Resilience to climate change in Patagonia, Argentina:

Evidence of impact and prospects for adaptation in natural resource sectors

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Table of contents

Executive summary

This study aims to broaden understanding of climate change and its impacts within Argentina – looking at evidence of existing change and future projections, with practical examples of existing or potential adaptation. Much focus on climate change in Argentina has been in the North, where impacts are more noticeable. But this study shows how changes in the South, in the Patagonian province of Chubut, are also likely to be significant.

Increasing temperature and decreasing rainfall in Northwest Chubut are shifting the patterns of agricultural viability. Predominant patterns of cattle and sheep farming are likely to face increasing shortages of dry season grazing. Natural forests and existing and planned plantations are also likely to face increasing aridity – exacerbating the risk of dieback, forest fires and pest and disease outbreaks. Water shortage is likely to become an increasingly pressing concern – especially with the heavy reliance on hydropower, major development plans for irrigated agriculture and forestry, heavy technological demands from the petrochemical industry for water pressure to drive oil extraction, and the importance of aquatic environments for regional tourism.

Adaptation to climate change in Chubut province is already occurring – overseen primarily by state institutions governing agriculture, forestland, energy production and tourism. But adaptation so far has been rather disjointed and ad hoc. Livestock farmers of their own volition have been reducing stocking densities in the wake of recent drought events. Forestry agencies have implemented new protocols to monitor fire and pest and disease outbreaks. Forest plantations have been established mostly to improve or diversify livelihoods – but in some cases also to mitigate climate change itself.

A more coordinated approach may be necessary in which the climatic risk of different forms of agriculture and forestry are specifically addressed. Land use planning needs better to take into account the environmental thresholds of different types of agriculture or forestland use – with incentives that induce greater diversity and consequent resilience. More emphasis is also needed on insurance against different types of climate related emergency in agriculture and forestry. The management of water is one area in which an integrated approach is urgently needed. Increasing demands on the resource from a range of sectors may result in conflict unless joint decision making procedures are introduced.

The study concludes by noting that while climate change in the South of Argentina has had less severe impacts to date – this should not be grounds for complacency. Rather it should be seen as an opportunity to plan for the future and build institutional capacity and policy coherence that better protects the population from inevitable climate change.

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Acronyms

AACLA	Asociación de Apicultores de la Comarca Los Alerces
ALAPA	Asociación Los Andes Productores Agropecuarios
APLA	Asociación Productores Los Alerces
APN	Administración de Parques Nacionales
CIEFAP	Centro de Investigación y Extensión Forestal Andino Patagonico
CNPV	Censo Nacional de Población, Hogares y Viviendas
CNE	Censo Nacional Económico
CREs	Certified Emission Reductions Credits
DCC	Dirección de Cambio Climático (Secretaría de Ambiente y Desarrollo Sustantable)
DGAyG	Dirección General de Agricultura y Ganadería de Chubut
DGARH	Dirección General de Administración de Recursos Hídricos
DGByP	Dirección General de Bosques y Parques del Chubut
DGEyC	Dirección General de Estadísticas y Censos de Chubut
EIAs	Environment Impact Assessments
FTDT	Fundación Torcuato Di Tella
HF	Hidroeléctrica Futaleufú
IAC	Instituto Autárquico de Colonización y Fomento Rural, Chubut
INTA	Instituto Nacional de Tecnología Agropecuaria
INTA EEA Esquel	Instituto Nacional de Tecnología Agropecuaria - Estación Experimental Agroforestal Esquel
ITDT	Instituto Torcuato Di Tella
IPCC	Intergovernmental Panel on Climate change
JPF	Japan Carbon Finance Foundation
MAyCDS	Ministerio de Ambiente y Control del Desarrollo Sustenatable, Chubut
PNMF	Plan Nacional de Manejo del Fuego (Secretaría de Ambiente y Desarrollo Sustantable)
PSA	Programa Social Agropecuario
SAGPyA	Secretaría de Agricultura, Ganadería, Pesca y Alimentos, Argentina
SAyDS	Secretaría de Ambiente y Desarrollo Sustantable
SCPL	Sociedad Cooperativa Popular Limitada (Comodoro Rivadavia – Chubut)
SEP	Sistema Estadístico Provincial – Chubut
SISCOM	Sistema de Información de Comunas y Municipios
SMN	Servicio Metereológico Nacional
SER	Sociedad Rural Esquel
UMSEF	Unidad de Manejo del Sistema de Evaluación Forestal Secretaría de Ambiente y Desarrollo Sustantable)

1. Introduction

Climate change is already affecting many natural systems around the world. Increases in temperature, changes in precipitation patterns, more frequent extreme events such as floods and droughts are well-documented examples (IPCC, 2007). In Latin America a mean warming to the end of the century is expected of 1 to 6ºC (depending on the model considered). This will almost certainly lead to an increase in species extinctions, a rise in the numbers of people experiencing problems with water supply and a decrease of yields for very important crops (Magrin et al., 2007). Argentina is not exempt from these changes. Unusual extreme whether events and changes in natural systems have already been reported, especially in the North of the country. For instance, there is a clear evidence of changes in the precipitation pattern in the Central North area of the country. Together with improvements in technology, this has led to a displacement of agriculture land towards the West (Barros and Bejarán, 2005). This agricultural expansion has been the main cause of large scale deforestation processes (1,975,136 ha has been converted between 1998-2006; UMSEF, 2007). The aim of this report is to have a look at the local situation in the southern part of the country in order to see whether climate change is as important an issue as in the North. The role that local institutions are playing in this context is also taken into account.

Argentina has signed the Climate Change Convention in 1992 (ratified by 1994) and the Kyoto protocol in 1998 (ratified by 2001). At national level, the Climate Change Office (DCC) has been created under the Secretary for Environment and Sustainable Development (SAyDS). By October 8th Argentina had presented its 2nd National Communication.

Patagonia is located in the Southern part of Argentina and it represents approximately one third of the country's continental surface. It includes five provinces (Neuquén, Río Negro, Chubut, Santa Cruz and Tierra del Fuego), with a total population of 1,750,000 inhabitants over its 900,000 km^2. With an average of 2,2 inhabitants per square kilometre, most of whom are in urban settlements (93%, FTDT and ITDT, 2006) – population is sparse. Climate change has been influencing the area in recent decades, but interviews found little in-depth understanding within the general population of those effects.

In Patagonia, three different kinds of ecological region are found: the Patagonian Steppe, the Monte and the sub-Antarctic Forest. The Andes Mountains in the West and the Patagonian Steppe in the East delimit the borders of the temperate forest area. It is 2,200 km long and a maximum of 75 km in width. Sub-Antarctic forest is defined by climatic conditions (temperature and precipitation patterns) in combination with soil characteristics. The most representative species in terms of cover are the *Nothofagus*. There are also species of conifers in the region; the four most representative ones are endemic of Argentina and Chile. They are pehúen (*Araucaria araucana*), ciprés de la cordillera (*Austrocedrus chilensis*), ciprés de las guaitecas (*Pilgerodendrum uviferum*), and lahúan or alerce (*Fitzroya cupressoides*), which can live until 3,000 years reaching up to 50 m of height. *A. araucana*, *P. uviferum* and *F. cupressoides* are protected under CITES convention (SAyDS, 2003).

Photo 1. Natural Sub-Antarctic Forest in Patagonia

The present case study is focused on the Central Northwest part of Patagonia, specifically within the sub-Antarctic Forest and the potential forestland[1] of Chubut Province (Figure 1, Annex I). It is located between latitudes 42º - 46º South and longitudes 70º 54' – 72º 10' West, with a total land area of 23,700 Km^2 (Table 1). The altitude in Esquel Airport is 797 masl. In Chubut, a natural sub-Antarctic forest species known as lenga (*Notofagus pumilio*) covers most of the higher altitude watersheds and is the most important species in terms of forest management. At middle altitudes natural forests include *N. dombeyi* and *A. chilensis*, and finally foothills and valleys are occupied by *N. antarctica*. Towards East dry steppe grassland is the main landscape component (Figure 2, and see Annex I).

[1] It is land suitable for establishment of (mainly) pine plantations.

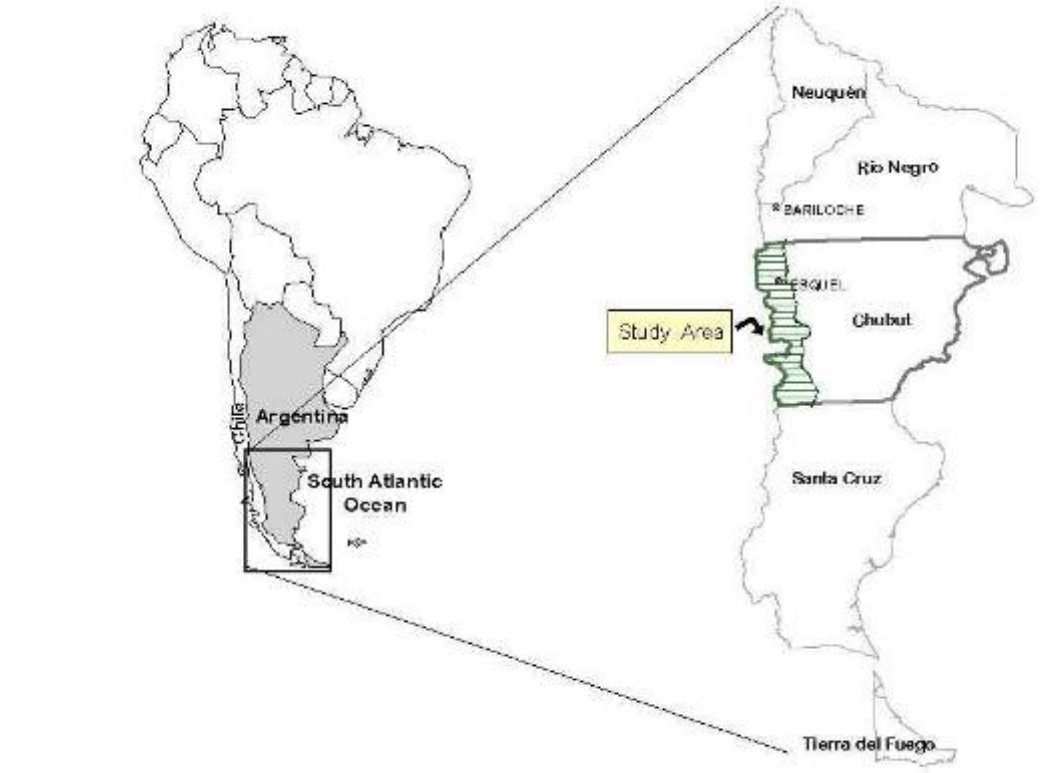


Figure 1. General location of the study area. In zoom it is showed Patagonia.

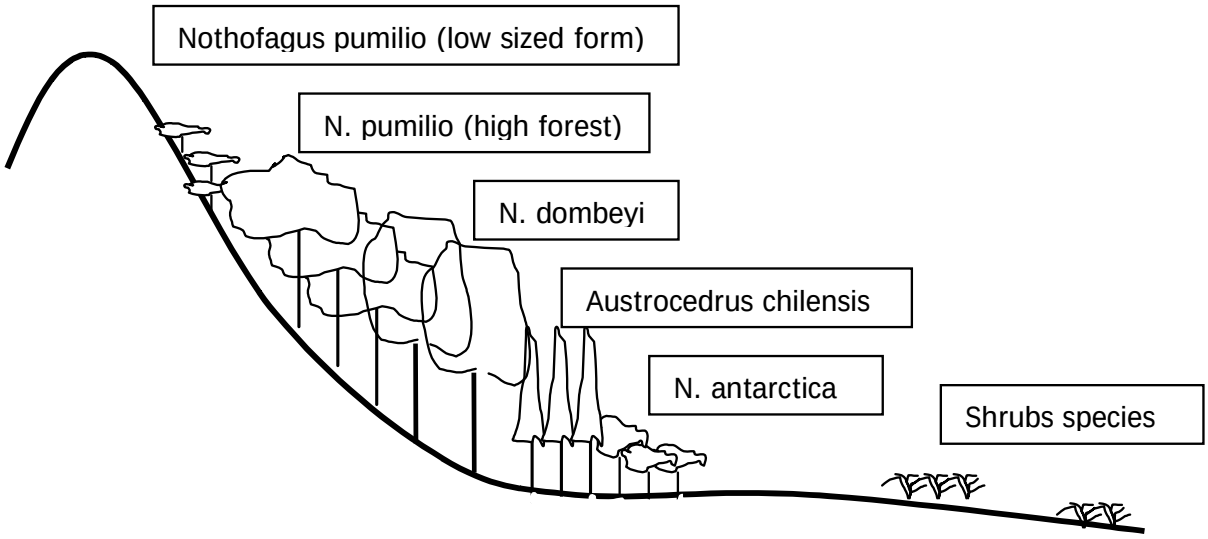


Figure 2. Schematic diagram showing the main vegetation types in a West-East transect.

Table 1. Natural and exotic forest covers in the study area by jurisdiction. In addition the available land suitable for afforestation projects is presented.

Kind of cover	Area (ha)	Source of data
Native Forests (under provincial jurisdiction)	726,000	DGByP, 2007a
Native Forests (under national jurisdiction)	155,453	SAyDS, 2005
Forest Plantations	24,000	DGByP, 2007a
Land available for afforestation	311,000	
Land available for afforestation with irrigation requirements (this could imply an area larger than the study case)	400,000	

1.1 Climate in Western Chubut Province

The Andes Mountains have a key role in determining the climate of the area by forming a barrier to the wet winds (westerlies) coming from the Pacific Ocean. Most of the rainfall is discharged in the Chilean side of the mountains, and then a dryer mass of air flows to the Argentinean regions. This pattern leads to a strong West-East gradient in the precipitation pattern (Paruelo et al., 1998), where over the Andes Mountains the rainfall reaches more than 1,000 millimetres annually (up to 3000 in some places) and just 100 km away to the East it can be 200 mm (Barros et al., 1980). Figure 2 illustrates differences between meteorological stations set only 50km apart from West to East.

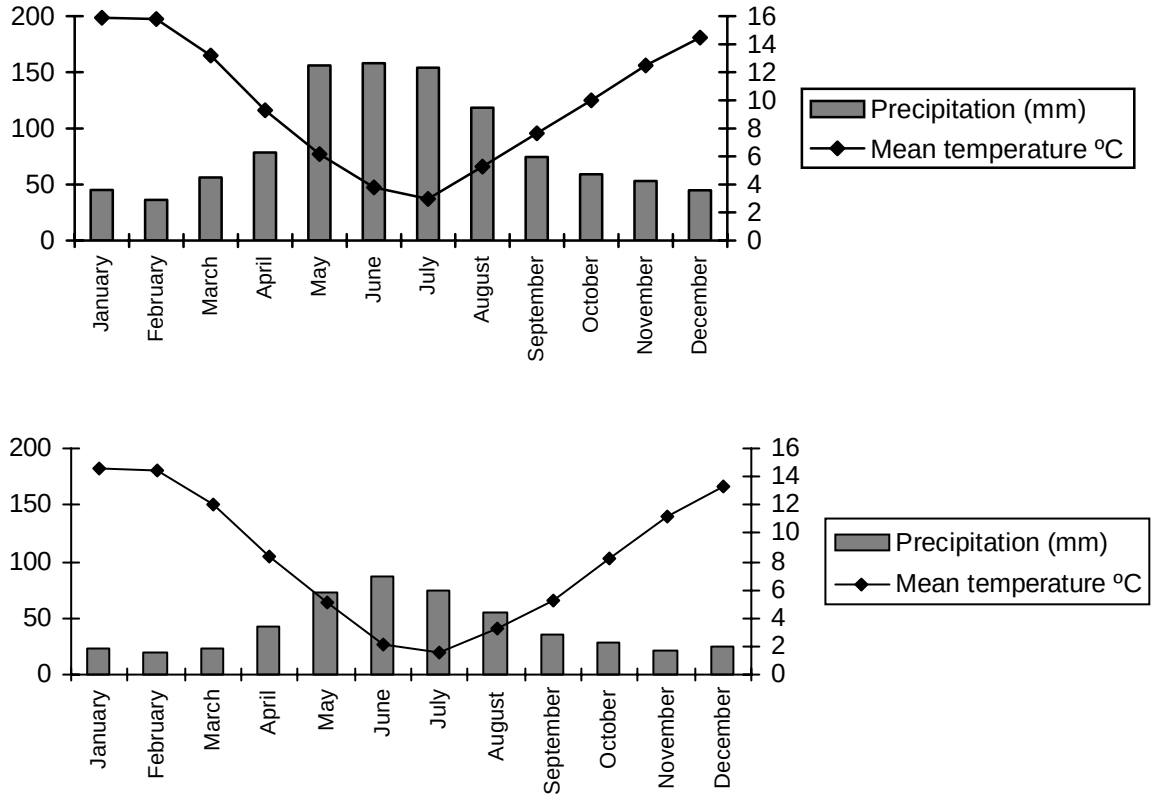


Figure 3. Climatograms for two different stations in the area. Top is Aldea Escolar and bottom is Esquel, which is located approximately 50 km towards the East. (Bars equal precipitation and line equals temperature). Aldea Escolar showed medium temperature of 9.7 ºC and a mean of 1018 mm per year from 1980-2006 (Source of data: Campo Experimental Trevelin, INTA EEA Esquel, 2007). Esquel showed medium temperature of 8.3 ºC and a mean of 508 mm per year throughout the period 1961-2006 (Source of data: SMN, 2007b). This comparison shows the characteristic strong gradient in the precipitation patterns.

Precipitation events are concentrated in winter and autumn (73% of the total rainfalls, Jobbágy et al., 1995), causing a significant water deficit in summer (see Figure 3). With regard to temperature, the area can be defined as a cool temperate region (Paruelo et al., 1998), with mean temperatures from 8 up to 10 ºC (SMN, 2007a, Table 2). The predominant westerlies affecting the area throughout the year have a chill factor, causing an average decrease of 4,2 ºC in the temperature perceived (Paruelo et al., 1998).

Table 2. Extremes temperatures (by season) observed at Esquel's meteorological station (period 1961-1990). Source of data: SMN[2], 2007c.

Temperatures	Summer	Autumn	Winter	Spring
Maximum (ºC)	33,8	31,3	21,2	29,9
Minimum (ºC)	-5,4	-12,5	-22,1	-14,8

1.2 Natural resource use in the study area

Livestock is the most important local land use. Grass production for cattle feed is the main crop. Some vegetables are cultivated within the North area (mainly for local consumption) as well as fruit crops, especially cherry and berries (such as blackberry and strawberry). Cattle farming dominates the areas with better grasses and water availability; sheep are used for meat and wool production in drier areas not at all suitable for cattle. A common practise is to graze the cattle/sheep inside the forest; this extensive livestock farming has been practiced over the last 120 years. There are two main seasons: cattle are transported to warmer valleys during winter and to the forest for grazing in summer. In some cases, agroforestry systems have been established to augment summer grazing. Those are mainly located in areas with *N. antarctica* natural forests, where forests are used for firewood and rural timber products as well as for livestock protection and grazing.

[2] Available at: http://www.smn.gov.ar/?mod=clima&id=30&provincia=Chubut&ciudad=Esquel

Photo 2. Livestock grazing in natural forests during the summer

Natural forests are also an important source of wood for local sawmills (which usually work at small size scales) and firewood as well as other products for rural communities. Firewood is the main product in terms of volume produced per year, followed by logs for use in sawmills (Figure 4). Firewood is mainly used for heating and cooking in rural areas. However a decrease in this consumption is expected because of the recent investments on the natural gas network, which is being expanded to rural areas.

Photo 3. Wood processed by local sawmills

In drier lands without natural forests, afforestation has been promoted[3]. Ponderosa pine (*Pinus ponderosa*) is the main species planted. The climatic limit of these plantations is given by the isohyet of 400 annual millimetres. Poplars and willows have also been planted, primarily used for windbreaks as well as river's channel protection. The establishment of poplar plantations usually requires water supply through irrigation.

Ecosystem services such as the production of water for human consumption, recreation, irrigation, hydropower, and industrial use play a very important role in the region. All water sources for larger urban settlements (located on the Atlantic Ocean coast, 700 km eastward) come from these forested catchments. Irrigated agriculture and forest plantations are growing rapidly in downstream areas. For instance, in 2006 a new irrigation system was inaugurated in the "16 de Octubre" valley (where Trevelin town is based), it makes available 2,000 more ha for agriculture purposes. Energy for both local and distant urban settlements is predominantly based on hydropower (for example the Futaleufú Hydropower plant). New extraction technology in the petrochemical industry requires large volumes of water to pump out oil reserves (i.e. Repsol YPF company takes water directly from Senguerr River in South of the province –outside the study area).

Another important ecosystem service is landscape beauty, which is the main source of increasing tourism development in the region. Within some parts of the region tourism is a very important source of income. There are two National Parks in the area (Los Alerces NP

[3] In former times forest plantations also where done by replacing native forests. That policy is no longer applied in Chubut.

and Lago Puelo NP) that in addition of their importance for conservations goals are playing a key role attracting visitors to the region.

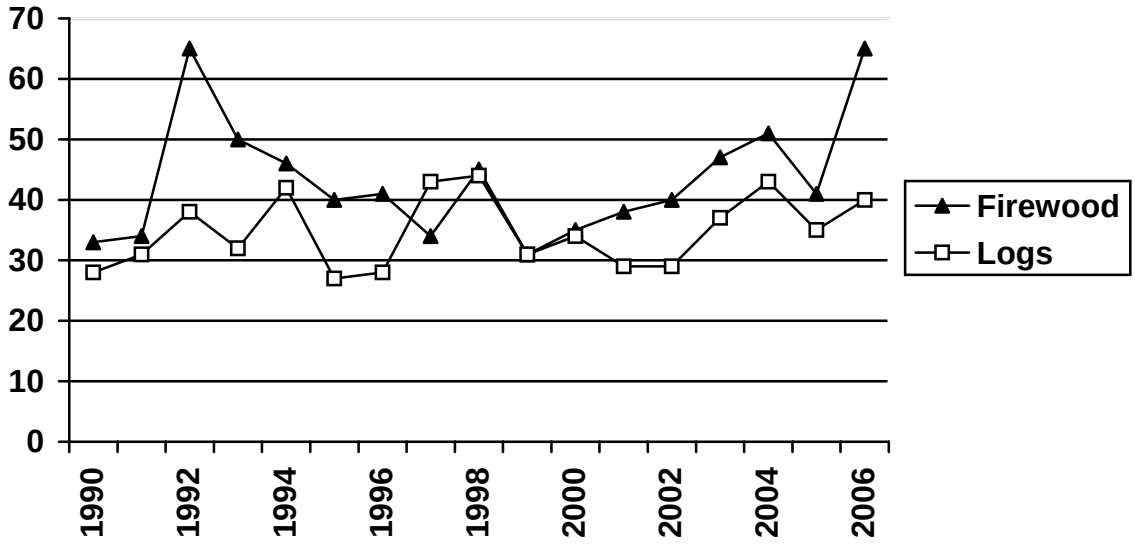


Figure 4. Trend in volume (thousands of m³) for Chubut's forest products for the period 1990-2006. Firewood has been converted to solid volume by applying a conversion factor of 0.6. Source of data: DGEyC, 2007.

1.3 The social context in Chubut Province

The origin of the current population of Chubut is derived from immigrants coming from within Argentina as well as from other countries. The Welsh colony established in 1865 on the seacoast was later expanded to the mountains, and has been a key factor in the region's development. In 2000, births occurring in Chubut accounted for 70% of the population's origin. Within this province, 89.5% of the population live in urban settlements. According to recent projections done by the Government, the total population in the study area is around 75,500 inhabitants[4]; where the main city is Esquel, followed by Trevelin and Lago Puelo (31,200; 7,000 and 5,250 inhabitants respectively). There are some dispersed populations in the region (5% of the total). The remaining population is distributed in several small towns (Table 3). Indigenous people make up 1.9% of the total inhabitants in the study area. However, this population represents 34.8% of the total indigenous people living in the province – most of whom now live in urban settlements (SEP, 2007).

In terms of the provincial economy, the gross geographic product (GGP) was ARS[5]11,807,540 by 2006 (26,207 ARS per inhabitant), this represents around 2% of the gross national production (GNP). Approximately 70% of the income is from commercial products, whereas 30% is from services. The most important sources of provincial income are petrol extraction (48% including mines) and manufacturing (9,03%). Agriculture, livestock, forestry, hunting and fishing all together represent 6,97% of the GGP (DGEyC, 2007c).

[4] It implies an area larger than the study area, because of the data aggregation in the census. Projections were done until June 2007, where the whole province reaches 455,600 inhabitants. Source of data: DGEyC, 2007b.
[5] 1 ARS (Argentina Pesos) equals to 0,247 EUR (Euro) by 31/12/06. Then the GGP in Chubut was € 2,916,462 in 2006.

Table 3. Poverty-related indicators for different settlements across the study area (from North to South). In education the codes mean: A: without; B: primary; C: secondary; D: university; E: illiteracy. In employment the codes mean: P: primary; S: secondary; T: tertiary. Primary includes agriculture, livestock, silviculture, hunting and fishing as well as mines (including petrol and natural gas extraction). Secondary includes manufacturing, electricity, natural gas, water and construction industries. Tertiary includes trade, restaurants and hotels, transport, storage, financial services, property businesses, community, social and personal services (including different governmental agencies).

Settlement (Source: CNPV, 2001; cited by SISCOM, 2007)	People below the poverty threshold (Source: SISCOM, 2007)	Access to drinking water (Source: CNPV, 2001; cited by SISCOM, 2007)	Education (Source: CNPV, 2001; cited by SISCOM, 2007)	Population without health cover (Source: CNPV, 2001; cited by SISCOM, 2007)	Source of employment by economic sector (urban assessment) (Source: CNE 2004/2005; cited by SISCOM, 2007)
Lago Puelo (4,046 inhabitants)	19,4%	96,4%	A: 19,27% B: 46,11% C: 22,96% D: 11,66% E: 2,61%	61,86%	P: 2,53% S: 3,86% T: 93,62%
Cholila (1,981 inhabitants)	34,67%	100%	A: 39,64% B: 44,92% C: 10,95% D: 4,49% E: 5,62%	66,63%	S: 2,46% T: 97,54%
Esquel (28,486 inhabitants)	25,71	99,2%	A: 21,09% B: 49,02% C: 21,60% D: 8,29% E: 3,74%	42,68%	P: 0,33% S: 10,80% T: 88,87%
Corcovado (1,644 inhabitants)	33,11%	100%	A: 44,59% B: 46,53% C: 5,82% D: 3,06% E: 7,44%	57%	P: 1,12% T: 98,88%
Río Pico (1,386 inhabitants)	28,44%	100%	A: 43,45% B: 45,32% C: 8,14% D: 3,08% E: 7,28%	65,30%	S: 9,21% T: 90,79%
Río Senguerr (1,700 inhabitants)	21,32%	100%	A: 37,12% B: 49,34% C: 9,59% D: 3,95% E: 7,24%	47,94%	No available data

1.4 Key natural resource institutions in the study area

Several key natural resource institutions are working in the area (Table 4). Their work is dominated by current priorities in the region, but each of them has some responsibility for likely areas of impact of climate change. Actions in line with other aims are likely to be increasingly affected by adaptation to climate change. For example, improving forest management practices (specially in the proximity of water bodies), and designing risk free forest plantations may require an increasing understanding of climate change. Farmers can find advice on forestry, livestock and agriculture within the range of local institutions – and such advice may also increasingly respond to climatic threats. Existing support institutions

are mainly governmental agencies and research institutions. In recent years, some projects have been developed related to CO_2 sequestration, but mainly with the aim of enticing forest investors to the area. At the moment, several forest restoration projects have been co-financed by funds coming from external investors.

Several conflicts related to forestland ownership have occurred since the province was created in 1955. In Chubut's first Constitution, the forest were declared as State property. Some years later some exceptions were acknowledged. Currently, four types of land rights can be found: national titles (they are properties conceded before the province was created); provincial titles (land ownership, but with forests belonging to the State); temporal tenure (with three different levels, the higher one is a previous step in order to obtain a title) and finally State ownership lands. The administration of the land belongs to the Land Colonization Commission (IAC) whereas the Forest Service (DGByP) governs forest management. This overlapping in terms of jurisdiction between two institutions (with their different aims, Table 4) has led to the generation of conflicts among forest companies and farmers. Such conflicts may grow if climate change affects the economic viability of different land uses.

Table 4. Main natural resources related institutions/organizations based in the area and short description of them.

Institution/Organization	Description
Agriculture and Livestock Office (DGAyG)	It is based in Rawson (Chubut's capital). Addressing the development of the agricultural and livestock sector of the province.
Andean Patagonian Forest Research and Extension Centre (CIEFAP)	It is a regional institution based in Esquel, working mainly in forestry related fields and spreading that knowledge in the area.
Forest Service (DGByP)	The main office is located in Esquel. It is in charge of protecting forest resources, defining and controlling management practices as well as promoting the generation of new forests through afforestation. Provincial protected areas belong to this institution. An advisory board (with key stakeholders involved) was created as model of conflict management in one of these protected areas.
Futaleufú Hydropower Plant (HF)	It is a private ownership company located within "Los Alerces" National Park (Southeast border). It deliveries energy to an aluminium factory based on the seacoast as well as several cities and towns in Chubut.
Land Colonization Commission (IAC)	It was created with the aim of promoting the land occupation through the Chubut's territory, and one of its attributions is the determination of the land ownership situation. Livestock has been central to its activities.
Ministry for the Environment (MAyCDS)	It is based in Rawson and addresses environment management towards sustainable practices. EIAs are used as a tool in the decision making process. Public consultancy is a key element of these EIAs.
National Institute for Agricultural Technology (INTA)	It is a national research and extension agency that has a close contact with local farmers, working in agriculture, livestock, agroforestry and forestry to improve management practices as well as extend techniques.
Nationals Parks Authority (APN)	It is the national authority in terms of nature conservation. In Chubut there are two National Parks (Annex I), those jurisdictions belong to the Nation. There are some old settlers in the area, that conserve the land rights but their activities are under strict Park rules.
Social Agricultural Programme (PSA)	It is a national programme that belongs to the Agriculture, Livestock, Fishing and Food Secretariat (SAGPyA). It has an office in Esquel, and works with small farmers promoting their organization. In this way PSA is looking to help small farmers to be able to better represent themselves in the future.
Rural Society of Esquel (Sociedad Rural Esquel)	It is one traditional entity in Argentina that has an important voice when talking about agriculture and livestock production. Its branch in the study area shows more importance in livestock production.
Water Office (DGARH)	It is based in Rawson. In charge of water management in the province, regulating its use and every development that could affect the public use of this resource. The institution is carrying out a river monitoring system. In 2006, four watersheds advisory boards were formed. Key stakeholders, representing governmental agencies as well as private parties, are part of those boards.
Other Organizations	Some farmers associations are present in the area. They were formed for specific aims. For example there exist: the "Los Alerces" Farmer Association (APLA); the Honey Producers Association (AACLA); the "Los Andes" Farmer Association (ALAPA), which mainly represents fruit's producers; and small farmer groups formed through PSA projects.

2. Changes in Climate

An important source of information for this study has been the Second National Report on Climate Change, where is included a special information briefing focused on Patagonia (FTDT and ITDT, 2006). Some key points extracted from that report include the following:

- In the Northwest of Chubut there is a negative trend in the annual precipitation pattern, with high variability within decades. The majority of this precipitation corresponds with the winter season, when the biggest drop in rainfall has been observed. For instance in Esquel the trend observed was –4 mm/decade (period 1967-1998, values with non statistical significance)[6].

- A negative trend in frequency of extreme rainfall events has been observed. This would be related to the negative trend in annual precipitation[7].

- Near Esquel changes in temperature have been determined from the year 1961 to 2000. Each ten years the medium annual temperature rose by 0,20 ºC, whereas for summer time that increment was 0,33 ºC.

- The 0ºC isotherm has been going up in the region. This has directly resulted in glacial melting and lower recharge of snow. Glaciers are receding within the latitudes of 37 to 55 South (with some exceptions).

2.1 Differential impacts along an East-West gradient

As mentioned above, changes in precipitation patterns are clearest in the study area (Annex II). In the drier Eastern meteorological station of Esquel a decrease of 86 mm in the mean winter precipitation (April – September) has been observed when comparing the period 1961-1983 with 1984-2006 one (Figure 5). In the wetter western meteorological station of Aldea Escolar the pattern observed is not the same (Figure 4). It appears that the winter rains are somewhat delayed but occur over a longer period of time. Unfortunately there is not a continuous series of data earlier than the 1980s for this second meteorological station. These trends are borne out by the observations of several interviewees located in Western and Eastern areas of Chubut (see Box 1).

[6] This trend is valid for the whole Norwest Andes region (within Latitudes of 37 to 45 South), and also similar patterns have been observed in the Chilean side. However the situation is different when considering other areas of Patagonia.
[7] The contrary has been observed on the Atlantic coast of Chubut Province.

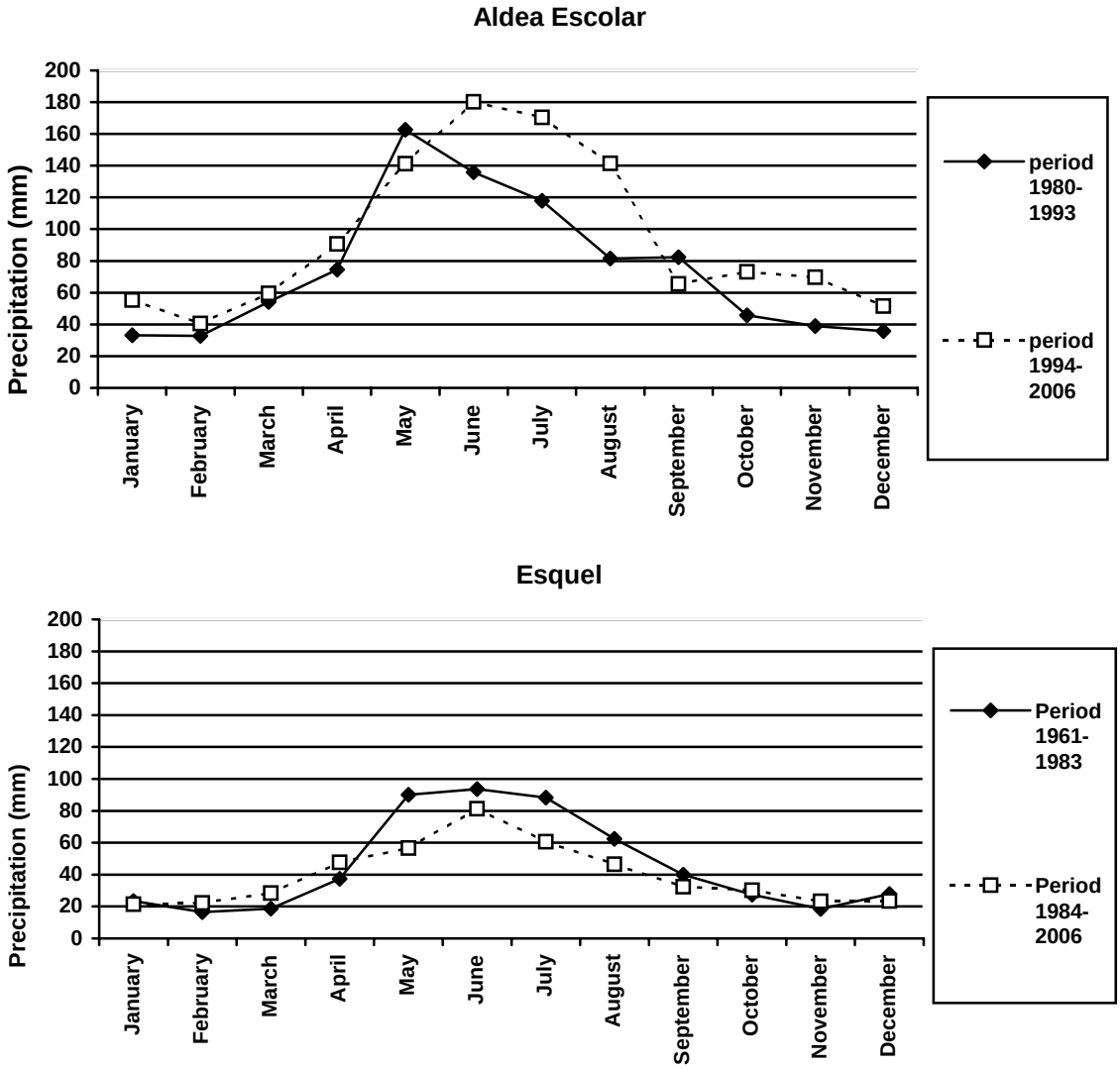
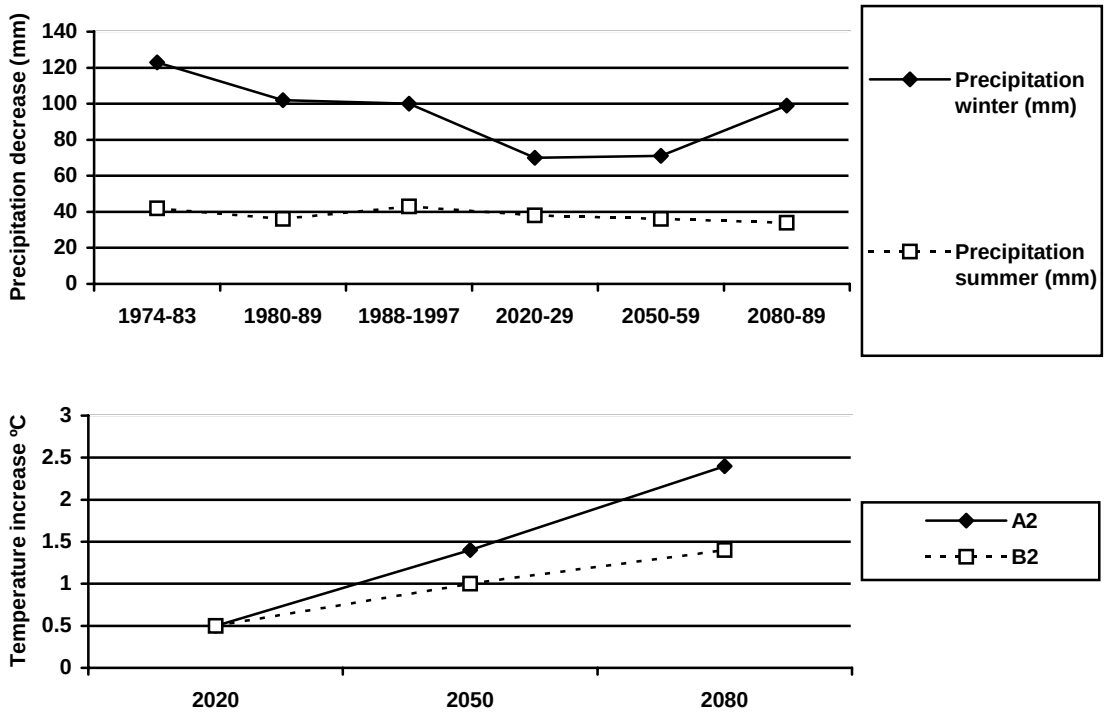


Figure 5. (Top) Trend observed of mean precipitation throughout the year for two different periods in Aldea Escolar. Source of data: Campo Experimental Trevelin, INTA EEA Esquel, 2007. (Bottom) Similar trend obtained for Esquel. (Notice that the periods are different). Source of data: SMN, 2007b.

Box 1. Perception of local interviewees relating to climate change in Chubut Province
Northwest - J. Nuñez is an organic farmer settled in Lago Puelo since 20 years (Northwest part of the study area). His feeling is that at the moment the climate is windier, colder and with longer winters that in the past.
Northeast - J. Simeoni is a farmer settled in Paso del Sapo since 23 years (towards Northeast of the study area). He said that the rainfalls are less frequent as well as less intense. In addition he noticed that this year the winter was drier and colder.
P. Gonzalo is the president of Esquel Rural Society and has lived in Esquel for 50 years. She think that 20-30 years ago the winter season used to be stronger and longer that nowadays. Also she feels a less clear seasonality. In her words "…a long time ago, strong snow storms occurred in winter that led in floods in spring time. Nowadays summers are drier and windy, and it is more common to see thunderstorms, a phenomenon that was not often seen before.
H. Jones (69) is a small cattle farmer settled near Trevelin since he was born. He shows scepticism when talking about climate change; his perception is that we are faced with cyclical periods. As well as P. Gonzalo, he sees less clear seasonality, "in the past, the summer was warmer and it lasted three months". He made the following statement: "perhaps people have the perception that past winters were stronger, but the thing is that there was a change in the living standard of rural people (e.g. transportation, telephone) that makes current winters seem not as strong as they used to be".
Southwest - R. Acinas is a cattle farmer and forest producer settled in Aldea Beleiro (approximately 90 km Southwest from Río Senguerr) for 42 years. He said that over the last 15-20 years a delay in seasonality is occurring. "Years ago, in May there was always snow. Nowadays the snow comes in July until October, and we never know when". In addition he feels that there may be less precipitation (although not too much less). Finally, he said that summers are not warm as it used to be, nowadays it is cooler and less stable.

2.2 Future projections of climate change in the study area

Future projections for the area show that temperature will increase by 0.5 ºC by 2020 and it will rise, in the worse case, up to 2.4 ºC by 2080 (Figure 5). According to FTDT and ITDT (2006), the precipitation modelling appears to be more complicated for the area. This is because of the high spatial and altitudinal variability (described before) found there. Global and regional models have a lot of noise in the output data, and the results are not compatible with some local observations. Projections are based on particular basins in Patagonia by using a mix method between the MM5/CIMA model and the current trends (Figure 6). Nevertheless, the trend of rainfall over the study area does show a continuous decrease expected in future years. The explanation of this can be found in the displacement of the Pacific anticyclone towards the South, since this pressure system is responsible for blocking up the precipitation systems on the way to the continent (FTDT and ITDT, 2006).



Fig

Figure 6. (Top) Projection of precipitation changes for the upper part of Chubut river basin. It takes into account two semesters, winter (from April to September) and summer (from October to March), and in this case the scenario considered is A2. Source: FTDT and ITDT, 2006. **(Bottom) Projection of temperature increases** according to MM5/CIMA model, for the decade 2080 based on the period 1981-90, when considering A2 and B2 IPCC scenarios.

3. Changes in Resources

According to FTDT and ITDT (2006) some changes have already begun to occur in the study area:

- Decreasing annual rainfall may lead to encroachment of shrubs on the forest, especially in the borders between the sub-Antarctic Forests and the steppe (transition called “ecotone”). Moreover, as less precipitation falls, less commercial production could be expected from forest plantations already established in the ecotone.

- This trend in the precipitation pattern would also lead to an increasing risk of forest fires across the area.

- In general, there is a negative trend in the stream flow of the main rivers of Patagonia. Within the study area that trend was reported for Chubut River[8], which is the source for water supply of the populations located on the Northeast coast. Most of the water consumed is currently used in for irrigation proposes to the East of the study area.

- Energy production is expected to decline. Most of the energy produced in Argentina comes from hydropower plants. A decrease in stream flows is leading to a decrease in energy production. In the study area there is one plant on the Futaleufú River. Also

[8] However, it was not statistically significant.

there is one on the Chubut River, which is located outside the study area but nevertheless under its influence.

Photo 4. Stream flows are expected to decrease across Patagonia

Some of these changes would be accentuated in the local environment by the current anthropogenic actions such as overgrazing in the steppe and forests (21,154 ha of high forests are degraded by this practice; Bava, et al., 2006), overuse of marginal forests for firewood production, intentional forest fires (36,604 ha of high forests are degraded by fire; Bava, et al., 2006), and lack of planning of afforestation in relation with future water requirements. Decreasing water yields may introduce new conflicts over water use between major sectors such as human consumption, irrigation, hydropower and industrial use. Towards the South (outside the study area) glacial meltwaters are leading to a increase in the stream flow of the Santa Cruz River. However, this is not the case in Northwest Patagonia (from 39º to 46º latitude South), where glaciers do not have a significant influence on stream flows (FTDT and ITDT, 2006).

3.1 Changes in patterns of livestock farming and downstream agriculture

Economic realities over the last 15 years have seen a change in livestock activity, with farmers changing from sheep to cattle stocks where it was possible (Figure 7, those changes started during the 1970s). This change has mainly been driven by economic reasons (the ratio between meat and wool prices). It is difficult to say whether those decisions will be affected by climatic factors.

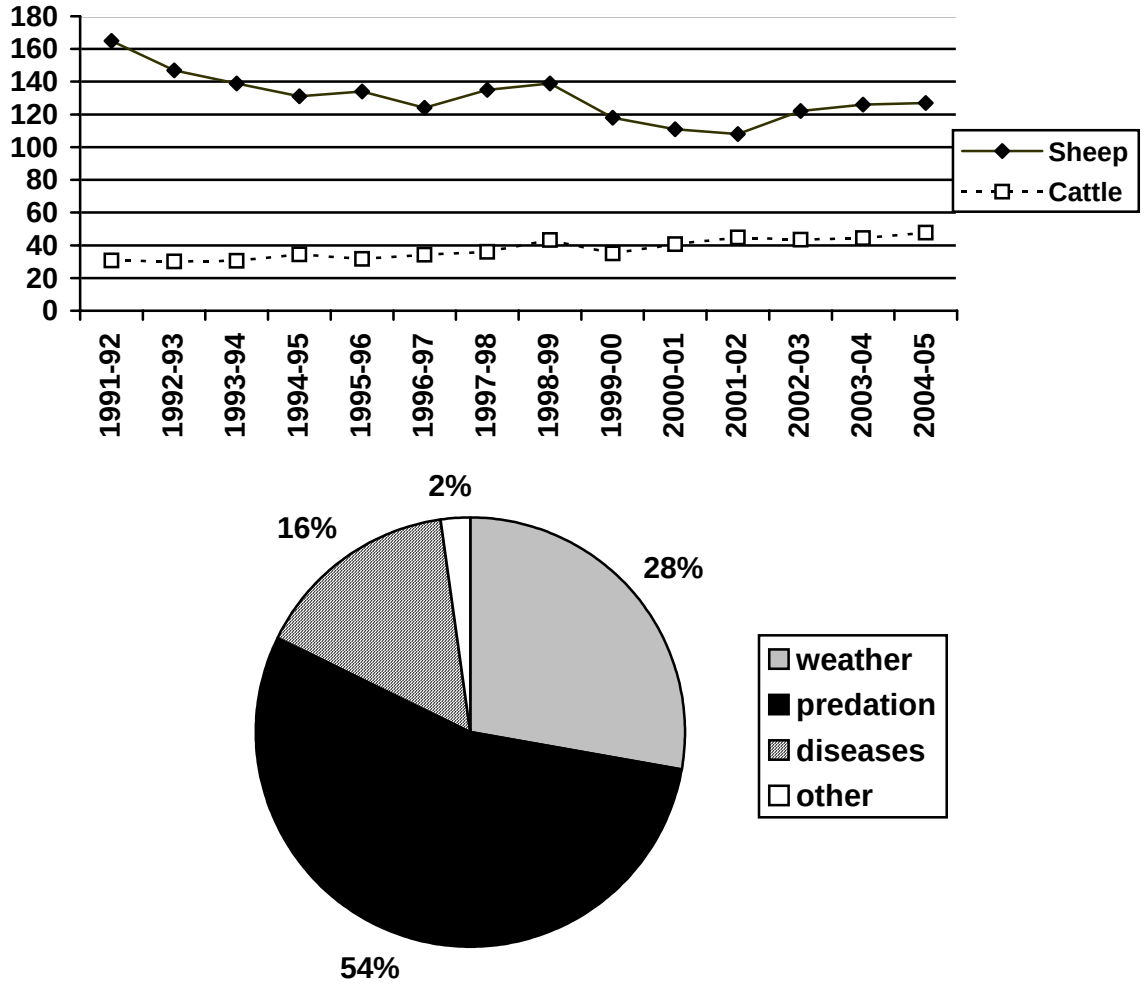


Figure 7. (Left) Livestock numbers (in thousands) in Futaleufú County; which is located at the North part of the study area. There is a decreasing trend in sheep stock whereas an increase in cattle. **(Right) Main causes of loss of livestock (mortality)** at the period 2002-2004 for the same area. Source of data: DGAyG, 2007.

There are some initiatives for irrigated agriculture outside the study area. At the moment a dam building over Senguerr River is analysed by the government, water supply for seacoast settlements is the main goal of this project[9]; moreover 15,000 ha could be available for agriculture purposes.

3.2 Changes in the incidence of forest fire

Forest fires have shown high variability in terms of the area affected over the past 29 years (Figure 8). In the study area, most of the fires are caused by anthropogenic reasons (less than 1% have origin on natural events such as thunderstorms). Nevertheless, drought years have had an influence on the number of fires and their intensity. Kitzberger et al. (2001) found that in northern Patagonia there is a relation among the major fires years, El Niño and La Niña events. According these authors during El Niño events a production of fine fuels is stimulated,

[9] Project's priorities are: source of drinking water, irrigation, sustain caudal levels of the Muster – Colhué Huapi Lakes, control of flooding caused by Senguerr River, preservation of aquatic fauna, recreation and tourism. Note that these lakes are outside the study area. Cohué Huapi Lake is probably under a natural cycle of size changing (FTDT and ITDT, 2006), and extreme episode occurred in 2000 when it was almost dry out (episode starting in 1998, see FTDT and ITDT, 2006 page 100).

which then are dried by La Niña conditions that lead in a widespread of fires. An institutional response to the big fires occurred in 1987, when a new fire service was developed under the DGByP structure (Epele, F. personal communication). In 2000 the Andean region of Chubut was one of the pilot areas in Argentina selected for evaluating the Canadian forest fire weather index (FWI) as tool to be used in forest fires management (Dentoni et al., 2007). At the moment the DGByP and the national authority in terms of forest management (PNMF, www.ambiente.gov.ar) are working together in the index operative implementation (Epele, F. personal communication). These activities will inevitably mask some of the impacts of climate on the extent of fire outbreaks.

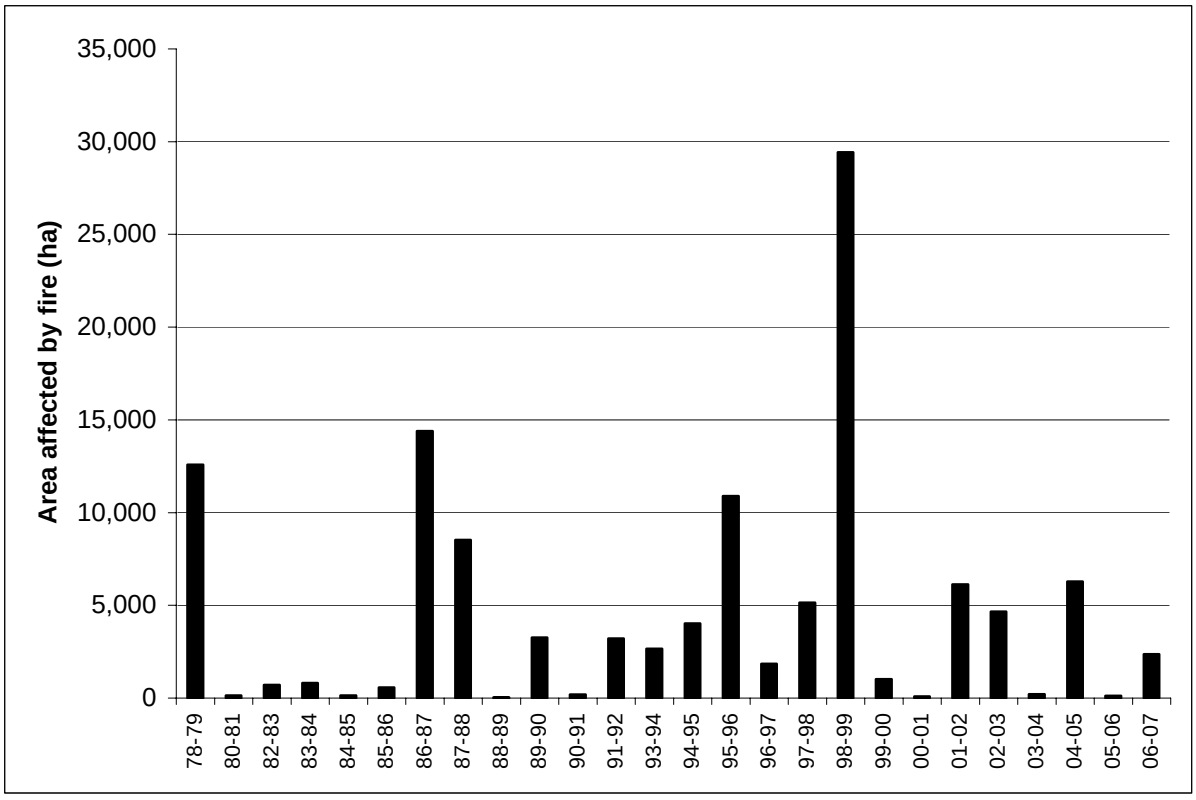


Figure 8. Area annually affected by fire in the study area throughout last 29 years (when considering forests, shrubs and grass lands). Notice that three of the five more affected years corresponds to dry periods. Source of data: DGByP, 2007b.

3.3 Changing patterns of forest plantation

In terms of afforestation, big efforts have been made with the aim of developing the forest sector. Although pine plantations are the most significant in terms of area planted, recent years have seen a growth in projects with irrigation requirements[10] such as poplars. Two main points require consideration. First, some areas at the moment marginally suitable for pine plantations would be lost if precipitation trends continue to decrease. Second, the decrease shown in stream flows also would be accentuated by the development of huge irrigated areas of poplar plantation.

[10] These kinds of projects require an especial permission by the Water Office (DGARH).

Photo 4. Expansion in irrigated poplar plantations

In dry years, some forest plantations as well as some native forests have shown direct damage (mortality) and indirect effects (predisposition to pests attacks). The severe drought occurred in 1998-99 was coincident with a strong La Niña event (Suarez et al., 2004), and it has had a direct effect on the forest by causing high mortality of *N. dombeyi*[11] as well as (perhaps) creating a pull of susceptible trees to future drought episodes. Bran et al. (2001) carried out a valuation of that event in Northwest Patagonia (outside the study area), and they reported that 41,75% (44,400 ha) of the *N. dombeyi* forests (including mixed forests) was affected. Davel et al. (1999) found for the same period increased mortality in Douglas-fir (*Pseudotsuga mensiezii*) plantations, with those already established on marginal sites being most severely affected. Lanciotti et al. (1995) reported similar effects occasioned by the drought in 1987 in these kinds of plantations.

[11] *N. dombeyi* is a species naturally associated to wet slopes and watercourses and lakes.

Box 2. Perceptions of local interviewees in relation to climate change impacts
Northwest - J. Nuñez noticed an increment in fungal diseases on his crops (mainly vegetables) as well as a lower height of the water table (phreatic surface), which is used for irrigation purposes.
Northeast - J. Simeoni said that as a result of the current drought there is less available water in the river from which he irrigates his poplar plantations. In addition he noticed that there is a low availability of grasses used for livestock feeding. Throughout recent years he suffered losses in his sheep stock, which never occurred before. P. Gonzalo gave a similar statement in relation to grass availability.
Southwest - R. Acinas does not see important effects on the forests, but he noticed changes in grass availability. He observed a later peak in the natural grass production. In relation to droughts, he said that in his area there is always a rainy month in summer that alleviates the situation and reduces the forest fire risk. On the other hand, he observed that intermittent streams are drying earlier than they used to.
"It does not rain since last year and the sheep are dying," said an article published on August 27th by the national newspaper "La Nación" (www.lanacion.com.ar). "Chubut suffers its worst drought in the last decade and the farmers think that will have important loses on sheep stocks" said a note published on September 1st by the national newspaper "Clarín" (www.clarin.com).

4. Adaptations in resource management

4.1 Adaptations to livestock

There are some clear cases in which farmers have decided to decrease their stocks in response to low grass availability in drought years. These changes are controlled by the farmers themselves and decisions are based mainly on own experiences. In the case of large farms, frequently with better economic prospects, professional advice is commissioned. Institutional projects in order to improve management practices are carried out in several farms, but nevertheless they have not been scaled up to the region. At the moment neither rule nor guidelines on livestock management exist (in terms of field use intensity or environmental friendly practices).

4.2 Adaptations in forestry

In terms of forestry, extensive afforestation projects[12] could lead to some water related issues in the future. But these projects are being promoted for other benefits:

- To decrease desertification process running in the area (mainly in the steppe because of overgrazing);
- To decrease pressure on native forests;
- To diversify the livelihoods of the area; and
- To contribute with the global CO_2 fixation.

In the past, several forest plantations were established in areas cleared of natural forests. Some areas were left without any management practice. The consequences have been seen 30 years later with the infestation of the woodwasp *Sirex noctilio*; which accidentally

[12] According to official data, the suitable lands available for afforestation in Chubut are 311,000 ha and other 400,000 ha with irrigation requirements (DGByP, 2007a).

appeared in the area. This wasp affects mainly pine species and may cause their death. Environmental factors such as drought or an excessive overcrowding make trees more susceptible to the attack. Important economic loses have been caused by the woodwasp in the area. In response, the Forest Service established a special program for pest and disease monitoring and management. Several investments have also been made in order to improve the forest fire management program and some changes were introduced in the management of native forests; which are not based on climate change perceptions but would have positive effects when facing those changes. An example of this are the prescriptions introduced for forest management near watercourses on *N. pumilio* covers. It could be beneficial not just for water protection but also to keep natural corridors for wildlife displacement or protection.

Photo 5. New Ponderosa pine plantation

There are already 24,000 ha of pine plantations in the study area (DGByP, 2007a) and the government goal in 2005 was to achieve 25,000 more ha in the period 2006-2011. In 2006, several small sized farmers showed an interest in establishing poplar plantations eastward from the study area. The main aim of those projects is not just to create windbreaks, but also because they improve conditions for agriculture practices (through the irrigation system). Activities such as these would have an important effect on farmers' livelihoods in the future. However that is just the starting point and it is necessary to wait for the success of those projects.

Box 3. Examples of adaptation to climate change among local interviewees
Northwest - In the case of J. Nuñez, he did not change his activities because the scale the effects are not significant. However he said that nowadays his firewood consumption is higher than before, and he decided to change the kind of corn and potatoes seeds used, privileging those of shorter cycle.
Northeast - J. Simeoni has changed his project of poplar's windbreak as a response to the problems with the water supply that are affecting him. In addition J. Simeoni as well as P. Gonzalo have decreased their livestock production because of less field capacity in terms of grass. P. Gonzalo says that the decrease of stocking is not the only response made by farmers. In some cases low grass availability has led to an increase in the pressure on native forests (specially on *N. antarctica*). Also she said that in dry years, like the current one, there is less availability of lambs as well as calves that implies a direct impact in the regional market, where a rise in the meat's price can be expected.
Southwest - R. Acinas said that because of lower grass availability he reduces his stock. This management practice is based on his own experience. Last year he started to crop 20 ha of grass (*Medicago sativa*) in order to obtain winter supplement for cattle feeding.

4.3 Adaptation involving ecosystem services

The valuation of ecosystem services has been seen as a possibility to shift management practices towards greater sustainability. Recent work was carried out in the area in order to explore the possibility of introducing some kind of forest ecosystem services market (SAyDS and UNSE, 2007). As more relevance is given by local people to climate change this option will become more important. If that were the case, it would be easier to implement some kind of environmental services payment in the area. To date, on September 24th a local cooperative (SCPL) in Chubut (outside the study area) sold the first Certified Emission Reductions credits (CREs) in the province according to the Kyoto Protocol. This operation was related to wind energy production, with Japan Carbon Finance Foundation (JCF) as the buyer. Some years ago, an attempt was made to sign a contract for the rights of possible carbon credits (originated in native forests) between the province and a German Foundation (PrimaKlima-weltweit- e.V). This project was unsuccessful because of the high opposition of the local people – based around uncertainties such as the kind of rights that could be implied by that contract involving native forests. Moreover, the political situation at that time and a lack of communication strategy contributed to that failure.

5. Roles of local Institutions

5.1 The role of institutions governing livestock

Livestock production was one, if not the main, driver of regional development. Nowadays it is still one of most important contributors in the local economy. It has been seen as necessary to use existing grasslands according to their carrying capacity. INTA gives some technical advices on this topic, but decisions are left to the farmers' own motivation. In this topic, DGAyG has a crucial role to play in order to advance its capacity in the face of climate change. Although achieving a norm that creates a rigid framework appears to be non-realistic, some initial steps could be done through a participative learning process. In addition DGAyG needs to involve other governmental policies such as promoted by DGByP when there is a forestland involved. A collaborative framework among those institutions is required.

Addressing agroforestry practices in natural *N. antarctica* forests towards more sustainable models should be done in the meantime. INTA have carried out several pilot projects (looking for a better understanding of the system as well as to improve farmers' livelihoods), but it is necessary to spread the experiences to as many farmers as possible. Lessons need to be

learned that have a positive effect in reducing the pressure on *N. pumilio* forests, where grazing is not compatible with their natural dynamics. In addition, promotion of agroforestry practices eastwards in marginal areas for afforestation proposals could reduce overgrazing on the steppe and simultaneously diversify farmers' livelihoods. The development of those models should be carried out by research institutions such as INTA and CIEFAP whereas their promotion and encompass by governmental agencies such as DGByP and DGAyG.

Photo 6. Need to manage land use interactions between forestry and livestock

5.2 The role of institutions governing forest resources

Ponderosa pine (*P. ponderosa*) is the main species promoted by afforestation projects (because its high adaptation to the local conditions). The development of forest plantations as monocultures has negative effects already documented worldwide. Climate change could increase those risks. Diversifying species to be used could be an alternative, but requires further research. Some findings were recently carried out by CIEFAP (searching for a range of alternative forest species), but it is necessary to go further and to develop policy incentives for change. Moreover to implement such programs at a regional scale will take several years. A first step would be to take special care on species and sites selection when planting in marginal areas. This also implies responsibilities on private parties (farmers and technicians). Future water requirements at landscape scale should be taken into account when promoting an extensive development of the forest sector. Research institutions as well as governmental agencies should work together in order to improve planning activities.

5.3 General requirements for better data

In order to improve the decision making process it is necessary to implement models based on climate data. This would have at least two positive aspects: first, the trends could be used to predict likely difficulties so that actions could be taken in advance. Second, decisions such as establishing agricultural emergency would be based on quantitative data. To allow this,

first of all an improvement on the meteorological network should be achieved, and the responsibility for that belongs to the SMN[13].

Box 4. Observation on the institutional framework governing adaptation to climate change
In P. Gonzalo words "the decision on how managing the stock belongs to each farmer, there are no rules for saying whether a field is overexploited or not". She thinks that there is a need for some research carried out by institutions with farmers as partners, but the problem is that the information is not sufficiently disseminated. This particular dry year, and after the claims of Rural Societies and farmers in the province[14], the government decided to provide them with grass, grains and water for the livestock in the affected areas.
All the local interviewees agree that there is no institution working directly on climate change and local adaptation. In addition M. Hartel (a governmental technician) said that in part the lack of belief in climate change is because there are a lot of speculation and diversity of hypotheses around the topic. She also added that maybe a problem is the clear lack of trusted information sources.

6. Conclusions

Climate change is happening. But better data is required in order to improve regional models of its impacts and facilitate the decision making process. Better data is also a key factor when looking for more efficient systems (i.e. where to concentrate adaptation efforts). Although there is no accurate official meteorological network in the study area, it could be improved by homogenizing those stations already present and which do not belong to the SMN. In addition, farmer's access to information should be improved. Facilitation of clear data interpretation by farmers should be part of any new process.

The impacts of climate change are not yet severe in comparison with other areas; the situation gives adequate time to prepare for the future. This is therefore a key time to build institutional capacity to adapt to the main threats. Even though no institution has been recognized as competent on the topic, several examples of adaptation were found. This should be seen as an opportunity to base an adaptation strategy around such changes.

Although the reality of the sub-Antarctic forests is quite different to that observed in the North of Argentina where deforestation processes are a huge issue, overlapping land uses in the study area such as cattle farming and forest management is leading to the degradation of these natural forests in the long term. This situation could be accelerated by climate change, for instance if the precipitation pattern trends continue to decline. Special research should be carried out on this topic, in order to see whether those climates related effects are the main drivers or not.

Finally, adaptation will require a coherent and coordinated set of policies between the main institutions. Throughout Chubut's provincial history, controversies between different institutional policies have been found. Those controversies were mainly because of promoting one resource development without taking into account its impacts on others. At the very least, communication channels between different institutions as well as within them and between them and other stakeholders should be improved.

[13] In the study area there is just one official meteorological station (Esquel Airport), and some years ago one automatic station was settled in Río Senguer (Southern part of the study area). In the whole province there are 5 stations (SMN, 2007d).
[14] The claims were in the way of getting a declaration of "agricultural emergency" that implies measurers such as extending periods of taxes and loans payments as well as access to special loans. According the law loses must reach 50% in order to state the emergency. That was not the case in the current drought.

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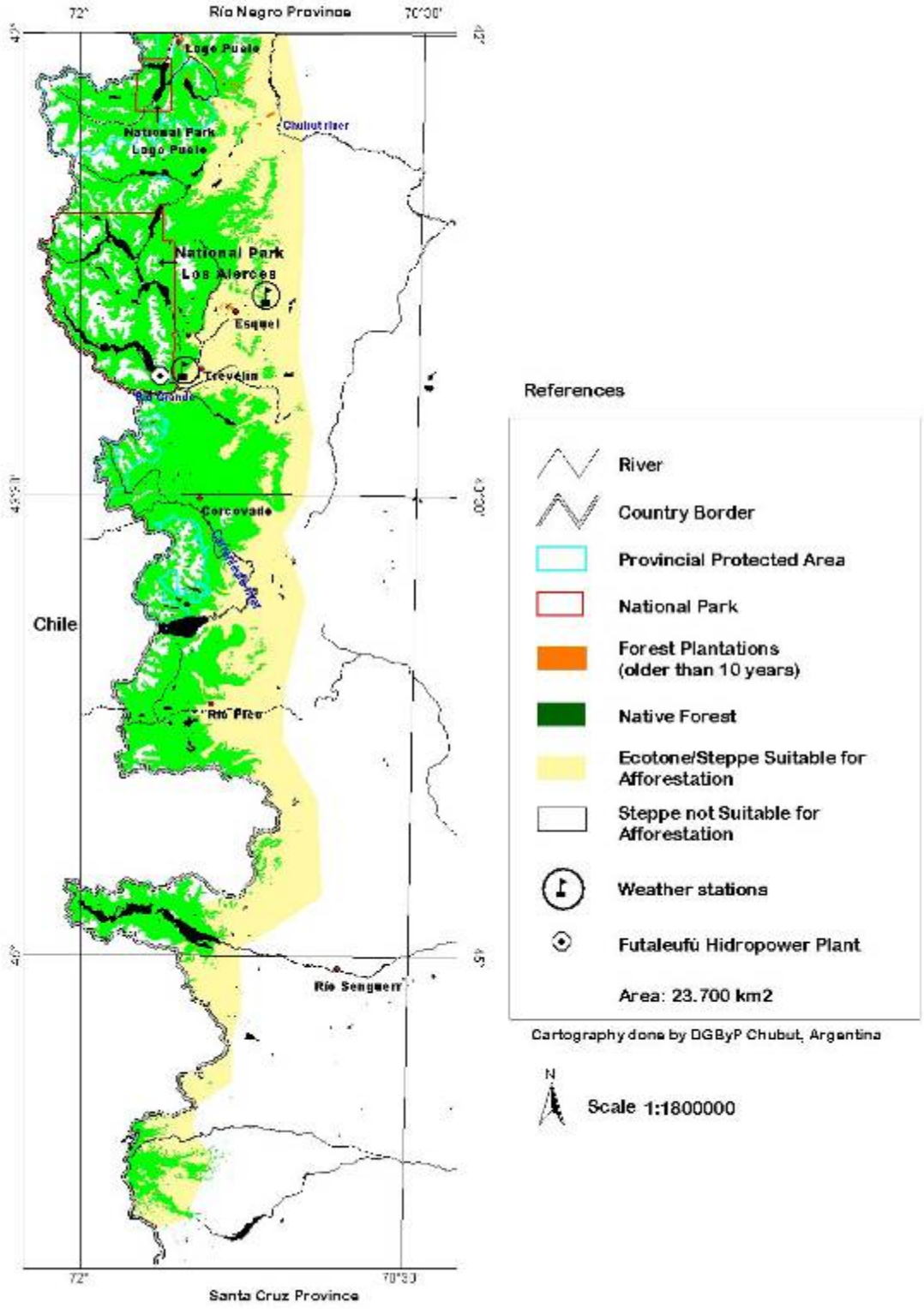
Photo 7. Walking through natural forest in Patagonia

Annex 1. Map of the study area

ANNEX I

Map of the study area, which is located in the west part of the Chubut province, Patagonia, Argentina



Annex 2. Trends in annual precipitation and mean temperatures for two stations in the study area

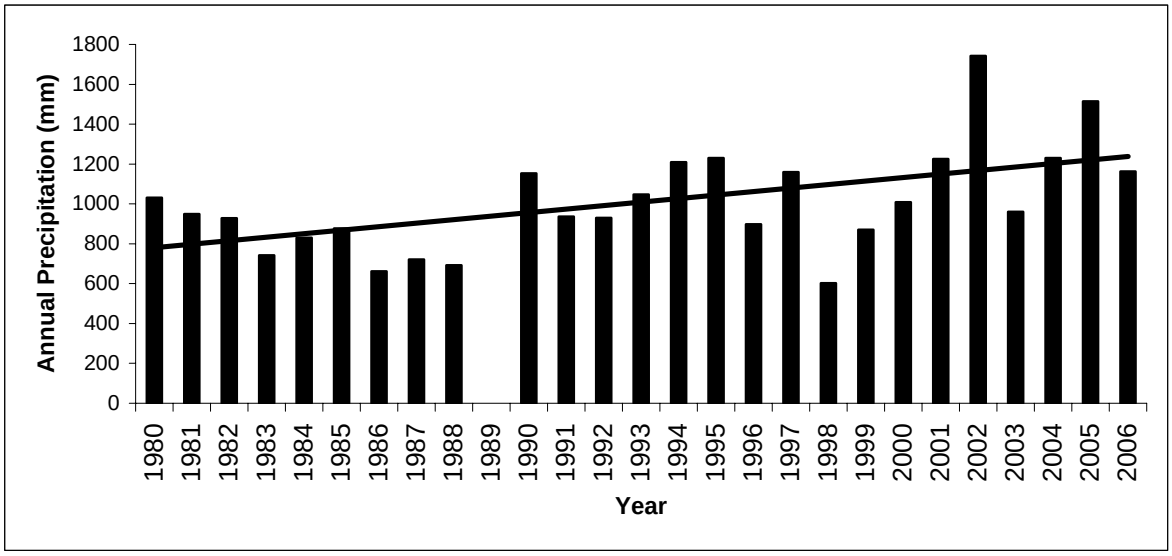


Figure 9. Trends observed for annual precipitation (mm) throughout the period 1980-2006 in Aldea Escolar.

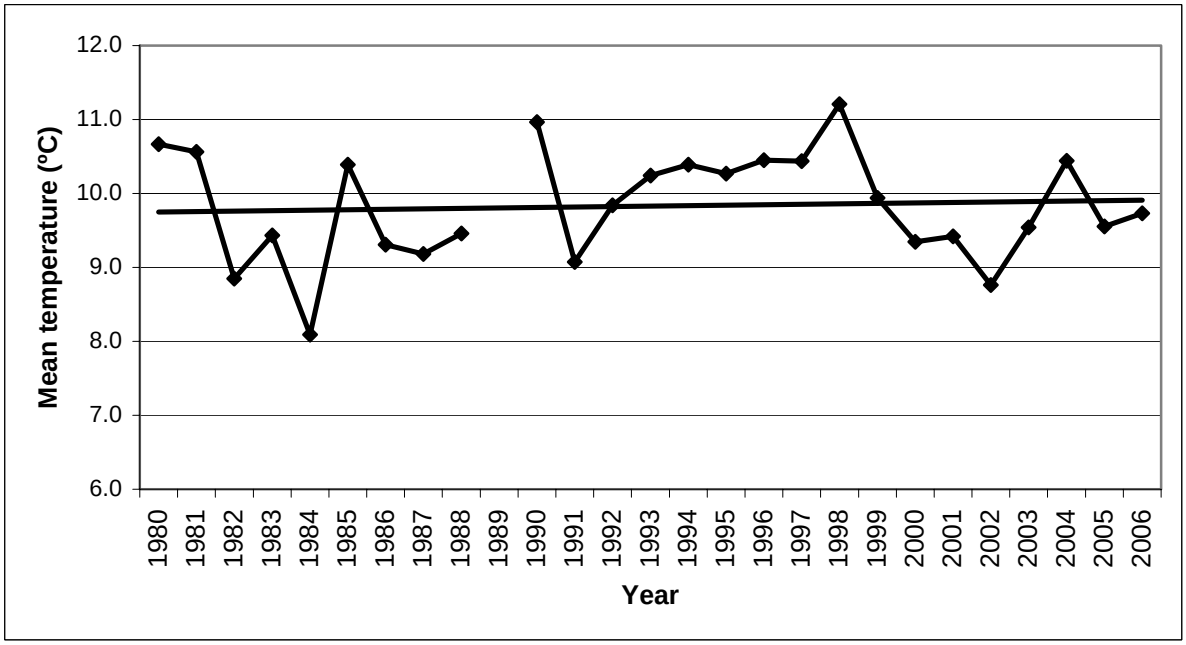


Figure 10. Trends observed for mean temperature (ºC) for the same period in Aldea Escolar. Source of data: Campo Experimental Trevelin, INTA EEA Esquel, 2007.

Notice that there is a lack on long term data for Aldea Escolar's station. This situation could be mask the real precipitation trend (compare the 1980s with other decades in Esquel).

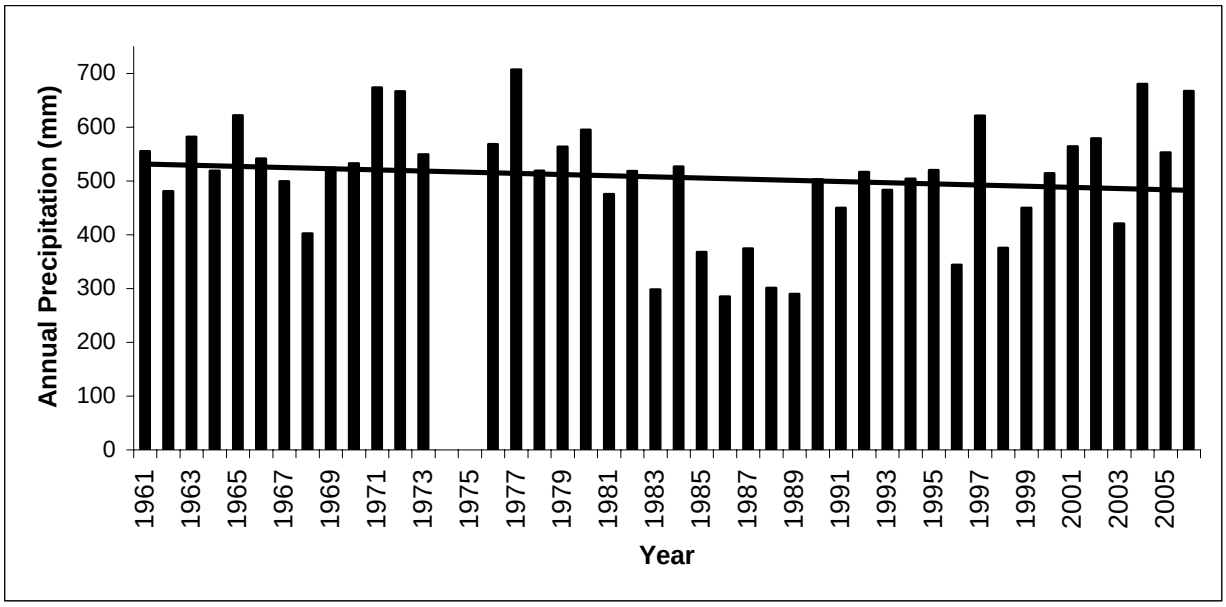


Figure 11. Trends observed for annual precipitation (mm) throughout the period 1961-2006 in Esquel.

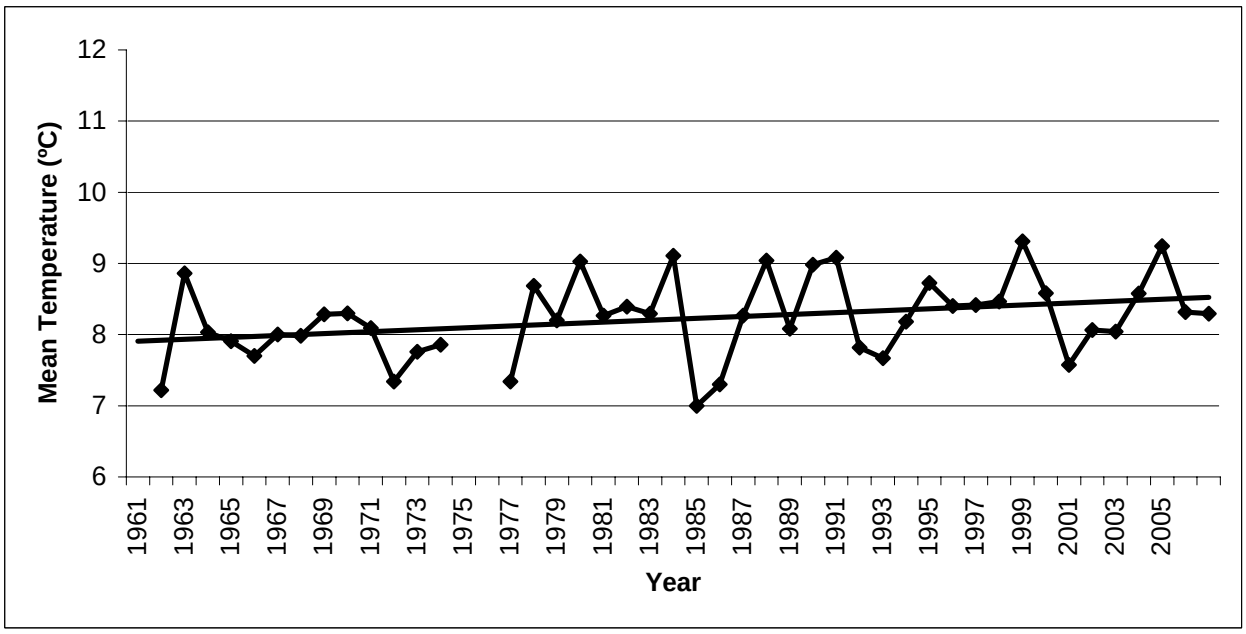


Figure 12. Trends observed for mean temperature (ºC) for the period 1961-2006 in Esquel. Source of data: SMN, 2007b. (Black line equals trend line).