Institutional Adaptations to Climate Change (IACC) Project
Integration Report –the case of the Elqui River Basin (ERB) Chile
October, 2009

EXECUTIVE SUMMARY

Since the early 1900s, the rural communities of the semi-arid Elqui River Basin (ERB) have had to face recurrent droughts and periods of intensive rainfall, which can lead to avalanches, mudslides and flooding. Shifts in climatic conditions and increasing aridity create risks that are further compounded by social conditions (e.g., access to land and water) that affect people's livelihoods. Communities have developed diverse social and technological adaptation strategies to confront these stresses. The success of these responses has been dependent on communities' social conditions and their access to resources. The Institutional Adaptations to Climate Change (IACC) project sought to understand and characterize the adaptive capacities of institutions to confront climate change risks in the ERB and in the South Saskatchewan River Basin (SSRB). This report integrates the most relevant findings of the ERB research activities.

Vulnerability assessments of several communities in the Elqui Valley highlighted the main climate-related risks and sensitivities of rural people to recurrent droughts, mudslide, avalanches, floods, soil erosion, frosts, and extreme temperatures. In addition to these risks, new stresses have been associated with land use changes. The modernization of agriculture has drastically changed the crops that are cultivated, land tenure systems, technology, and shifting market conditions, all of which impact rural peoples' livelihoods. Global market fluctuations and changes in agricultural policies have intensified the impacts of climatic stressors, further increasing the vulnerabilities of rural communities. Communities' have developed adaptive strategies to reduce exposures and sensitivities associated with a broad array of stressors; strategies include income diversification through seasonal and permanent migration, crop diversification, the construction of water storage infrastructure, improved irrigation technology, seasonal migration of livestock, and social networks. Public investment programs have effectively improved water storage capacity and water use efficiency through state-subsidized irrigation programs. This has secured agricultural production and reduced some of the risks associated with drought. But the rural poor and subsistence and small farming communities have not benefited from these programs, and their vulnerability may increase further given the projected changes in climate.

Climate models for the ERB predict increases in temperature and decreases in precipitation. Recurrent droughts and short, intense rain in winter will be a prominent feature of the ERB's future climate. Agriculture will face challenges due to a reduction in daily cool hours, which will affect the quality and productivity of several fruit crops requiring cold winters, such as vineyards, that dominate the basin and are rapidly expanding. Warmer winters and hotter summers will create opportunities for some crops, while others may require shifts in planting and harvest schedules. The greatest challenge will be the increased competition for diminishing water resources and increasing water demands during prolonged drought periods.

The current adaptive capacity of rural communities and of local and regional governments reveals some important limitations to confronting the emerging challenges of future climate change and extreme climatic events. Coordination among public institutions, water data availability, and integrated water resources management emerged as some of the major factors influencing adaptive capacity. Policies aimed at reducing resource concentration and improving

planning and risk prevention measures are needed to reduce rural community vulnerability to climate stresses.

1 INTRODUCTION

Chile's northern semi-arid regions are warming at a faster rate than the global and national average. Future climate models project increases in temperatures and decreases in precipitation. Recurrent droughts and short, intensive rainfall events during winter will be the prominent feature of the Elqui River Basin's (ERB) future climate. Agriculture will be challenged by a reduction in cool hours, which will affect the quality and productivity of several dominant, expanding fruit crops requiring cold winters, such as vineyards. However, warmer winters with fewer cool hours could become an opportunity for frost-sensitive crops, although they may have to deal with a potential expansion of pests and diseases. At higher elevations in the valley, increasing temperatures will likely further displace the zero isotherm higher into the Andes, causing reductions in water reserves at high altitudes, and accelerating glacier ice-melt rates at the El Tapado glacier. This will affect spring and summer river flows that sustain the intensive, export-driven agriculture that is present in the ERB. The El Niño Southern Oscillation (ENSO), which contributes to inter-annual climatic variability in the ERB, and the associated El Nino (wet phase) and La Nina (dry phase) events ENSO brings, may become more prominent, resulting in greater climatic variability, and exposing the ERB to more frequent droughts and extreme precipitation events, that negatively impact soil stability and lead to mudslides and floods.

A major challenge to institutional adaptive capacity in the ERB is associated with decreased water availability and increased demand. The Institutional Adaptations to Climate Change (IACC) project identified the current vulnerabilities of a sample of rural communities in the South Saskatchewan River Basin in Canada and the Elqui River Basin in Chile and assessed the capacities of institutions to address these vulnerabilities.

This research initiative integrates the information emerging from past and current vulnerabilities of local communities with the institutional capacities associated with land use changes in the ERB (e.g. land tenure and market oriented productive systems). The study integrated community vulnerability assessments, and the analysis of the role of institutions on the resolution of water conflicts. It also incorporated the assessment of biodiversity and plagues in natural ecosystems, as well as environmental vulnerabilities. Climate models were used to generate climate change scenarios, and the potential impacts of future climate change for the ERB were assessed. The impact assessment was complemented with an assessment of water governance institutions.

The rural communities chosen for the community vulnerability assessments are: Pisco Elqui, Diaguitas, Marquesa and El Molle. These communities are located in the ERB and are predominately engaged in agricultural-based economies.

A vulnerability assessment model was developed to guide the project's research activities. This model integrates past, present and future vulnerability. For this project, vulnerability is conceptualized as the exposure of a system to a physical stimulus (e.g. climate), the system's sensitivity to the stimulus, and the system's capacity to deal with the stimulus— its adaptive capacity (Smit and Wandel, 2006; Díaz et al, 2005). The project assessed the vulnerabilities of rural communities to climate and water stresses, as well as their adaptive capacities to deal with these stresses.

This paper integrates the findings of the research activities undertaken in the ERB into one comprehensive report. This report is divided in four sections. The first section provides an introduction to the project. The second section describes the past and current vulnerabilities of rural communities. The third section describes the expected future climate conditions, while the fourth section describes future potential vulnerabilities and some recommendations to improve institutional adaptations.

2 PAST AND PRESENT VULNERABILITIES

This section provides a description of the ERB, a summary of the present and past vulnerabilities identified by the ERB research team, and a discussion of the main institutional adaptations to the identified vulnerabilities.

2.1. Past/present drought and other climate-related exposures

The Elqui River Basin is located in the northern most basin of the Coquimbo region in northern Chile (29°40'S to 32°10'S). It spans 9,675 km^2, from the Pacific coast to the Andes Mountains. Its northern limit is the arid Atacama region; its southern limit is the Limari Basin, the second of three basins within the Coquimbo region; its western limit is the Pacific Ocean; and its eastern limit is the Argentinean border. Its climate is influenced by the desert to the north and the semi-arid Mediterranean climate of the central region to the south (Cepeda et al, 2008). The ERB has four major geographic and physical zones (described from west to east): (1) the lowlands of the coastal fringe, with gentle slopes ascending from the sea toward the mountains that transport coastal humidity, which influences the climate regime as far as 25 km into the valley; (2) the narrow Elqui valley slopes from east to west, at an average altitude of 850m at Rivadavia, broadening up as they reach the gentler slopes of the coastal plateaus; (3) the mid-mountain range with altitudes between 800 to 3,000 meters; and (4) the high Andean mountains range in altitude from 3,000 to peaks up to 6,332 meters. The fourth zone experiences the greatest precipitation, with snow accumulating during winter periods, and glacier melt feeding the highland tributaries of the Elqui River. The majority of agricultural production occurs in the second zone.

The climate of the ERB is strongly influenced by the high pressure of the Pacific sub-tropical anti-cyclonic system that moves north during the winter, allowing low pressure systems to bring precipitation one or two months of the year. Average precipitation is 100 mm per year, although it may double or triple during the El Niño phase of ENSO, and be half the average or less during the dry La Nina phase of ENSO. Aside from this high inter-annual variability in precipitation, precipitation also increases in the third and fourth zones described above (Fiebig-Wittmaack et al, 2008; Zavala et al, 2008). Therefore, eight to ten months without precipitation is a common feature of the ERB, with the exception of the high mountain areas.

Temperatures in the basin are mild, with summer temperatures ranging from 13° to 23°C in Zone 1, and reaching 14° to 29°C around the middle valley area of San Carlos (Zone 2); whereas in the winter they range from 7.8° and 16°C on the coast (Zone 1), to 9.5° to 18.5°C at San Carlos station further into the valley. At 1600 meters of altitude, temperature starts to decrease rapidly (approximately -6.5°C per 1,000m change) (ibid). The relative humidity also decreases from the coast (85%) to the drier, more arid interior (40% at San Carlos).

A shift in precipitation has been recorded at the oldest coastal station at La Serena airport. It shows a reduction in precipitation over the past century from between 150 and 180 mm in the early 1900s to 100 mm currently. In the last 25 years, the decreasing precipitation trend has levelled off, and even shows a slight recovery (Fiebig-Wittmaack et al, 2008). Still, this is among the most pronounced decreases in all of Chile, and it represents a risk that affects both human and natural systems (Cepeda, 2009).

There are diversified agricultural production operations within the ERB that are highly dependent on runoff from the Andes (Fiebig-Wittmaack et al, 2008; Zavala, 2009). The low precipitation regime that naturally characterizes this region acts as important exposure for communities, as precipitation can vary drastically from year to year (e.g. from 40 mm to 360 mm). ENSO has a strong influence on precipitation (e.g. years 1982, 1986, 1997, 2002), and can result in over 40mm of rain in a few hours, which increases the risk of mudslides and floods, particularly given the unstable nature of the denuded and meteoric soils, and steep slopes on both sides of the valley (ibid, 2008).

Historical records show a steady decrease in precipitation, especially during the first half of twentieth century, with a smoothing trend during the past 50 years. However, this trend is not evident at higher elevations in the mountains (Fiebig-Wittmaack, 2008). In the ERB, the majority of precipitation falls during the winter months. Yet, an intensive rainfall event that brings a substantial amount of precipitation in a short period of time (just a few hours) can lead to mudslides. There are four natural conditions that increase community exposure to mudslides: (1) the presence of dendritic and loose material on the steep valley slope; (2) intensive rainfall on poorly developed soils with slopes greater than or equal to 25%; (3) human activities such as the construction of infrastructure (e.g. roads and irrigation channels), deforestation, overgrazing and unsustainable agricultural practices on unstable soils; and (4) unstable mine tailing sites (Cepeda, 2008: 291).

Mudslides were often mentioned by community members as the climatic exposure to which the four selected communities of the ERB are most sensitive, particularly in Diaguitas and Marquesa (Salas et al, 2009). This is due to the fact that all too often communities are located on the foothills, close to the river and ravines, which render them particularly vulnerable to mudslides and floods. The steep hills and narrow valleys of the ERB leave few options for community dwellings. Concentrated rain patterns along with precarious location of rural housing and hamlets (lacking early warning systems, with poor contingency and emergency plans, close to river beds, and located in risk prone areas) highly increase rural communities' exposure to mudslides and floods (Cepeda, 2009; Salas et al, 2009).

A devastating mudslide took place on the night of April 22, 2004 in of the community of Diaguitas, which received 90mm of precipitation in twelve hours. The soils of vineyards located on the hillsides of Quebrada Puyayes became waterlogged and a mudslide rushed along the ravine, collecting large rocks, trees and debris. More than 150 families were affected; over 60 families lost their homes, around 800 hectares of agricultural land had its irrigation infrastructure badly damaged, and the school was destroyed. Four years later the community has still not fully recovered from its losses (Salas et al, 2009: 292).

Floods are also a common characteristic of the ERB. There were 373 flood events documented in the ERB between 1900 and 1981. This figure is almost four times more than what was observed in the other two southern basins of the Coquimbo region. In 1997, an ENSO year, mudslides and floods killed two people at El Almendral and negatively affected the economy (Perez et al, 2008). Low income families and subsistence farmers are more sensitive to high precipitation events because they often settle in areas with higher probabilities of mudslide or floods, as is the case in Marquesa and Diaguitas.

In addition to extreme precipitation events, droughts create risks for rural communities. Between 1915 and 2003 there were 11 years of extreme drought (less than 30mm of annual precipitation) and 16 years of moderate drought (30-60 mm of annual precipitation). Some communities are more sensitive to drought than others, and droughts have different affects on different communities. A review of the period 1980-2003 showed that Montegrande suffered extreme drought in 8 of 23 years (35%), while Rivadavia had 9 of 23 years (39%) and Pisco Elqui had 8 of 23 years with moderate drought (Perez, 2009).

Goat herders that rely on natural grasslands and shrubs for fodder are particularly sensitive to droughts. Goat herding is an important component of communities' subsistence economy (Salas et al, 2009). For over 300 years herders have used common pasture lands for winter and summer grazing, but land use changes and overgrazing have drastically reduced the availability of natural pastures (Jorquera, 2001; Cepeda, 2008). Many herders move their herds to the upper reaches of the ERB where natural grasses thrive (Cepeda et al, 2008). In recent years, the number of herders, as well as the size of herds, has decreased, as fodder is becoming scarce in winter as a result of droughts and limited access to lands due to crop expansion (Salas et al, 2009:17). Recent studies show a 43% decrease in the number of goat herders in the last 17 years[1]. The number of registered herders in the Elqui province was 1,155, with close to 160,000 goats (CEAZA, 2009; Salas et al, 2009)[2]. During severe droughts, herds may be decimated. Farmers themselves claim that "nature is regulating how much cattle we can manage" (Varas, Madariaga, Largo, 2007 cited by Salas et al, 2009). Still, herding has helped build the adaptive capacity of subsistence farmers by providing income opportunities (e.g. through milk by-products, meat and leather products).

Droughts also affect natural ecosystems. Native species have been subjected to climate variability and they have developed the ability to cope with a certain range of variability. The regional arid and semi-arid biota is expected to be well-adapted to greater aridity induced by future climate change (Arroyo et al, 1988; Huenneke, 2001). Nevertheless, biota will experience accelerated changes that are 10 to 40 times faster than the changes they have had to adapt to in the past (Peters, 1988 cited by Cepeda, 2008). This rate of change would produce a strong increase in extinction rates for many species; however, it may favor others, or promote diversification. Human activities such as the expansion of agriculture limit the opportunities for many species because their environments have been destroyed or modified by overgrazing, deforestation, fires and pesticides/herbicides (Cepeda, 2008).

Occasional cold spells and near-freezing temperatures in winter also affect agricultural producers. The 2007 cold spell that lasted several days had severe impacts on vegetable and fruit crops (Salas et al, 2009) — over 50% of the crops in the ERB were lost. This motivated the Ministry of Agriculture to declare an agricultural emergency in order to protect farmers against financial bankruptcy (Portal Coquimbo, 2007).

Water quality is an issue for communities. Mining accounts for much of communities' employment opportunities (e.g. Marquesa and Nueva Talcuna), and community members accept

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[1] The information provided by the National Statistic Institute (INE) portray a 45% increase in the number of goats between 1997-2005 period with 78,000 heads for the Province of Elqui (Trujillo, S., INE, 2006)

[2] Transhumance, the seasonal migration of livestock, is common strategy used by over 25% of the goat farmers moving their animals from lowlands to higher altitude pastures during the summer. Almost 46% of goats are raised in this fashion (INE, 2006)

seasonal employment on labour intensive, small-scale mining operations that leave behind unmanaged tailings sites. These tailings are later removed by floods, which results in the contamination of soil and water resources (Salas et al, 2009). Many of the communities believe contamination is a result of the unmanaged tailings as well as pesticide residue that is applied on agricultural lands in surrounding areas. However, there is little institutional regulation and no enforced legislation pertaining to mine tailings. Another factor influencing water quality is the lack of proper sewage infrastructure for the collection and treatment of all rural drinking water systems, which are managed by the communities themselves (Reyes et al, 2009).

2.2. Past and present institutional adaptation

Adaptation to climatic and other conditions that create risks and opportunities for rural communities has been a historical process in the ERB. Community adaptations include: migrating to northern mining districts to diversify income, diversifying crops and income, building water harvesting and irrigation infrastructure, building flood control infrastructure, adopting new technologies, and changing targeted markets. These are some of the strategies revealed through the community vulnerability assessments.

The construction of water and irrigation infrastructure started early in the nineteenth century in the ERB (Jorquera, 2001), but it was not until the mid-twentieth century that the construction of large water reservoirs became a central element of government policies aiming to regulate river flows and water storage. Adaptations to secure reliable water resources during periods of scarcity has been primarily achieved through the construction of dams and irrigation systems, and more recently, by introducing more efficient forms of irrigation, such as drip irrigation systems. The early construction of the La Laguna Dam in 1941 in the upper reaches of the ERB was the first major attempt to regulate river flow and store water for irrigation[3]. This small dam and the management of the irrigation system assisted in the early development of social adaptations to cope with water scarcity. The creation of an Irrigation District at Estero Derecho helped secure water resources as well as ensure crop yields in the upper and lower reaches of the Valley. It took another 57 years before another dam—the Puclaro Dam—was built in the lower mid-reach of the Elqui River in the late 1990s[4]. Together, these two dams secure irrigation for approximately 25,000 hectares (62,000 acres) of crops. There are three Irrigation Districts managing an irrigation system that consists of 126 channels, reflecting the social learning in the valley. The Department of Hydraulic Works (DOH) of the Ministry of Public Works provided the technical training and initial managerial support to the Irrigation Districts, which are now autonomous, well-structured organizations that satisfy other social roles in the communities (Salas et al, 2009; Reyes et al, 2009). The dams, the irrigations systems and the Irrigation Disctricts managing them are considered proactive adaptations that increase water security and reduce the effects of drought on agriculture. The Puclaro Dam, for example, secures a two-year water supply for irrigation. However, conflicts have arisen as a result of the construction and management of the dam. The construction of the Puclaro Dam required the relocation of the town of Gualliguaica and three nearby hamlets, sparking several years of conflict and controversy in the area (Rojas et al, 2008). Without proper environmental and social assessment studies for this major project, the institutional response to the demands of local

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[3] The Laguna dam has a capacity to hold 40 million m^3 of water

[4] The Puclaro dam is located at an elevation of 432 meters, with a reservoir 7 km long, 2 km wide and a 200 million m^3 holding capacity.

communities was controversial; they undermined their social capital, and created serious social conflicts among the communities and with the project development[5]. The major issues in the conflicts were both the loss of access to water for irrigation and agricultural lands flooded by the dam. The compensation packages could not replace the social capital lost nor their traditional orchards and river habitats.

The relocated communities were relocated next to the dam, but cannot extract water for irrigation nor use it to develop income generating activities (e.g. tourism) (ibid). Villa Puclaro, the result of an amalgamation of three communities, located in the southern portion of the dam's reservoir, has a seriously undermined social capital, as many of the community members now suffer from depression. The better-compensated inhabitants of New Gualliguaica, located in the northern portion of the reservoir, feel they were adequately compensated for their relocation; however, they lost their ability to engage in agriculture, and the social relations within the community have been forever changed. The two relocated communities are representative of the negative consequences of a successful irrigation project in the ERB. Their new location is probably safer in terms of flood risk, but they are now more exposed to mudslides and drought, and are lacking land and water for subsistence farming and other activities (Rojas et al. 2008).

Another adaptation relates to more efficient forms of irrigation. The introduction of water saving technologies has been closely associated with the expansion of vineyards and avocado plantations for sale in export markets. Drip irrigation in the Elqui Valley is an advanced adaptation that eases the growing demand for diminishing water resources. Vineyards and avocado plantations on hillsides are adopting this technology, with powerful pumping systems, allowing agricultural producers to plant more crops while using the same amount of water than prior to the adoption of drip irrigation. Vineyards are the one crop that grows in extreme conditions. Harsh winter conditions and strong summer sun tend to result in high quality vintages. This new technological achievement has facilitated the expansion of agriculture to the steep valley slopes; commercial fruit plantations and production has more than doubled in the area in the last ten years[6] (INE, 2007).

The adoption of more efficient irrigation and other water-saving technologies is not enjoyed by all producers of the ERB. Access to water and improved technologies, as is demonstrated by the IACC's community vulnerability assessment, is unevenly distributed. Most agro-industrial operations have the financial resources and know-how to secure the latest technologies and reduce water stress risks. These operations may even acquire water rights through the water market. Small producers and traditional farmers, on the other hand, have little access to water resources and tend to mainly use traditional irrigation systems (e.g. flood irrigation). Government agencies' financial support for water infrastructure has reinforced the trends towards high productivity goals and the export–led agricultural model, which marginalizes the small and subsistence farmers, sparking conflicts and leading to exclusion (Rojas et al, 2009).

High-tech drip irrigation systems and other technological innovations associated with modern agriculture are not always embraced in communities; they are often accepted with hesitation, as many community members expressed concerns regarding the future impacts of

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[5] The relocated communities complained of poor and unequal access to information, inequitable housing arrangements and social infrastructure for those with greater negotiating capacity, and early access to information versus the weaker and poorer communities

[6] The region of Coquimbo has shown one the largest increases in cultivated area in the last agricultural census of 1997-2007 with more than 26,000 hectares (65,000 acres), doubling the cultivated area in one decade. VII CENSO Nacional Agropecuario y Forestal. Enfoque Estadístico. INE 2007. p4

these technologies on the environment. One area of concern is related to the availability of water for irrigation downstream. In traditional irrigation systems, water usually feeds back into the system, which ensures that all users' water rights are generally satisfied and that the lower reaches of the river receives the full water allocation. After the water is used for irrigation, the infiltrated water re-enters the river system. Drip irrigation systems, on the other hand, ensure effective water use but limit aquifer recharge in the lower zones of the valley. More area can be irrigated and less water is "lost" compared to traditional systems. However, producers are concerned that there may not be sufficient recharge and that allocations in the lower reaches are subsequently not satisfied. They are also concerned that drip irrigation could cause conflicts among farmers in the lower reaches (Lira, 2003), which may be compounded by droughts and aquifer exhaustion, already experienced in the Copiapo Basin north of the ERB. Water governance institutions have not yet addressed the pressing issue associated with the over-exploitation and depletion of aquifers. Small farmers with limited access to water rights fear their rights will be compromised by their technologically advanced neighbors.

Salinization of soils is another important concern associated with drip irrigation technology that has yet to be properly addressed in the ERB. The intensive use of pesticides in the expanding plantations is another cause of concern for communities in the valley (Salas et al, 2009). Community members expressed concerns about the potential risks of mudslides in the hillsides that have been drastically changed by the new terracing and new cropping patterns that have arisen after the adoption of these new irrigation technologies. Extreme precipitation events have already devastated communities in the basin and their members fear that the recent land use changes will increase the risk of mudslides (Salas et al, 2009).

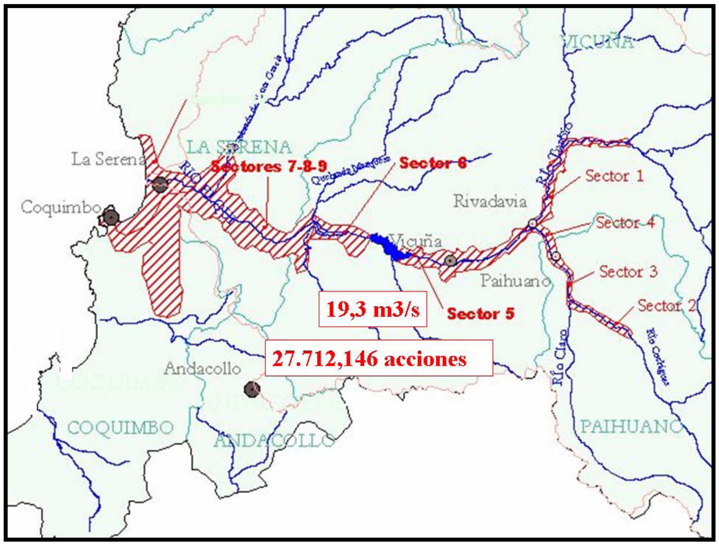

Figure 1. The Elqui River Basin (Source: Caminar Project, 2007)

The National Irrigation Plan (2006) acknowledges that the construction of reservoirs and dams do not always take into account long-term agricultural plans, or include integrated basin management plans or adaptation policies (National Irrigation Plan, 2005). Dams and reservoirs are often constructed because of the political and social commitments made during elections, rather than being based on an integrated water and basin management approaches that take a holistic perspective on water management.

A comprehensive assessment of ground and surface water is incomplete for most basins, and hence water right allocations as well as irrigation infrastructure follow the logic established by the 1981 Water Code—first come, first serve; no priority use or performance demands are incorporated into the water rights system. The net result has been an active water market and a large mobilization of technical and financial resources to manage water as a private good and commodity (Hearne and Easter, 1997). Current public work policies are aiming to privatize dams and give users full control of the related infrastructure.

The State is also shifting its public investment policies, creating new protocols that permit private investment in irrigation infrastructure and that demand financial investment from water users before an irrigation project is approved. Thus, this requirement for users to pay the State for the construction of water infrastructure such as dams and irrigation systems ensures that water is used efficiently and that water users have a more market-oriented perspective regarding water resources. As a result, water associations and regional governance institutions need to reach agreements, and hence, new rules and administrative capacities emerge.

The Irrigation District of Rio Elqui has made an agreement to pay the construction costs of the Puclaro Dam. It will take ownership of the dam's operations and be responsible for its maintenance costs; neither will be carried out by government agencies anymore. Private ownership of dams has sparked new institutional arrangements that integrate energy generation as a cost recovery and income-generating alternative. The ERB showcases the first regional case of the integration of irrigation and energy generation schemes[7]. This win-win situation provides opportunities for dam shareholders to diversify income, and is an important step towards renewable and low-impact energy production, that could also be extended to other dams in the region. This adaptation strategy is also linked with emissions reduction strategies (CNR, 2008)[8]. Institutional capacities to manage climate, water and other stresses are emerging through the management, diversification and administration of the Irrigation District of the Elqui River.

The benefits of this strategy are not equally shared among water rights holders—one drawback of this strategy. The strong and powerful become even stronger and more powerful, and there is no mechanism to bring those without access to irrigation water on-board, unless they can pay market-price for water rights, which many cannot.

Sufficient, quality water plays an important role in rural community members' health. An important goal of government in the 1960s was to improve access to potable water in rural areas. The potable drinking water systems were built by the government and are community-operated; Rural Potable Water Committees (CAPRs) were established and serve as administrators. There are more than 1500 CPRs that serve over one million people in Chile's rural areas. The construction of the drinking water systems and the autonomous management and administration of the CAPRs have helped build social capital in communities. This is an important adaptation strategy that seeks to collectively secure a basic necessity of rural communities.

Although there are institutional and legal gaps with respect to the rural services offered by CPRs[9], the CPRs have managed to remain autonomous and self sustaining, fighting attempts to privatize their services, as is what happened with all major water facilities in the 1990s in the

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[7] This arrangement is in stark contrast with growing conflicts among farmers and energy companies over the priorities for water resources in large dams in south-central Chile ((Reyes et al, 2009).

[8] The National Energy Commission hopes that its assessment of over 290 irrigation opportunities with potential to generate 890 MW (Reyes et al 2009) will be fulfilled with similar agreements in the future. Chile's energy dependence of imported oil, gas and coal is in dear need for non conventional energy generation

[9] Regular and frequent water quality control and sewage recollection systems are two of the major weaknesses of the rural drinking water systems.

entire country (Reyes et al, 2009). Even though CPRs exist and help provide rural communities with drinking water and sewage collection services, the more isolated and dispersed communities (close to half a million people) still rely on water trucked in by rural municipalities, their own wells, or makeshift systems. Poor coordination among government agencies and a lack of resources has seriously affected water quality management. Sewage collection and water treatment will require major government funding to meet the needs of the rural population and to avoid health risks. So far, no major diseases or contamination situations have seriously affected communities, but poor management is gambling with community health. Mining, sewage and pesticides are among the major threats to drinking water sources. Currently there are no comprehensive regulations, programs or policies to address these activities, which could turn into major water quality risks for rural communities.

The return of a democratic government to Chile in the early 1990s saw an increase in public investments to establish several large irrigation infrastructure projects, and to upgrade existing ones. The initial focus was on the arid and semi-arid regions (Huasco, Elqui, Limarí and Choapa Basins), followed by the Mediterranean basins of La Ligua and the Aconcagua rivers. The Puclaro Dam at the Elqui River was built between 1997 and 1999[10]. Between 1990 and 2000 almost 275,000 hectares (700,000 acres) of agricultural land in Chile were converted to irrigation (Lira, 2003). In the ERB, over 20,000 hectares (50,000 acres) of agricultural land have irrigation (Reyes et al, 2009).

The National Irrigation Commission (CNR) also increased its efforts and resources to attain ambitious irrigation targets set by the current government[11] (CNR, 2008). Irrigation is considered a key component to agricultural expansion, to achieving the goal of Chile being among the top ten agricultural exporting countries in the world, and to strengthening Chile's current position as the largest fruit exporting nation in the Southern Hemisphere[12].

Irrigation programs within agricultural policies have become increasingly important for agricultural producers in terms of enhancing economic activity and reducing the risks associated with unpredictable weather conditions. Currently, close to 330,000 hectares (816,000 acres) is under fruit production in the country, three times the area in 1990. Fruit exports jumped fourfold from US$800 million in 1990 to US$3,500 million in 2007. There are approximately 60 major water reservoirs and 1,180 medium and small dams, irrigating over 1,200,000 hectares (3,000,000 acres), being managed by 212,000 users**.** Presently, irrigated land accounts for 80% of agricultural exports, and hence, CNR's goal is to turn family farms into food exporters. CNR's mandate and policies were strengthened in 2005 when they received a substantial amount of funding for irrigation projects after the Ministry of Agriculture set a mandate to turn Chile into a "Food Exporting Power". Climate change is not yet among the concerns of CNR, as they believe that irrigation has already protected agricultural producers against drought, one of the major climate change risks for the ERB (Reyes et al, 2009).

There is no doubt that public investments in irrigation infrastructure has helped secure water resources, and enhanced the adaptive capacity of large and medium farmers, but a major drawback of this strategy is that it lacks an integrated approach to water resource management, and the incorporation of social equity. The "National Irrigation Plan" (2006) of CNR recognizes this:

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[10] The "El Bato" reservoir is currently being built in the Choapa basin in the Coquimbo region.

[11] The goal established by the Ministry of Agriculture is 460,000 hectares (1,140,000 acres) of new irrigated land by year 2014.

[12] See Ministerial discourse at Eurofruit Southern Hemispheric Congress, 2-4 December 2008.

> "*Save for few exceptions, irrigation projects have not followed a set of national priority criteria; there has been, poor institutional coordination and poor methodologies for project development; also there were inadequate assessments of agricultural development associated with irrigation projects, and the projects often lacked meaningful participation of stakeholders*."

A major deficit of agricultural and irrigation programs is that family and subsistence agriculture, producing mainly for domestic markets, have not developed technologically, nor have they developed access to water for irrigation. One factor limiting their incorporation into irrigation systems is that surface water rights and most groundwater are fully allocated. Farmers already holding water rights are therefore the only ones that can be the subject of irrigation subsidies, as those without rights do not qualify. Poor farmers without water rights do not have access to water and new technologies, a recurring situation among small farmers in the ERB. Thus, irrigation policies are still strongly biased towards large and medium farmers and companies that hold or can purchase water rights.

Three major factors have enhanced agricultural modernization and diversification in the ERB: (1) The agrarian reform of the late 60s and early 70s that broke the traditional land holding system and redistributed land to many peasants and farmers; (2) Many indebted farmers lost their lands in the 80s and early 90s; a few cooperatives survived the harsh economic and political period, managing to maintain and expand their vineyards and pisco processing plants. Most sold their land to agro-industrial companies and landowners seeking to expand into export-sized farms. This initiated modernization in the valley. Cereals, pasture land and orchard production gave way to vineyards, citrus and avocado plantations that have higher input costs associated with them and a need for sophisticated irrigation systems (Jorquera, 2001). Soil quality stopped being a barrier as they conquered the hillside with drip irrigation and fertilization. Former farmers turned to migration, and many have become seasonal laborers for large agricultural operations, while others have maintained their traditional migrations to mining areas to secure and supplement farm income; (3) Public investments and incentives to support exports and new market opportunities associated with free trade have been the essential ingredient in the drive to modernize agriculture in the Elqui valley. In the coastal areas, however, some family farms and orchards have continued producing traditional crops (e.g. vegetables) to sell in regional and metropolitan areas (e.g. La Serena and Santiago).

In the rural communities of the ERB, local traditional knowledge systems and social capital are being rapidly lost to migration and land transformation, with the exception of Irrigation Districts, rural drinking water committees, and a few neighbourhood associations (Salas et al, 2009). Small and medium sized producers of the valley have trouble organizing and are poorly represented in decision making structures. This limits their capacities to negotiate with government institutions for funding to adopt new innovations, to adapt their operations to changing market demands, to purchase crop insurance, and to be able to bear the financial burdens of crop losses when they experience extreme events. However, at the regional level there is renewed interest in understanding and responding to social and economic challenges posed by expanding aridity and desertification processes[13].

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[13] The recently established "Regional Water Dialogue", is a multi stakeholder approach to integrate different social actors in a broader regional water strategy and the "Caminar" Project with a specific focus in the ERB, integrating regional research institutions, producers and government agencies. See www.cazalac.org/caminar

Institutional research capacity has increased in the region. A research cluster on arid zones and water governance is being created in the region. The Center for Advanced Studies on Arid Zone (CEAZA) created in 2003 integrates two regional universities (Universidad de la Serena and Universidad del Norte) and the National Institute for Agricultural Research (INIA) of the Ministry of Agriculture. Also, in 2006, the United Nations Educational, Scientific and Cultural Organization (UNESCO) and the Chilean chapter of the International Hydrological Program (IHP) created the Centre for Water in Arid Zones for Latin America and the Caribbean (CAZALAC). Its objective is to strengthen the development of technical, social and educational capacities of the region to manage water in arid and semiarid zones and to enhance the role of communities in the development of a new water culture (Reyes et al, 2009).

Water governance institutions are also seeking ways to face the challenges of integrated water resource management through new initiatives, as in the case of the recent public discussion in the emerging Regional Water Dialogue established in 2008. This dialogue brings together the water concerns of public, private and social organizations in order to provide leadership and water policy direction. The influence of this emerging initiative on policy making is still unclear. A similar, smaller scale initiative for the ERB and other basins are non-existent[14]. In fact, multi-agency coordination is weak and aside from the emerging policy on integrated basin management, there are no major concerted efforts to strengthen adaptive capacities, and no multi-agency planning initiatives to anticipate more severe drought and flooding events associated with climate change. Public agencies are focusing their efforts on expanding agricultural production and improving irrigation and water regulation infrastructure (ibid: 2009)

Data on surface water availability and flow patterns in the ERB is fairly complete (Zavala et al, 2009), but there is insufficient knowledge on groundwater withdrawals and the recharge capacity of aquifers in the ERB. There are important gaps in the collection and integration of water data, especially when it comes to water quality, quantity, and climatic data for higher altitudes of the Elqui Valley. The information needed to model the ways in which subsurface water and glaciers will respond to future climate change scenarios is incomplete, and the data sets that do exist have high levels of uncertainty associated with them (Fiebig-Wittmaack et al, 2008). This uncertainty reduces the capacity of water governance institutions to plan in the medium and long term, both regionally and nationally. Locally, most stakeholders complain that they do not have access to the data they need to fully understand the challenges that climate change may bring (Reyes et al, 2009).

One institutional adaptation strategy developed to help producers manage the risks associated with extreme climatic events is crop insurance. Almost all crop insurance programs are geared towards medium and large producers. However, the Ministry of Agriculture via INDAP recently created a program that seeks to integrate small producers into crop insurance programs. For now, just a small group of these producers can afford it, even though 50% of the costs are covered by INDAP. Crop insurance could compliment other government aid programs (e.g. drought bonuses) that do not cover the economic effect of droughts on producers, and those that do, do not provide pay-outs in a timely manner. (Salas et al, 2009). No plans in the near future exist to develop an income guarantee system for producers during extreme events, and the capacity of small producer groups is not strong enough to convert this into a political priority.

The recurrence of mudslides and floods in the ERB tests the capacity of the National Emergency Office to coordinate responses in light of these natural hazards. Community

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[14] The exception is the “Caminar Project” recently initiated by CAZALAC which focus on the ERB in Chile and two basins in Peru and Bolivia). www.cazalac.org/caminar

members of Diaguitas and others feel that institutional responses during mudslides and floods are inadequate, and that there is insufficient communication and coordination among public regional institutions, municipalities and the affected communities (Salas et al, 2009: 19). Effective disaster relief capacities require close coordination and preparedness among public institutions and local governments. Yet, communities have difficulties identifying which public institutions are responsible for what, and how the institutions go about completing their tasks. Thus, poor planning, enforcement and communication limits the capacity of state institutions to take preventive action and build adaptive capacity; the fact that schools and housing are located in risk prone areas with no plan to relocate them to safer areas in times of crises is commonly cited as an example of the challenges faced by institutions that negatively affect rural communities (ibid).

Although local governments have the most direct links with local community organizations, they do not have clear legal mandates regarding water issues[15]. However, during droughts, mudslides and other disasters, drinking water systems are often damaged or stop working, and local government is the first to organize relief operations and truck water in for human and animal consumption. But in case of water contamination or other water management issues, they have no capacity to either respond or provide direction to water users. It is unclear if the emerging integrated basin management approach, which is still in the pilot phase, will be effective in enhancing the capacities of local governments in water management areas, which would improve coordination, planning and communication, and improve institutional learning.

Centralization is a common complaint among regional water governance institutions, as regional agencies have limited power to change water policies and resources. (Reyes et al, 2009). The 1981 Water Law is perceived as a major obstacle in the adoption of a regionalized perspective on integrated water management. Multi-agency coordination and planning, that integrates regional and national agencies, is weak and has limited capacities to undertake anticipatory or preventive measures to effectively deal with drought and other climatic stresses. Water policies are defined at the central level and regional approaches for integrated water management are still in their early stages (ibid: 2009). There are new institutional efforts to establish an integrated approach water management at the basin level under the leadership of the National Commission on the Environment (CONAMA). The National Strategy and Pilot Plans for Integrated Basin Management were approved in 2007[16] and three pilot basins have been selected. If these results are relevant and applicable, they may help to secure political support for implementation in all regions of Chile and ensure the meaningful participation of different stakeholders in planning processes. However, without clearly established institutional roles, this integrated management approach may not work. The recently created Water Table could be the basis for social learning that strengthens integrated water management at the basin level. However, it is not clear whether this initiative would permit a positive change in regional water governance institutions.

Limited access to information is perceived as an important factor that is negatively affecting institutional adaptive capacity. Local stakeholders state that they do not have the information necessary to fully understand the risks of climate change. The managers of the Elqui River Neighborhood Watch, for example, recognize that climate change could be a threat, but they cannot understand what it means for them. The relevant information regarding climate

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[15] An exception could be the development of Municipal by-laws, but these are not developed in the ERB

[16] The background and process ofr the development of the National Strategy and Plan for IBM is described in http://www.conama.cl/portal/1301/article-42435.html

change is scarce and is not appropriately communicated to those stakeholders and institutions that would make use of, and benefit from, having it (Salas et al, 2009).

3 CLIMATE CHANGE IN THE ERB

Future climate scenarios required the application of downscaling techniques in order to provide relevant information for decision making and to produce plausible future climate change impact scenarios for the basin (Fiebig-Wittmaack et al, 2008). Vicuña was selected as being representative of agricultural productivity in the ERB. Statistical downscaling was realized on the Vicuña site, using the Long Ashton Research Station Weather Generator (LARS-WG) (Semenov and Barrow, 2002). The study shows the results from the Canadian CGCM3 with the T47 and T63 resolutions (CCCma 2005) and the emission scenarios SRES A2 and B2 (ibid).

The period of observed meteorological data for Vicuña (baseline) was 1960-1990, and output data were calculated for the periods 2011-2030, 2046-2065 and 2070-2100 for most of the climate indices defined by the ETCCDI (Expert Team on Climate Change Detection and Indices). The first two periods were chosen because these periods are likely more relevant to Chilean decision makers and planners.

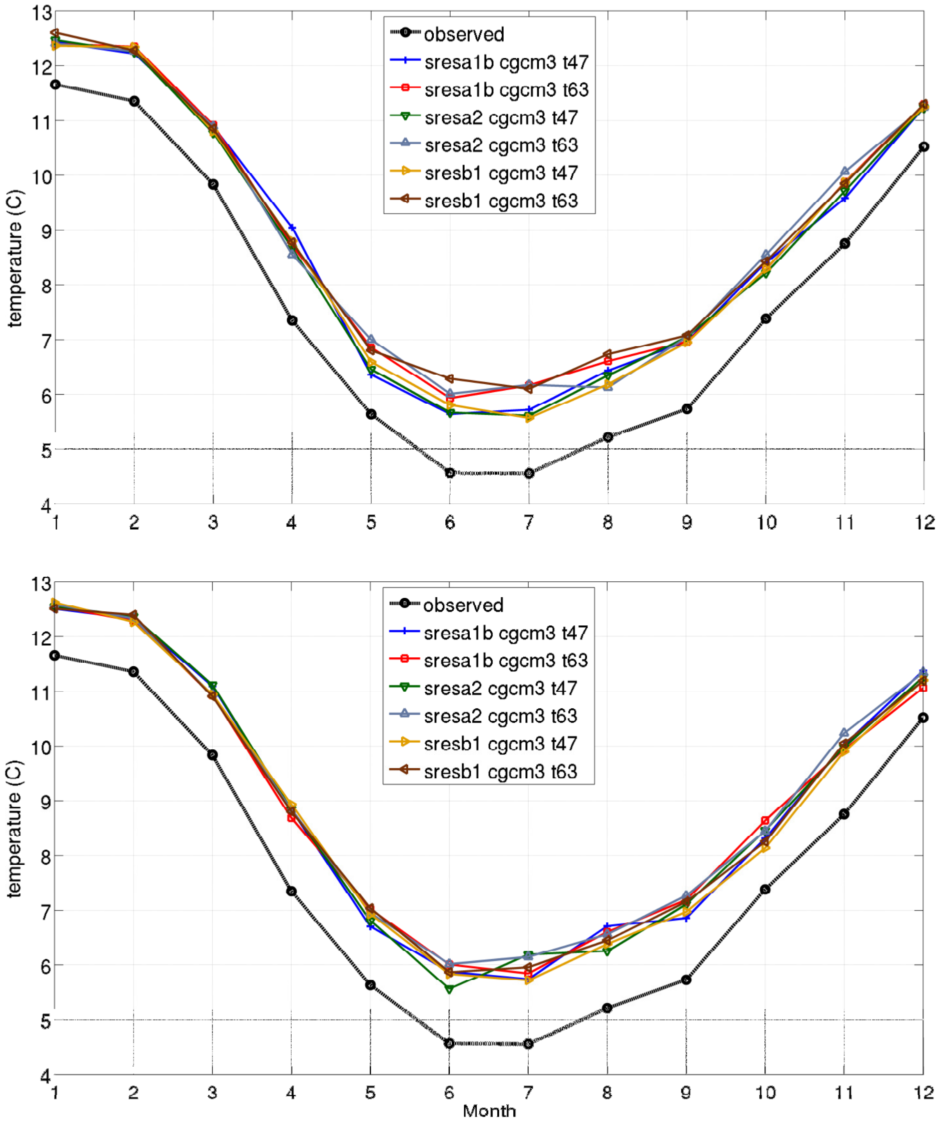

Figure 2. Monthly Average Minimum Temperature for Vicuña. The black line represents the baseline (1960-1990), while the others correspond to results calculated with LARS for different emission scenarios, for the period 2011-2030 (above) and 2046-2065 (below).

The following climate indices that are relevant for agriculture and/or represent sensitivities for rural communities in the ERB were the focus of the scenario analysis:

1. monthly average minimum temperature;
2. monthly average maximum temperature;
3. monthly average degree day (monthly sum of hours with temperatures >10°C) (DG10);
4. monthly average number of hot days (maximum temperature >30°C) (SU30);
5. monthly average number of frost days (minimum temperature <0°C) (DO0);
6. annual precipitation; and
7. number of extreme precipitation events (daily precipitation >40 mm).

Future scenarios for the two periods (2011-2030 and 2046-2065), shown in Figures 2 and 3, illustrate a trend towards increased higher minimum and maximum temperatures, especially in winter (i.e. June and July). The warming is reflected in the increasing degree day index (DG10), where increases of: 36% in September, 30% in October, 15% in November, 9% in December, 11% in January, 24% in February and 25% in March are seen (see Figure 4). The degree day index significantly affects crops, from germination to harvest (September through to March). The analysis for the number of hot days also shows a strong increasing trend, mainly during the period October to April (Figure 3); but this result should be taken with caution, given common overestimations in the simulations. In addition, the number of days with frost decreases during June to September, and slightly increases in May (Fiebig-Wittmaack et al, 2009).

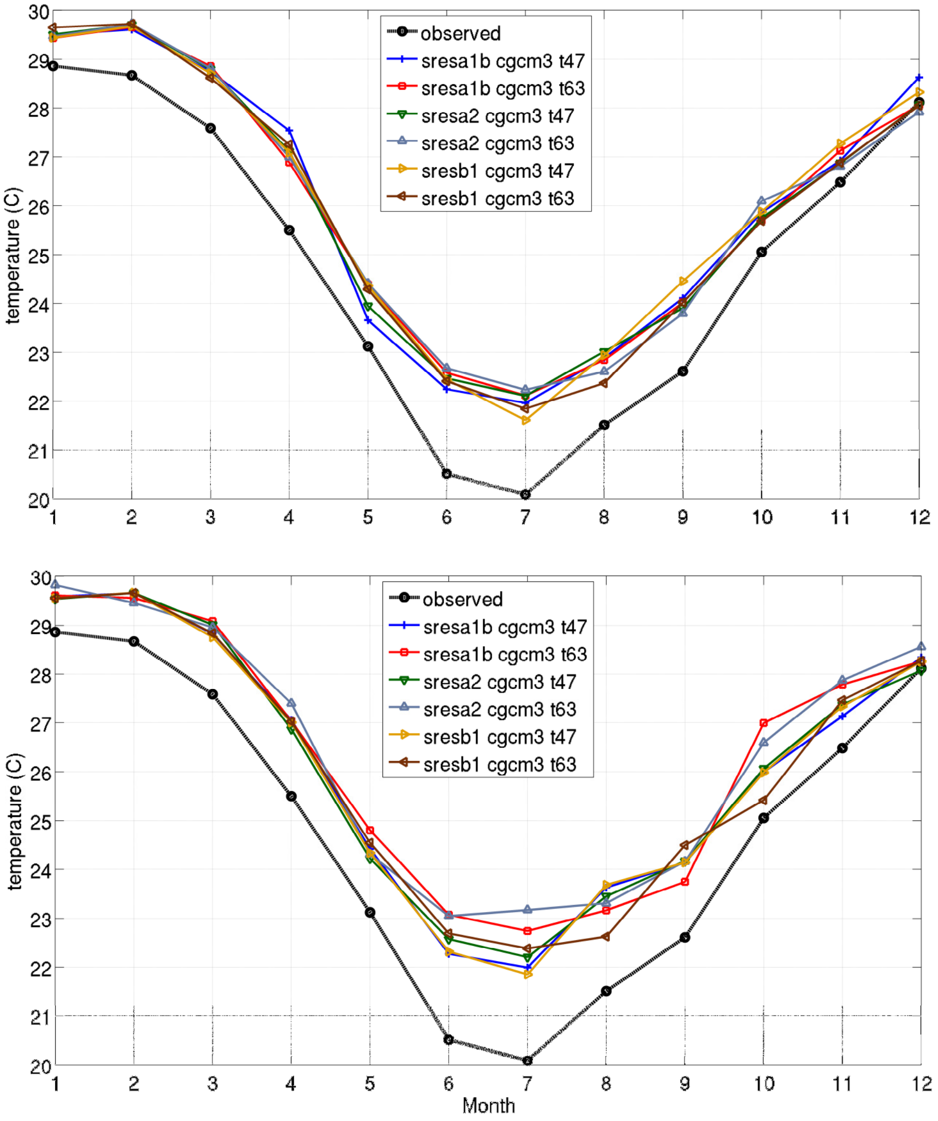

Fig. 3: Monthly Average Maximum Temperature for Vicuña. . The black line represents the baseline (1960-1990), while the others correspond to results calculated with LARS different emission scenarios, for the period 2011-2030 (above) and 2046-2065 (below).

The downscaling results for precipitation show that annual precipitation will remain close to, or be lower than, the observed, but interpretations concerning precipitation are subject to caution, given the high level of uncertainty in its simulation. Even without a clear negative trend for future precipitation amounts, annual precipitation during the last decades have been low enough that the potential continuation of this trend is a great cause of concern. Extreme precipitation from April through to August may decrease slightly in both periods, but a slight increase of these events is shown for the two scenarios in the later part of the year.

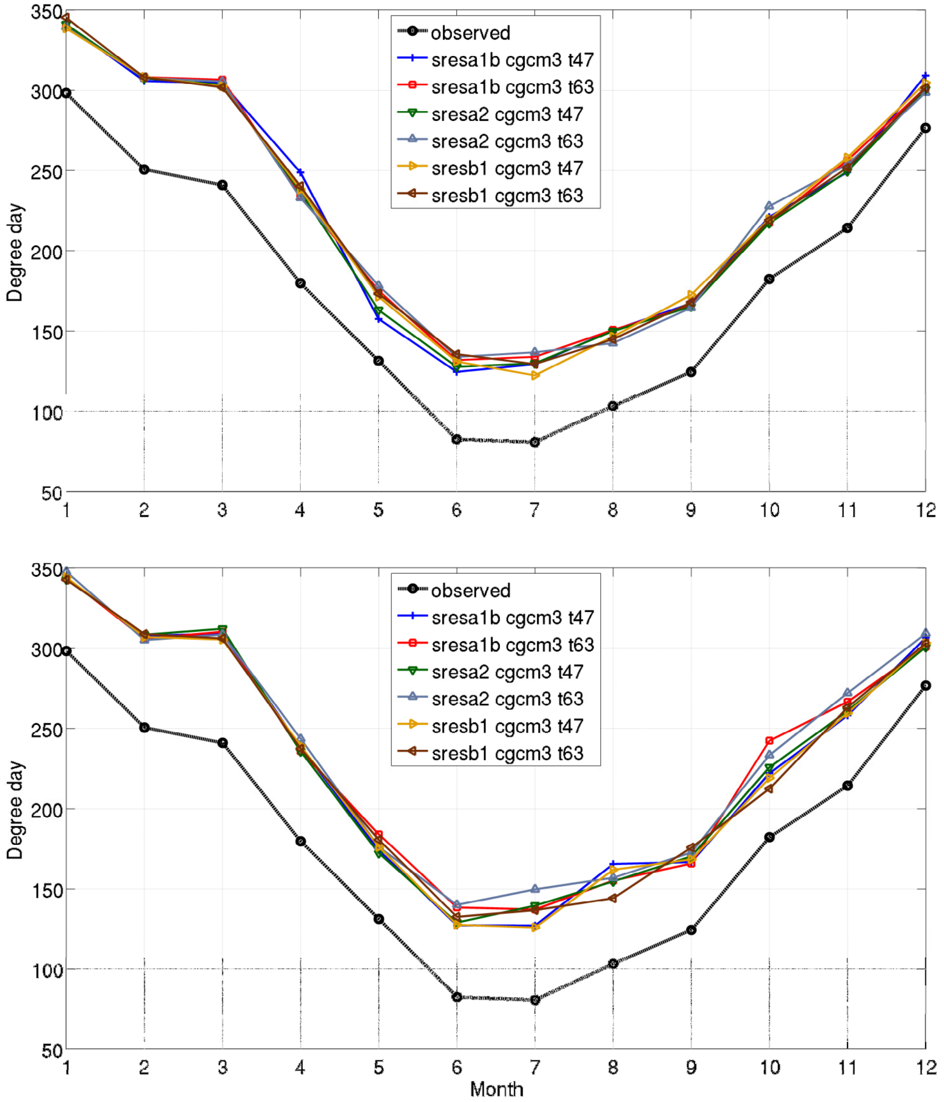

Fig. 4: Monthly Average Degree Day Index (temperatures >10°C).
The black dotted line represents the baseline (1960-1990), while the others correspond to results calculated with LARS for different emission scenarios, for the periods 2011-2030 (above) and 2046-2065 (below).

The scenarios generated by the models have important consequences for agricultural activities in the basin, particularly vineyards, fruit trees (orchards) and vegetable production. The increase in average minimum temperature will reduce chilling hours (i.e. the number of hours when the temperatures range between 0ºC and 7ºC) during the dormancy period of plants (May through August) will result in irregular budburst in grapes and deciduous fruit trees, and plant productivity may decrease. On the other hand, the decrease in frost days will reduce the sensitivity of some frost-sensitive crops, primarily early harvest vegetable crops (e.g. potatoes, tomatoes, bell peppers) and fruit trees (e.g. papayas, chirimoyas, avocados, citrus).

The increase in days with temperatures greater than 30ºC during the spring and summer will have negative effects on the photosynthetic process of all fruit trees cultivated in the ERB (Ferrini et al, 1995; Jackson and Lombard, 1993). Yield and quality will be affected. However, this may reduce the incidence of some common plant diseases in the ERB.

Higher winter temperature could have positive effects on the productivity of early spring-summer horticultural crops because these could then be cultivated earlier during the year, potentially enabling producers to obtain premium prices in urban markets. However, as a consequence of higher temperatures, evapotranspiration rates will increase, which will increase water demands from agriculture and irrigation. This may result in increased competition and conflicts among water users, and between communities and other sectors (e.g. tourism and mining).

The projected increase in the degree day index will induce a shorter growing period for grapes, which will allow an earlier harvest, potentially resulting in higher prices for the grapes (El-Hadi and Al-Habash, 1995; Jimenez and Sotes, 1995). However, the productivity vineyards and fruit quality will likely diminish as a consequence of the shorter growing season, as grapes will not have the necessary time to reach preferred maturity. This warmer weather could stimulate the expansion of insect plagues, resulting in higher input costs for pest control and increasing the risk of contamination (Cepeda et al, 2009).

The future shifts in these climate indices not only create risks, but also opportunities. Some new agricultural crops may be introduced in the ERB, and some traditional crops could be relocated to higher elevations in the valley. Maximizing opportunities, however, will require enhanced adaptation in terms of the awareness various agro-climatic trends, for example, and of their implications for current and future possible agricultural products.

For some communities and farmers living on dryland or rain-fed agriculture, or with limited access to irrigation water, the impacts of the above scenarios will be dramatically different, as water is already a major limiting factor. On the other hand, the slight decrease in frost days may be beneficial by reducing the vulnerability of some frost-sensitive crops, mainly early harvest crops and some fruit trees currently characterizing their multi-cropping practices. Without access to irrigation, many of the crops cultivated by small farmers, from which they draw their income, will experience reduced yields.

Higher winter temperatures may be beneficial for the productivity of some horticultural crops, as they may be cultivated earlier in winter, when precipitation is available in the ERB. Yet, the overall increase in evapotranspiration and subsequent increases in water demand will limit the potential for farms with poor access to water for irrigation.

Goat producers are most sensitive to reduced water availability since this will translate into lower productivity of natural pasture lands and shrubs, on which they depend. The overall decrease in rain and humidity would likely further decrease the fodder, which may negatively affect herd size and quality. Goat herders may have to graze larger areas for their herds to obtain the same amount of food, and this may accelerate the erosion process in the already stressed and highly eroded hillsides.

Community members engaging in subsistence economies may have to migrate to find seasonal and/or permanent employment opportunities in order to supplement their income (Salas et al, 2009). The scenarios show a small decrease in the number of extreme precipitation events during April to August but a slight increase in the latter part of the year. For low income families living in mudslide and flood prone areas, this may mean either a reduction in these risks or a shift in the timing of these events into the early spring.

With increasing temperatures, the isotherm will continue to shift towards higher altitudes, decreasing snow and ice reserves at higher altitudes, resulting in decreased precipitation, higher evapotranspiration, and reduced river flows. Decreased precipitation and higher evapotranspiration rates, along with a higher demand for water, may mean greater risks for the wells feeding the potable water systems. Reduced river flows and future potential increases agricultural and urban-industrial effluents may increase the risk of water contamination, as the dilution potential of rivers will be reduced. Overall, communities will experience greater water stress as there will be greater competition for water because there will be less water available to meet growing demands in the future.

In terms of river flow, it is unclear as to whether or not there will there be enough water in rivers to meet future environmental and social needs. The fact that there is sparse high mountain precipitation data and a lack of knowledge concerning the cryosphere of the ERB, stream flow behavior is difficult to understand and predict (Fiebig-Wittmaack et al, 2008).

On the east side of the Andes Mountains, at monitoring sites in Argentina, precipitation has shown an increasing trend in the past century (IPCC, 2001, Minneti et al, 2003). To the west, it is uncertain whether or not precipitation at higher elevations in the Andean zone of the ERB has decreased, or if permafrost and glaciers have melted, or are melting (including rock and debris covered ice). Also uncertain is whether or not these have added water to rivers; if they have, higher stream flows could be temporary. This is alarming because besides the changes in the temperature-related indices in the ERB, the loss of valuable water resources stored in the form of snow, permafrost and glaciers can result in environmental and socio-economic stresses in the near future. This emphasizes the critical importance of monitoring of the cryosphere in the ERB, evaluating of current and future trends, and discussing of adaptation measures to water scarcity (Fiebig-Wittmaack et al, 2008).

Improving data collection, integrating information and enhancing coordination between public agencies and research institutions may yield more realistic, reliable climate change models, and contribute to the development of more pertinent adaptation measures.

4 FUTURE VULNERABILITIES AND RECOMMENDATOINS

Future climate models project decreases in precipitation, increases in temperatures and in the severity of extreme climate events (e.g. droughts and intense precipitation events), decreases in annual river flow, and fewer frost events.

4.1. Future exposure

Aridity in the basin will be exacerbated by the projected increases in monthly average minimum and maximum temperatures, monthly average degree day (DG10), and monthly average number of hot days. Many of those expected changes will be outside of the currently experienced climate and beyond the coping range of communities.

Warmer winters and higher maximum summer temperatures will create stress for human activities and natural systems. The increases in temperature will lead to higher evapotranspiration rates, reduced water availability, and increased water demands. Future exposure-sensitivities may include greater competition for water, which may result in conflicts among water users in ERB.

As the climate of the region becomes more arid, snow and ice reserves in the Andes are expected to diminish. This will affect the seasonality and amount of snowmelt and surface runoff, which has implications for annual river flows, groundwater recharge and water ecosystems located at lower elevations.

The forecasted increases in temperature will also have an impact on wild species, and it is unclear how they will respond to a warmer climate. It is possible that species with fast biological cycles and high biotic potential (e.g. insects, rodents, rabbits) can benefit from future warming, potentially becoming more abundant, and subsequently becoming plagues (Carey, 2001 cited by Cepeda et al, 2008).

The frequency and magnitude of the intense rainfall events associated with ENSO will increase in the future, creating risks for communities, including landslides, avalanches, and flooding. ENSO will also bring more severe droughts (Cepeda et al, 2009). There is evidence that extended, severe and multi-year droughts will seriously amplify aridity trends. An expansion in aridity may increase water scarcities in the ERB and have negative implications for agriculture and people's livelihoods.

New exposures will arise in the future in the ERB. A reduction in the amount of cold hours will affect the productivity of some crops, such as grapes, whose dormancy period is critical for uniform budding, for example, which influences yields and quality. Irregular budding resulting from an inadequate dormancy period will decrease productivity in fruit trees and reduce the number of temperate fruit species that could potentially be cultivated in the ERB.

Increases in the degree day index will cause decreases in fruit quality and productivity, and affect the financial returns of the fruit plantation operations in the valley, although earlier crops may capture higher prices.

Increasing water demand is likely to drive farmers and enterprises to invest in water saving technologies (e.g. drip irrigation), the development of new water sources (e.g. purchase new or more water rights, which will result in more active water markets), and/or underground water sources and technology. As a result, the risk of over-extraction and depletion of aquifers may increase.

There may be opportunities for productive systems in the future if there is better access to information, technology and financial capacities that facilitate shifts in current agricultural practices to new, more climate-appropriate crops. The warmer climate will provide an opportunity to introduce new crops that demand fewer cold nights and days, while frost-sensitive crops will benefit from a reduction in frosts events.

The forecasted increases in aridity will cause an expansion and intensification in the desertification process, potentially reducing yields and opportunities for subsistence agriculture. This will reduce the food production capacity and income generating potential of subsistence agriculture. Communities reliant on dryland agriculture are already exposed to drought; further droughts will negatively affect cultivated areas, water storage capacities and income opportunities. Animal husbandry, particularly goat herding, which has been an important diversification of farm income, will feel the impacts of water stress in the ERB. With less natural fodder available as result of lost moisture, herd sizes will continue to decrease, and herders will be forced to migrate further distances to highland areas to feed their animals, or they may change their livelihood altogether.

There is a slight decrease in the intensity of rain events in the winter, with a shift towards the early spring. However, since torrential rains are often associated with ENSO years, it is unclear if mudslides will be more or less common, while the forecasted decrease in precipitation in the highlands may reduce the risk of flooding. Currently, communities do not have access to early warning systems, nor can do they have the institutional support required to anticipate or respond to emergencies arising from sudden climatic changes. This significantly reduces their adaptive capacity to deal with hazardous events such as mudslides.

The CAPRs will experience great difficulties as a result of decreases in the water table and greater competition for water among different economic sectors. Water contamination may also be a more common occurrence, if they continue to not have the tools necessary for to prepare for these stressors. Local governments do not have the human and financial resources to support and improve drinking water systems in rural areas, nor do they have the resources to secure water supplies and efficient technologies for rural communities. Unless regional and central governments are prepared to invest in water security in these rural communities, they will experience great risks related to water security.

4.2. Institutional adaptation strategies

Until recently, the Chilean government had not developed many adaptation strategies or policies to confront climate change. Most of its efforts and commitments within the United Nations Framework Convention on Climate Change (UNFCCC) have been associated with greenhouse gas emissions in different economic sectors, and linking them to reduction processes through the Clean Development Mechanism and carbon credit projects. The National Strategy on Climate Change was approved by the Council of Ministers in 2006 (CONAMA, 2006), while the National Action Plan on Climate Change was launched just days before the UNFCCC Conference in Poznan in December, 2008 (CONAMA, 2008). More recently, the Ministry of Agriculture has created a “Climate Change Council for Agriculture” (MINAGRI, 2008), formed by multiple agencies and researchers from different institutions to provide advice and direction regarding adaptation policies. The completion and release of climate change scenarios for Chile, and a recent analysis of climate change vulnerabilities in silviculture, agriculture, water, and soil resources have contributed to the incorporation of climate change considerations into public and policy discussions (CONAMA, 2006; 2008). There is still a long way before those discussions are reflected in effective adaptation policies and become well funded, decentralized programs. A major drawback of future climate projections for 2070-2100 is that they are too far removed for policy actions to take place. The scale of the projections is also too broad to be able to make informed decisions at a regional and basin scale.

Statistical downscaling makes an important contribution for the early development of adaptation programs and policies at regional and basin scales, and the assessment of vulnerabilities and institutional capacities at the community, basin and regional levels demonstrate the local capacity to manage current climatic stressors, but it is unclear if those capacities will be sufficient under future climate change.

The following recommendations emerged from the IACC’s research activities as ways to increase the adaptive capacity of institutions in the ERB in order to alleviate the risks and maximize the opportunities of climate change for rural communities:

- Create an umbrella organization that can effectively monitor and more accurately generate water scenarios (e.g. generate, collect and process climate and hydrological data and integrate climate change scenarios for both highlands and lowlands in the ERB).

- Improve climate monitoring, paying particular attention to improving and integrating highland monitoring and data collection stations, including teledetection in the high Andes where climatic conditions are critical for understanding the hydrology of the ERB.

- Improve inter-institutional coordination and develop new tools to disseminate climate change information and build local and regional institutional adaptation capacities.

- Establish and develop a watershed authority that would both effectively manage and coordinate institutional responses to changing climatic conditions and their effects on rural communities, people's livelihoods, household income, agriculture, and other aspects of society.

- Coordinate and develop decentralized tools and programs that improve water use efficiency and both water storage and harvesting potential, with particular attention to the most vulnerable (i.e. small and medium size farmers and rural communities).

- Create networks and training programs that sustain an early warning system for droughts, floods, mudslides, and other hazardous climatic events.

- Develop an integrated pest control program. This would reduce the risks as well as the costs associated with the wide use of pesticides on mono-cropping operations.

- Public institutions and basin authorities should develop conflict management and conflict mediation capacities, since future increases in water demand will lead to both increased competition and conflict among sectors.

- Regional water governance institutions would benefit from better surface and groundwater coordination, monitoring and documentation. This is particularly important for securing adequate quality drinking water for communities and CAPRs and for avoiding groundwater contamination and aquifer overexploitation.

- Municipal governments are the first to respond to rural community needs, and they therefore need to develop and strengthen their capacities to communicate climate adaptation measures and water management issues to communities.

- Water and development agencies need to develop an institutional framework to enhance municipal, community and other stakeholder involvement in water conservation, protection and restoration processes.

- Current and future climate change risks and opportunities require programs that strengthen civil society organizations (e.g. capacity building for local, regional and national CAPR associations, Irrigation Districts, research and education teams, etc.). A strong and well-organized civil society will be in a better position to deal with climate change.

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