Climate Change in Chile:
climatic trends and farmer's perceptions

Jorge Alvar-Beltrán

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Título / Titre / Titolo

El cambio climático en Chile: tendencias climáticas y percepciones de los agricultores.
Changement climatique au Chili: tendances climatiques et perceptions des agriculteurs
Cambiamenti climatici in Cile: tendenze climatiche e percezioni dei contadini

Abstract / Resumen / Résumé / Riassunto

This paper suggest the need to use both qualitative and quantitative research methods to engage stakeholders across scales so as to improve Chile´s adaptation policy framework. Historic climatic trends show alarming changes, both in rainfall and temperature patterns. In large parts of central Chile annual rainfall has considerably diminish by more than 1 mm per m^2 per year since the 20th century. Moreover, throughout the 20th and first part of the 21st century, minimum and maximum mean temperatures have generally increased, but in some cases they have decreased. Socioeconomic groups, such as farmers, are highly exposed to extreme weather events, being in all cases aware of climatological changes. In addition, farmers are a reliable source of past/present weather information, while being imperative on the understanding of other socioeconomic and environmental related issues. Nevertheless, instead of being considered in the decision making-process they are often left apart. Finally, this paper thoroughly analyzes climatic trends in central Chile, Coquimbo and Maule regions, the ways they are being perceived by weather dependent groups and whether the government is generating sufficient tools for adaptation to the changing weather conditions.

Este documento sugiere la necesidad de utilizar métodos de investigación tanto cualitativos como cuantitativos para involucrar a las partes interesadas en diferentes escalas en el marco de la política de adaptación de Chile. Las tendencias climáticas históricas muestran cambios alarmantes, tanto en la precipitación como en los patrones de temperatura. En gran parte del centro de Chile, la precipitación anual ha disminuido en más de 1 mm por m^2 por año desde el siglo XX. Además, a lo largo del siglo XX, han disminuido los grupos socioeconómicos, como los agricultores, están muy expuestos a los fenómenos meteorológicos extremos, siendo conscientes del cambio climático. Además, los agricultores son una fuente confiable de información, mientras que son esenciales para la comprensión de otros temas relacionados con el entorno socioeconómico. Sin embargo, en lugar de ser tomados en consideración durante el proceso de toma de decisiones, a menudo se los deja a un lado. Finalmente, este artículo analiza a fondo las tendencias climáticas en las regiones de Chile central, Coquimbo y Maule, las formas en que los grupos que dependen del clima las perciben y si el gobierno está generando herramientas suficientes para adaptarse a las condiciones climáticas cambiantes.

Ce document suggère la nécessité d'utiliser des méthodes de recherche qualitatives et quantitatives pour impliquer les parties prenantes à tous les niveaux afin d'améliorer le cadre de la politique d'adaptation du Chili. Les tendances climatiques historiques montrent des changements alarmants, à la fois dans les régimes de précipitations et de température. Dans la majeure partie du centre du Chili, les précipitations annuelles ont diminué de plus de 1 mm par m^2 et par an depuis le 20ème siècle. De plus, tout au long du 20e et de la première partie du 21e siècle, les températures moyennes minimale et maximale ont généralement augmenté, mais dans certains cas elles ont diminué. Les groupes socioéconomiques, tels que les agriculteurs, sont fortement exposés aux phénomènes météorologiques extrêmes et sont dans tous les cas conscients des changements climatiques. En outre, les agriculteurs constituent une source fiable d'informations météorologiques passées / présentes, tout en étant indispensables à la compréhension d'autres problèmes liés à la vie socioéconomique et à l'environnement. Néanmoins, au lieu d'être pris en compte dans le processus de prise de décision, ils sont souvent laissés à l'écart. Enfin, cet article analyse de manière approfondie les tendances climatiques dans les régions du centre du Chili, de Coquimbo et de Maule, de la façon dont les groupes dépendant du climat le perçoivent et si le gouvernement ne dispose pas, au contraire, d'outils suffisants pour s'adapter.

Questo documento suggerisce la necessità di utilizzare metodi di ricerca sia qualitativi che quantitativi per coinvolgere a tutti i livelli le parti interessate per migliorare il quadro della politica di adattamento del Cile. Le tendenze climatiche storiche mostrano cambiamenti allarmanti, sia in termini di precipitazioni che di temperature. In gran parte del Cile centrale le precipitazioni annuali sono diminuite di oltre 1 mm per m^2 all'anno nel corso del XX secolo. Inoltre, durante il secolo scorso e la prima parte del XXI secolo, le temperature medie minime e massime sono generalmente aumentate, ma in alcuni casi sono diminuite. I gruppi socioeconomici, come gli agricoltori, sono altamente esposti a eventi meteorologici estremi, e sono in ogni caso consapevoli dei cambiamenti climatici. Gli agricoltori, una fonte affidabile di informazioni meteorologiche passate / presenti, pur essendo indispensabili per la comprensione di altri problemi socioeconomici e ambientali, vengono spesso appartati dal processo decisionale invece di essere più pienamente coinvolti. L' articolo analizza infine, in maniera approfondita, le tendenze climatiche nelle regioni centrali del Cile, Coquimbo e Maule, e se il governo dispone o no di strumenti sufficienti per l'adattamento alle nuove condizioni climatiche.

Keywords / Palabras clave / Mots-clé / Parole chiave

Chile; Climate Change (CC); Farmer´s perceptions; El Niño Southern Oscillation (ENSO); Climate Change Adaptation

Chile; Cambio Climático (CC); Percepciones del granjero; Oscilación del Sur de El Niño; Adaptación al cambio climático

Chili; Changement climatique (CC); Les perceptions de l'agriculteur; L'oscillation australe d'El Niño; Adaptation au changement climatique

Cile; Cambiamenti climatici (CC); Percezioni del contadino; El Niño Southern Oscillation; Adattamento ai cambiamenti climatici

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Introduction

Chile is a country with a wide latitudinal range, 17 to 55°S, entirely lying on the east coast of the Pacific Ocean and west slope of the Andes, thus giving the region a unique bio-climatological diversity (Rosenblüth *et al.*, 1997). Its geographical singularity significantly influences Chile's climatological mosaic, characterized for having one of the wettest regions in the southern hemisphere, while northern regions are one of the driest (Cáceres *et al.*, 1992). The role played by the Andes range is crucial, as it acts as a barrier and isolates the region from the eastern Atlantic influence. Rainfall intra-annual fluctuations are associated with cold fronts and migratory low pressures, shifting the humid-arid boundary from 28°S in winter down to 35°S in summer (Montecinos and Aceituno, 2003). Furthermore, in central Chile, summers are semi-permanently affected by high-pressures over the southeast Pacific Ocean, while during winter the westerlies are responsible for orographic precipitation (Rütlland and Fuenzalida, 1991). Rainfall inter-annual anomalies are associated with the south-east Pacific subtropical anticyclone. As a result, when the anticyclone becomes stronger than usual a new negative ENSO phase is under way, often associated with droughts in so-called La Niña event.

In addition, scientists have determined with a very high degree of certainty, above 90%, that global warming is induced by anthropogenic interference thus altering earth's climate systems (IPCC, 2007). In 1992 the United Nations Framework Convention on Climate Change (UNFCCC), Article 4.8, placed Chile among the countries at higher risk highlighting its vulnerability to CC impacts. Alongside, the need to avoid dangerous anthropogenic interference has been firmly recommended in the political and scientific discourse, as well as the different forms of adaptation of human systems to forthcoming extreme weather events (Adger *et al.*, 2003; Schellnhuber *et al.*, 2006).

The increasing need to implement actions to fight CC has not slip passed among policymakers in Chile, and since 1992 is periodically addressed at national committees. In 2008 the National Climate Change Action Plan (here after referred as NCCAP) defined short and long-term mitigation strategies and identified the most fragile economic activities, i.e. agriculture. Even though, the most vulnerable sectors were identified, CC adaptation strategies did not thoroughly examined the ways farmers could adapt, leaving the latter responsible of self-adapting. Among the most common practices in agriculture, the use of new crop varieties, irrigation technology and changing planting dates are often pointed out (Bradshaw *et al.*, 2004).

Governmental efforts to reduce poverty from 38.6 to 13.7%, for the period 1990-2006, could be thrown overboard as climate threats have already started to grow (Agostini *et al.*, 2008). Consequently, there is a need to better understand how farmer's perceive climate threats and if they are already adapting to it. This research explores, to some extent, CC in Chile, farmer's perceptions and Chile's CC adaptation policy framework. Subsequently, meteorological data and its spatial visualisation has provided the investigation with sufficient information to better understand the climate within the area of study. The emerging results from farmer's perceptions and meteorological data is examined to better comprehend similarities as well as differences between actual and perceived CC. To conclude, the research gives a set of recommendations that could potentially be useful for increasing resilience amongst farmers.

Literature review

Climate Change In Chile

Historically the study of Chile's climate variability has its roots on Walker'sand Bliss' pioneering research of 1932, when the ENSO was first described. Nonetheless, it is not until the second half of the 20th century when their insights are formerly corroborated. This was done by Rubin (1955) who analysed southern hemisphere pressure anomalies. The 1980's is a tipping point in the

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scientific literature with a plethora of investigations focusing on Chile's seasonal and inter-annual climate variations (Pittock, 1980; Fuenzalida, 1982; Quinn and Neal, 1983). Despite the fact Peña and Nazarela (1987), and Rosenblüth and Fuenzalida (1991) studied regional CC in Chile, it is with the millennia when thorough research started to focus on past rainfall and temperature changes, as well as its impacts on water resources. However, the trend in plausible knowledge regarding glacier mass has not been consistent, being Liboutry's (1956) work the most influential glaciological investigation. This gap within the scientific literature has been pointed out by Rivera *et al.* (2007) as well as Bown *et al.* (2008), all considering that Chilean glaciers are poorly understood, while based upon inaccurate maps. Since then, scientists have started to meticulously describe past/future rainfall and temperature trends as well as its impacts on glacier mass.

In regards to temperature variations, scientific literature in Chile started in the 90's. Several authors assert that temperatures have experienced a rapid mean annual increase at latitudes 20 to 30°S, while decreasing at latitudes 35 to 45°S for the period 1960-1992 (Aceituno *et al.*, 1993; Jones *et al.,* 1994; Rosenblüth *et al.*, 2007). This aspect was in the scope of Carrasco's *et al.* (2005) research for central Chilean Andes, concluding that since 1975 the 0°C isotherm has risen by ±120metres in winter and by ±200 metres in summer. Despite of the alarming increase of past temperatures, it is far more concerning the rate at which it is expected to happen during the second half of the 21st century. Using IPCC's moderate and severe scenarios, the *Department of Geophysics* (DGF) at *Universidad de Chile* predicts a temperature rise of 1-3 and 2-4°C respectively in northern and central parts of Chile, whereas in high altitude areas it is expected to increase by up to 5 °C at the end of this century.

Additionally, there is little evidence in Chile's historical rainfall variations. The latest and most influential piece of research is the *Atlas of Arid and Semi-arid regions* (Santibáñez *et al.*, 2014), showing a greater rainfall decrease in coastal areas of central and north Chile, i.e. Ovalle city. Moreover, Rusticucci and Penalba (2001) point out that other southerner weather stations, i.e. Valdivia, have also recorded a precipitation decline, principally in winter, in the period 1901-1990. In fact, the DGF in 2006 forecasted rainfall changes in Chile, estimating a notable decrease in the Pacific coast, particularly at mid-latitudes, during summer and winter. Nonetheless, changes are expected to be more acute in IPCC's severe scenario for summer, with a rainfall reduction of half or even one-quarter of current levels for south-central parts of Chile.

Recently, temperature and rainfall trends are more and more studied as 80% of South American glaciers lie on the Chilean side, while its volume is dramatically decreasing (IPCC, 2007). Furthermore, scientists have indicate that the state of mountain sub/tropical glaciers is an important indicator of global warming as its impacts refer to glacier-based water resources and systems dependent on them (Rivera *et al.*, 2007; Coudrain *et al.*, 2009; Thompson *et al.,* 2011). In this line, Rivera *et al.* (2007) state that glacier water loss in central Andes is the immediate response to atmospheric warming and precipitation reduction. They have estimated a total volume loss of glaciers due to thinning and retreat of approximately 17km^3 of water equivalent for the period 1945-1996.

In respects to climate anomalies, they are often associated with ENSO events, being considered as the principal reason for water resource fluctuations along the country. During La Niña, severe widespread droughts can affect central and north parts of Chile being glaciers the main source of water. For instance, during the 1960's drought glaciers generated up to 67% of the water (Peña and Nazarela, 1987). In the last decades, several El Niño events have shown a direct impact on water run-off, with a moderate rainfall increase in central and northern regions, hence having a positive impact on glacier mass balances (Escobar *et al.,* 1995; Rivera *et al.*, 2000; Masiokas *et al.*, 2006). Moreover, the IPCC estimates that under continuous greenhouse gas (GHG) emissions, both El Niño and La Niña will tend to intensify (IPCC, 2013). Other hydrological models

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predict significant decays in water storages, limiting its availability in agriculture, mining and human consumption (Coudrain *et al.,* 2009). As acknowledge by Bown *et al.* (2008), water scarcity will sooner or later create conflicts in densely populated areas of the country. As a result, adapting the different socioeconomic systems to forthcoming extreme events is seen as an urgent need.

Farmer's perceptions on climate change

Until the present there has not been a relevant piece of research that explicitly focuses on the ways Chilean farmers perceive CC. These scientific gaps are even greater when comparing meteorological data and farmer's perceptions. Both qualitative and quantitative research methods have not been simultaneously studied, indicating that existing CC threats might not be thoroughly understood. Consequently, scientific research must come along with further research on farmer's perceptions and meteorological evidence.

In addition, most of the plausible knowledge, worldwide, examining farmer's perceptions and their adaptation to CC is merely focused in Africa. For instance, Thomas' *et al.* (2007) insights on *Farmers' responses to intra-seasonal precipitation trends in South Afric*a; Sleger's (2008) research on *Farmers' perceptions on rainfall and drought in semi-arid areas of Tanzania*; Mertz *et al.* (2009) investigations on *Farmers' Perceptions of Climate Change and Agricultural Adaptation Strategies in Rural Sahel*, among many others. The previous authors determine that farmers are aware of climate variability, unanimously identifying different climatic phenomena responsible of yield reduction. Moreover, Simelton's *et al.* (2013) work entitled *Is Rainfall really changing? Farmers' perceptions, meteorological data and policy implications*, uses qualitative and quantitative approaches to identify harmony between observed and recorded data. Other studies determining farmer's choice on CC adaptation strategies is Deressa's *et al.* (2009) in the Nile Basin of Ethiopia, while Hassan's and Nhemachena's (2008) focus on Africa's most arid areas.

Outside the African continent other relevant studies can be found in Europe, South America and Asia. For instance, Otto-Banaszak *et al.* (2011) investigate extreme weather events as well as forms of adaptation in those European countries at higher exposure. They use interviews to examine experts' perceptions in non-governmental/administrative organizations as well as in the private sector. Moreover, in South America Seo's and Mendelsohn's (2008) examine crop choice and farmer's adaptation to CC, concluding that global warming will push farmers to different type of crops. Other studies using both qualitative and quantitative methods are Vedwan and Rhoades (2001), they compare farmer's perceptions on CC with rainfall and snowfall records for the western Indian Himalayan's. Despite of the previous efforts, Maddison's (2007) work, conducted on behalf the World Bank in 11 African countries, is consider the most important piece of research. In his work, entitled *The Perception of an Adaptation to Climate Change in Africa,* Maddison discusses the problems that farmers face when selecting the most optimal adaptation strategies for their crops, often lacking of agro-climatological knowledge that experts might have. Finally, Roncoli (2006) identifies a set of participatory approaches that are useful to better understand the reasons that shape farmers perceptions about climate.

To conclude with this section two aspects deserve mentioning. The first one is the considerable amount of research produced in this topic since 2000. The second one is that the research is site-specific, being Africa the region that agglutinates most of the scientific attention.

Adapting agriculture to climate change in Chile

The article 4.8 of the UNFCCC has placed Chile among the countries at higher risk to prevailing changes in global climate patterns, hence extremely vulnerable to imminent climate fluctuations (UNFCCC, 1992). Climate is a powerful environmental constraint for human activities and among the human systems most likely to be affected, agriculture is often pointed out (Smitet *et al.*,

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1996). Moreover, the IPCC acknowledges that CC in Chile will reduce crop yield, increase salinization and desertification of agricultural land (IPCC, 2007). In accordance with the IPCC, Seo and Medelsohn (2007) estimate that South American farmers will loose on average 14% of their income by 2020, 20% by 2060 and 53% by 2100. Nonetheless, the most prone to temperature rise are small household farmers, whereas large scale farmers are more susceptible to rainfall increase (Seo and Mendelsohn, 2007).

Other general circulation models estimate that extreme weather events are expected to increase in frequency and intensity throughout this century (Easterling *et al.*, 2000; Frich *et al.*, 2002). Although human and environments are, to some extent, resilient to variability and extremes of CC, there is a critical threshold where the different social, natural and economic sectors will no longer cope with its impacts, thus having irreversible consequences (Füssel, 2007). Additionally, there is a growing need to implement adaptation strategies that elevate resilience amongst the most vulnerable socioeconomic groups, for example farmers. This has been reflected on the political discourse and currently, adaptation is seen as a complementary pathway to CC mitigation (IPCC, 2001).

In this manner, since the late 90's policy-makers have started to work along with scientists to identify the most vulnerable people and higher risk areas within the Chilean territory. As a result, in 1996 the *National Steering Committee on Global Change* was created, while in 1998 *Strategic Guidelines and Working Plan for Climate Change* was ratified (UNFCCC, 1999). In their reports the following recommendations for agricultural activities are often pointed out: crop replacement and re-allocation, changes in planting schedules, pest management systems as well as early warning systems. Finally, Chile's commitment with emission reduction became clear in 2002 when the Kyoto Protocol was signed, nonetheless does not yet have a legally binding emission reduction commitment (UNFCCC, 2014). Later on, in 2006, the National Climate Change Strategy was approved, identifying three main focal areas: adaptation, mitigation and capacity building. In the meantime, Chile must periodically elaborate *National Communication Inventories* in coordination with the DGF (NEC, 2010). So far Chile has prepared two inventories, 2000 and 2007, settling the basis for the NCCAP, identifying guidelines of action, institutions involved as well as adaptation strategies for the period 2008-2012 (NEC, 2010). In regards to agriculture, the following points are of interest:

– Generate climate scenarios at local level (2008-2010).
– Update available information concerning the vulnerability of the agricultural, livestock and forestry sectors (2009-2010).
– Formulate National Programs and Sectorial Plans to adapt to CC effects (2010-2012).

The preceding precautionary pathway demonstrates growing concern among policymakers to diminish vulnerability among certain groups, i.e. farmers. However, these are not reflected in the NCCAP where weaknesses are still evident. For instance, endogenous knowledge nor autonomous adaptation is not yet considered. Finally, the NCCAP merely focuses on mitigation strategies, while adaptation is left apart.

Area of study and methodology

This study has been carried out in central Chile between June-July 2014. It has been designed to better understand the ways farmers perceive CC in two climatologically contrasted regions. The Choapa valley, Coquimbo region, has a "BSk" climate, arid-steppe and cold, with mean annual temperatures lower than 18°C,while most of the precipitation, 70%, falls during winter months. On the contrary, the Maule basin has a "CSb" climate, temperate with dry and hot summers. Precipitation in the driest month is lower than 40mm, while temperatures during the hottest month are above 22°C.

In regards to the structure of this work, it is divided into three main parts: literature review, qualitati-

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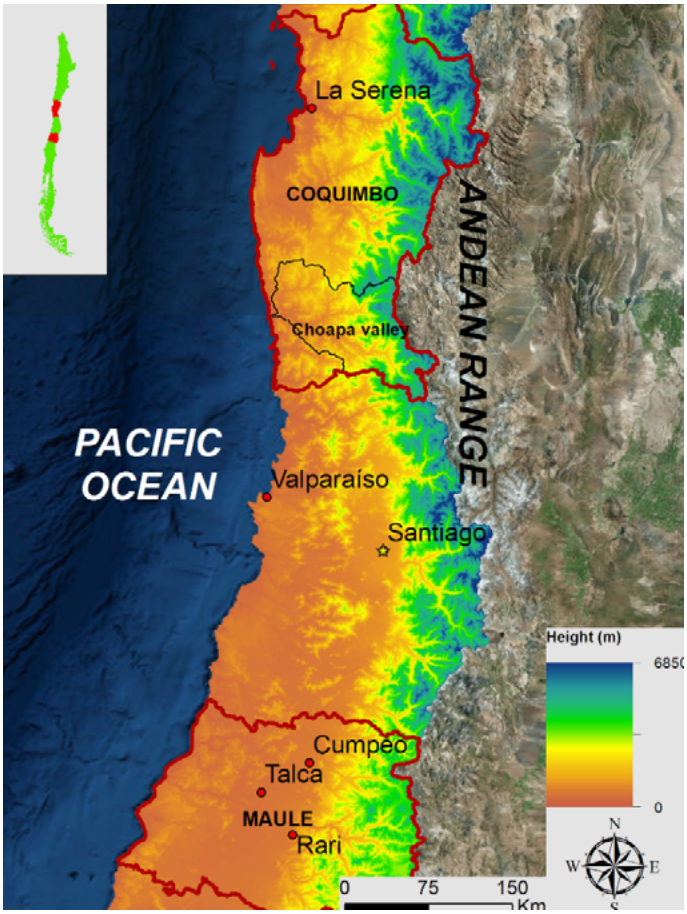

Figure 1. Area of study: Coquimbo and Maule regions

Uncompleted temporal data of some weather stations has been overcome using a correlation coefficient between two nearby observatories. If the value was greater than 0.7, estimating methods were used to complete years without data. Other weather indicators could have been used to better understand how climate is changing. For instance, maximum precipitation in 24 h, number of days with hail, frost, snow and hours of sunlight per year could have been taken into account. Moreover, an important known uncertainty is that weather stations could have been re-allocated, thus altering recorded values. This aspect is not mentioned on annual climatological inventories, hence could not be controlled.

Even though, surveys and interviews have been conducted in the researcher's mother tongue, some semantic barriers and Chilean idiom issues have emerged. Other communicating barriers concerning farmers' interpretations of questions need to be pointed out. Nonetheless, the previous have been overcome thanks to a tight interaction between messenger-respondent. In some circumstances respondents' behaviour and affection has been distant. To gain farmers' confidence the interviewer politely sympathises, while trying to rapidly engage the respondent with the survey, but was a minor issue. Other known uncertainties influencing the way in which questions have been answered are the emotional state, political view, socioeconomic, academic background and age of the respondent.

Research findings
Farmer's perceptions on climate change in Choapa and Maule

Each of the 63 surveys is divided into 28 questions, every including three sections: socioeconomic aspects, perceptions on extreme weather events, adaptation and vulnerability to CC. Finally, remarks regarding additional farmer's perceptions and researcher's observations has also been included.

Socioeconomic aspects

The majority of respondents, 59% are older than 50, only 9% are women, while illiteracy rates account for 13%. Some farmers acknowledge that *"the small farmer is disappearing, there are fewer young people. The government does not invest sufficient money to avoid migration from rural areas"*. In addition, farmer's education level is generally basic, with 63% of the respondents having completed primary studies (8 years of school attendance). In regards to the Choapa valley 51% of the farmers are landowners of small size crops, less than 5ha. On the contrary, in Maule basin 44% of the farmers work in large scale farms, greater than 10ha, and 61% are not land tenures. Food production in Choapa is based on

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fruit trees for exportation, while vegetables are for personal consumption. On the other hand, in Maule, crops are heterogeneous with fruit trees, cereals, vegetables and tobacco plantations. Finally, very few respondents work in vineyards and some are actively participating in government reforestation schemes.

Furthermore, 39% of respondents acknowledge that crop yield is smaller in the present, whereas 36% consider it greater. However, it crop yield changes is perceived differently between the two regions of study. For instance, in Maule region large scale crops use modern agronomic-techniques, such as drip irrigation systems, while farmers receive subsidies and bonds from the government. Moreover, changes in crop yield have been attributed to CC, 39% of respondents assert so; whereas the planting calendar has remained the same, except during ENSO events.

Perceptions on extreme weather events

Farmers unanimously perceive changes in rainfall season, being 84% those who consider so. Some farmer's in Choapa argue that: "*The normal rain is 160mm, in 2012 it rained 58mm, while in 2013 62mm*"; "*In June 2012 and May 2013 it rained twice, that's all!*"; "*Droughts have lasted for 7 years*" or "*Since 2003 it rains less*". Nevertheless, few discrepancies emerge between respondents, hence needing further attention. For instance, 13% of the farmers perceive actual rainfall season as longer than before, in fact most of these respondents are found in Maule. Finally, flash floods are predominantly affecting farmers in the Choapa valley, but only 7 out of 27 have reported economic impacts to their crops.

The following questions are focused on historic temperature changes. First of all, 65% affirm that winters are colder in the present, however opposed perceptions within the same region are observed. For example, in Maule, 21 out of 36 perceive colder winters, while 11 consider them warmer. In regards to summer temperatures, 90 % assert that summers are getting warmer, while none consider them colder. They often associate temperature rise with ENSO events. Moreover, in regards to the number of freezing days, more than half of the farmers perceive an increase in frequency, particularly in Maule.

Droughts and triggers for water scarcity have also been examined. For instance, 84% of the farmers perceive droughts longer in the present. Nevertheless, in Choapa valley farmers are more aware of drought intensity and frequency, acknowledging the following: "*This drought has lasted for 8 years*" or "*My dad told me that severe droughts hit the region in 1930, however I think that droughts are longer now*". Additionally, questions regarding water scarcity, admitted more than one answer, being as follows: 51% attributes water scarcity to CC, 18% to reforestation/deforestation processes, 12 % to agriculture, 10 % to population increase, 8% to mining (respondents for this answer are all found in Choapa, a traditional mining valley) and 1% to overgrazing. For instance, in Maule, farmers affirm that "*Reforestation with non-autochthonous and invasive species, such as eucalyptus and pine trees, are the main reasons for water scarcity*". Moreover, other weather events such as hail have been analysed. For instance, 68%of the farmers consider present hail storm less frequent and intense than before. Finally, the latter question analyses snow cover, being 62 % of the farmers those that opted for the "less snow" answer. In regards to the previous a farmer that used to work in a ski resort affirms the following "*It is evident that there is less snow in the region",* while others acknowledge "*We are highly dependent on rain and snow; if not, how are we supposed to water our land?"* as well as "*There are no longer permanent snows!!!*".

Perceptions on vulnerability and adaptation to climate change

In regards to farmer's vulnerability only 13 % see themselves very vulnerable to CC, 32% moderately, while 13% not vulnerable at all. In this case, farmers in Choapa affirm that "*Current drought has made them very vulnerable*" or "*I found myself more vulnerable to CC than before*". In addition, surveys also examine the degree of governmental response and if they are providing, or not, farmers with sufficient means to adapt to CC. In this

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line, 62 % consider that the government does not help them at all. This evidence is exemplified: "*Government helps us only when disasters happen*". However, differences are found between Choapa and Maule. For instance, in Choapa, 52% acknowledge to have receive governmental support, while in Maule this value drops to 28 %.

Moreover, among the farmers that recognize having received external support: subsidies-bonds, private funding, credits and stalk are often pointed out. Also, some remarks regarding governmental support deserve mentioning: "*INDAP (Institution for Livestock Development)gave me 200000 pesos(±300USD)to buy hay*"; "*INDAP gave me 63000 pesos (±90USD)to recover the walnut tree plantation from the drought"; "INDAP does not want to help us because we are not landowners*" or "*If you want to receive support from INDAP you must be a category "A" farmer*". In the latter question, farmers are asked if they need or not governmental support to adapt and increase their resilience to CC. In this case, 54 % affirm and 42 % denied so. Dichotomy in their responses are reflected on the following comments: "*How are we going to live without the help of the government?*" or "*I have always adapted to climate variability without governmental support*"

Climate change in coquimbo, Maule and metropolitan region

Historical rainfall trends

Statistical tools are used to analyse rainfall trends in three weather stations. Firstly, mean annual rainfall is 110 mm in La Serena, 1869-2010, 666 mm in Maule, 1920-2010, and 340mm in Santiago for the period 1901-2010. In addition, moving averages is a useful statistical technique which gives further information on how rainfall is behaving over time (refer to Figure 2 for baseline). The first moving average in La Serena is of 132mm,while the second average is of 90 mm, hence rainfall has decreased by 33 %. Moreover, in Curicó and Santiago first moving average is respectively 691 mm and 352 mm. In regards to the second moving average, the value drops down to 648mm in Santiago and to 329 mm in La Serena, therefore experiencing a 7 % reduction in both places.

Furthermore, a linear regression is calculated to better understand rainfall trends over time (refer to Figure 3). In all cases rainfall has decreased: in Curicó by 1.22 mm per year since 1920, in La Serena 0.63mm per year since 1869, while in Santiago 0.28mm per year since 1901. In addition, the standard deviation shows how dispersing the values are from the mean: in Curicó "σ" is of 228.5mm, followed by Santiago and La Serena with "σ" values of 153.8 mm and 76.7mm, respectively. Strong inter-annual variation is observed in minimum and maximum rainfalls. For instance, La Serena has recorded 4.3 mm in 1979,while in 1886as much as 411.6 mm. Extreme values are also observed in Curicó with 111.5 mm in 1924 and up to 1250 mm in 1926, whereas in Santiago 59.3 mm were recorded in 1968 and on the contrary 760mm in 1926.

Weather station	Mean	Standard deviation (σ)	1st moving average	2nd moving average	Regression line
Santiago	340	153.8	352 (1901-1955)	329 (1956-2010)	y = -0.28x +364.5
La Serena	110	76.7	132 (1869-1939)	90 (1940-2010)	y = -0.63x +154.7
Curicó	666	228.5	691 (1920-1965)	648 (1966-2010)	y = -1.22x + 783.4

Figure 2. Rainfall trends (in mm) in Santiago (1901-2010), La Serena (1869-2010) and Curicó (1920-2010)
Source: modified from data provided by *Dirección Meteorológica de Chile*

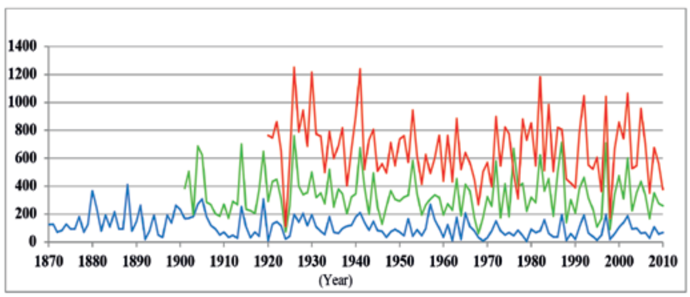

Figure 3. Rainfall (in mm) trends in Santiago (green), La Serena (blue) and Curicó (red), (mm)
Source: modified from data provided by *Dirección Meteorológica de Chile*

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Additionally, the Standardised Precipitation Index (SPI) and drought classes formulated by Mckee *et al.* (1995) and Agnew (2000) are interesting indexes for evaluating the severity of droughts. The SPI thresholds are: extreme (less than -2.0), severe (-2.0 to -1.5), moderate (-1.5 to -1.0) and mild drought(-1.0 to 0.0). For instance, in Curicó, extreme SPI values have been of -2.29 as well as -2.13,respectively in 1924 and 1998. Furthermore, historical studies of SPI values reflect an increase in frequency and intensity of the number of years with precipitation lower than the mean. Clear evidences are seen in La Serena, where the percentage of years with SPI values lower than -1.0, moderate drought, has augmented by 7 % between the periods 1869-1939 and 1940-2010. Far more concerning are the values for Santiago. In this case, the percentage of years with SPI values lower than -1.0 has increased by 18 % between the periods 1901-1955 and 1956-2010. At last, rainfall time series permit to identify the most severe ENSO events within the area of study, among which the 1978-79, 1986-87 and 1997-98ENSO events deserve mentioning. Time series calculations show that ENSO events are more frequent, however a priori these results do not show greater intensity.

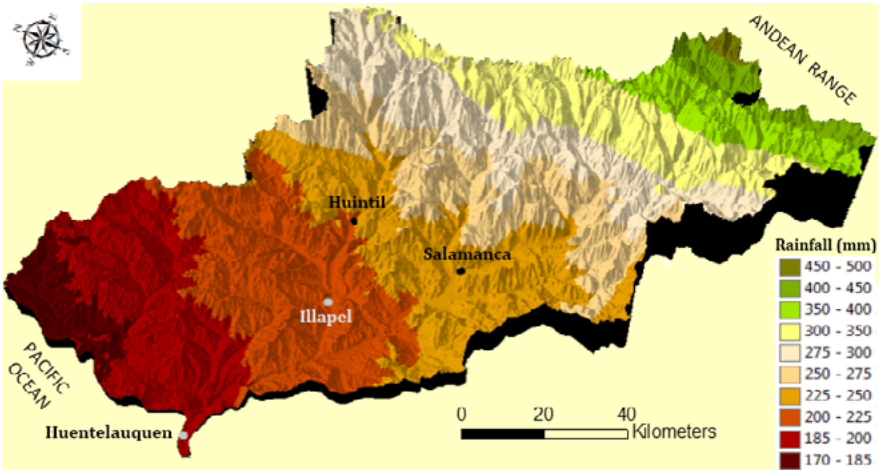

Figure 4. Mean annual rainfall (in mm), Choapa valley

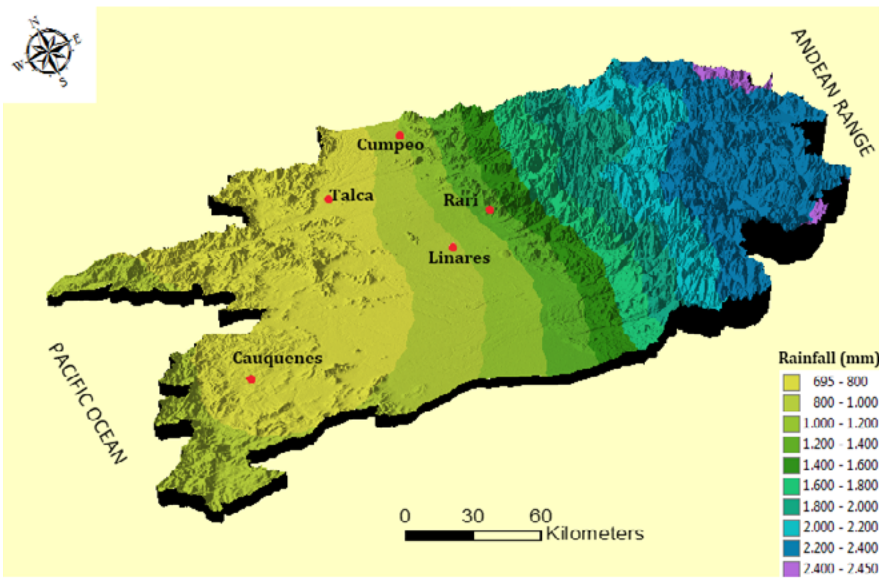

Figure 5. Mean annual rainfall (in mm), Maule basin

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Historical temperature trends

Temperature trends are analysed using the same statistical tools as for rainfall. Before doing so, general physiographic conditions within the area of interest deserve mentioning. The most important one is the Pacific Ocean acting as a thermic regulator, thus reducing the amplitude between mean maximum/minimum temperatures, for example in La Serena compared to Curicó and Santiago (refer to Figure 7). In addition, historical changes in mean maximum/minimum temperatures are also observed using moving averages. In regards to La Serena, mean minimum temperatures have augmented from 7.9 to 8.5 ºC between the periods 1922-1966 and 1967-2010. Same pattern can be observed in Santiago and Curicó for the two periods of study, with a respective increase of 0.5°C and of 0.4°C (refer to Figure 6 for baseline). Finally, if results between the three different weather stations are compared, it can be concluded that mean minimum temperatures are experiencing a greater increase as we move towards the north.

Furthermore, it is interesting to highlight that the behaviour of mean maximum temperatures is different to that of the minimum. For instance, mean maximum temperatures in La Serena and Curicó have experienced a decrease of 0.7 and 0.5°C, respectively between the two periods of study. On the contrary, in Santiago, mean maximum temperatures have increased by 0.4°C for the periods 1911-1960 and 1961-2010. Additionally, and due to the lack of climatological information, historical mean annual temperatures have only been calculated for Santiago. In this case, temperature inter-annual variability and its correlation with ENSO events is highly significant. Historical values show that during the 1997-98 ENSO events Santiago's mean temperatures rose from 14.5°C in 1996 up to 15.2 °C in 1997. Another aspect is the rising of mean temperatures by 0.3°C for the periods 1920-1965 and 1966-2010. Finally, Santiago's climatological database gives further information on absolute maximum/minimum annual temperatures. The most significant increase is observed in maximum absolute temperatures, with an increase of 0.65°C for the periods 1920-1965 and 1966-2010.

Weather station	Mean	Min/Max	1st moving average Min/Max	2nd moving average Min/Max	Linear regression Min/Max
Santiago	15.5	3.2 / 29.9	2.9 / 29.7 (1911-1960)	3.4 / 30.1 (1961-2010)	y = 0.011x + 2.6 / y = -0.008x +29.5
La Serena	14.5	8.2 / 22.2	7.9 / 22.6 (1922-1966)	8.5 / 21.9 (1967-2010)	y = 0.011x + 7.5 / y = -0.019x +23.3
Curicó	14.7	2.6 /30.2	2.4 / 30.4 (1926-1968)	2.8 / 29.9 (1969-2010)	y = 0.003x + 2.4 / y = -0.012x +30.9

Figure 6. Temperature trends (in ºC) in Santiago (1911-2010), La Serena (1922-2010) and Curicó (1926-2010)
Source: modified from data provided by *Dirección Meteorológica de Chile*

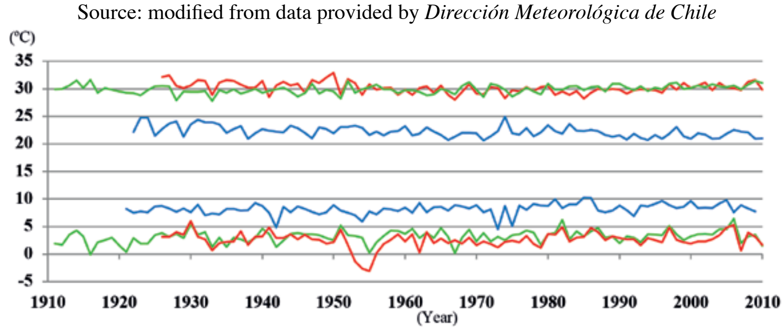

Figure7. Historical mean maximum and minimum temperatures (in ºC) in Santiago (green), La Serena (blue) and Curicó (red)
Source: modified from data provided by *Dirección Meteorológica de Chile*

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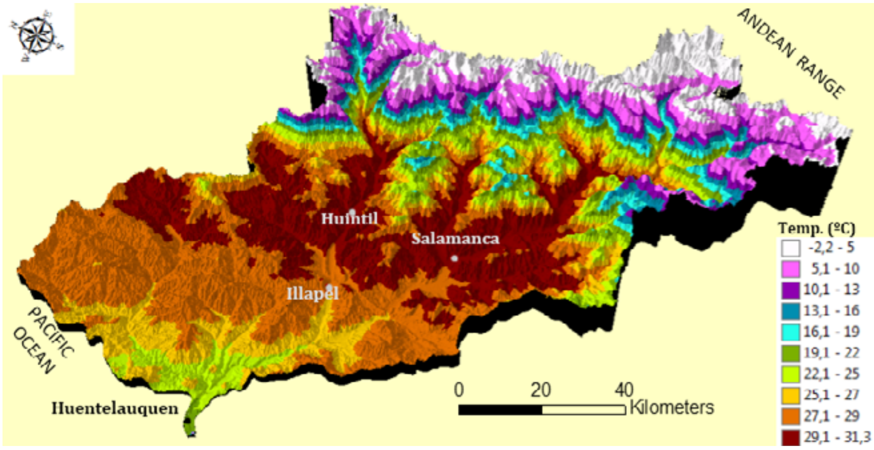

Figure 8. Mean January temperatures (in ºC), Choapa valley

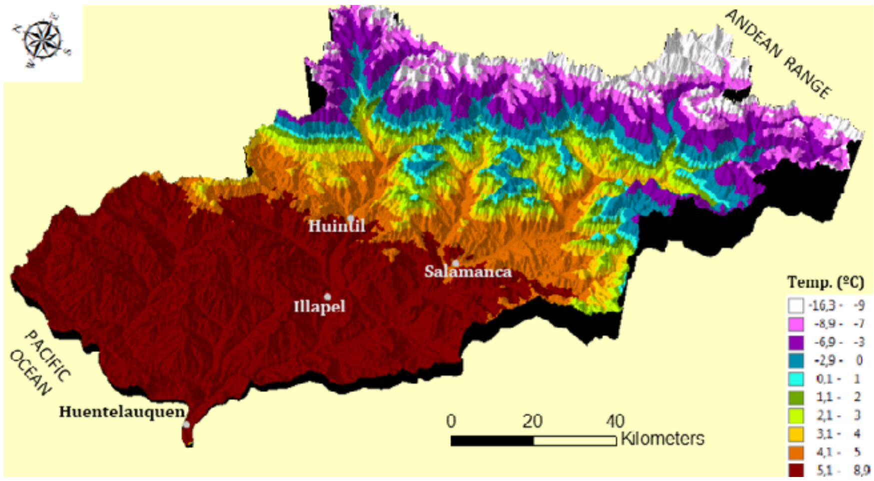

Figure 9. Mean July temperatures (in ºC), Choapa valley

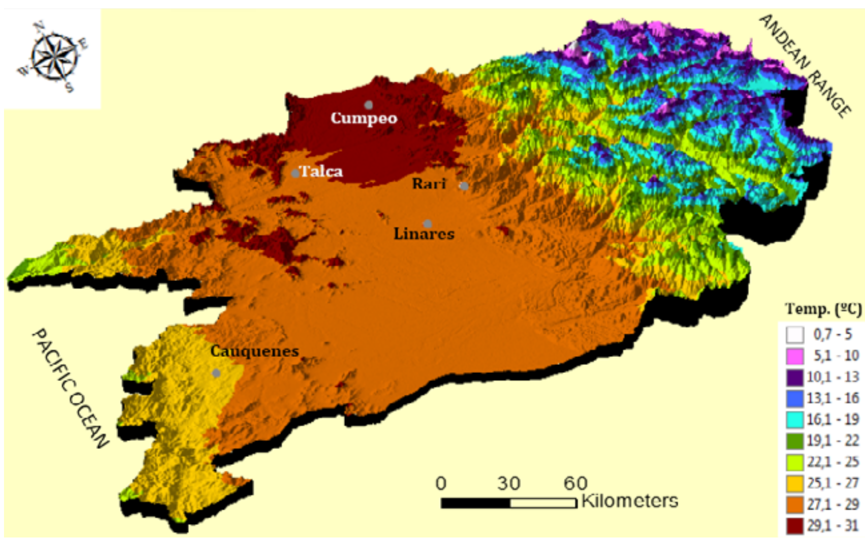

Figure 10. Mean January temperatures (in ºC), Maule basin

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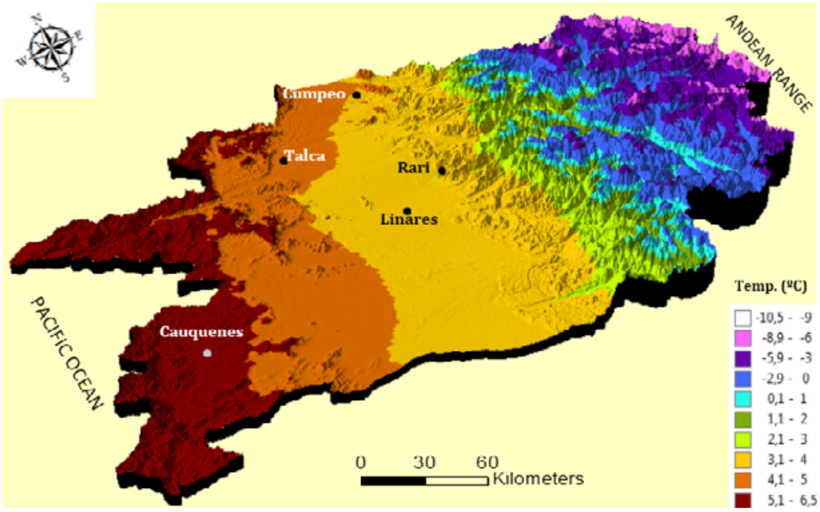

Figure 11. Mean July temperatures (in ºC), Maule basin

Social leader's perceptions on climate change

In this section, semi-structured interviews are used to address the following topics: extreme weather events, vulnerability and adaptation to CC in Chile. Firstly, all interviewee's are perceiving actual extreme weather events, such as droughts, as more severe than in the past. For instance, one respondent asserts that maximum/minimum absolute temperatures are nowadays more extreme. In addition, when asked to identify the moment when extreme weather events become more virulent, some argue that human perceptions are too short to critically evaluate a change, especially when young. Nevertheless, a respondent affirms that on the last five years weather has suddenly changed. Moreover, two respondents consider the overflow of river Mapocho, in 1982, as the most remarkable natural event of their life. Finally, the last question in the first section seeks to better understand the spatial impacts of CC throughout the Chilean territory. In this case, some respondents assert that in a 4500km stretched country is normal to have significant impact differences. Nevertheless, they consider that the most profound rainfall changes are occurring along the coastline from Coquimbo to Puerto Mont.

In the second section, respondents agree upon the fact that Chilean's are vulnerable and not prepared to CC impacts. In addition, they often point out differences between urban and rural areas, while the first one is far more resilient than the second one. All interviewee's assert the lack of awareness of Chilean's in respects to CC, hence making them more vulnerable. In this line, is far more concerning when the government is the one facilitating the development of residences in high prone areas. However, they acknowledge that recent environmental campaigns are slowly rising public awareness.

The third section focuses on CC adaptation. For instance, all respondents agree on government's responsibility on providing citizens with the right tools for effective adaptation, affirming that actions are only taking once the disaster has happened. Also, they blame the state for not generating sufficient opportunities to self-improve. Ultimately, interviewee's point out government efforts to implement preventive strategies, but not seeking to palliate exposure to natural hazards.

To conclude, the interviews evaluate social leaders' role on rising public awareness. In this case, while some do it through national-international conferences others actively participate in awareness campaigns and protests. At last, Cumpeo's water cooperative representative is responsible on rising concern on water use efficiency within the village.

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Discussion

Farmer's perceptions vs. Meteorological data

This research results show similarities and differences between the different approaches, qualitative and quantitative, hence deserve to be discussed. This part will also compare fieldwork results with social leaders' perceptions as well as plausible scientific knowledge within the area of study, Maule and Coquimbo's regions.

In regards to rainfall trends, Chilean farmers in Choapa and Maule basin unanimously agree on changes in the rainfall season, fact perfectly matching recorded data. In addition, Choapa's farmer report that current drought has lasted for more than 7 years. This observation is also reflected on nearby weather stations where rainfall has decreased by more than one third since 2003. Moreover, social leaders admit that coastal areas, especially those extending from Coquimbo to Puerto Montt, are the ones suffering from greatest rainfall decrease. In accordance to the previous, Haylock's *et al.* (2006) acknowledge that water deficits are greater at higher latitudes, 40 to 45°S. Nevertheless, different general atmospheric circulation models, HadGEM2 and HADCM3, generate different results, hence making it uncertain. In respect to the area of study, the *Atlas of Arid and Semi-arid regions* predicts a rainfall decrease of 20 % by 2050 in Illapel (Santibáñez *et al.*, 2014). On the contrary, the DGF elevates this value to 40 % for higher latitudes than 33 ºS (DGF, 2006).

Moreover, there is a general consensus on temperature trends among farmers and recorded values. For instance, the *Atlas of Arid and Semi-arid regions* has estimated an increase in the number of days with temperatures greater than 29 °C, fact reflected on the answer given by 89 % of survey respondents. In regards to mean maximum temperatures, Rosenblüth *et al.* (1997) discover a temperature cooling at mid-latitudes for the period 1950 to 1960. However, recorded mean maximum temperatures show a temperature rise in the last decades, reality corroborate by 92 % of the respondents in Maule. On the other side, minimum mean temperature trends show an increase overtime, nevertheless results show a decrease since 2007. As a result, farmers' responses are probably influenced by this anomaly, as 77 % of them affirm that minimum mean temperatures are nowadays colder. In this line, some interviewee's mention an increase in the number of frost days, being in accordance to that stated by 53 % of the farmers. Leaving apart sporadic anomalies, overall mean temperatures in Chile have increased by 2.8°C since the end of the 19^{th} century (Carrasco *et al.*, 2005).

Moreover, phenomena such as snow deserve to be discussed, as it is the consequence of low temperatures and precipitation. For example, 62 % of survey-respondents affirm that snow reserves in the Andes is depleting, resulting in water scarcity in low-lying areas. In this line, researchers have identified a rapid decrease of glaciers mass at latitudes 30 to 38°S (Cassassa, 1995; Rivera *et al.*, 2002). In addition, Rivera *et al.* (2002) estimate glacier loss, in central Chile for the period 1945-1996, to be of up to 13%. Others, Cadier *et al.* (2007), Rivera *et al.* (2007) and Vicuña *et al.* (2011), attribute glacier fluctuations to inter-annual variability of rainfalls occurring during ENSO events. Finally, researches have also indicated that combining factors, such as rainfall reduction and elevation of the 0 ºC, result in less snow cover while at the same time fostering glacier mass loss. As a result, farmers are indeed observing changes in snow cover, as the amount of available water for agriculture is depleting.

National climate change action-adaptation plan

Successful adaptation of agricultural activities to CC is now playing an important role at the international political discourse. For instance, the Conference of Parties (COP) has settled the guidance's and strategies for effective adaptation policies. Moreover, the Chilean government is now taking solid steps on defining CC mitigation strategies. Nevertheless, and despite the fact that the NCCAP establishes some adaptation ac-

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tion points, there is still room for improvement (Barton, 2009). Some of these strategies are unique, such as cloud seeding, seeking to increase rainfall by 15% in Coquimbo's region (El Observatodo, 2014). As a result, adaptation is seen as an effective strategy complementing mitigation, while increasing resilience amongst the most vulnerable groups.

In addition, the NCCAP continues to be somehow vague having several weaknesses. For example, the action period has expired, and since 2012 there has not been a monitoring nor evaluation report explicitly examining the progress of each of these action points. In fact, the plan does not mention interactions between state agencies nor farmers, thus the latter ones are not involved nor consulted for designing local adaptation strategies. What is more, leaving farmers out of the decision-making process will definitely trigger conflicts, while hampering the effective implementation of adaptation strategies. In this line, Chambers (1994) sees the participation of communities as fundamental to ensure social sustainability and durability of policies. Moreover, the NCCAP must bear in mind other successful plans such as the *Agricultural Meteorology Program*, conducted on behalf the WMO in western Africa. This program seeks to create capacity building through seminars making farmers more self-reliant and resilient to CC threats. Seminars are alternated with workshops where impacts of climate change in crops are estimated, while receiving feedback from experts on their day-to-day issues. As a result of WMO's innovative participatory, learning and action approaches adaptation policies tend to succeed, while engaging farmers in the decision-making process.

Leaving apart the weakest aspects of the NCCAP, other governmental efforts deserve mentioning. For instance, INDAP has begun to support farmers against CC impacts by promoting project finance schemes. In addition, the FNDR (Regional Development Fund) and PADIS (Programme supporting Small Farmers) are already building small reservoirs as well as drip irrigations systems in the Choapa valley. Another strategy was to provide farmers with fodder during long droughts, however as asserted by farmers temporary solutions palliate the problem but do not solve it. In such a way, an interviewee acknowledges that governmental support is often through contingency strategies instead of creating capacity building that increases resilience amongst the most vulnerable. Consequently, governmental support in Chile's most remote areas is clear, reason why farmers have decided to adapt using their own means. Some of the observed strategies are the following: introduction of resistant species, changing crops and moving to higher areas within the valleys.

Conclusion

This research project has provided sufficient background to acknowledge that CC is a fact, being reflected both on farmers' and social leaders' perceptions as well as on the meteorological recorded data. In addition, rainfall is definitely the weather event that is changing the most within the area of study, while already constraining crop production. In regards to temperature rise, its immediate effect on glacier retreat is already threatening water resources; especially in central Chile, the most densely populated region of the country. Finally, historical weather observation shows that ENSO events are becoming more frequent, while rainfall inter-annual fluctuations are now greater. Overall farmers are certainly perceiving these changes, and can provide policy-makers with useful information on site-specific weather related issues.

Additionally, from emerging results it can be concluded that farming activities within the area of study are highly exposed and vulnerable to climate threats, in particular the Choapa valley. Consequently, pressure among policymakers is undoubtedly greater, being the most responsible for increasing farmer's resilience. Moreover, current NCCAP policy top-bottom approach reveals some weaknesses, needing to work firmly on a policy framework that tackles growing climatic threats. As long as it does not do so, farmers will continue to be neglected with scarce tools to undertake appropriate CC adap-

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tation. Hence, there is a need to complementary work on creating capacity building, as well as on including farmers on the design of new CC adaptation policies.

Policy recommendations

A set of advices are given to efficiently and effectively implement adaptation strategies, while reducing social oblivion and stigmatization of rural life, often neglected during policy formulation. Some recommendations for policymakers are the following:

- Farmer's perceptions need to be used as a complementary source of meteorological information, while helping scientists and policymakers on the understanding of changes in local climate.
- Participatory methods are advantageous, while being necessary to further know about farmer's vulnerability, perceptions on extreme weather events and self-adaptation to CC.
- Engaging farming communities on CC adaptation through workshops and seminars will definitely ameliorate the designing and implementation of policies as well as ensuring its temporal sustainability.
- Considering that the baseline information is reliable, NCCAP strategies need to be internally and externally evaluated. To do so, specific outcomes need to be defined including milestones, activities and indicators. Periodical monitoring and evaluation process will trace the quality of the program at both administrative and field levels.

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