, strengthen their organizational capacity and improve their sustainable production practices.

Different activities are developed in Ancoraimes to improve the potato production: workshops; sowing of new seeds; technical assistance in the production; capacity building in agro-ecological management of the crop (e.g. use of organic compost, soil conservation practices and integrated pest management) and in potato seed production under controlled environments.

The main results and lessons gained from this activity are the strengthening of productive and organizational capacities of the farmers in the communities, and improved knowledge of agro-ecological techniques and how to use these techniques to reduce the vulnerability of production systems to climatic variability and change while improving productivity.

Biomass Production in Wetlands Cultivating White Clover

One of the main characteristics of the wetlands in the municipality of Batallas is their capacity to support continuous production, representing the main source of food security and the main area for breeding cattle for income generation in the municipality. Families in Batallas have intensive, semi-intensive, and extensive cattle breeding systems. The majority (85%) work with traditional extensive systems of mixed production (cattle breeding and crop production). In general, the low technological level of the production systems and the degradation of the wetlands increase the vulnerability of families that depend on these production activities to withstand climatic variability and extremes that affect these areas. To improve this situation, the municipality has decided to introduce white clover as a species that will improve the biomass production in the wetlands and contribute towards the conservation of these areas. Additionally, they focus on strengthening the ability of farmers to manage and recover wetlands, and create awareness of the potential climate change impacts on wetlands and cattle production.

To conserve and improve the biomass production in wetlands, different activities are carried out in Batallas. Firstly, workshops are held to train farmers in the potential impacts of climate change on the area. Secondly, training is given to farmers on biomass production in wetlands and production techniques to cultivate white clover. Thirdly, participative workshops are conducted to raise awareness of the importance of wetlands for animals and soil, environmental protection, sustainable production practices, and soil conservation. Fourthly, a participative assessment is carried out to evaluate white clover productivity using known techniques to measure floristic composition and biomass.

The main results and lessons obtained from the process are from the pilot plots where white clover is cultivated: the identification of the best practices to obtain higher levels of biomass production in the area; a higher interest among the farmers of new forage species; the practical knowledge of alternatives to adapt to climatic variability and to reduce the risks on forage production for cattle breeding; a better understanding of the effects of climatic variability and environmental degradation on the wetlands and the associated consequences; and a higher awareness level of the importance of conserving wetlands to improve the conditions for cattle breeding and crop production.

Capacity building of soil and water resources management and conservation

Soils in the Altiplano present high erosion levels. In addition to erosion processes, soil degradation in this area is exacerbated by higher climatic variability negatively affecting food production. To deal with this situation, the municipality of Batallas has decided to develop alternatives adopting preventive strategies aimed at conserving soil and protecting it from erosive actions. To do this, conservation systems are developed using traditional knowledge that allows not only for the conservation of soil fertility but also for making better use of water resources and improving production thereby improving food security in the area.

Different activities are organized in the municipality of Batallas to improve soil and water resources management and improve productivity. Firstly, workshops are organized to explain the impacts of climatic variability and change on vulnerable production systems and to share experiences of soil and water resources management. Based on the “Learning by Doing” philosophy, soil and water conservation practices based on traditional knowledge are implemented in demonstration plots. Finally, the monitoring and final results are evaluated in participative workshops aimed at promoting discussion and learning.

The main results and lessons obtained from the process are: strengthening of 125 farmers who participated in the implementation of demonstration plots; better understanding of climate change effects and environmental degradation on production systems; development of conservation systems that are suitable for the region using traditional knowledge; and strengthening of organizational development to adopt preventive strategies to adapt to climatic hazards while improving the local production and management of natural resources.

Organizational Development
In both study regions there are institutions and associations that focus on building organizational capacity, strengthening the production systems, and improving the management of natural resources. Farmer associations play an important role in the municipalities as they have contributed towards improving the generation and distribution of income from production activities, as well as improving access to technical assistance and new and better markets. Farmer associations are generally associated with support institutions working in the area. In particular, in the Vallegrande region there are several local and international institutions working on different activities supporting the sustainable development of the families in the area.

In the Lake Titicaca region, institutions have not yet adopted adaptation measures to reduce the effects of climatic variability and change, while in the Vallegrande region the combined institutional efforts along with strong demand from farmers have resulted in the construction of numerous water reservoirs that could contribute towards coping with the negative effects of climate change. Also, soil conservation practices implemented in the Vallegrande region could serve as adaptation measures to climate change effects.

Considering the organizational development context in both study regions, some conditions can be identified as key factors for the successful implementation of adaptation measures and adaptive capacity building among the local communities: 1) the generation of a proactive vision in the institutions that can create the dynamics that allow for changes and flexibility to adapt to fluctuating conditions and higher climatic variability; 2) the decentralization of institutions to allow for more autonomous decision-making in relation to the local for adaptation; 3) the continuity of projects implemented by existing support institutions (in both regions there is institutional supply, but in the Vallegrande region the project continuity is better); and 4) the introduction of market-oriented strategies and an entrepreneurial approach to increase the adaptive capacity of the communities as opposed to the current state-/support-dependent character of the communities and farmers.

4. Lessons Learned

Building Adaptive Capacity

- Implement a positive approach. A positive approach entails focusing mainly on the capacities rather than on the vulnerabilities and problems. The existing capacities can be part of the solutions to face the challenges. A positive approach can therefore contribute towards finding potentials and opportunities for development. In this sense, resilience can be considered a positive way of looking at vulnerability. To implement a positive approach, the process needs to be based on the stakeholders' experiences and the current technical and institutional capacity to ensure sustainability in the capacity building process.

- Development from inside-out. Adaptation needs to go in harmony with the priorities of the communities, otherwise any technological solution proposed will not be sustainable. To achieve a continuous process of capacity building it is important to consider the following principles: 1) it is fundamental that the actors become the owners of the process and the process needs to develop in a way that the stakeholders perceive is the most appropriate regardless of if errors are committed; 2) the continuous involvement of stakeholders can increase the number of activities that can be conducted, therefore it is important to reach a consensus on the activities to be prioritized and the planning of activities.

- Snow ball process. The continuous involvement of stakeholders in the process motivates the social transformation needed to create adaptive capacity. Adaptive capacity building is a learning process that involves learning by doing and reflection along the way.

- The lessons learned on adaptive capacity building enrich the initial conceptual framework proposed for the project and allow for generating a more evolved and consistent framework. For instance, building adaptive capacity can help to understand that the concept of social capital can be enriched through the traditional activities and knowledge of the Aymara communities.

- Finally, building adaptive capacity is not only applicable for creating the capacity to cope with climate change effects, but also for reacting to other challenges and dilemmas, whether these are socio-economic, political or legal.

Production Systems Vulnerability and Adaptation

- Human actions exacerbate the impacts caused by climate change, increasing the vulnerability of natural and socio-economic systems. The impacts of climatic variability and change affect not only biodiversity, but also the sustainability of livelihoods. Livelihoods in the semi-arid mountainous regions are currently vulnerable and threatened by climate change effects directly and indirectly.

- Water access, agricultural production, food security and human health among others could be seriously affected if prevention measures are not implemented. Among the main prevention measures to reducing the impacts caused by climatic variability and change, the study identifies the protection and conservation of natural ecosystems, their components and services.

- In particular, the study identifies water resources to be the central theme in developing an adaptation strategy to climate change effects in the study regions.

Human Health Vulnerability to Climate Change

- Vector transmissible diseases, parasitic diseases, as well as acute diarrheic diseases and acute respiratory infections are highly sensitive to climatic variability. Climate change is causing an increase in the incidence of these diseases, their expansion into new areas and the emergence of new diseases. This is affecting the population, in particular children below 5 years of age causing high mortality rates.

- The methodology used to evaluate vulnerability in the health sector at the local level including an assessment of the bio-climatic system allows a more systemic analysis of climate change impacts on human health.

- The participatory approach and local development of adaptation strategies contributes towards a bottom-up process initiated by local communities and staff working in local health centers which will complement national strategies.

- The use of a participatory approach helps guarantee sustainability, as well as institutional and community acceptance.

Traditional Knowledge

- Traditional knowledge on climate estimation/prediction is maintained and commonly used in rural areas. This system is based on the systematic observation of indicators. However, predictions and indicators have become less reliable in the past decades and farmers claim this is attributable to the changing climate. As a result, farmers cannot plan agricultural activities as usual.

5. Strategic Recommendations

Recommendations for Public Policy and Institutional Capacity

- From a public policy perspective, the challenge is not only to build adaptation capacity, but also to recognize the existing or potential capacity of society to adapt. To do so, it is first important for state agencies and organizations to recognize the limitations of understanding reality with certainty and the implications this has for planning and management. Moreover, it is of great value to acknowledge a diversity of perspectives, knowledge and constructions of the world by the people who determine social reality. Finally, it is also essential to recognize the ability of the social and natural ecosystems to sense contingencies and react with innovative and adaptive strategies.

- Currently, in both study regions there is a lack of institutional coordination. Organizations are conducting studies independently and information is not properly shared. In workshops that were held, stakeholders pointed out the importance of ensuring more effective and permanent relationships between the different institutions working in the study regions. By doing so, the participation and agreement process will be strengthened thereby improving the national and local capacity to cope with climate change effects.

Recommendations for Subsistence Systems

- From an environmental and water security and management perspective, municipal authorities in cooperation with other social and economic actors need to invest in ensuring the sustainable and efficient use of water resources. In the Lake Titicaca region, it is important to increase the number of rain water reservoirs and to protect natural pastures. In the Vallegrande region, it is fundamental to protect water recharge zones (upstream areas of the micro-basins) and reforest these areas with native species. Also, measures to collect rain water and use it for irrigation need to be introduced.

- Concerning the development of new technologies, the National Institute for Agricultural Research can play a key role in the technological development in the study regions working in coordination with farmers, universities and the current foundation system. For the Lake Titicaca region, it is essential to work on technologies to improve the forage for dairy cattle, while for the Vallegrande region, the emphasis needs to be placed on reducing the over-exploitation of forests for firewood by providing alternative sources of energy.

- Also, it has been observed that Andean crop varieties that are more resistant to climatic variability can be introduced, improving productivity whilst contributing towards the conservation of soil and water resources. The successful results of cultivating these crops in demonstration plots could promote their broader use in the region.

- To achieve sustainable agricultural production and enhance food security it is fundamental to conserve the local biodiversity, incorporate sustainable production practices, and adopt a more ecological approach in the production systems.

- With regards to the finance and insurance systems, the National Development Plan establishes the creation of an agricultural insurance that should work in accordance with the context of each study region. Agricultural insurance systems subsidized by the national government and international cooperation could be implemented as an adaptation measure.

Recommendations for Human Health

- Currently, national policies promoted by the health sector in Bolivia are isolated and do not consider other sectors. It is necessary to develop national integrated policies that incorporate sanitary strategies into the other sectors, in particular into the environment sector. This would be the first step in the assessment of climate change impacts on human health and the planning of national integrated policies for adaptation.

- Health has been incorporated as a main issue into the National Adaptation Plan and an agreement with the Ministry of Health and Sports has been signed to implement adaptation measures to climate change in the health sector.

- Climate change needs to be a cross-cutting issue within the National Health System (NHS). To incorporate climate change and build adaptive capacity in the NHS six adaptation measures have been proposed: 1) mainstreaming climate change in health policies and programs; 2) generating proactive management in the NHS; 3) promoting social participation; 4) implementing environmental prevention and protection; 5) developing bio-climatic vigilance systems; and 6) developing current and future scenarios for human health vulnerability at the national level.

- Moreover, staff working in the health centers that compose the NHS need training and better equipment to treat diseases that are sensitive to climatic variability. This is important in endemic areas, but also in other areas that have become highly vulnerable due to the spread of diseases and emergence of new ones caused by climate change.

- At the local level, health insurance such as the Universal Insurance for Mothers and Children and the Old Age Insurance cover the study regions. The Local Health Network also covers the area with health centers that provide primary and secondary attention and mainly cover maternal and child health. These organizations need to be trained in the effects of climate change on human health and possible risk prevention measures, as well as being strengthened to improve their treatment and research capacity.

- Given the high vulnerability of human health to climate change impacts in the study regions it is necessary to implement adaptation measures that consider the improvement of housing infrastructure, capacity building and awareness raising.

- At the international level, the project contributed towards the discussions about climate change issues affecting human health at the Community of Andean Nations (CAN) and the Regional Health and Climate Change Plan of the Pan-American Health Organization. The experience and results obtained in building adaptive capacity at the local and national levels in the health sector could serve as a basis to provide insight on methodologies to implement adaptation measures at local level in the international debates.

Recommendations for the Use of Traditional Knowledge

- Traditional knowledge to predict/estimate climate conditions and plan agricultural activities based on systematic observation of indicators needs to be re-valued and recognized as complementary to weather and climate assessment methodologies that currently exist. Moreover, traditional knowledge could contribute towards building adaptive capacity in the areas.

- Due to difficult conditions in rural areas, a large portion of the younger population has migrated to the cities. It is important to re-value and share traditional knowledge with the youth that stay in rural areas through education centers and universities so that traditional knowledge is not lost over time.

General Recommendations for the Project and Further Steps

- Standardize the applied methodologies.

- Establish a database to be used as a reference and baseline in the evaluation of the bio-climatic processes and adaptive capacity in the study regions.

- Establish bio-climatic monitoring systems in the study regions based on the suggested bio-indicators to determine the relationships between climatic variability and change, the population behavior of selected species, and disease incidences.

- Share the generated information using a web-based tool with the national and international research community and decision-makers.

- Promote discussion and analysis of climate adaptation and the results obtained in the studies in the pilot regions to support decision-making and planning.

- Expand the coverage of the study and involve more municipalities.

ANNEX 1. Soil Capability Classification

The Land Use Capability Parameters of the U.S. Soil Conservation Services are used to classify the soil into the following capability classes:

Soil Class	Description
I and II	Soils suitable for agriculture and exploitation with acceptable yield.
III and IV	Soils have severe limitations for agriculture. The crops cultivated in these soils require more farm work for their successful development. It is more economical to use these soils for pasture and forest exploitation.
V	Soils are not likely to erode but have other limitations that are impractical to remove and that limit their use. These soils can be suitable for pastures.
VI and VII	Soils have severe limitations that make them generally unsuitable for cultivation.
VIII	Marginal soils not suitable for any agricultural activity or forestry. Areas that have these soils can be designated as protected areas.