AIACC Final Reports

Vulnerability and Adaptation to Climate Variability and Change: The Case of Farmers in Mexico and Argentina

A Final Report Submitted to Assessments of Impacts and Adaptations to Climate Change (AIACC), Project No. LA 29

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2006

Published by
The International START Secretariat
2000 Florida Avenue, NW
Washington, DC 20009 USA
www.start.org

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About AIACC

Assessments of Impacts and Adaptations to Climate Change (AIACC) enhances capabilities in the developing world for responding to climate change by building scientific and technical capacity, advancing scientific knowledge, and linking scientific and policy communities. These activities are supporting the work of the United Nations Framework Convention on Climate Change (UNFCCC) by adding to the knowledge and expertise that are needed for national communications of parties to the Convention.

Twenty-four regional assessments have been conducted under AIACC in Africa, Asia, Latin America and small island states of the Caribbean, Indian and Pacific Oceans. The regional assessments include investigations of climate change risks and adaptation options for agriculture, grazing lands, water resources, ecological systems, biodiversity, coastal settlements, food security, livelihoods, and human health.

The regional assessments were executed over the period 2002-2005 by multidisciplinary, multi-institutional regional teams of investigators. The teams, selected through merit review of submitted proposals, were supported by the AIACC project with funding, technical assistance, mentoring and training. The network of AIACC regional teams also assisted each other through collaborations to share methods, data, climate change scenarios and expertise. More than 340 scientists, experts and students from 150 institutions in 50 developing and 12 developed countries participated in the project.

The findings, methods and recommendations of the regional assessments are documented in the *AIACC Final Reports* series, as well as in numerous peer-reviewed and other publications. This report is one report in the series.

AIACC, a project of the Global Environment Facility (GEF), is implemented by the United Nations Environment Programme (UNEP) and managed by the Global Change SysTem for Analysis, Research and Training (START) and the Third World Academy of Sciences (TWAS). The project concept and proposal was developed in collaboration with the Intergovernmental Panel on Climate Change (IPCC), which chairs the project steering committee. The primary funding for the project is provided by a grant from the GEF. In addition, AIACC receives funding from the Canadian International Development Agency, the U.S. Agency for International Development, the U.S. Environmental Protection Agency, and the Rockefeller Foundation. The developing country institutions that executed the regional assessments provided substantial in-kind support.

For more information about the AIACC project, and to obtain electronic copies of AIACC Final Reports and other AIACC publications, please visit our website at www.aiaccproject.org.

Summary Project Information

Regional Assessment Project Title and AIACC Project No.

Vulnerability and Adaptation to Climate Variability and Change: The case of Farmers in Mexico and Argentina (LA 29).

Abstract

Through case studies of agricultural production in Mexico and Argentina, this project has utilized expertise in climatology, agrometeorology, rural development, political science, economics and geography to address two principle questions: To what degree is adaptation to climate change at the regional or farm level constrained and/or facilitated by current trends in institutional change and water and agricultural sector policy? And how can new climate change and variability research be integrated better into practices and policies?

Extreme climatic events and dramatic changes in agricultural and water resource policies have had significant impacts on farmers' livelihoods and thus on their vulnerability. Our objective was to understand how these multiple sources of change were affecting the livelihoods of vulnerable populations. We developed an interdisciplinary assessment involving an analysis of climate variability and change; an analysis of the institutional context of production and resource allocation; surveys of farm households concerning climate and non-climate impacts on livelihoods as well as capacity for adaptation; interviews and ethnographic research with a variety of actors in the agricultural sector; and a continued dialogue with key stakeholders.

Historic climatic events were analyzed using "climatic threat spaces", where anomalies of temperature and of precipitation where used to visualize those conditions that might have impacted the agricultural sector. These spaces were contrasted with several sources (i.e. newspaper reports) that documented not only the effects of those anomalies, but also who were the principal actors in those situations and what were the measures and roles that those actors applied and played.

The project successfully identified particular sub-sectors within each case study that demonstrated either higher sensitivity and/or low adaptive capacity to both climate impacts and economic change. Through linking the evaluation of household capacities to trends in the policy environment, the project identified possible public sector interventions that could facilitate local-level risk management.

Administering Institution

Centro de Ciencias de la Atmósfera, Universidad Nacional Autónoma de México (UNAM), Ciudad Universitaria, Circuito Exterior, 04510 México, DF, México

Participating Stakeholder Institutions

Mexico: Universidad Veracruzana; Universidad Autónoma de Tamaulipas; Instituto Nacional de Investigaciones Forestales, Agricolas y Pecuarias (INIFAP), Campo Experimental Xalapa, Veracruz; Consejo Regional de Café de Coatepec; Asociación Agrícola de Coatepec; Secretaría de Desarrollo Regional; Centro de Ecología, Xalapa; Distrito de Desarrollo Rural, Secretaria de Desarrollo Rural, GONZALEZ; and Instituto Mexicano de Tecnología del Agua (IMTA).

Argentina: Municipio Oncativo, Intendencia; Municipio Laboulaye, Intendencia; Municipio Marcos Juarez, Intendencia; Municipio de Río Cuarto, Intendencia; INTA Marcos Juárez; INTA Río Cuarto; Asociación de Cooperativas Argentinas (Argentina Cooperative Associations) - different branches; Federación Agraria Argentina (Argentina Agrarian Federation); and Sociedad Rural de Laboulaye (Laboulaye Rural Society).

Countries of Primary Focus

Argentina and Uruguay

Case Study Areas

Mexico: Central region of the state of Veracruz and southern region of the state of Tamaulipas (*Mexico*) and Argentina: Center-South of Cordoba Province (*Argentina*)

Sectors Studied

Agriculture (crop, livestock and mixed crop-livestock production systems); and water resources

Systems Studied

Regional economy; Food security; Rural settlements; and Sustainable Livelihoods

Groups Studied

Commercial farmers producing cash crops and livestock – Cordoba (Argentina); Subsistence farmers producing coffee - Veracruz (Mexico); and Commercial farmers producing cash crops and livestock, water resources management- Tamaulipas (Mexico).

Sources of Stress and Change

Climate variability and extremes; land use change; technological change; institutional change; and policy change

Project Funding and In-kind Support

AIACC: US $225,000 grant; Centro de Ciencias de la Atmósfera, UNAM. Mexico: US $82,800: Universidad Nacional de Río Cuarto. Argentina: US $73,600; Agencia Nacional de Promoción Científica y Técnica, Proyecto PICTO, Argentina: US $9400; and Secretaría de Ciencia y Técnica, UNRC, Argentina: US $2000.

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Executive Summary

Research problem and objectives

The capacity of particular sectors to adjust to changes in climatic parameters depends in large part on the specific political, economic, institutional and biophysical factors that structure economic activities (IPCC, 2001a). Our understanding of the capacity of agriculture to adapt to climatic change has been constrained by the lack of the integration of crop and climate models with studies related to changing social circumstances in agricultural decision-making, which might take into account the full complexity the systems under study. Recent case studies of agricultural adaptation have illustrated that non-climatic factors are often bigger determinants of individual farmers' strategies than climatic factors, throwing into doubt assumptions that farmers will necessarily and autonomously respond to climate signals and pursue optimal strategies - see, for example, Brklachich *et al*, 1997, Ziervogel, 2005. This situation is particularly observed when high losses in agricultural activities are reported in those years with "normal" climate conditions (Conde *et al*, 2006). Thus it is critical to understand how the specific social and environmental context of production influences strategic choices of farmers, and why some farmers and some farm systems may be more prepared to adapt to climatic changes than others.

In this project, we have studied how different types of farmers in Mexico and Argentina are adapting to multiple uncertainties originating, on the one hand, from changes in the frequency, intensity or duration of extreme climatic events (which might be associated to a climate change trend), and, on the other, from dramatic socioeconomic changes associated with the embrace of neoliberalism in the Americas (O'Brian and Leichenko, 2000). While farmers in both countries are being exposed to similar processes of economic globalization in the context of high climatic risk, these processes have been translated into distinct national and sector policies. By explicitly addressing how farmers' strategies reflect not only climatic changes, but also privatization and decentralization of agricultural and water institutions, new price regimes for inputs, products and services and increased resource competition, we have illustrated how broader economic and sector polices affect adaptation capacities, and how policy can better address climatic risk to facilitate adaptation (IPCC, 2001a).

Using selected farm types as the unit of analysis, our main objective was to answer the following research questions: How are broad-scale socio-economic and climatic processes of change in Mexico and Argentina, translated into region and sector-specific policy and institutional reforms, affecting the vulnerabilities of different types of farm systems and their capacities to adapt? What are the implications of particular agricultural and water policy reforms for the production strategies of different types of farmers, and what is the significance of these strategies in terms of enhancing or diminishing the vulnerabilities of farmers to climatic risk and their capacities to adapt to such risk? How can existing water and agricultural institutions and decision-makers make better use of climate research? How can adaptation capacities be enhanced within the context of current policy trends?

Approach

Climate Analysis

Observed changes in rainfall and temperature patterns and their impacts on agricultural activities were documented for both countries, particularly during El Niño/Southern Oscillation (ENSO) events. The years of strong ENSO were shown in the "climatic threat spaces", and the possible increases (decreases) of climatological data during those years were determined, and presented to key stakeholders, so that the story associated with those events could be reconstructed.

Responses during strong ENSO events and its impacts were also documented using in depth interviews and other sources of information (such as newspapers and "grey" literature). Also, simple characterization of cultivars' (maize, coffee, sorghum) temperature and precipitation requirements were also attached to the "climatic threat spaces", in order to take into account the possible events of climatic anomalies with respect to specific crops, during their different growing stages.

Climatic anomalies were calculated using as a base scenario the period 1961 – 1990. Years of strong El Niño/Southern Oscillation (ENSO) events were selected using the multivariate ENSO index (http://www.cdc.noaa.gov/~kew/MEI/) giving special attention to extreme events at interannual time scales.

Climate change scenarios were generated using the outputs of atmosphere-ocean coupled GCMs (AOGCMs) and employing simple downscaling techniques The simple climate models called MAGICC – Model for the Assessment of Greenhouse-gas Induced Climate Change (Hulme et al., 2000), and a climatic database (SCENGEN) with the outputs of 4 GCMs was used. Those scenarios were then included in the "climatic threat spaces" to assess the possible future impacts on the crops under study.

One issue that was addressed in this study was to explore possible changes in climate variability under climate change conditions. This was studied considering that the distribution of the principal climatological values was preserved, and that the changes projected by the GCMs were related to changes in the mean values. Other numerical experiments were performed to explore other possible changes. By means of these methods, even those scenarios that reported relatively small changes could in fact produce important impacts, since the possible extreme events (tails of the distribution) could be associated with an increase in the probability of harmful events.

Also, in an effort to detail the relationships between climatic variables and the impact of climate hazards in agriculture, farmers and water managers were consulted from the beginning of the project to include their perceptions in this subject. Their participation provided guidance on the information needs and the role of particular climatic events and variables in their decision-making.

Farm-level and policy analysis

Adopting a political-ecology approach, our research considered both the physical environment and social environment as dynamic, evolving and highly uncertain contexts in which farmers are making strategic decisions about their livelihoods (Scoones, 1999). The policy and institutional context of the agricultural sectors of the two countries were analyzed through the use of primary and secondary literature, national and regional databases (population, economic and agricultural), interviews with key informants and a review of regional newspaper and popular media. This analysis was used to understand the limitations and opportunities for adaptation and adaptive capacity building in the case studies, as well as to explore the production of social vulnerability through development processes.

The institutional analysis was complemented by a farm-level survey implemented in three regions: four communities in south of Cordoba province (Argentina); *municipio* of González, Tamaulipas (Mexico); and two communities in Coatepec, Veracruz (Mexico). The survey instrument was designed to evaluate farm-level adaptive capacities and sensitivities to climate and non-climatic shocks. The survey data was then analyzed descriptively, and indices for sensitivity and adaptive capacity were created for each of the case studies. These indices were then analyzed together to determine the vulnerability of the farm populations. This quantitative analysis of livelihood vulnerability was complemented with individual and group interviews with farmers to capture farmers' perceptions of risk and the importance of planning for adaptation. The participation of farm stakeholders in our research design and implementation was critical.

We did not assume that any particular set of adaptation options or management strategies are available to farmers. Instead, we have worked directly with farmers to determine what "choice set" for adaptation they perceive is currently available to them and how these choices are currently being affected by broader social, political and economic change.

Scientific findings

It has been well established that strong El Niño events in Mexico are associated in general with important decreases in summer precipitation and an increase in summer temperature (i.e. Magaña, 1999), which leads to important decreases in rainfed crop production (Conde et al, 1999). Even though these are the expected changes under such events, the regions under study in Mexico (central region, Veracruz; southern region, Tamaulipas) are characterized by a small increase in the summer period called Mid-Summer Drought (MSD, known by farmers as the canícula) that obscures these processes and represents a different signal than the one expected in the country. On the other hand, strong La Niña events, that lead to important increases in summer precipitation i.e. Magaña, 1999, represent a climatic threat for the stated regions, since this excess in rainfall causes flooding events that affect agricultural activities.

Considering temperature trends, the central region of Veracruz has presented an important increase in temperature (particularly in minimum temperature values) since the beginning of the XX century, which is consistent with the projected changes reported in the Third Assessment Report of the IPCC (2001b). However, frost events are still one of the major events that impact coffee production, and are a cause of great concern for farmers (Conde, et al, 2005). On the other hand, the southern region of Tamaulipas presents a possible decadal trend in precipitation, which can been seen in the climatic data but also in the newspapers articles that report consecutive years of drought followed by several years of flood events.

In Argentina, changes were observed in the seasonal maximum and minimum temperatures in the region. Maximum temperature has decreased particularly in the spring and summer while increasing values of minimum temperatures are observed during all the seasons. Precipitation also showed changes in time with a consistent regional increase in the precipitation during the summer and fall over the entire region with a well defined positive time trend. The spring shows increased precipitation in the east and south and winter in the west and south of the region. In addition to natural climate variability, the perceived increased variability is also a consequence of climate change. Fluctuation of the climate during the seasons, the occurrence of anomalous temperature and precipitation events, as well as soil moisture availability exert in the region the greatest influence upon both intra and inter annual onset of crop seasons and on the consequent crop growth, development and yield.

While there is no doubt about the beneficial impacts the increasing precipitation may have on regional agriculture in most cases, climate variability and extreme events (floods, droughts, etc.) in the region are responsible for major uncertainties in agriculture, at least in the short term. Floods events may be exacerbated in the future in the flood prone zone in the south of the region since climate change scenarios indicate an increment in rainfall mainly during summer and fall but with the highest increases during April (the month with bigger floods in the area). Expected rainfall diminution during the winter may jeopardize the possibility of double cropping although this effect might be ameliorated by the increments expected for the fall. Climate scenarios indicate higher temperatures, which on one hand diminish the risk of frost but on the other hand will reduce the length of the growing season for the summer crops possibly causing yield reductions.

The method of “climatic threat spaces” was applied by both country teams as a tool to visualize possible threats to agricultural activities, and it proved to be an interesting tool to integrate social, agronomical and climate studies.

Social vulnerability to climate at the farm-level is determined as much or even more by socioeconomic factors than simply by climatic variability and change. Particular sub-populations of the systems of study demonstrated that their risk management priority is adjustment to recent domestic policy changes and market liberalization; climate risk being a secondary consideration. This means that their adjustment strategies are necessarily in relation to improving their livelihood stability in face of these types of changes and that these strategies may not address their climatic risk. Collectively, the responses of farm households to the new opportunities and obstacles in the economy may indirectly exacerbate the sensitivity of the case study regions to future environmental change due to environmental degradation and land use change. We did not find that any particular system of production is necessarily more sensitive to climate impacts over other systems, but rather, in an economy favouring large-scale commercial production, family and smallholder farmers face economic difficulties that undermine their traditional risk management strategies and diminish their capacities to adjust to new shocks.

Methodologically, we found that comparison between very different farm systems is possible on the basis of similar factors creating vulnerability (global trends in economic development, similarities in the ideology driving domestic policy and similarities in the impacts of such policy), and compatibility in the generic attributes of adaptive capacity and sensitivity in each case study. However, we also found that the experience of vulnerability is necessarily site specific and vulnerability assessments need to be relevant to the particular governance and/or decision-making unit of the population of study. This means that the variables used to measure vulnerability in each case and the recommendations for enhancing adaptive capacities were developed to reflect the important local social, economic and institutional characteristics of each case.

We found that in each case study farmers considered climate risk in their livelihood strategies, although their strategies were not determined by their perceptions of these risks (Gay, 2005). The measures that households currently take to reduce their sensitivity or to enhance their capacity to manage climate impacts are those measures that are most compatible with the type of economic strategy that they are able to pursue given the range of choice and opportunities available to them. For this reason our results focus on deficiencies in the adaptive capacity of vulnerable populations and the possible interventions that would enhance the capacities of farmers to adopt and implement adaptation measures. In this respect, despite the fact that neoliberalism implies a reduced role for the public sector, it is clear that there is a need for public sector support not only for enhancing farmers' capacities but also to ensure a more equitable distribution of resources and the sustainability of agricultural activities in the case study regions.

An integrated model was developed including climatic and socioeconomic variables (Gay et al, 2005), which showed that the coffee production in the central region of Veracruz was based in areas of optimal climatic conditions, therefore small changes in these variables can imply decreases in coffee production. The model also showed that the most important economic variable was the minimum wage. Future changes in climate or/and economical conditions could greatly worsen the situation.

Capacity building outcomes and remaining needs

This project was designed to initiate, in the regions of study, a process in which issues of climatic change, variability and extreme events are given new consideration in the development of sector policy. This was accomplished through raising awareness among appropriate sector agencies and stakeholders of the importance of these issues through outreach efforts, and motivating support for the contributions of scientific research in decision-making. Not only did our project reinforce the development of innovative research methodology and interdisciplinary collaboration among the region's academic institutions, but we also evaluated the particular factors that make each region vulnerable, and provided a forum for dialogue on how this vulnerability could be reduced through adaptive strategies. Building the regional capacity to sustain this dialogue in the academic community is a critical component of this project. Climate change research is relatively new in both countries, and as yet there are only a limited number of experts to address a wide range of concerns and issues. This research has depended on the substantive contribution of at least ten graduate student researchers in Mexico and Argentina. By providing funding and research experience for students who participate, our interdisciplinary project has broadened the intellectual basis for debate on climate change policy and planning in both countries, as well as contributed theoretically to climate research in Latin American countries.

In Veracruz, for the climatic component of the project, students from the University either completed or began their thesis on the topic: two bachelor students (meteorology) completed their thesis, one master student (geography) also completed her thesis and will begin her PhD with us (two more master students utilized the climate change scenarios proposed by the AIACC team), and two students started began PhD thesis (geography). Dr. Adalberto Tejeda, Dr. Carlos Gay and Dr. Cecilia Conde were or are their tutors. All of them have related their results to the possible impacts of climate variability and climate change in Veracruz. In UNAM, one masters student (geography) and one bachelor's student (biology) have completed their thesis. This is very relevant for capacity building, since there is now a "critical mass" of young scientists in the state and in UNAM that will help to develop further research in the region, and become part of a network that will collaborate on one ongoing project and submit future research projects.

In Tamaulipas, one geography student completed his social service and is now writing his bachelor's thesis, similar to the case of another bachelor's student in biology. One PhD student (geography) will complete her PhD thesis in 2007. No students in Tamaulipas developed their thesis during this AIACC project. Dr. Gerardo Sánchez and researchers in UNAM have agreed to include two students in one ongoing project and to submit another project to create a stronger research team in the region.

No researchers in the social area (such as Dr. Tejeda and Dr. Sánchez) were involved in the AIACC project. No students from these areas were involved in the research team with the academic output of a thesis.

Future research will involve more social scientists and regional experts. Also, the submitted or accepted ongoing projects are now focussed on adaptation measures, and are "stakeholder driven". New funds and a stronger research network must be developed to accomplish these purposes.

In Argentina, the Project supported the masters thesis of highly qualified students; three are in the writing phase and are expected to be presented this year. Two undergraduate students' thesis were also supported. About seven undergraduate and graduate students with different backgrounds (economists, social workers, agronomists, geographers, etc.) made meaningful contributions to the project by creating and completing the project database, surveying farmers and other stakeholders, collecting and processing information from different sources, participating in field work activities, etc.

The involvement of different stakeholders (farmers, farmers' organizations, grain dealers, city mayor, city council, etc.) and mass media support for the project activities resulted in a broad diffusion of information on climate variability and climate change issues in the region creating a fertile and collaborative environment for the development of the project. Continuous reinforcement of these relationships (through workshops, conferences, brochure, booklets, web site, etc) would be necessary to improve current adaptive capacities and enhance future adaptation to climate variability and change in the region.

National communications, science-policy linkages, stakeholder engagement

Local workshops with different stakeholders were organized during the project to present project goals, methods and to share perspectives and empirical knowledge that could be used to determine new research foci. These workshops fed into the ongoing collaborative discussions between the Argentinean and Mexican research teams to continually refine and improve upon the project's research agenda. Through our discussions of results with both policy makers and stakeholder groups (i.e., farmers, water user organizations), we developed practical applications in water and agricultural practices and policy. We have produced, collaboratively with stakeholder groups and governmental and non-governmental agencies in the regions of study, technical and information brochures to facilitate public education on vulnerability, climate impacts, and adaptation and to foster continued public support for climate change and variability research. Finally, our dialogues with stakeholders and policy makers allowed us to catalogue a number of possible adaptive strategies for addressing climatic uncertainty and risk, which, although specific to the regions of study, may provide the basis for action in other regions facing similar vulnerabilities.

For the Mexican case study, Carlos Gay and Cecilia Conde are currently involved in the research team that will elaborate the Third National Communication, and are CLA or LA in the Fourth Assessment Report for the IPCC.

In the two final workshops for policy makers in Tamaulipas and Veracruz, several decision makers agreed to participate in future research with us. In Tamaulipas, directives and researchers from the Mexican Institute for Water Technology (IMTA) agreed to use the methodology proposed by Dr. Gerardo Sánchez, the AIACC collaborator and coordinator in the region. This is to be developed in an ongoing project (CONACYT – SEMARNAT) that will focus more on adaptation measures. In Veracruz, Dr. Adalberto Tejeda organized the final workshop with the support of the Minister of Regional Development (Secretaría de Desarrollo Regional, SEDERE) and the participation of representatives of the Minister of Environment (SEMARNAT – Veracruz), regional farmer leaders, and directives and researchers from the University (UV) and the Center of Ecology (CE). Mainly, SEDERE, UV and CE agreed to support the ongoing project, focusing also on possible adaptation measures.

Farmers did not participate in the final workshops held in Mexico. The worst situation occurred in Veracruz, where coffee producers' leaders refuse to participate in the final workshop. It is clear that without a systematic and continued stakeholders involvement, misinterpretations of climate change information can be a "mal adaptive" measure. This situation was discussed in the final workshops and was taken as a lesson that must be learned for future projects.

In Argentina, the activities of the Second National Communication to the UNFCC were assigned to consultants, scientific groups or institutions according to an open bid and selection was based on scientific merits. We are not participating in the Second National Communication since the centre of Argentine (our research region) was not included in that assessment for the Argentina Government.

Policy implications and future directions

On a regional basis, the project results have launched future research (bachelor, master and PhD students are still developing their thesis using the methods proposed by this project). This has provided the basis for changes in the bachelor and postgraduate courses offered by the two universities involved in Mexico (Universidad Veracruzana and Universidad Autónoma de Tamaulipas) and in the Universidad Nacional de Río Cuarto in Argentina.

Several ongoing projects will enable the continuation of this project's efforts. One of the projects is now being supported by the Minister of Environment (SEMARNAT) and by UNAM. The new features in that project are mainly supported in the Adaptation Policy Framework (APF, Lim, 2005). Particularly: a) the scope of the project is guided by stakeholders' needs, b) policy makers are involved and will monitor the possible achievements c) focus groups and workshops are programmed and decided along with the key stakeholders, d) new methods for climate scenarios (i. e. downscaling) are being developed and are a part of the thesis stated above, e) all students (from climate and social areas) must participate and present their research to key stakeholders and include that feedback in their thesis.

Two specific projects have been submitted (one approved) to be developed in Tamaulipas and Veracruz. The first one, (Sánchez, et al, 2005) will address current and future availability of water in the southern region of Tamaulipas and possible adaptation measures, using climate change scenarios to project future conditions and involving regional decision makers.

The second project (Castro et al, 2005; accepted), will be developed in the central region of Veracruz, and will focus on analysing and developing "environmental services" as a possible source of adaptation. Also, forests sources and sinks of CO_2 will be studied, as part of a larger project for carbon sequestration. Finally, the results of this AIACC project will be included in the Mexican Third National Communication to the UNFCCC.

The development of the Project in Argentina helped, on a regional basis, to increase awareness about climate change and climate variability and their impacts and to create consciousness at the institutional level. The capacity building created through this project set the Universidad de Río Cuarto as a reference institution for other institutions, organizations or individuals working on this topic in the region. A couple of new interdisciplinary research projects are being discussed and designed to be submitted for funding during the present year in order to continue with the lessons learned from this AIACC Project. Discussion has also been initiated with researchers from two universities from nearby provinces to develop a network for permanent research, knowledge exchange and adaptation practises and experiences about climate change issues. New research pathways are being undertaken through collaboration with different stakeholder associations.

In addition the debate initiated in society through the project outcomes resulted in an increase in the solicitations to the government for the design of new infrastructure to deal with floods in the south of the area. New policies and regulations need to be developed to face increasing environmental risks in the area; the outputs of this Project will help to provide technical support to develop and implement these measures.

1 Introduction

1.1 Research Problem and Problem Context

The capacity of particular sectors to adjust to changes in climatic parameters depends in large part on the specific political, economic, institutional and biophysical factors that structure economic activities (IPCC, 2001a). Our understanding of the capacity of agriculture to adapt to climatic change has been constrained by the limitations of crop and climate models in accounting for the full complexity of changing social circumstances in agricultural decision-making. Recent case studies of agricultural adaptation have illustrated that non-climatic factors are often more determinant of individual farmers' strategies than climatic factors, throwing into doubt assumptions that farmers will necessarily and autonomously respond to climate signals and pursue optimal strategies –see, for example, Brklachich et al., 1997. This obvious conclusion lead us to search for a method that will partially aid us to explain the relative weight of social, economical and climatic "stressors", visualizing the history of climatic extreme events, and relating them with the actors, responses and barriers to the possible actions that could be taken, given one of those events. Thus it is critical to understand how the specific social and environmental context of production influences strategic choices of farmers, and why some farmers and some farm systems may be more prepared to adapt to climatic changes than others.

In this project, we have studied how different types of farmers in Mexico and Argentina are adapting to multiple uncertainties originated, on the one hand, from a possible increase in the frequency, intensity and or duration of extreme climatic events, and, on the other, from dramatic socioeconomic changes associated with the embrace of neoliberalism in the Americas. While farmers in both countries are being exposed to similar processes of economic globalization in contexts of high climatic threats, these processes have been translated into distinct national and sector policies. By explicitly addressing how farmers' strategies reflect not only climatic changes, but also privatization and decentralization of agricultural and water institutions, new price regimes for inputs, products and services and increased resource competition, we aimed to illustrate how broader economic and sector polices affect adaptation capacities, and how policy can better address climatic risk to facilitate adaptation (IPCC, 2001a).

1.2 Broad Objectives of the Research

Using selected farm types as the unit of analysis, our main objective to answer to following research questions: How are broad-scale socio-economic processes of change in Mexico and Argentina, translated into region and sector-specific policy and institutional reforms, affecting the vulnerabilities of different types of farm systems and their capacities to adapt to climatic adverse events? What are the implications of particular agricultural and water policy reforms for the production strategies of different types of farmers, and what is the significance of these strategies in terms of enhancing or diminishing the vulnerabilities of farmers to climatic risk and their capacities to adapt to such risk? How can existing water and agricultural institutions and decision-makers make better use of climate research? How can adaptation capacities be enhanced within the context of current policy trends?

1.3 Importance of the Research

The importance of this research can be seen in three main features:

- Capacity building: National an bi-national network of researchers and students dedicated to vulnerability and adaptation to current and future climate.
- Stakeholder involvement. Stakeholders were included in decision making during the process of the research, mainly in Argentina and in Tamaulipas, Mexico. .
- New methods were developed to address climate change and climate variability, and to assess current and future vulnerability. Those methods have been described in published or submitted articles, will be included in the Mexican National Communication and are being cited in the Fourth Assessment Report of the IPCC.

1.4 Main Components of the Research and their Relation to Each Other

The main components of the research were climatic and social studies, surveys and in depth interviews related to climate were contrasted with observed climate and trends. Climate risk spaces were used to "integrate" the possible research questions: which were the major climatic extreme events? What were their effects? What actions did the main actors in the regions developed? Why, if the climatic conditions were normal, high impacts were detected in the past?.

1.5 Main Characteristics of the Case Study Areas

1.5.1 Mexico

Based on the main research problem and objectives of the global project, two case studies in Mexico were selected to apply the research methodology to evaluate the vulnerabilities of different types of farm systems and their capabilities to adapt to climate change. The characteristics of these two cases studies were: (1) a small-scale, export-oriented (coffee) case study in the State of Veracruz, and (2) a large-scale, diversified (grains and livestock) in the irrigated southern region of Tamaulipas, Mexico (Sánchez et al, 2005)[1]. .

Agriculture is an important economic activity in the state of Veracruz, generating 7.9% of the state's GDP and providing jobs to 31.7% of the state's labor force (Gay *et al*, 2005). In 2000, coffee production was developed in 153,000 hectares, and involved 67,000 producers; also, 95% of the coffee produced was exported, with a production value of 151.1 million dollars (Informe de Gobierno, 2001).

Veracruz is the second largest coffee producer in the country. Coffee plantations in the state are relatively recent, becoming an important agricultural activity until the 40's and 50's decades, particularly due to the good prices after the Second World War (Bartra, 1999). Until the eighties, governmental policies favored an increase of nearly 75% of the production and a duplication of the number of coffee producers in the country, most of them with plantations of less than 10 Ha. Currently, most of those coffee producers are suffering the consequences of the 1989 – 1994 "megacrisis" (Bartra, 1999) of coffee prices, situation that prevails until today. Since that period, international prices of coffee have been decreasing, the coffee market is saturated with production (stocks of coffee are high), and Vietnamese coffee is being imported to Mexico. Even though the quality of that coffee is very low compared to the Mexican product, it is preferred by industries of processed coffee (Nestlé, for example). These conditions have exacerbated poverty in the state: in the year 2000 about half of the municipalities were classified as under very high and high poverty levels[2].

Veracruz (Fig.1.1) is one of the largest states, located in the Gulf of Mexico, between Tamaulipas and Tabasco. The region under study is situated in the central region of the state of Veracruz, between 18° 30' – 20° 15' (north latitude) and 95° 30' – 97° 30' (west longitude), within a surface of 183,600 km^2 (Palma, 2005) and with high altitudes where coffee production is developed in almost optimal conditions, so that this region contributes to 90% of the total state production (Araujo and Martínez, 2001).

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[1] Case Study: Municipality of Gonzalez, Tamaulipas, Mexico. Final report written by Gerardo Sánchez Torres Esqueda, Rocío Vargas Castilleja, Graduate Division, School of Engineering Universidad Autonoma de Tamaulipas. Tampico-Madero University Campus. 89339 Tampico, Tamaulipas, México (Climate scenarios used were based on the results presented in the final workshop by Cecilia Conde).

[2] Consejo Estatal de Población, Xalapa, Veracruz (http://coespo.ver.gob.mx/boletin11dejulio.htm,).

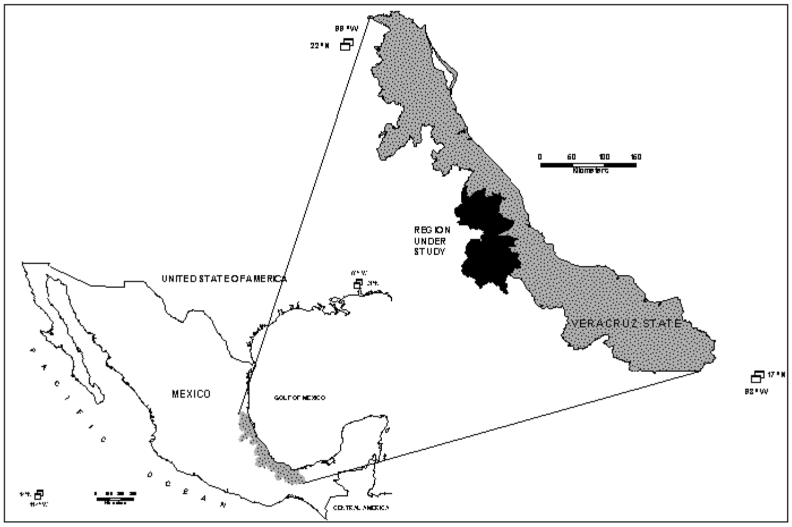


Fig. 1.1: The state of Veracruz and the region under study. Locations described here situated 1000 and 1500m above the sea level. (Elaborated by R. Araujo).

The analysis of climatic data has lead to the conclusion that the central region of Veracruz can be analyzed as a single region, considering that the precipitation and temperature regimes (dependant of altitude) are similar in some of the counties or *municipios* (Douglas, 1993[3]; Palma, 2005). This fact simplifies the climatic studies, and was also useful for the development of climate change scenarios.

For Tamaulipas, the region under study is situated in the southern region, between 22° 3′ and 23° 2′ (north latitude) and 99° 2′– 98° 2′ (west longitude), The main county analyzed was Gonzalez, located northwest of the urban area of Tampico-Madero-Altamira (Fig. 1.2).

[3] Arthur Douglas (1993) criteria for establishing regions in Mexico are: "1) similarity in slope aspect and station elevations, (2) minimum data recovery of 95% for the period 1947-1988, and (3) climatological rainfall totals (annual) within 20% of the area-wide mean". These criteria where applied by Palma (2004) and Bravo (2005) to study in more detail climatic regions in Veracruz, also validating the series of data in each station.

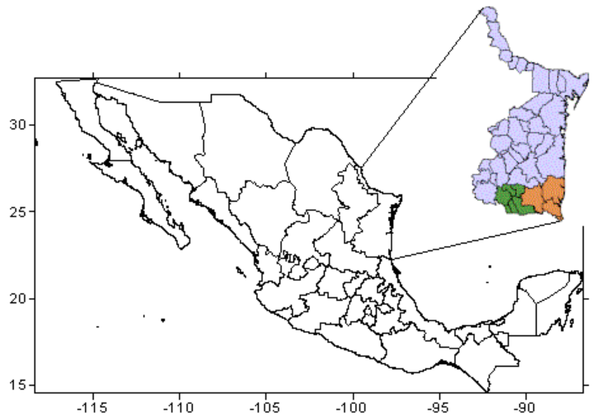


Fig. 1.2: The state of Tamaulipas and the region under study. González and Mante counties.are highlighted

The main economic activities in the Gonzalez case study area are agriculture and livestock. Several kinds of crops are produced in this area, being sorghum, safflower, maize, grass and soy the most common crops. Water resources were analyzed for the region by Dr. Sánchez (Sánchez et al, 2005), with the cooperation of the state's institutional agency (IMTA).

During the 1980s and 1990s this region suffered the effects of the combination of the climatic events: El Niño Southern Oscillation (hot phase of ENSO) and La Niña (cold phase of ENSO). During a typical El Niño year, precipitation is less than average during summer and greater than average during winter, and during a typical La Niña year, precipitation is greater than average during summer and less than average during winter. The presence of these two climatic events in the study area during these two past decades affected the productivity of the crops and the corresponding income of the farmers.

Also, the changes in public policies and market conditions as a result of the ratification of the North American Free Trade Agreement (NAFTA) between Canada, the USA, and Mexico, had far more negative impacts, especially in the small farmers in Mexico, than the variability of the climate due to El Niño-La Niña interactions.

1.5.2 Argentina

Based on the research problem and objectives of the project, one case study comprising commercial farmers producing cash crops and livestock was selected in Argentina to apply the research methodology to evaluate the vulnerabilities of different types of farm systems and their capabilities to adapt to climate change.

The study area (Fig. 1.3) is about seven millions hectares of the half south of the province of Cordoba in Argentina. It is in the western portion of the "Pampas Region" of Argentina, located between 32º and 35º S latitude and 52º y 76º W longitude. The Cordoba province is in the center of the Argentina and ranked fifth in size among all the argentine provinces. Eighty three percent of its surface is dedicated to different agricultural activities developed under variable edapho-climatic conditions from soils with no limitations to others that can only allow livestock production. Cordoba contributes about 14% of the national agricultural GDP (Gross Domestic Product), 14% of the national livestock, 17% of the cereal and 25% of the national oilseed production. The agri-food and agro industrial systems are the most dynamics and important in the economy, representing 25% of the state GGP (Gross Geographical Product) (INTA, 2002). This province is the second largest maize producer in the country contributing about 32% of the total national production (SAGPYA, 2004).

The area of study is divided in departments (political divisions) and comprises the departments of Calamuchita, Tercero Arriba, General San Martin, Union, Marcos Juarez, Rio Segundo, Juarez Celman, Pte. Roque Saenz Peña and General Roca. The surface is flat except for a small range of mountains north-south oriented in the west of the departments of Rio Cuarto and Calamuchita. The representative soils in the east and in the south are the Mollisols. To the west of the region there is a predominance of sandy soils. An added advantage of the soils in the region is that they do not freeze in winter, making the tillage feasible the whole year around. Available soil water storage within 150 cm depth from the surface is in the order of 150 mm in the east according to the soil's texture. To the west of the region the soils have a lower water holding capacity. Water storage capacity is an important differentiating factor among the different types of soils, and even small differences can affect yield, particularly in crops such as corn, which are very sensitive to stress in particular stages of crop development. In the south and south east of the area there is a flood prone zone of poorly drained plains. Floods are cause mainly by excess rainfall in the flood-prone basin and by overflowing of rivers and stream that drain the runoff (Seiler et al. 2002).

From the climate point of view and given the small proportion of the area compared to the total extend of the agricultural area in Argentina, normal or mean values of the climate variables do not show significant gradients across the area. Climate classification is for a semiarid-sub-humid temperate area (INTA, 1987) with moderated thermal conditions during summer and winter. However, the absolute values of the climate variables, their time of occurrence, the extreme values, the seasonal variability, and their interaction with other physical variables of the environment, are very important to determine the potential production of the region, the year to year yield of the crops and pastures, the quality of the natural resources and the economy of the region. Temperature and water, are the most limiting climate variables for the vegetation and crop responses and yield, and also responsible for the variability in production in the region and the increasing agricultural risk. Temperature and water variability are also responsible for climate hazards such as frosts, heat waves, floods and droughts.

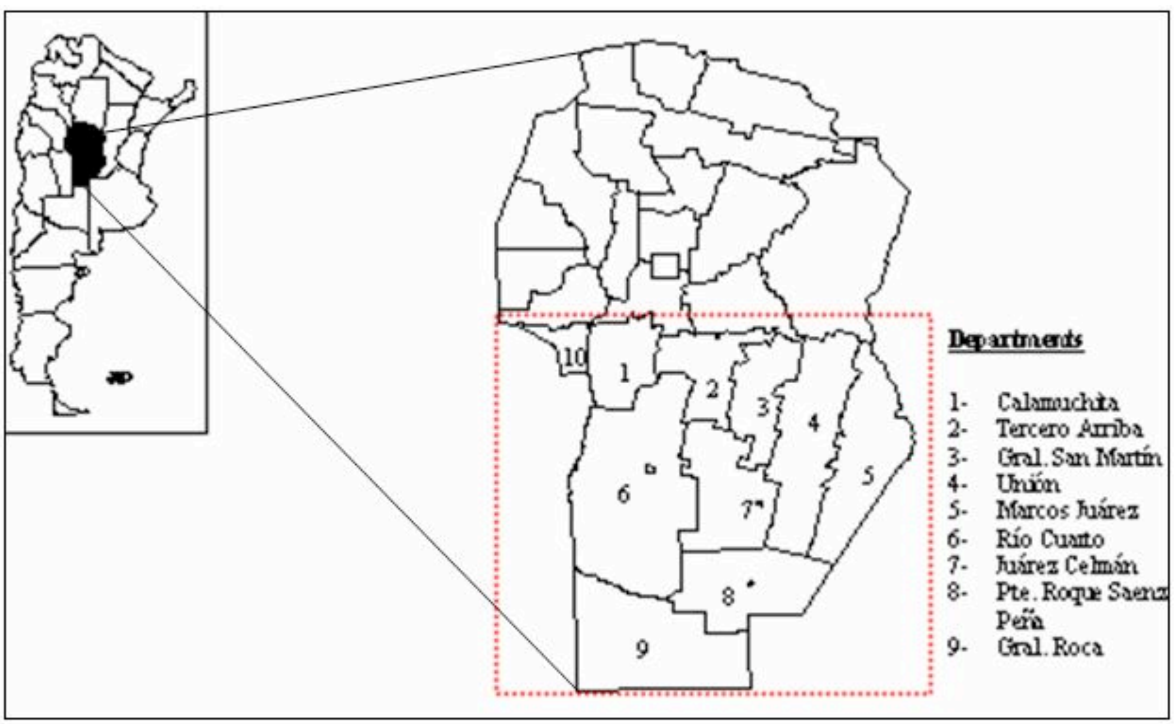


Fig. 1.3: Location map of the south area of Córdoba

2 Characterization of Current Climate and Scenarios of Future Climate Change

2.1 Activities Conducted

In previous research the participants of the AIACC project have worked with GCMs outputs to study the impacts of climate change (Conde et al, 1997; Vinocur et al, 2000a, Vinoucur et al, 2000b).

Basically, during the *Country Study: Mexico* project (1994-1996) simple interpolation methods were applied to generate climate change scenarios. In that study it was concluded that Mexico would be likely to experience higher increase in temperatures and hence higher evaporation rates in the northern part of the country with doubling of CO_2 (Gay et al., 1996; Gay et al., 1995). Statistical downscaling methods also indicated that summer rainfall might decrease in most of the country and increase during winter in the northern region (Magaña et al., 1997).

Results from five coupled general circulation models (GCMs) with doubling CO_2 indicate that the western and central regions in Argentina would experience increased temperatures and decreased precipitation during the summer (IPCC, 1998).

In contrast with those previous studies, the climate change scenarios constructed for this study have a better resolution, are coupled with ocean, include the socio-economic scenarios A2 and B2, were generated for two time horizons (2020 and 2050) and the outputs of several General Circulation Models that were chosen given the similarities between their 1961-1990 data with the observed ones. All of these characteristics are relevant to policy makers, but still the challenge to communicate the uncertainties associated to future climate persist.

The decision of the future socio-economic scenarios was taken between all the members of the working team, and the discussion was guided by the economist involved in the research. A more difficult task was to decide how to downscale the outputs of the GCMs to regional scales. We decided to continue with simple interpolations, but a simple program was made to help the "impact" researchers to obtain from the GCMs outputs those variables that were relevant for their work.

In this project we decided to propose a technique to include possible changes in climate variability. This issue is quite relevant for the agricultural sector, since climate variability is determinant for its activities, more than the possible changes in the mean values of the climate variables. Particularly, it was decided that if only changes in the means were communicated, it was possible that the key stakeholders considered that some future scenarios were not related to future risks. An effort was then made to discuss with them future climate variability, particularly the increase in the frequency, intensity or duration of the climatic events that were more worrisome for them. Even though there is no consensus in the scientific community in how this problem will be address, for the stakeholders in the region it is a major concern.

The climate characterization for both Countries was primarily undertaken through the following complementary activities:

- Compilation of time series of weather data for different locations in the study regions (Year 1, 2, 3)
- Regional analysis of historical data for information on weather events and agricultural and social impacts (Year 2, 3)
- Technical training on generation of future climate scenarios (Year 1, 2)
- Interview with key stakeholders in each region (i.e., academics, agricultural officials, politicians, farmer association representatives, merchants and traders, agricultural service providers, farmers of different scales). These interview provided information on climate impacts, public policy, empirical unpublished data and information, perspectives on institutional change and trends (Year 1, 2, 3)

- Workshops in each study region (with technicians in agriculture, agricultural officials, politicians, representatives of farmers associations, merchants and traders, agricultural service providers, farmers of different scales) (Year 2, 3).

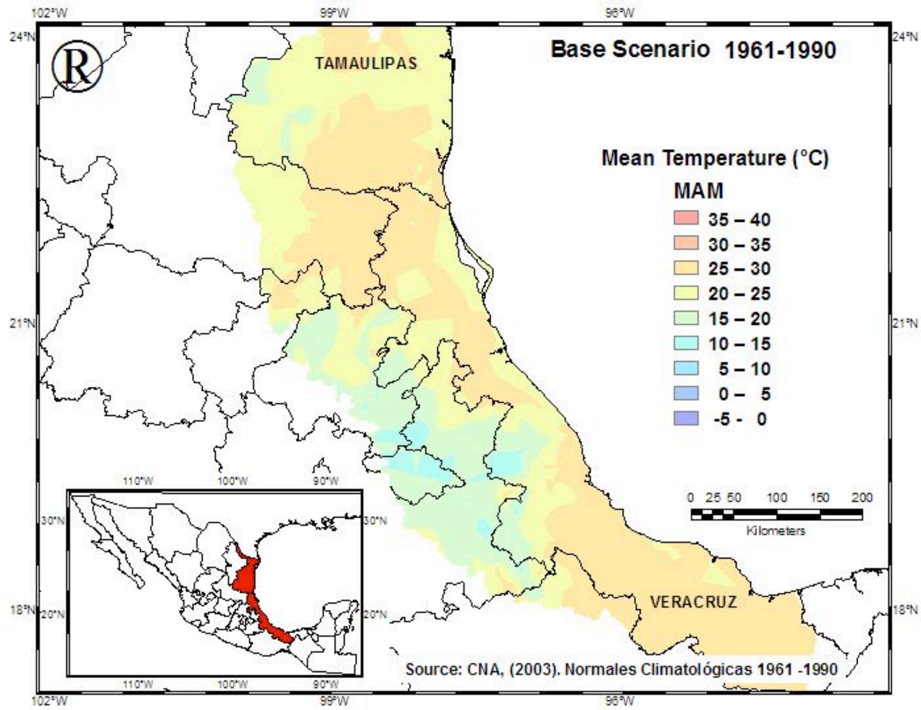
2.2 Description of Scientific Methods and Data

2.2.1 Climate base scenarios and data sources

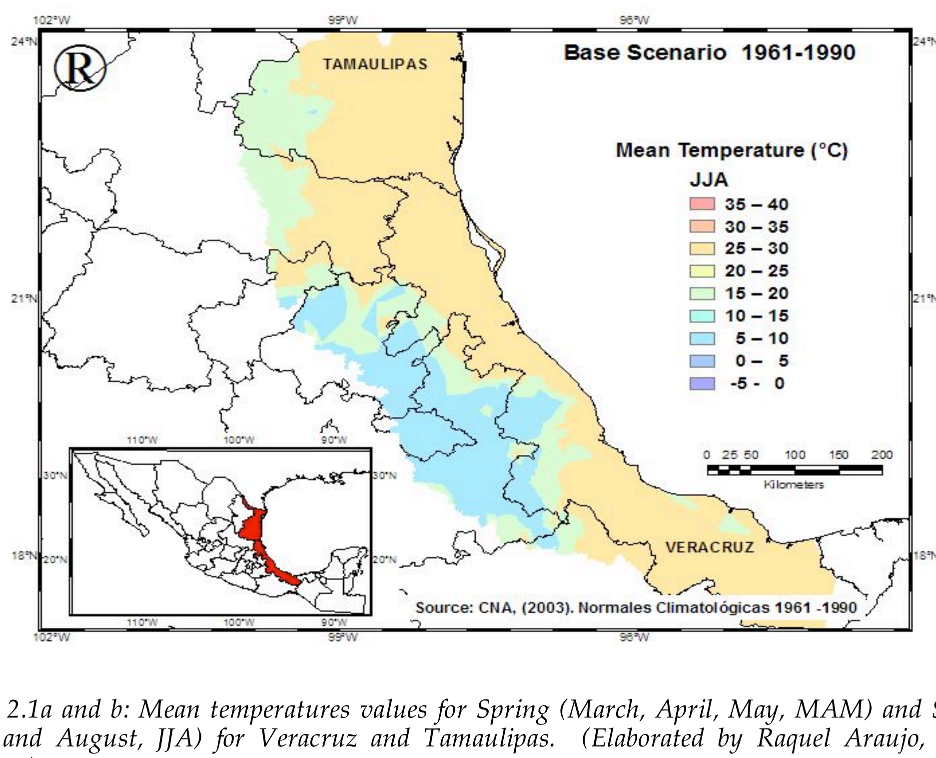
Climate base scenarios were constructed using the time series 1961-1990 (30 years) of the basic variables temperature (average, maximum, minimum) and precipitation. These baselines were used to address the possible impacts of ENSO events and also to generate climate change scenarios.

For the Mexican case study, given the fact that the two states under study are located in the Gulf of Mexico, the results are presented in the same maps for the seasonal averages for mean temperature (figures 2.1 a-d) and precipitation (figures 2.2 a-d), as examples of the work done.

2.1a

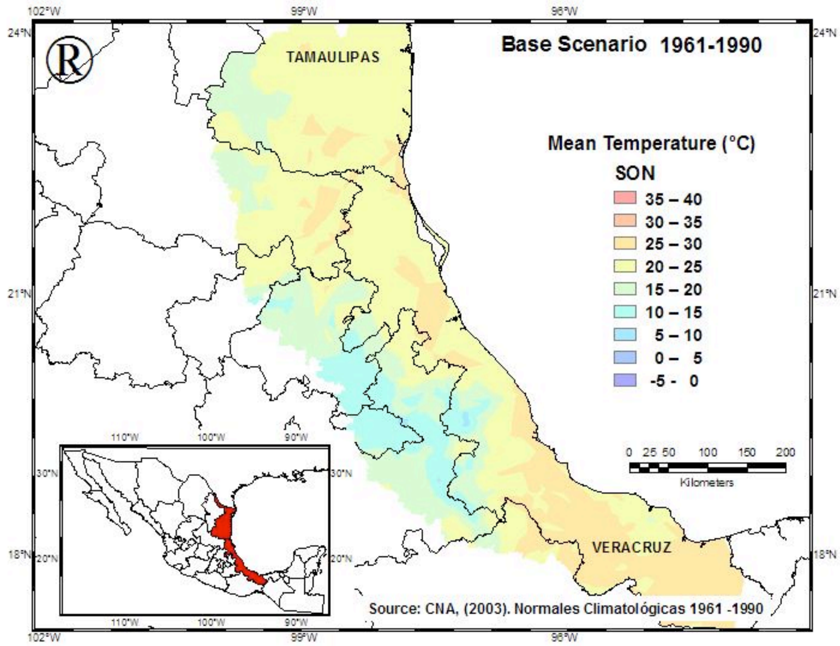


2.1b

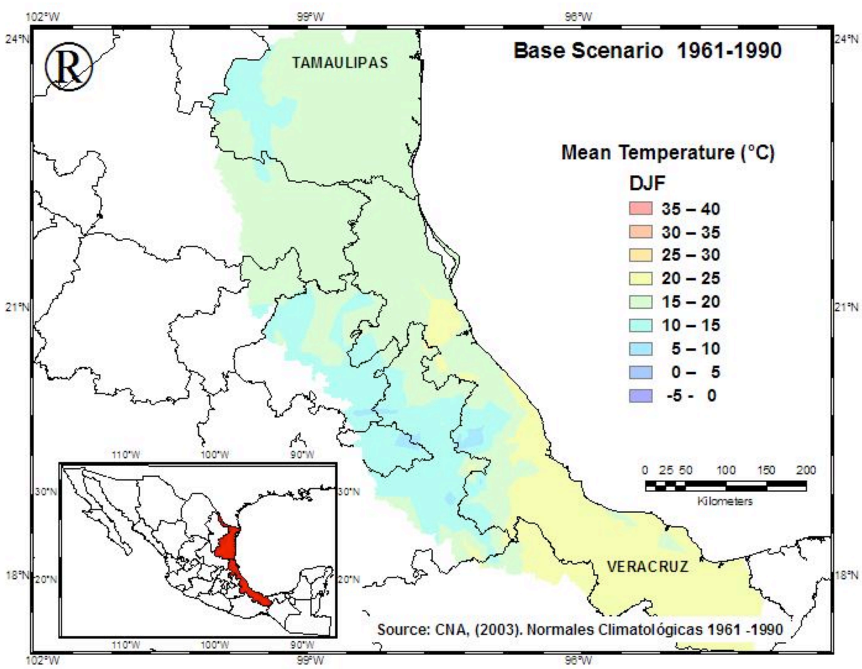


Figs. 2.1a and b: Mean temperatures values for Spring (March, April, May, MAM) and Summer (June, July and August, JJA) for Veracruz and Tamaulipas. (Elaborated by Raquel Araujo, AIACC mater student)

2.1c

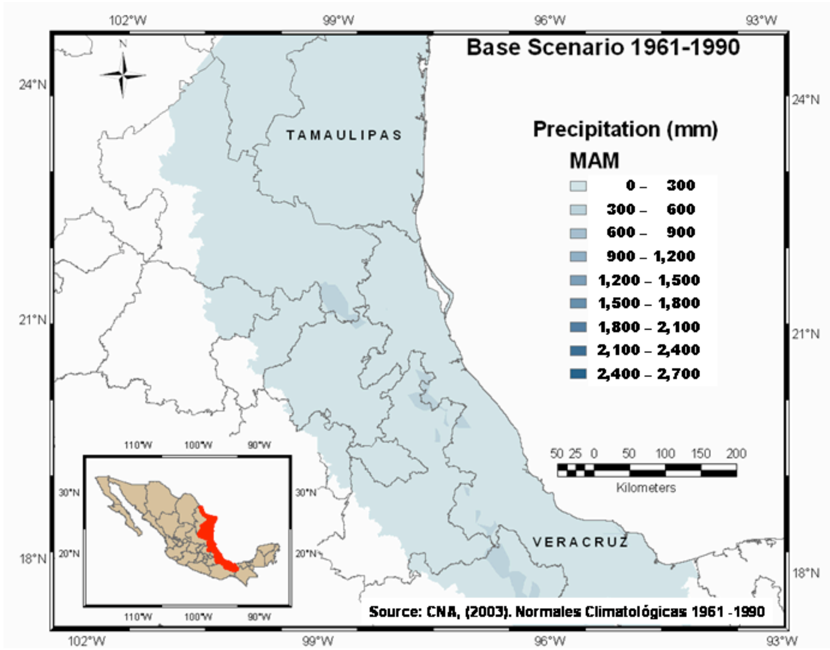


2.1d

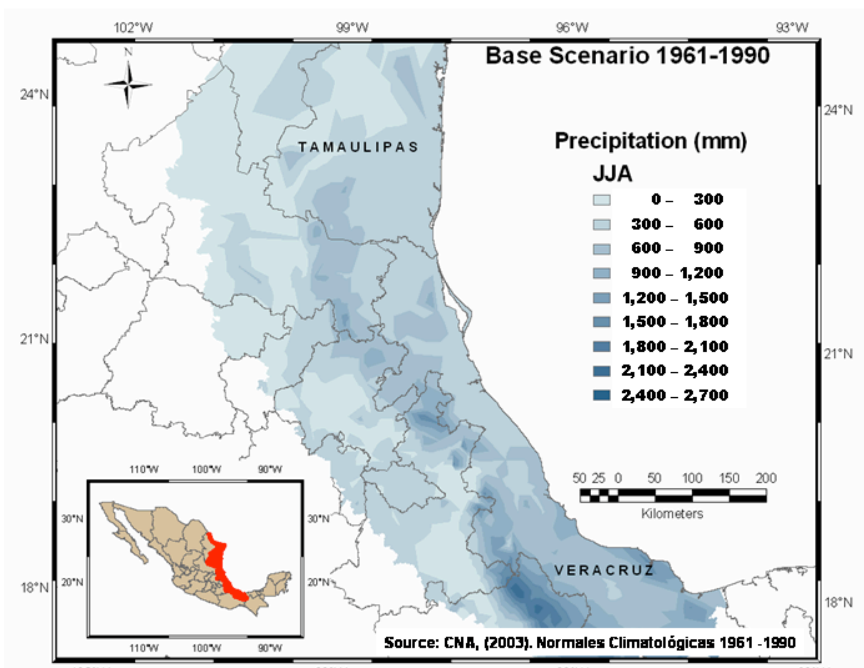


Figs. 2.1c and d: Mean temperature values for Autumn (September, October, November, SON) and Winter (December, January; February, DJF for Veracruz and Tamaulipas. (Elaborated by Raquel Araujo, AIACC mater student)

2.2a

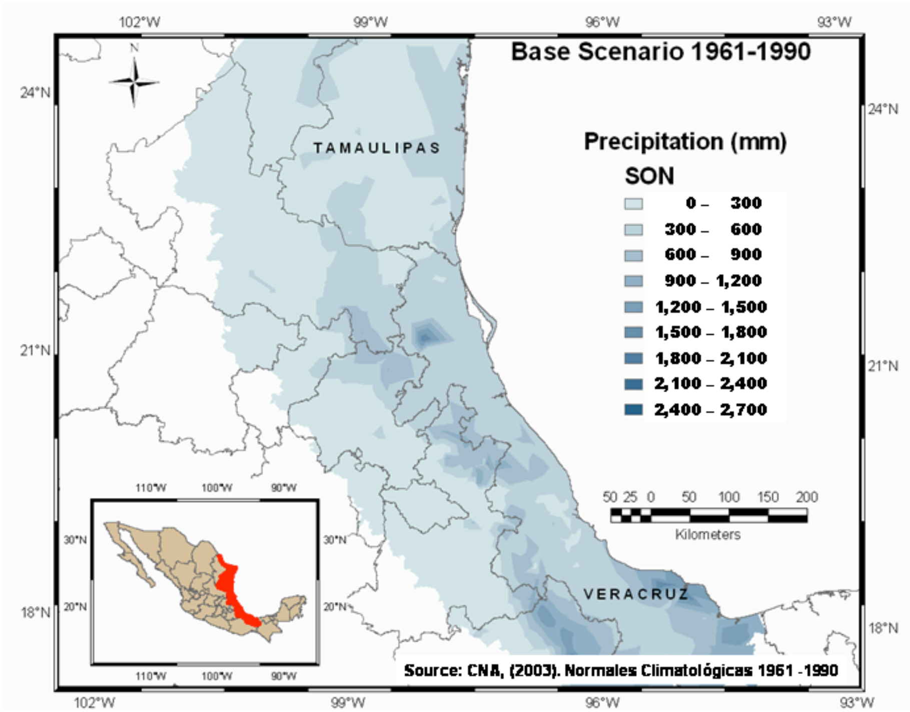


2.2b

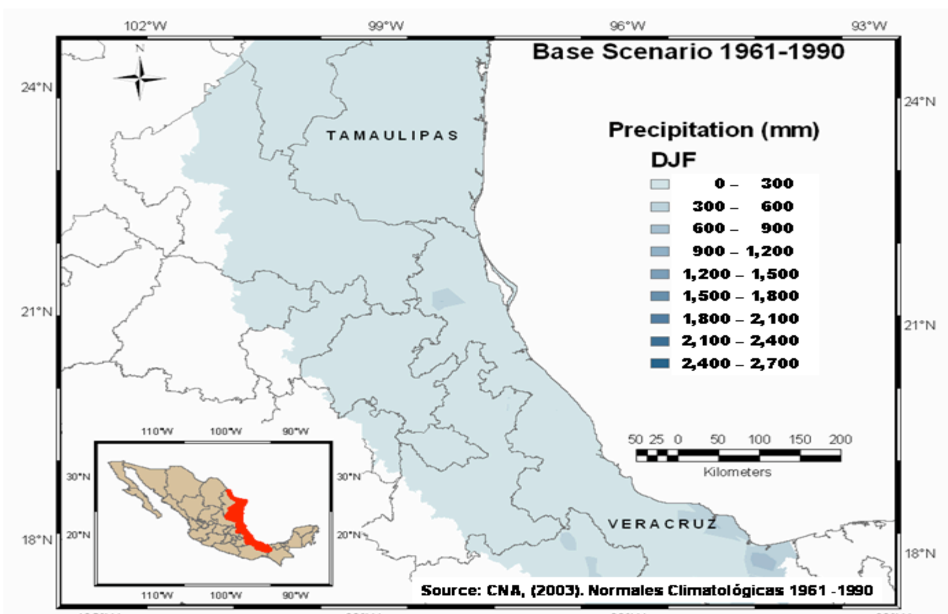


Figs. 2.2a and b: Mean precipitation values for Spring (March, April, May, MAM) and Summer (June, July and August, JJA) for Veracruz and Tamaulipas. (Elaborated by Raquel Araujo, AIACC mater student)

2.2c



2.2d



Figs. 2.2c and d: Mean precipitation values for Autumn (September, October, November, SON) and Winter (December, January; February, DJF for Veracruz and Tamaulipas. (Elaborated by Raquel Araujo, AIACC mater student)

For Mexico, the main data sources were the National Commission of Water and the National Meterological Service. Some of those data bases needed to be validated, given the high number of errors in their data bases (Bravo et al, 2006). Given this fact, the researchers and master students involved in this project needed at least one year to start the climatic analysis.

On the other hand, previous research (Douglas, 1993; Conde, 2003) showed that the Mexican regions under study could be in fact treated as single regions, which facilitated the analysis and also allowed us to use re-analysis data, particularly those included in the IPCC Data Distribution Center (http://ipcc-ddc.cru.uea.ac.uk/). These data supported our study related to climatic trends, but specific stations data were used for the study cases.

Since the study involved specific regional stakeholders, regional and local variables were more intensively used to develop this research. Thus, specific scenarios were also develop for the study cases.

For the central region of Veracruz, 37 years of climate date were analyzed to account for the relationship between temperature and daily extreme events of precipitation (Bravo et al, 2006). It was shown the ENSO influence in the characteristics of the Mid Summer Drought (MSD), increasing the total amount of precipitation, thus reducing the strength of this phenomenon.

For the southern region of Tamaulipas, 41 years of climate data were used to study the normal climate conditions and trends. It was observed a possible decadal trend in the precipitation data.

To communicate the results to regional experts and stakeholders, the climate threat spaces (Conde et al, 2006) was used to analyzed extreme events in the past, particularly those related to strong ENSO events.

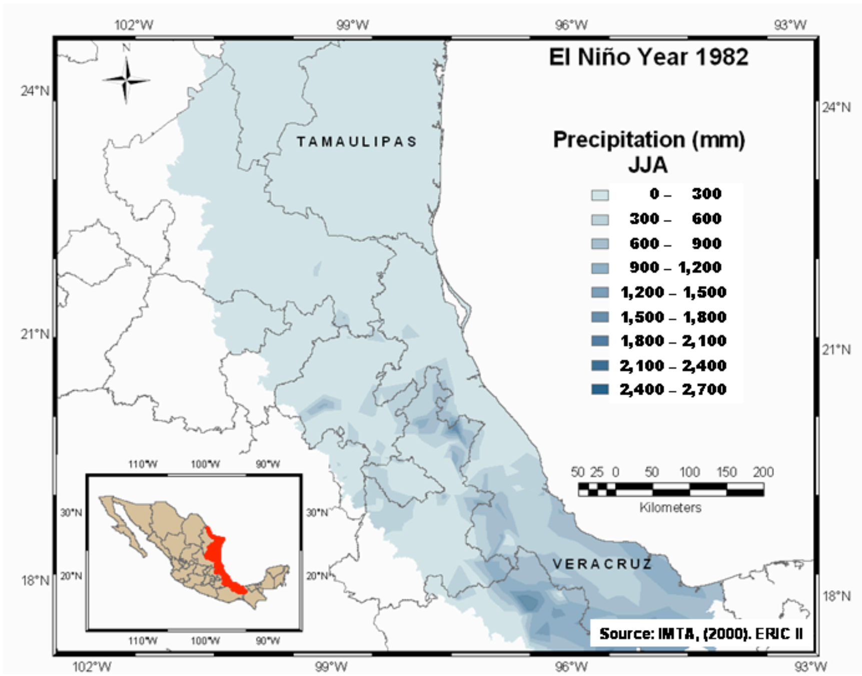
These climatic threat spaces (Conde, 2003) are constructed by means of seasonal or monthly scatterplots of precipitation and temperature, similar to those constructed for climate change scenarios (i.e., Hulme and Brown, 1998; Parry, 2002), but for climatic threat spaces, we focus first on current climate anomalies and we use one standard deviation or the interquartile range of the two variables to decide which years could be classified as normal years and which could be considered critical.

The use of the interquartile range is a more robust method than using the standard deviation, "since this range is generally not sensitive to particular assumptions about the overall nature of the data." Also, the interquartile range "is a resistant method that is not unduly influenced by a small number of outliers" (22; Wilks, 1995). We can then use this method without considering the shape of the data's distribution and also be sure that the extreme climatic events (outliers) will not influence the limits of the initial coping range for the analysis of climatic events. Using the quartile range leaves out the 50% of the distribution (25% in each tail) in which extreme values occur. To get a more precise description about the tails of the data, a crossed schematic plot can be used. This type of plot helps classify extreme values with respect to their degree of unusualness. According to Wilks (1995), the unusualness of an extreme value depends on the intrinsic variability of the data in the central part of the sample. If the quartile range is large, then a given extreme value is less unusual; on the other hand, if the quartile range is smaller, it is considered more unusual. Schematic plots classify unusual observations as "inside," "outside," and "far out," through the construction of inner and outer "fences". Crossed schematic plots provide an objective, robust, and resistant classification for extreme values of paired climatic observations.

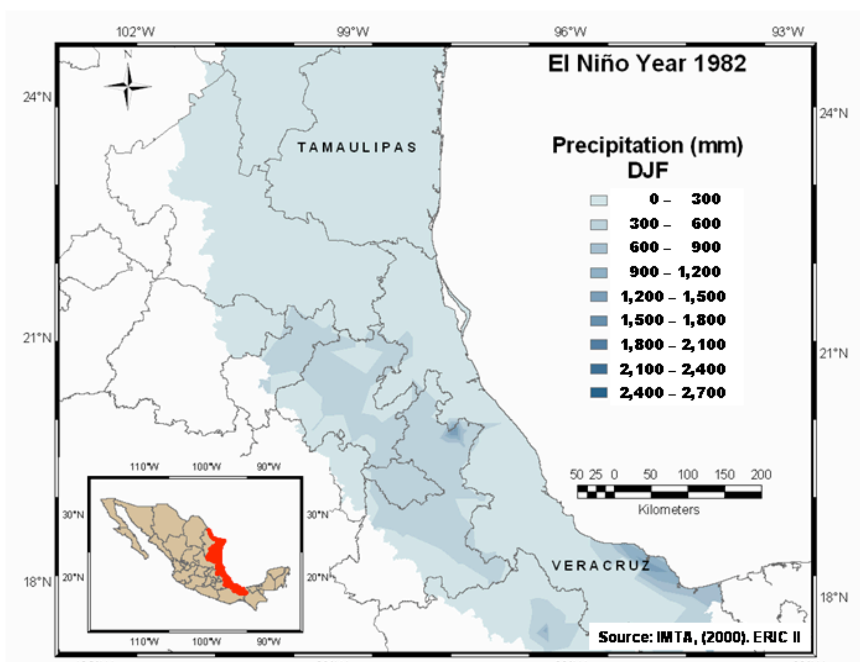
Strong ENSO events have modify climate conditions in the two countries involved in this project.

For the Mexican study cases, changes in rainfall patterns were observed during the strong El Niño events (1982-183, 1997-1998) and for example during the strong 1988 – 1999 La Niña event. Almost in all the Mexican territory severe droughts have affected the agricultural activities during strong ENSO events (Magaña et al, 1999, Conde et al, 1999). As examples of those events, in figs. 2.3a and 2.3b summer and winter conditions are shown for the Gulf of Mexico, which includes Veracruz and Tamaulipas. Compared to the base scenario (figures 2.2b and 2.2d) it can be clearly seen the drought conditions over an extended area during summer (particularly for Tamaulipas and the central region of Mexico), and an important increase in winter precipitation during winter. However, during the Mid Summer Drought period (July or August, depending on the region), this study has shown that there is an important increase in precipitation that weakens the MSD event.

2.3a



2.3b



Figs. 2.3a and b: Summer precipitation values for the Gulf of Mexico and winter precipitation values for the Gulf of Mexico respectively.

More specific details of normal climate conditions, ENSO effects and climate extreme events were analyzed for the specific study sites in the study cases presented in the next chapters.

2.2.2 Climate change scenarios

Climate change scenarios were constructed using the Model for the Assessment of Greenhouse Gas-Induced Climate Change and a Scenario Generator (Magicc/Scengen Model; version 4.1) (Wigley, 2003; Hulme et al., 2000). The outputs of three general circulation models (GCMs) obtained from Magicc/Scengen were used: EH4TR98, GFDLTR90, and HAD3TR00, considering the two emission scenarios A2 and B2 (Nakicenovic et al., 2000; Intergovernmental Panel for Climate Change (IPCC), Working Group III, 2001), and for the years 2020 and 2050. These combinations were selected to introduce the uncertainties associated to climate change in the future. This important issue is quite controversial and difficult to communicate to stakeholders, specifically for those interested policy makers, who specifically find difficult to understand the two possible outcomes for precipitation (increase or decrease, with similar probability to occur).

Simple interpolation methods have been applied to obtain the possible changes in the mean temperature and precipitation values for specific locations and regions (Sánchez et al., 2004; Palma, 2005). Particularly for the study case in Veracruz, a downscaling technique was applied to enhance the resolution and results of the climate change scenarios (Palma, 2005).

Changes in temperature and precipitation obtained from the outputs of each model were introduced into the climatic threat spaces (Conde et al, 2006) that were constructed to assess current vulnerability, in order to visualize possible future climatic threat conditions and to analyze future vulnerability to climate change. When the anomalies for both variables are outside the limits of the coping range defined above, the climate scenario is considered to increase importantly the climatic threat and therefore is relevant in terms of assessing vulnerability and for developing adaptation strategies for the agricultural activities in the region.

The above does not imply that the other climate change scenarios with values within the coping range should be discarded in the future threat analysis. The changes obtained from the climate change scenarios only relate to changes in the means of the variables, and consideration should be given to the distribution (variability) of the mean. A simple approach to visualize the possible changes in variability is to suppose that the other parameters of the distribution of the data will not change and the distribution will be transposed to the new mean without altering its shape. The changes in the frequency of extreme events can be used to describe the possible increase in climatic threat. Another approach to include variability in climate change threat spaces is to draw schematic plots constructed with observed data around the future mean value, providing a plot of future minimum, lower quartile, median, upper quartile, and maximum. Therefore, the probability of having climatic events outside the coping range of a given crop (or activity) can be estimated. Although these methods are based on the assumption that current and future variability are the same, they can provide a rough scenario of future variability that can be helpful for stakeholders and decision makers to visualize that, although the new mean can still be inside the coping range, a large part of the distribution can turn out to be outside. This is an important issue in the climate threat spaces, since it is helpful to communicate uncertainty. The increase or decrease in the mean values of a climatic variable those not imply that the extreme events of the “oppose” tail in the distribution are negligible for a risk assessment.

Further analysis should be made to consider the possible changes in climatic variability associated with the change in the climatic means and changes in extreme events.

2.3 Results: Tamaulipas, Mexico Case Study

2.3.1 Impacts and vulnerability

The Tamaulipas study case focus initially its attention to the agricultural sector. Several ungraduate, master and PhD students in the project are applying crop models to achieve the possible impacts of climate variability and change. This was a challenge at the beginning of the project, since the major and more important crops in the Southern region of Tamaulipas were not included in the programs available to the researchers involved and was not included also in the initial project protocol. Various workshops were developed for this purpose, and finally the use of CROPWAT (*Crop and Water Tool*; FAO, 1998), was decided. Preliminary results show important decreases in the yield of most of the crops analyzed, particularly those related to maize, but also for sorghum and soy. One purpose of our future research is to decide which crops might be planted, and in what proportion, in the same field.

Given the importance of irrigation in the region – which is a requirement in the CROPWAT model, and also because the expertise of the researchers in the project, the study of the hydrological current and future conditions was incorporated in the AIACC project.

The characterization of the climate scenario for the period 1961-1990 in the Gonzalez case study area is shown in figure 2.4 This was the basic climate period considered for establishing climatic anomalies and climatic tendencies in the study area. It is seen in the figure that the average annual climate conditions show that maximum temperatures and the rainy season take place during summer season, and the minimum temperatures and dry season take place during winter season. Thus, maximum temperature is about 35 degrees Celsius during the month of June, and minimum temperature is about 12 degrees Celsius during the month of January. The rainy season takes place from June to October, being June, July and September the wettest months of the year, and February the driest month of the year.

In figure 2.5 it is shown the time series of the average temperature in southern Tamaulipas for the months of June-July-August for the period 1901-1995. Based on these records, the average summer temperature for this period was 27.3 degrees Celsius, with a standard deviation of about 0.6 degrees Celsius. However, it can also be seen that from the 1970s the temperature showed a greater variability between cooler and warmer years. Also, it is shown that during the late 1970s and early 1980s, and again during the late 1980s and early 1990s the temperature during summer time was higher than the average plus a standard deviation. Those two periods corresponded to drought conditions in the study area of Gonzalez, Tamaulipas.

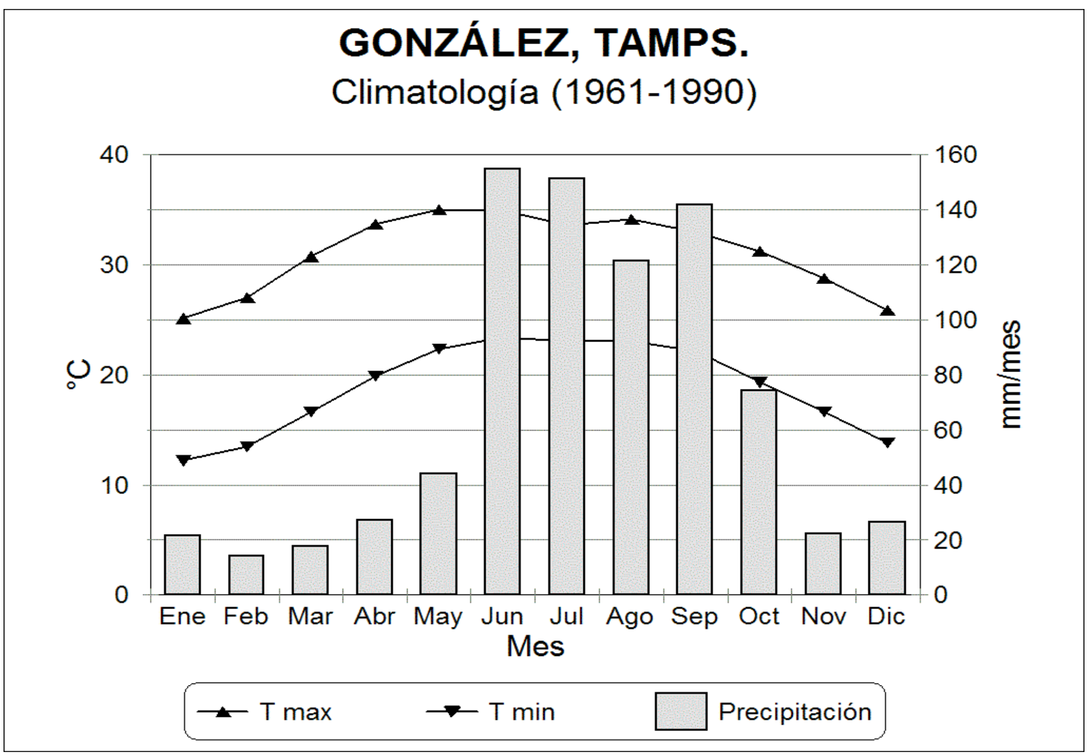


Fig. 2.4: Climate scenario of Gonzalez, Tamaulipas. Period: 1961-1990

Figure 2.6 shows the average daily precipitation during summer time in the case study area for the period 1901-1995. The average daily precipitation was 3.85 mm per day, with a standard deviation of about 1 mm. Looking closely at this figure, it can be seen that before 1970 there were more years with a precipitation about normal and less than normal, but after 1970 the precipitation started to show greater variability with very wet years in the early 1970s and very dry years in the early 1980s. In terms of total annual precipitation, see figure 2.7, for the period 1945-1995 it is shown that the southern Tamaulipas region is getting more rainfall. These data were obtained from the IPCC Data Distribution Center, since longer series of climate variables were needed to discuss possible trends.

Therefore, one conclusion that can be stated at this time is that there is less rainfall during summer time and more rainfall during winter time, with a greater variability between a wet and dry year, and also with a greater total annual rainfall depth. Figure 2.7 shows this increasing pattern of total annual rainfall in the case study area of Gonzalez, Tamaulipas.

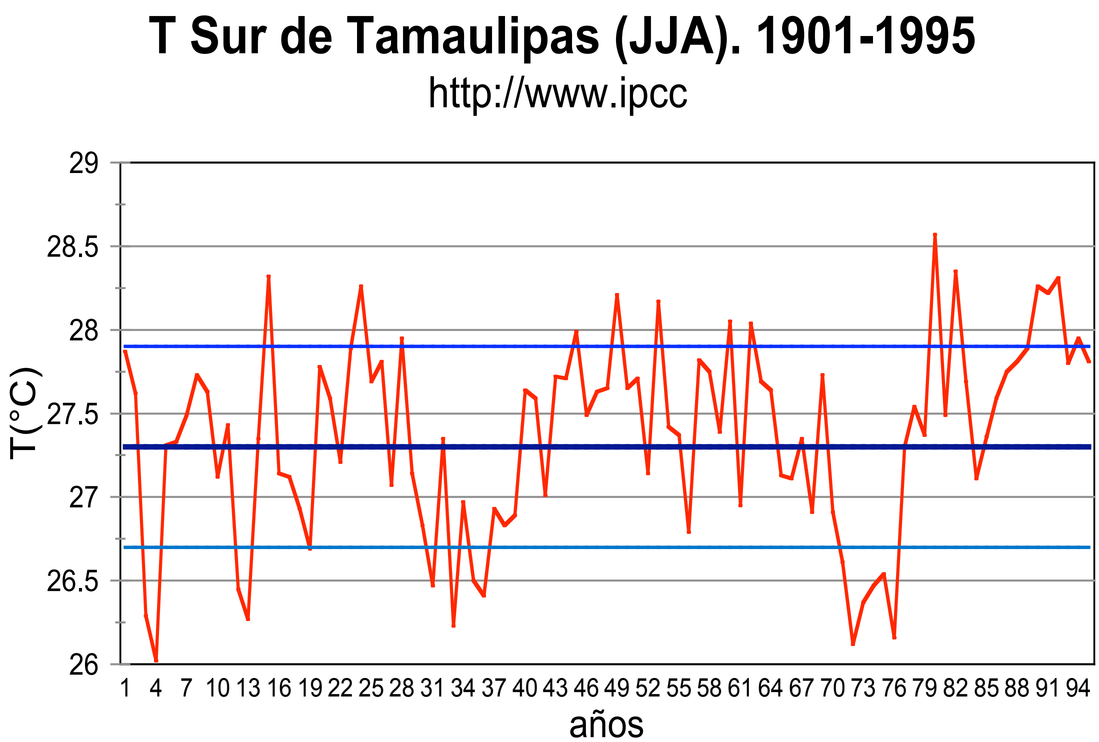


Fig. 2.5: Average summer temperature in southern Tamaulipas. Period: 1901-1995

Figure 2.8 shows the behavior of precipitation during spring time in the Gonzalez, Tamaulipas, study area for the period 1961-2001. This figure clearly shows the decreasing pattern of precipitation during spring time in the case study area. Therefore, based on the information shown on figures 2.7 and 2.8, it is clear that the conclusion stated above, regarding the decrease of rainfall during spring-summer time and the increase of rainfall during winter time, is correct.

These changes in the temperature and precipitation patterns in the Gonzalez study area are extremely important for the local farmers because they will have to adapt to these climatic changes in order to keep their farm business running without major setbacks.

In the years to come farmers will depend more on climate forecast, especially on issues related to climate patterns, extreme events, start of rainy seasons and rainfall distribution along the growth of crops. However, adaptability to climate change by farmers is not the only issue to consider when dealing with the consequences of climate change. Adequate public policies established by the national governments will also be extremely important for dealing with climate change.

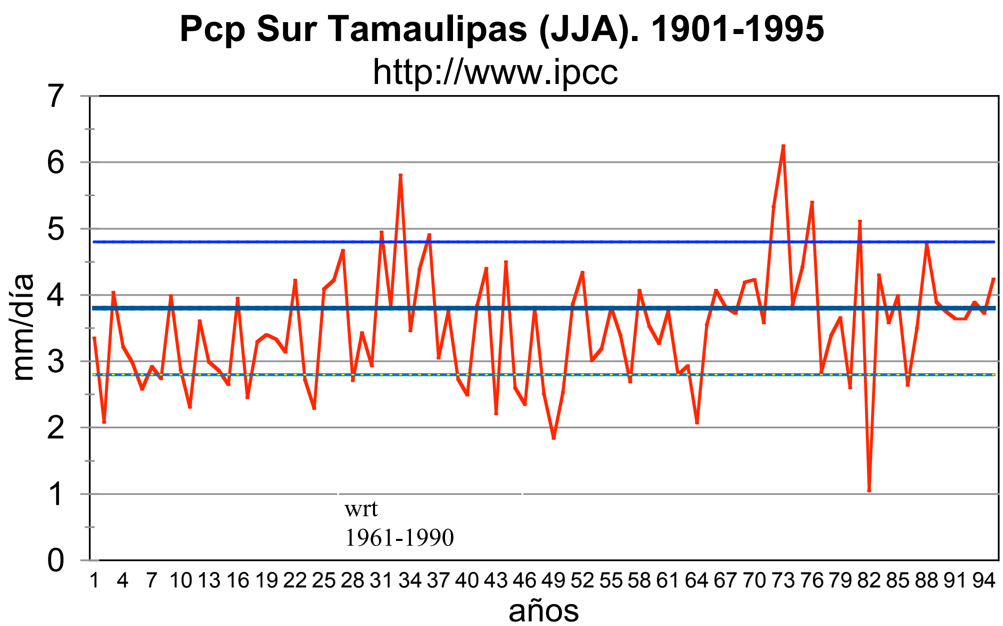


Fig. 2.6: Daily average summer precipitation in southern Tamaulipas. Period: 1901-1995

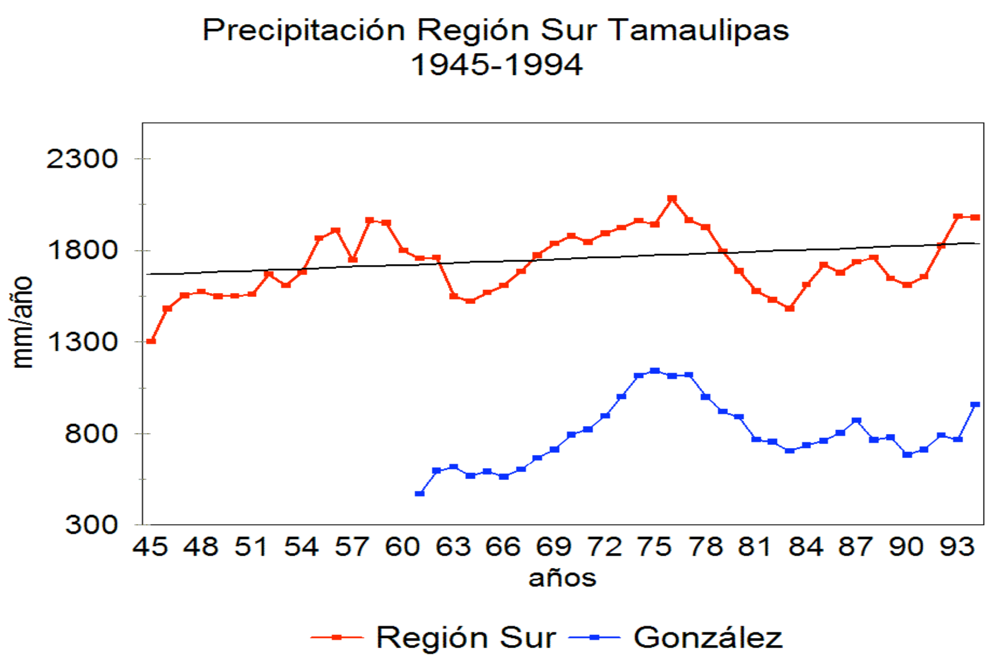


Fig. 2.7: Annual precipitation in southern Tamaulipas. Period: 1945-1994

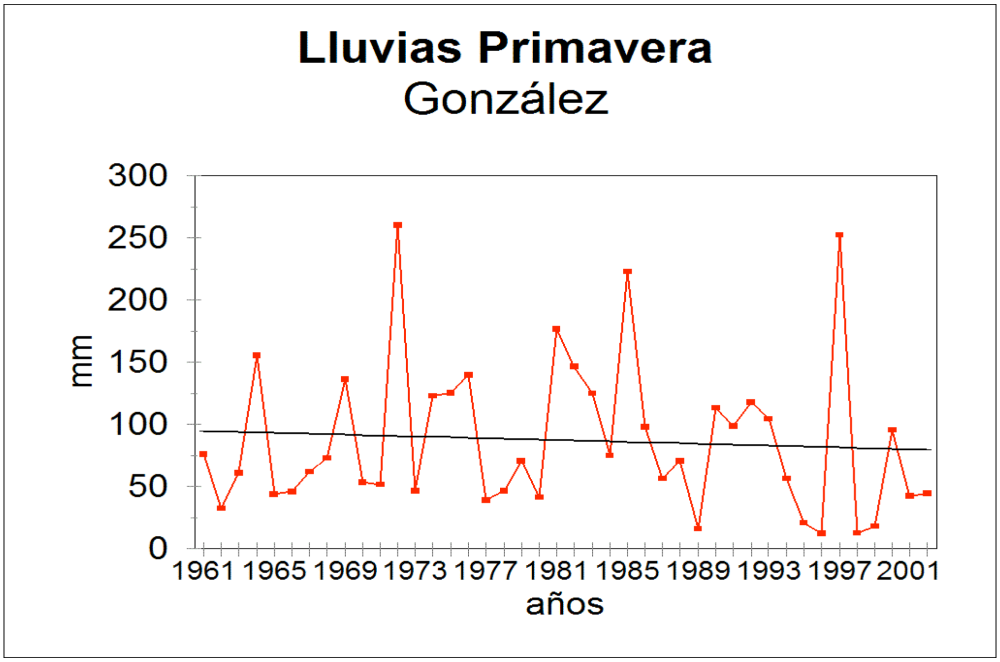
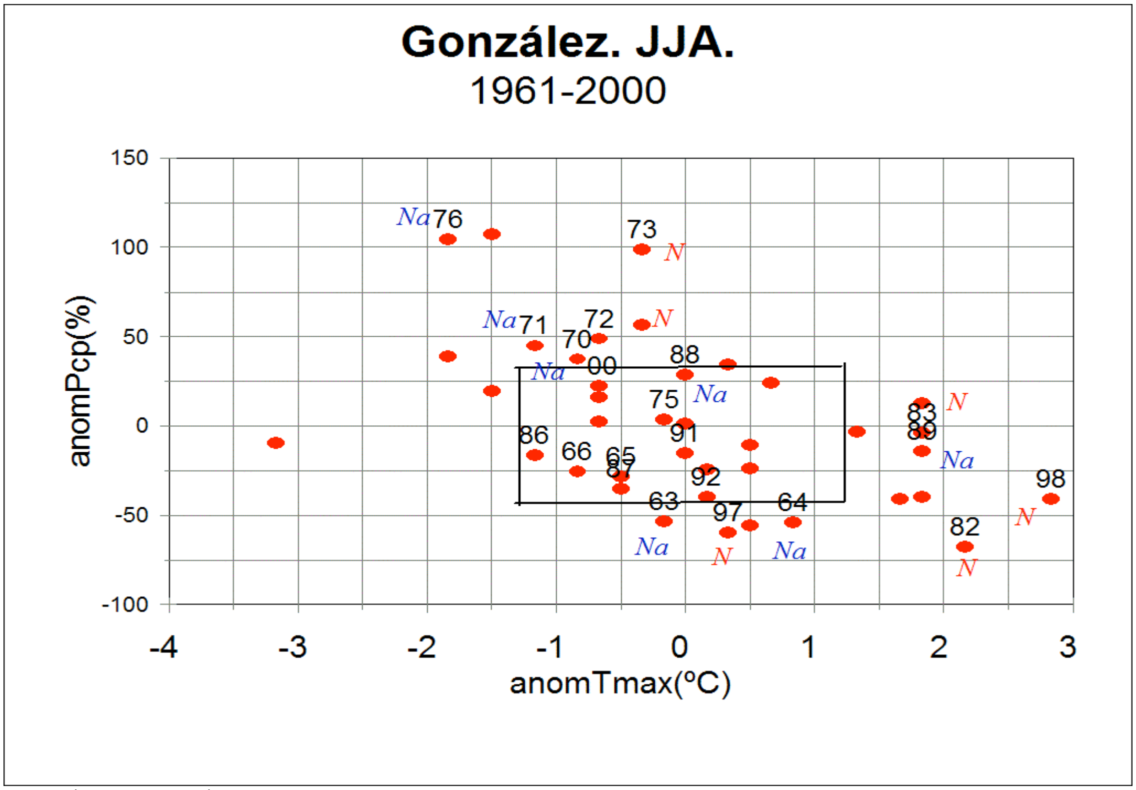


Fig. 2.8: Precipitation during spring season in Gonzalez, Tamaulipas. Period: 1961-2001

Figure 2.9 shows the results of the computation of maximum temperature and precipitation anomalies in the Gonzalez, Tamaulipas, study area for the period 1961-2000, and also shows the corresponding classification given to different years as a Niño or Niña year. Figure 2.9 shows that the Niño years of 1982, 1997, and 1998 were warmer and drier than a normal year, and also shows that the Niña years of 1971 and 1976 were cooler and more humid than a normal year.

Not all the results shown in Figure 2.9 for other years fit the typical classification of a Niño or Niña year, and not always after a Niño year follows a Niña year. These results also show how complex these climatic processes are, and therefore, how difficult it is to forecast this climate events because they do not follow a clear pattern, nor can be established a correlation among them. This is why the vulnerability of farmers to these climate events could be very high, and therefore, adaptability measures adopted by farmers and the government become very important.

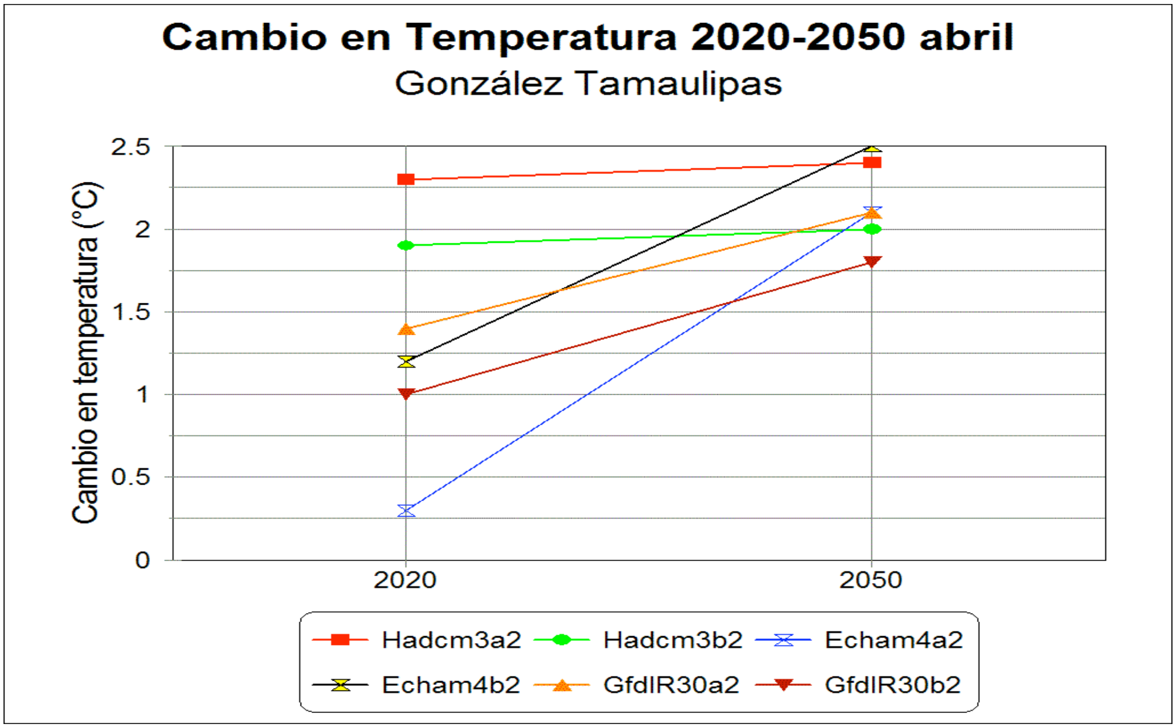


N: Niño year; Na: Niña year

Fig. 2.9: Climate anomalies in Gonzalez, Tamaulipas. Period: 1961-2000

In the case of Mexico, the federal government will have to review its current policies for providing funding to farmers (small and big) to adapt those policies to climate change, but also to support those farmers in a more efficient and effective way to face the current difficult market conditions aggravated by climate change and by the policies established to comply with the NAFTA accord.

Regarding the climate change scenarios issue of future climatic conditions in the study area of Gonzalez, Tamaulipas, Figure 2.10 shows the results of applying different climate change forecast models for spring in the study area, to estimate how temperature and precipitation might change for the period 2020-2050. These scenario models apply different criteria to compute changes of different climate parameters in the future, and that is why, each model comes up with a different result.



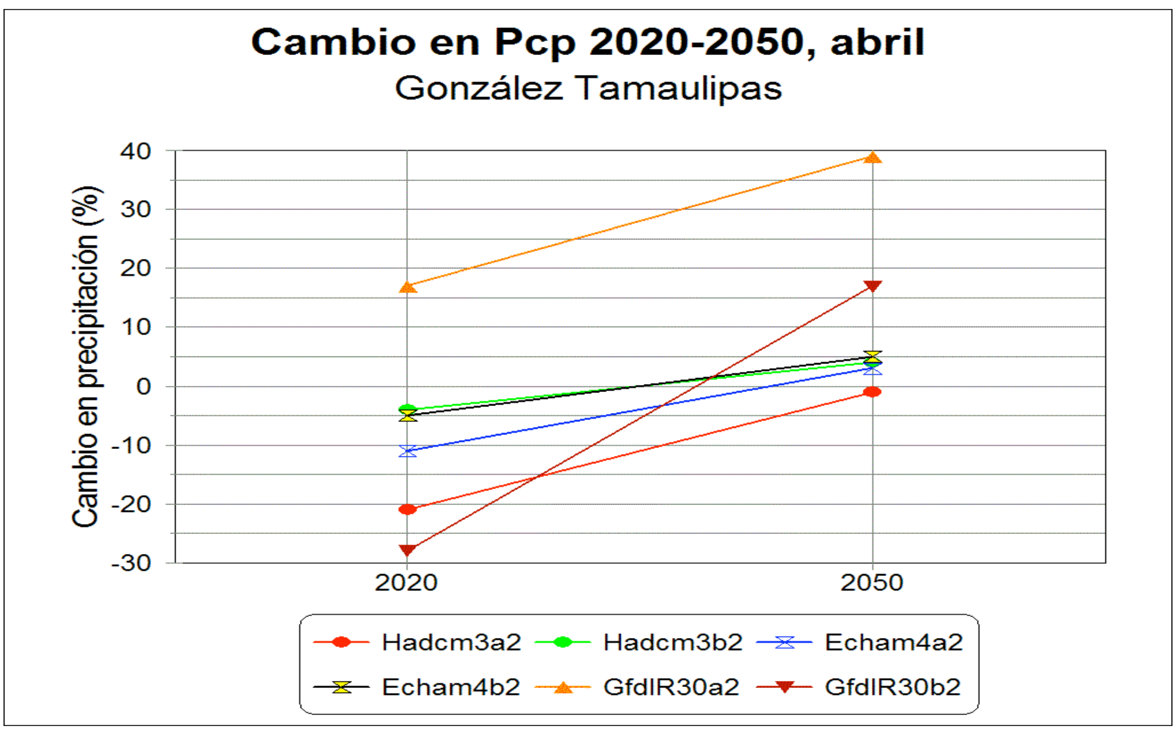
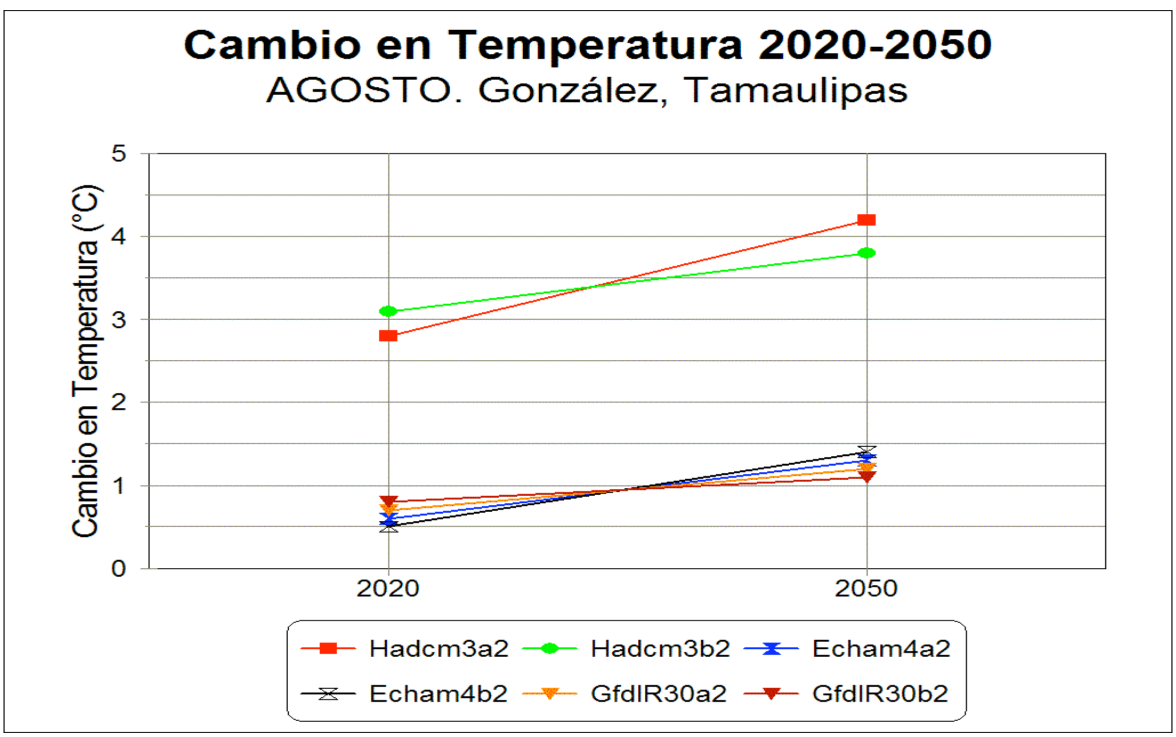


Fig. 2.10: Climate change scenario for spring in Gonzalez, Tam. Period: 2020-2050

In terms of temperature, the climate change scenario applied estimated that by the year 2020, the temperature during spring season in the study area of Gonzalez, Tamaulipas, could be between 0.25 to 2.3 degrees Celsius higher than spring of 2005 temperature, and for the year 2050, the temperature in the study area could be between 1.8 to 2.5 degrees Celsius higher than spring of 2005 temperature. With regard to precipitation, the scenarios applied estimated that by the year 2020, the precipitation during spring season in the study area of Gonzalez, Tamaulipas, could be between 30% less to 16% higher than spring of 2005 precipitation, and for the year 2050, the precipitation in the study area could be between 0% to 40% higher than spring of 2005 precipitation.

So far climate change studies in Mexico have identified two extreme scenarios: (1) higher temperature and less rainfall, and (2) higher temperature and more rainfall. Therefore, based on the results obtained in the Gonzalez, Tamaulipas, study area, it can be concluded at this time that during spring season temperature is likely to increase up to 2.5 degrees Celsius by the year 2050, and also, rainfall is likely to increase up to 40% greater than spring of 2005 precipitation. In other words, the second extreme scenario mentioned above is likely to occur in the case study area, which is, in the years to come during spring time it is possible to expected to have higher temperatures and more rain.

Figure 2.11 shows the results of temperature and rainfall forecast during summer time in the case study area. In terms of temperature, the scenarios applied estimated that by the year 2020, the temperature in the study area of Gonzalez, Tamaulipas, during summer season could be between 0.5 to 3 degrees Celsius higher than summer of 2005 temperature, and for the year 2050, the temperature in the study area could be between 1 to 4.25 degrees Celsius higher than summer of 2005 temperature. With regard to precipitation, the scenarios applied do not show a uniform pattern of rainfall increment. All the models applied estimated that by the year 2020, the precipitation during summer season in the study area could be between 40% less to 35% more precipitation than that of summer of 2005, and for the year 2050, three models showed a decrease in precipitation in the study area between 20% to 45% less rainfall, and the other three models showed precipitation between 20% to 60% higher than that of summer of 2005 precipitation.



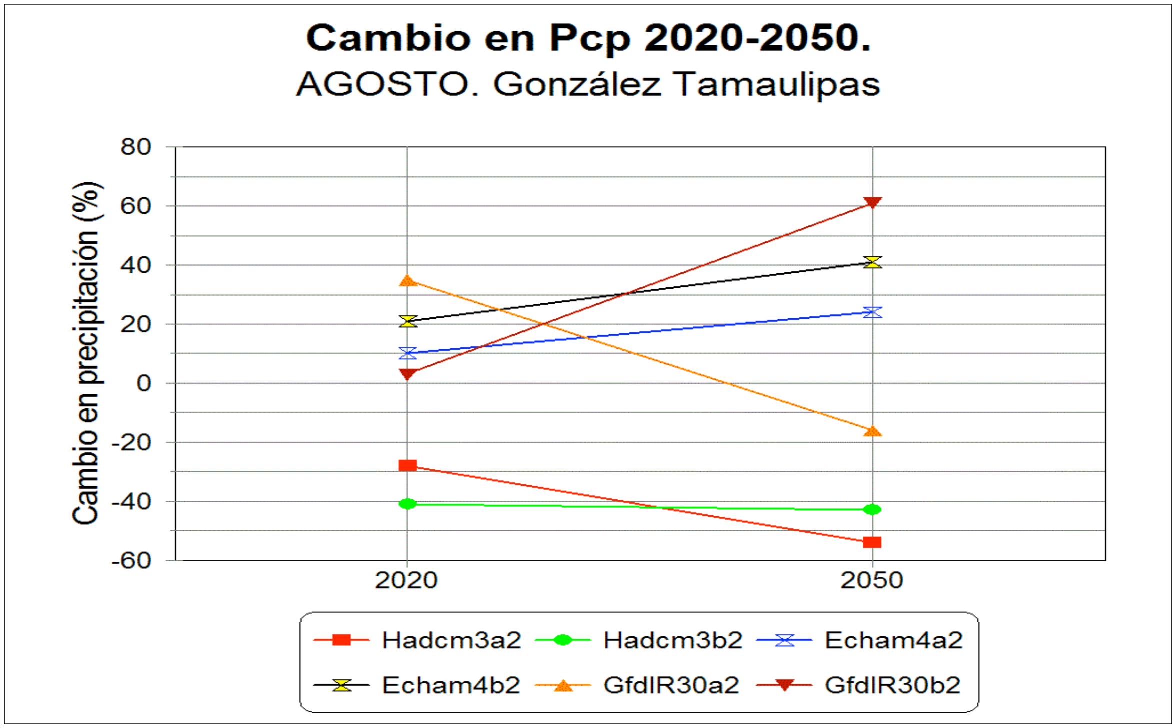


Fig. 2.11: Climate change scenario for summer in Gonzalez, Tam. Period: 2020-2050

2.3.2 Water resources management issues

In addition to climate change and socio-economic issues studied in the Gonzalez, Tamaulipas, case study area, water resources management issues appeared as another important factor for evaluating vulnerability and adaptability to climate change. During the 1990s water resources management issues in Mexico became a national security issue. Increasing water demand throughout the country along with continuing water pollution problems, and a severe drought during the 1993-1996 period, created a situation of severe water shortages, especially in the central highlands and northern region of the country. According to the National Water Commission (Comisión Nacional del Agua, CNA, 2004), the State of Tamaulipas was severely affected by the 1993-1996 drought period.

The southern region of the State of Tamaulipas is located within the Guayalejo-Tamesi River basin, which is the last tributary of the Panuco River, before it discharges into the Gulf of Mexico. The Guayalejo-Tamesi river basin has an estimated basin area of 18,478 km^2 (Haces 1999), and based on CNA records, an estimated mean annual runoff volume of 2.96 billion m^3, equivalent to an average annual flow of 94 m^3/s. The basin area of the Panuco River is about 84,956 km^2, with an estimated mean annual runoff volume of 19.087 billion m^3, equivalent to an average annual flow of 605 m^3/s (CNA 2004).

Water use in 2004 in the Guayelejo-Tamesi River basin included 1,283 surface water users and 645 groundwater users, and their corresponding water rights volumes are shown in table 2.1. These data show that total water use in the river basin represents about 14.8% of the mean annual runoff volume in the Guayalejo-Tamesi River. According to criteria applied by CNA, this percentage of water use in this river basin represents a "moderate pressure" on the water resources of the river basin. All agricultural water uses represent 51.7% of the total water use in the river basin; therefore, it is very important that both the irrigation techniques and the irrigation systems being used in the river basin be the most efficient in order to save and use water in the most rational manner. Currently, the irrigation systems operated in the Guayalejo-Tamesi River basin require major updates in order to accomplish those goals.

Water Users	Surface water (m^3/year)	Groundwater (m^3/year)	Total (m^3/year)	%
Agriculture	215,421,998.0	10,390,959.2	225,812,957.2	51.68
Domestic(1)	81,690.2	117,520.8	199,211.0	0.05
Industrial	128,127,199.0	30,024.0	128,157,223.0	29.33
Livestock	272,341.7	172,416.6	444,758.3	0.10
Municipal(2)	79,313,342.8	2,522,916.6	81,836,259.4	18.73
Services(3)	133,272.0	50,999.5	184,271.5	0.04
Other uses	295,151.9	---	295,151.9	0.07
Total:	423,644,995.6	13,284,836.7	436,929,832.3	100.00

(1) Domestic users in rural areas

(2) Cities and water utility companies providing domestic and commercial water supply services

(3) Industrial and commercial water users no served by water utility companies

Source: Gerencia Regional Golfo Norte de la CNA, GRGN-CNA 2004

Table 2.1: Water use in 2004 in the Guayalejo-Tamesi River basin.

Another major water user is the industrial sector with 29.3% of the total water use in the river basin. Also, the industrial sector will need to adopt new industrial processes and technologies to recycle and use less water. The same situation applies to the municipal sector, with 18.7% of the total water use in the river basin, where poor maintenance of the hydraulic infrastructure has created water leaking problems in some cities greater than 25% of their water use.

Other major issue is water tariffs for all water users. In general water tariffs are very low for all water users, which contribute to an overall water culture by the general public of disregard about water issues like rational water use, water conservation and payment of the real cost of water supply services. Also, if the water pollution problem is included in the analysis of water issues in the Guayalejo-Tamesi River basin, then the whole water concept reaches a different dimension.

Regarding water quality in the Guayalejo-Tamesi River basin, there are some serious water pollution problems created by agriculture activities in the middle basin, and municipal wastewater discharges into the Guayalejo-Tamesi River in the middle and lower river basin. However, because of reaeration processes and biodegradation of organic matter that take place within the downstream river flow, there is an improvement in the water quality of the Guayalejo-Tamesi River, especially at the entrance of the Tamesi River Lagoon System (TRLS) in the lower river basin. These water pollution problems, however, could have a negative impact on the water availability of the Guayalejo-Tamesi River basin, since they could limit the use of water because of high concentrations of pollutants, especially during a drought period.

Due to these existing water issues in the Guayalejo-Tamesi River basin, and also due to the fact that the case study area is highly vulnerable to extreme climate events (droughts and floods), a decision was made in the Gonzalez, Tamaulipas, case study to develop a water availability model of the entire river basin to analyze how the existing water rights and hydraulic systems will respond in case of a extreme climate event. The Water Evaluation And Planning (WEAP) System computer program was used to develop this water availability model. The results obtained from this model, for the current conditions or "business as usual" scenario, are described below.

2.3.3 Water availability model of the Guayalejo-Tamesi River basin

The WEAP computer program was developed by the Stockholm Environment Institute at its Boston Center, Tellus Institute. The WEAP model algorithm is based on the hydrologic water budget approach for a river basin, incorporating water users, water allocation policies, hydraulic infrastructure, water tariffs, water resources, and water pollution parameters that can be analyzed under different operation or management scenarios to establish when a water rights system meets its water demands, and when water shortages are going take place (WEAP21 User Guide 2001).

In order to develop the WEAP water availability model, major data information was collected and input into the program input data structure. Thus, a digital basic map of the river basin was developed, and data related to the water rights system, hydraulic infrastructure, and water resources (stream flow records) were collected. Due to the lack of adequate data and time constraints, it was established for the purpose of this project, that the scope of the water availability modeling included only the 2000 base year and a 30-year scenario considering a "business as usual" approach for water resources management in the river basin.

The main WEAP graphical interface, after all the input data was incorporated into the program, is shown in figure 2.12. The image showing the river basin scheme included all major components of the model. In relation to water resources and hydraulic infrastructure the model included all major tributaries of the Guayalejo-Tamesi River, three dams, five diversion dams, four pump stations, and eight gage stations. In relation to water demand centers the model included fourteen cities, 1,283 surface water users, 645 ground water users, two irrigation districts and the industrial port of Altamira.

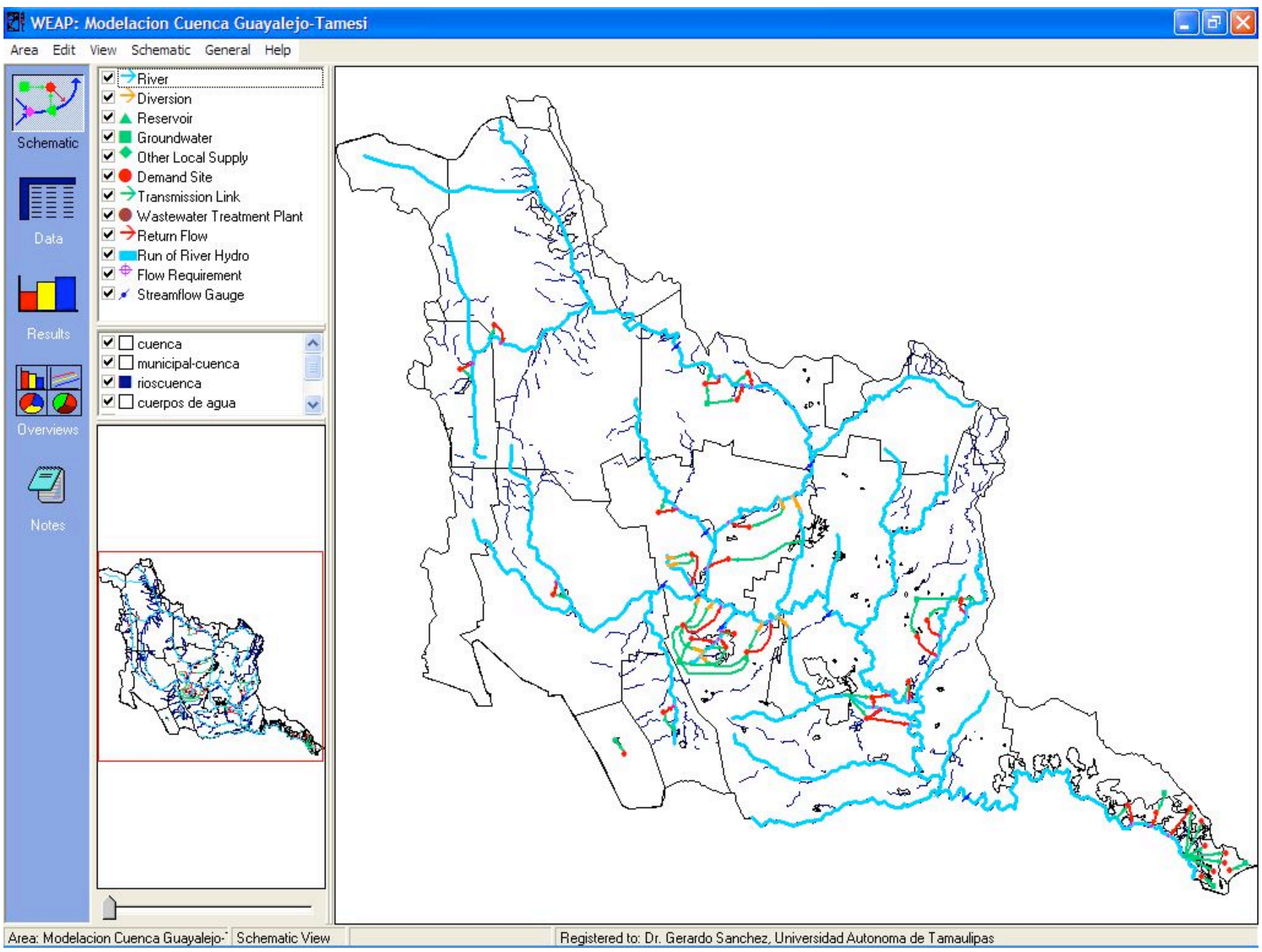


Fig. 2.12: Schematic of the Guayalejo-Tamesi River basin in the WEAP model

In this first phase of the modeling process only average monthly flows for the different tributaries and main channel of the river basin were considered, and no water pollution data were included at this time. In the second phase of this modeling process, historical monthly flows, water pollution data, water tariffs, and different climate conditions will be included in different scenarios to obtain a wide range of results for a wide range of water resources management policies applied throughout the river basin. However, the most important and difficult part of the modeling process, related to the drawing and definition of interactions between water rights, hydraulic infrastructure, and water resources systems have been completed. Figure 2.13 shows the current model and the different interactions established in the model in the mid section of the river basin area, where some of the major water use activities in the river basin take place.

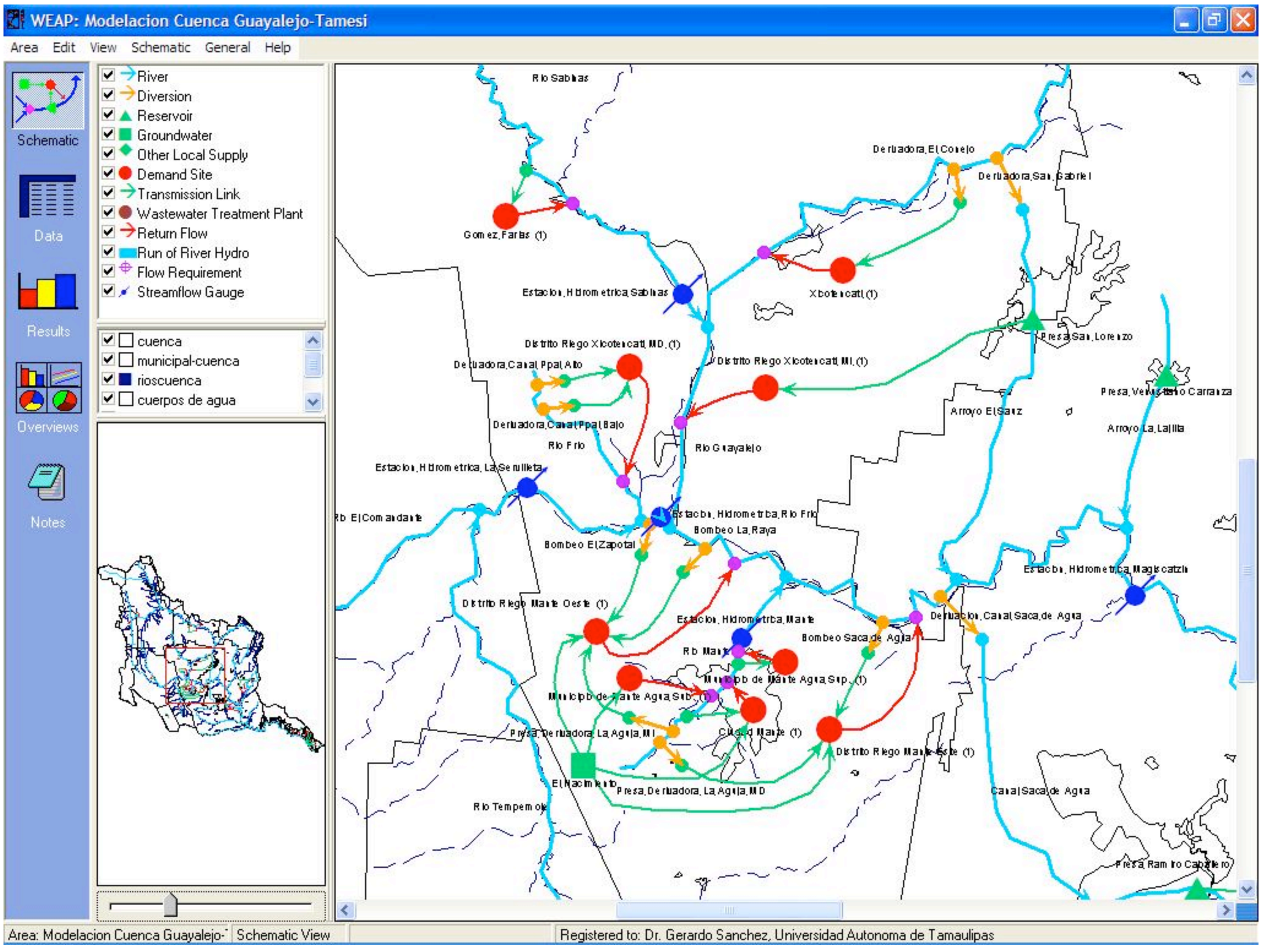


Fig. 2.13: Water availability model elements interactions in the mid river basin area

Therefore, in order to improve the quality and reliability of the results of the water availability model, in the future few changes of the existing model will be required, until an accurate, representative schematic of the real world system will be obtained, and then the results of the water availability model will represent accurately how the system might behave in the real world. This improvement and calibration process of the availability model will be a lot easier than building the system in the first place. Figure 2.14 shows the interactions between water demand centers and water supply elements in the lower section of the river basin, where the industrial port of Altamira, and the largest cities of Tampico, Madero, and Altamira are located. The main water supply elements are the Tamesi River and the Tamesi River

Lagoon System (TRLS), which is a set of shallow and environmental fragile lagoons located on the floodplain area of the Tamesi River.

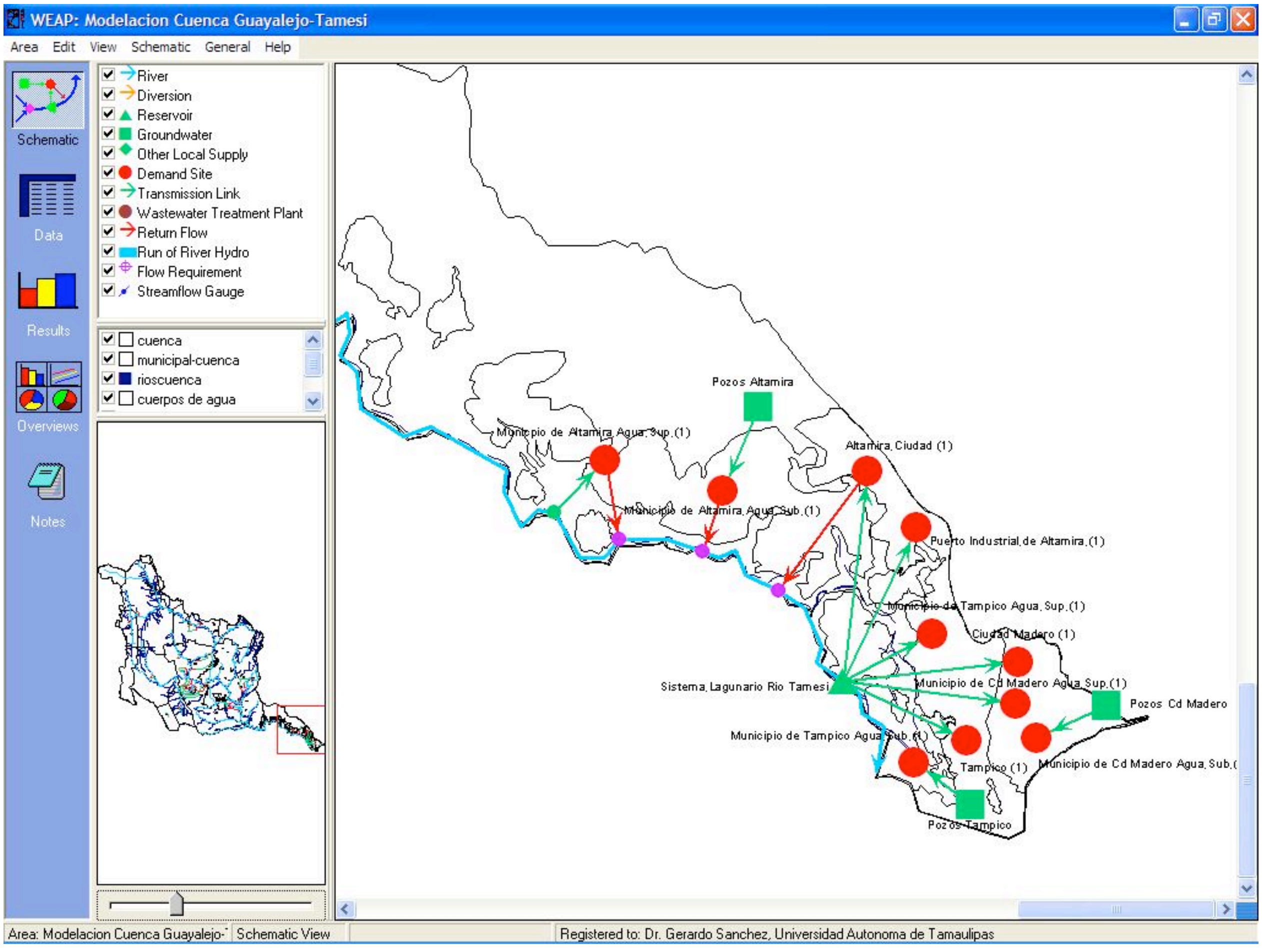


Fig. 2.14: Water availability model elements interactions in the lower river basin area

The integration of the scenario analyzed by the WEAP model included the year 2000, as a base year, and a 30-year period where a "business as usual" approach was included. This scenario took into account different annual growth rates for population growth, industrial, livestock, and services activities, and considered a constant 2000-year water demand for agricultural activities. In relation to climate conditions, this scenario included a repetition in the future of the last 30-year period, where based on the estimates of the stream flow anomalies, a 30-year sequence of very wet, wet, normal, dry, and very dry years was established.

2.3.4 Conclusions Tamaulipas case study

Some results of this first run of the WEAP model are shown in the following figures 2.15 and figure 2.16. The WEAP model has a wide range of options for showing results in a graphical and tabular form. Therefore, for the purpose of this report, only three graphs are shown, and the main results and conclusions are discussed below. For example, figure 2.15 shows the water supply requirements, including losses, of some of the main water demand centers at every five years for the entire period of analysis. In this figure can be seen the water requirements of the Xicotencatl and Mante irrigation districts, the surface and ground water requirement of Ciudad Madero (large city), the surface water requirement of the municipalities of Llera and Tampico, and the water requirements of the city of Mante.

The more water demand centers and longer time periods are incorporated in the model, the more options for showing the results are available in the results module of the WEAP program. Thus, the modeler can select any specific group of water demand centers, for any specific number of years, for a specific type of graph to show the results of the WEAP model. Also, for any specific type of graph defined, the modeler can also obtain the results in an Excel format file to analyze the results in a tabular form, and eventually export those results to Excel. Therefore, figure 2.15 is more an example of the multiple options available to show results of the WEAP model.

Figure 2.16 shows a more specific type of results from the WEAP model. The figure shows the water demand centers where, according to the criteria incorporated into the scenario being modeled, water demands are not met. Thus, figure Figure 2.16 represents the unmet demand graph of the scenario being analyzed. Here is very interesting to see that, according to this "business as usual" approach incorporated into the scenario, the municipality of Gonzalez, where the case study area is located, will not be able to satisfy its current surface water demand along the entire period of analysis 2000-2030. This result was corroborated in the field, where people living in the city of Gonzalez confirmed that the city of Gonzalez already has water supply problems, especially during the dry season. This result can help the local authorities to make a decision regarding how to improve their water supply system for solving the current and future water supply shortages that the city and municipality, as a whole, is suffering.

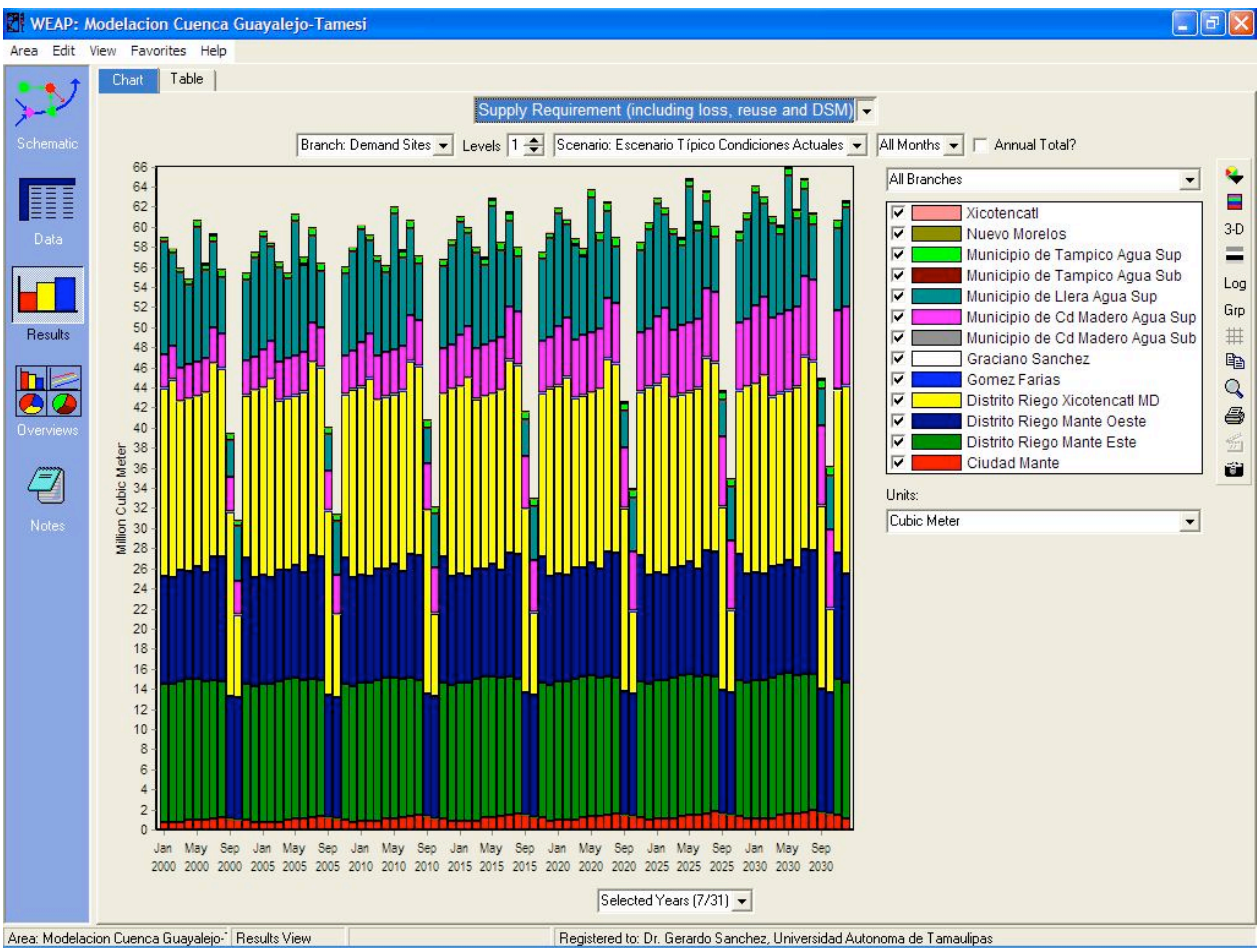


Fig. 2.15: Water demand requirement, including losses, of different water demand centers

Further analysis of the results shown by the unmet demand graph for different water demand centers, for different years, under different scenarios can help the decision makers to identify all those water demand centers that could be vulnerable to water shortages under different water resources management policies, including those related to facing or adapting to extreme climate events, like droughts. The municipality of Gonzalez is a show case of the vulnerability of a region to extreme climate events.

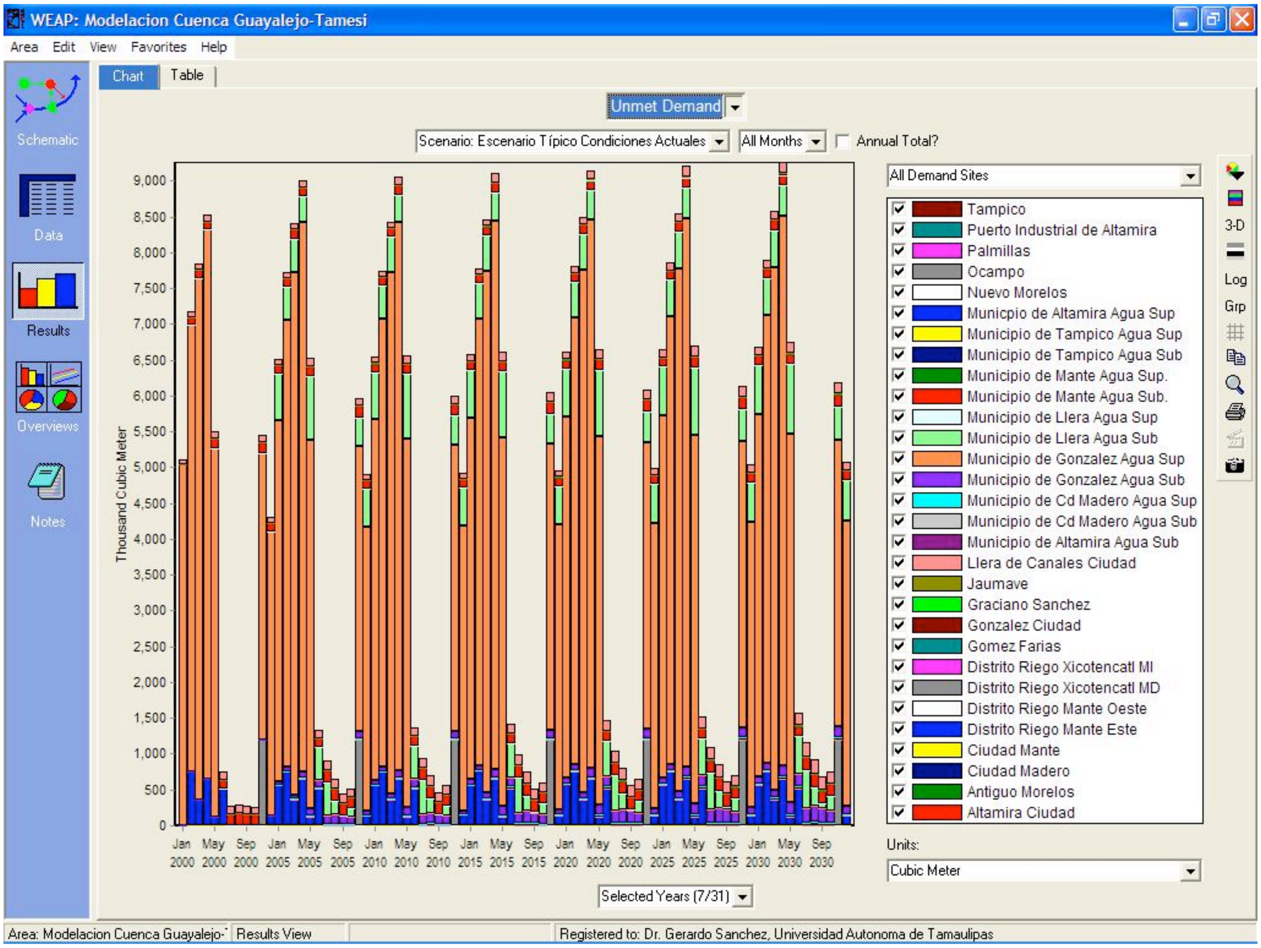


Fig. 2.16: Unmet water demand graph in the Guayalejo-Tamesi River basin

In addition to identifying which water demand centers are vulnerable to water shortages by the application of the unmet demand graph, and since the WEAP model can also provide these results in a tabular form, therefore, the WEAP model can help the decision makers to estimate the amount of water shortages and establish general guidelines for the design of new hydraulic infrastructure aimed at solving those water shortages at different water demand centers. In the case of the municipality of Gonzalez, it is clear that the current source of water supply and the current hydraulic infrastructure are not enough to satisfy the current and future water demands of this region. New infrastructure that will take water from the main channel of the Guayalejo River and convey it to the city of Gonzalez will have to be built in order to solve the current and future water shortages of the municipality of Gonzalez.

Figure 2.17 shows another type of results also related to unmet water demand. Figure 2.17 shows the demand site coverage or the percentage of water volume during the period of analysis that the water requirement is met at any water demand center, so the results given by this demand site coverage graph can also help to identify which water demand centers could have water shortages problems, and when those problems could appear. Looking at figure 2.17, it can be seen again that the municipality of

Gonzalez has serious problems regarding meeting its surface water demand, where during the dry season of each year the percent coverage is just about 25% of the total surface water demand.

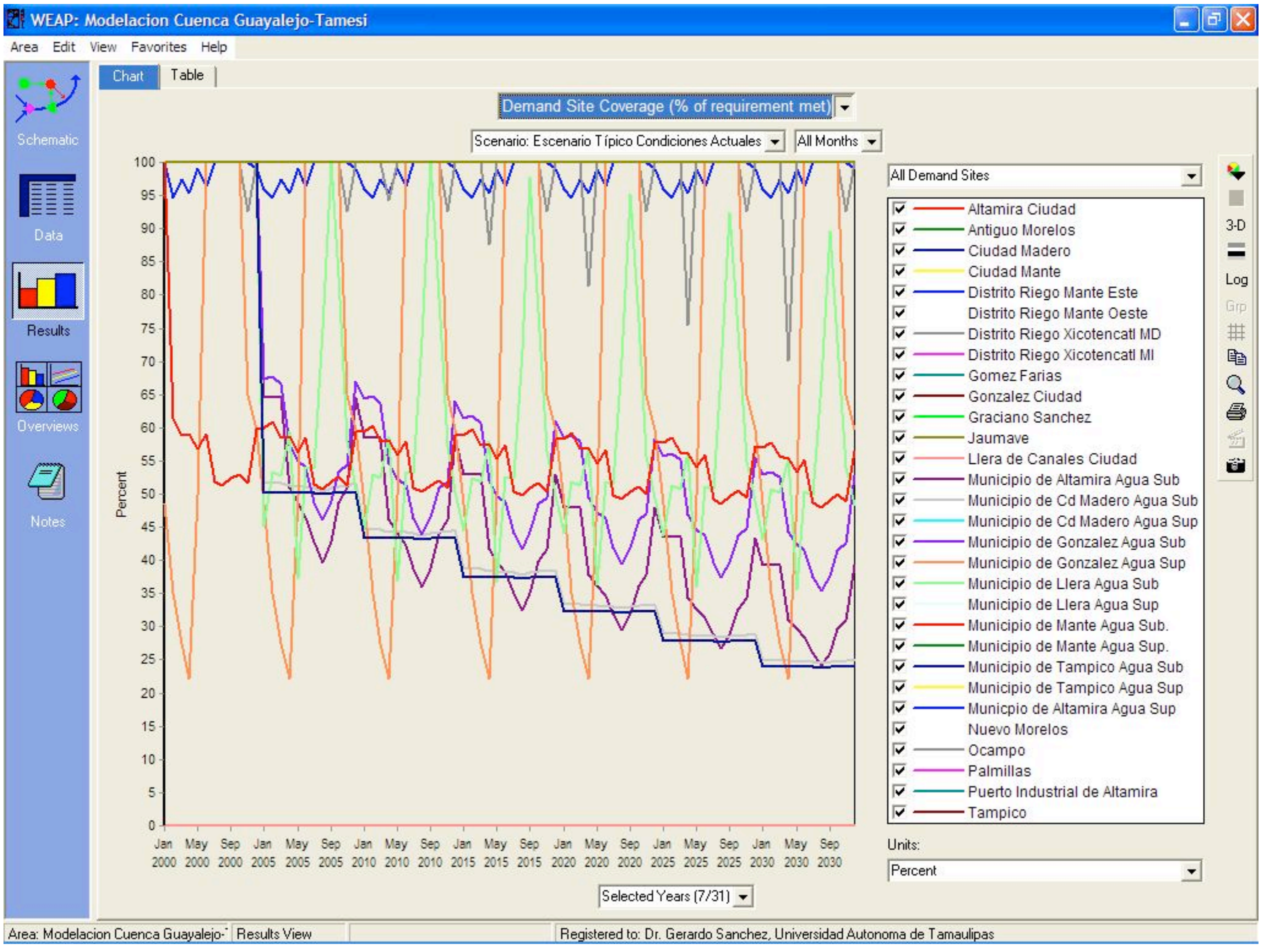


Fig. 2.17: Demand site coverage graph in the Guayalejo-Tamesi River basin

Other water demand centers, whose sources of water are groundwater, like the municipalities of Tampico, Ciudad Madero, Mante, and Gonzalez show serious problems related to very low percent of demand site coverage. Groundwater is an issue that will require further research and the establishment of a permanent monitoring program to determine the water availability and water quality at each aquifer being used in the river basin. Nowadays there is very little information about the behavior of all the aquifers located in the river basin during the development of an entire hydrologic cycle.

In some regions within the river basin, groundwater is the only or main source of water, therefore, it is very important to learn more how those aquifers behave in order to manage them in a sustainable manner. At this time, based on the very limited groundwater information that was available to building the WEAP model, the main conclusion could be that most of all groundwater rights in the Guayalejo-Tamesi river basin will have to be either cancel, or reviewed to limit future water withdrawals to preserve and recover those water bodies.

The Gonzalez, Tamaulipas, case study area is a very important region in terms of agricultural and livestock activities to promote further economic development of this region. The potential for future economic growth is very good, as long as adequate policies are put in place to deal with climate change, extreme climate events, sustainable water resources management, and an adverse agricultural and livestock market conditions.

The climate in the case study area is changing, and based on the results obtained during the development of this research project, it is likely that in the years to come the temperature will be higher, and the precipitation will also be higher, with less rainfall during summer and more rainfall during winter. Also, extreme climate events (droughts and floods) will continue to take place, with even a greater variability. This means that droughts and floods are likely to be more severe.

An integrated approach to water resources management and planning in the Guayalejo-Tamesi river basin will be necessary to contribute and secure further economic growth, and also to deal with climate change and extreme climate events. In terms of water resources, it will be indispensable to establish public policies aimed at using the available river basin water resources in a sustainable manner. In order to reach that condition of sustainability in the water resources sector, further research and work in the field will be necessary to develop comprehensive data bases throughout the river basin to better understand the rainfall-runoff processes that take place in the river basin, and also to allow the application of new approaches and tools that will facilitate the establishment of those public policies aimed at reaching sustainable water use scenarios.

The WEAP model was used as a tool to evaluate current and future water availability in the Guayalejo-Tamesi river basin. The results obtained from the WEAP model showed that the municipality of Gonzalez, Tamaulipas, where the case study area is located, will have serious water shortages in the near future if the water rights and hydraulic infrastructure systems continue to operate the way they are. Also, the two main irrigation districs, Xicotencatl and Mante, will have some water shortages in the future. Furthermore, most of ground water rights, especially in the mid and lower sections of the river basin, are not sustainable. The holders of those ground water rights will have severe water shortages in the years to come.

The results of the WEAP model also showed that, despite the fact that just 15% of the mean annual runoff volume is used, still some regions of the river basin like Gonzalez are highly vulnerable to the stream flow variability and the inefficiencies of their current hydraulic infrastructure, so they are currently suffering water shortages, and will continue to do so in the years to come, unless they build new hydraulic infrastructure, or apply stringent measures to adapt to water shortages, especially during the dry season. This situation could only get worse if a drought take place in the Gonzalez area in the years to come.

The current WEAP model, despite its limitations due to the lack of basic data regarding how the water rights and hydraulic systems work, represents a step forward in the right direction in terms of water availability modeling and water resources management in the Guayalejo-Tamesi river basin. This WEAP model will just require further refinement, at a very low cost, until a final model representing the real world of the Guayalejo-Tamesi hydraulic system is reached. When this situation will be reached, the water availability modeling process in the Guayalejo-Tamesi river basin will be very easy to do, and the decision-making process aimed at reaching water use sustainability will be quite feasible. Also, once the WEAP model will represent the real world situation in the Guayalejo-Tamesi river basin, the results obtained from that model will help the CNA to review and to reassign water rights for surface and ground water rights holders so new public policies, based on hard scientific facts, could be established to manage the Guayalejo-Tamesi water resources in a more rational and sustainable manner.

Another very important outcome of this project was the involvement and partnership established during the development of this project between the local and regional authorities, and the researchers from the National Autonomous University of Mexico (UNAM) and the Autonomous University of Tamaulipas (UAT). The interest and commitment from the authorities to continue collaborating in future joint research activities is very promising. This secures that the results of the project will actually be used by the authorities, and that the recommendations might eventually become a public policy or strategy to adapt to future climate change and extreme climate events.

With regard to continuing collaboration between CNA authorities and UAT researchers, a visit to the entire river basin to verify hydraulic infrastructure and water uses will take place from June 6th to 10th, and the information collected will be input into the WEAP input data base to refine the model as much as possible. After this is completed, new WEAP model runs will be made and the results will be used by the CNA to start reviewing its entire water resources management approach in the Guayalejo-Tamesi river basin. This collaboration looks very promising for all water stakeholders in the Guayalejo-Tamesi river basin, and it is definitely a step forward in the right direction for seeking a sustainable water resources management and planning approach in the Guayalejo-Tamesi river basin.

Also, the incorporation of all feasible climate change scenarios into the WEAP input data base will allow the UNAM-UAT researchers to provide a wide range of water resources management options to adapt to climate change and extreme events, and also help the local authorities (CNA and SAGARPA), water rights holders, and farmers to make good decisions about how to adapt to such climate change and extreme events.

2.4 Results: Veracruz Case Study

2.4.1 Impacts and vulnerability

The climate study in the central region of Veracruz represented a difficult task. Most of the databases presented several gaps and different sources indicated different values for the same stations and periods of time. Hard analysis work was performed to use validated data (Bravo et al, 2006; Palma 2005).

On the other hand, in Veracruz and Tamaulipas students gather newspaper information associated to extreme climate events and their impacts at a regional level. A useful source of information was found in DesInventar database (developed by La Red, 2004), which contains the newspapers reports at a national level. It was found that only the major climatic events that occurred in the regions under study reach the major national newspapers.

Dr. Lourdes Villers (ecologist) and Cecilia Conde directed a bachelor thesis (Arizpe, 2005) related to coffee phenology, which was very helpful in deciding the climatic thresholds for the coffee plants used in the region.

The participation of climate researchers and students in depth interviews, focal groups and in fieldwork, help us recognized which climatic events were more worrisome to coffee producers and were importantly studied in the central region.

Deciding that the coffee locations in Veracruz in the central region could be treated like one single region, normal climatological conditions were analyzed using those climatic data that were considered validated and with sufficient data. In figure 2.18, the averages for the period 1961 – 1990 of maximum and minimum temperature and precipitation (used as the base line for climate change scenarios) are shown, for Teocelo, Veracruz, located at latitude 19º38′ N, longitude 96º97′ W, at a height of about 1218 m above sea level.

For coffee production the optimum average annual temperature range is from 17 to 24 ºC, and the optimal yearly precipitation is between 1500 and 2500 mm (Nolasco, 1985). These climatic conditions are observed in Teocelo, Veracruz. It has a mean annual temperature of 19.5ºC and an annual precipitation of 2046.9 mm, which are within the optimal ranges for coffee production (Nolasco, 1985).

However, seasonal analyses must be developed and related to the specific requirements at the different stages of the plant development. Because coffee is being produced at near-optimal conditions, it is reasonable to expect that the boundaries of the coping climatic range are nearly equal to those delimited by the quartile range, determined with the climatological conditions of Teocelo, Veracruz (figure2.18).

Regional experts informed us that a small or relative drought ((Nolasco, 1985; Castillo et al., 1997) in spring is needed for the flowering stage of coffee (which can be seen in the April precipitation data in the figure). Also, the midsummer drought (MSD, or *canícula*) is an important event that will determine, among other factors, the quality and quantity of the produced coffee.

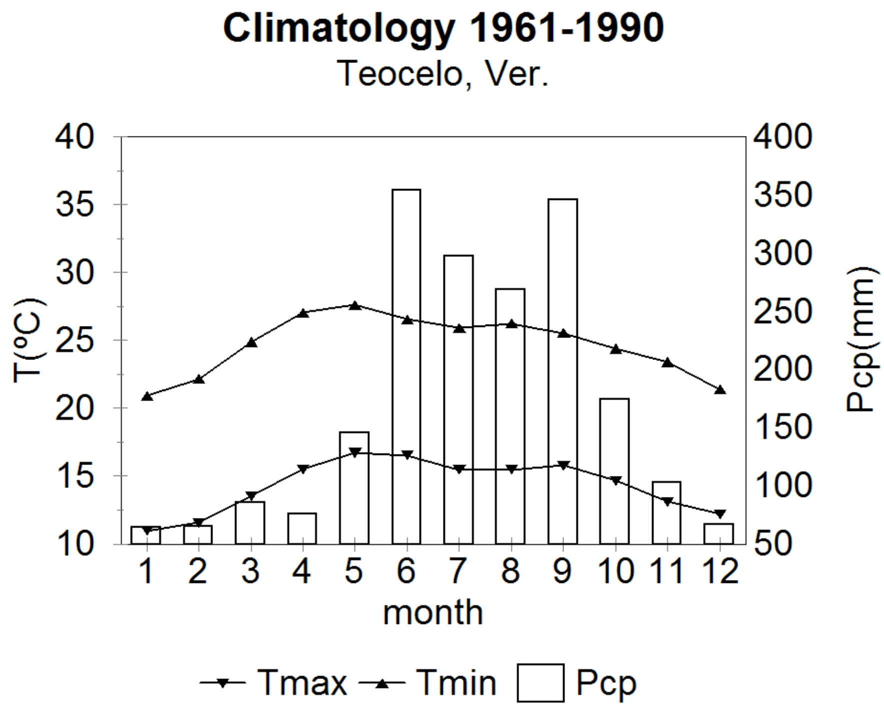


Fig. 2.18: Normal climatic conditions for Teocelo, Ver considering maximum temperature (Tmax), minimum temperature (Tmin) and precipitation (Pcp).

During winter and spring, frost could reduce coffee production, so minimum temperature is the variable that must be analyzed for those two seasons, combined with the possible changes in precipitation. For summer, maximum temperature and precipitation are the two variables that must be considered for the analysis of possible heat waves, drought, or floods that could affect the development and maturity of the coffee cherry. During autumn, the coffee fruits undergo development and maturing, so climatic extreme events and pests are the two factors that can damage them.

Climatic Threat Spaces (Conde et al, 2006) were used to visualize the extreme events, and above them, considering the temperature and precipitation requirements of the coffee plants, thresholds for them was depicted (figures 2.19a and b).

2a **2b**

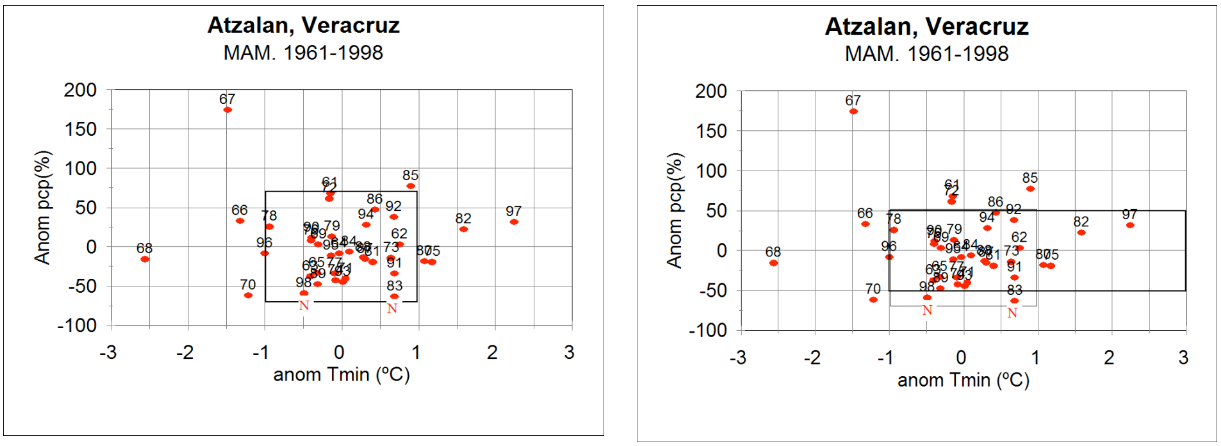


Fig. 2.19: a) Threat space for Atzalan, Veracruz in spring (MAM). Anomalies for minimum temperature (Tmin ºC) and for precipitation (%) and the year they occurred are indicated by the dots. Years are represented by their last two digits (i.e., 97 equals 1997). The rectangle represents the quartile range (1961–1990) for this season. N represents strong El Niño years. Years with greater anomalies lie outside the rectangle; b) Climatic threat space for coffee during spring (MAM), considering the minimum temperature and precipitation requirements of the coffee plant. The square box represents the initial coping range proposed. Climatic anomalies outside the rectangle are considered to be risky for coffee.

Similar analysis was performed for all the months and for the other seasons (Conde et al, 2006). It was concluded that Analyses of regional climatic variability help in defining the current climatic threat. In this sense, climatic threat spaces can be a useful tool for defining "threat" with stakeholders and for communicating risk. The dispersion diagrams for temperature and precipitation illustrate climatic threat to a specific agricultural production and the damages that they could cause to specific crops. The magnitudes of the hazard and of the losses can be used to characterize the vulnerability of agricultural producers. Regional climate change scenarios can be introduced to the climatic threat spaces, and future threats or opportunities can be discussed with key stakeholders in the region.

Two techniques were applied to generate climate change scenarios. The first one was based on the results obtained from the Magicc /Scengen program. The other was to downscale the output of the models to match the observed changes in temperature in function of the altitude (Palma, 2005).

In the first case (figures 2.20a and b), temperature change ranges from 1.5ºC to 4ºC, approximately, depending on the season and the time horizon: 0.9ºC in 2020 to 2.7 ºC in 2050 in July, for example.

Changes in precipitation were found to possible change between minus 30% to plus 40% (figure 2.20b**)** These uncertainty in the precipitation scenarios are a source of confusion among the stakeholders and is difficult to communicate.

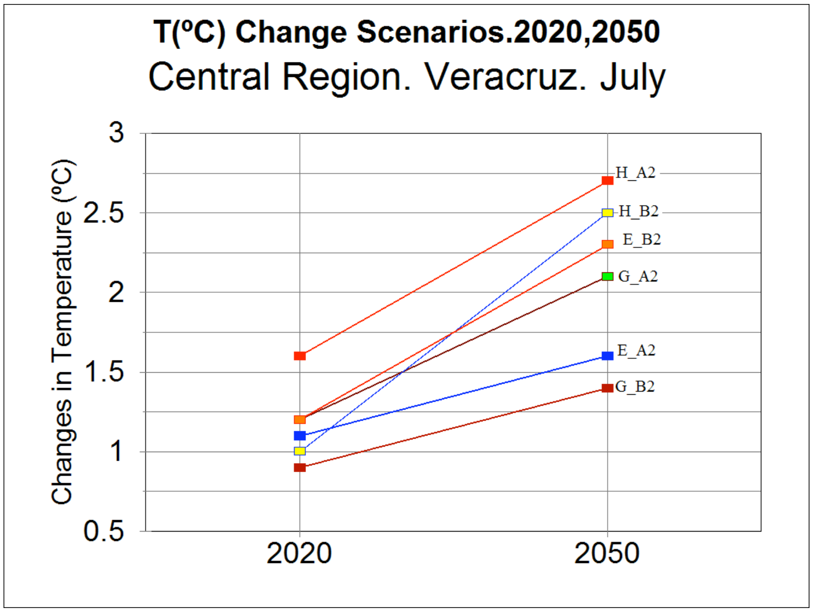


Fig. 2.20a: Projected changes in temperature for the central region of Veracruz (2020 and 2050), using 3 GCM (G: GFDL; H: Hadley; E: ECHAM) outputs and two SRES scenarios (A2 and B2).

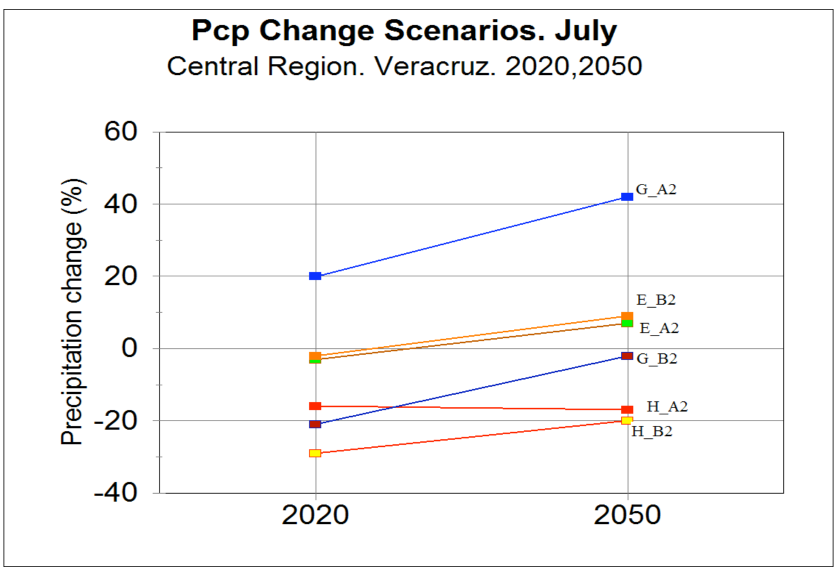


Fig. 2.20b: Projected changes in precipitation for the central region of Veracruz (2020 and 2050), using 3 GCM (G: GFDL; H: Hadley; E: ECHAM) outputs and two SRES scenarios (A2 and B2)

The changes in temperature and precipitation for each scenario could be introduced in threat spaces described in the previous sections. When the anomalies for both variables are outside the limits of the coping range (figure 2.21), the climate scenario is considered to increase climate threat importantly in the future, and therefore special attention should be paid to it in terms of assessing potential future impacts to agricultural activities in the regions.

In July, the limits of the threat space for coffee production are related to precipitation and to maximum temperature. In this case, the proposed coping range must not exceed an increase of 30% or a decrease of 40% for precipitation and must not exceed a change in maximum temperature of 1.5ºC (figure 2.21).

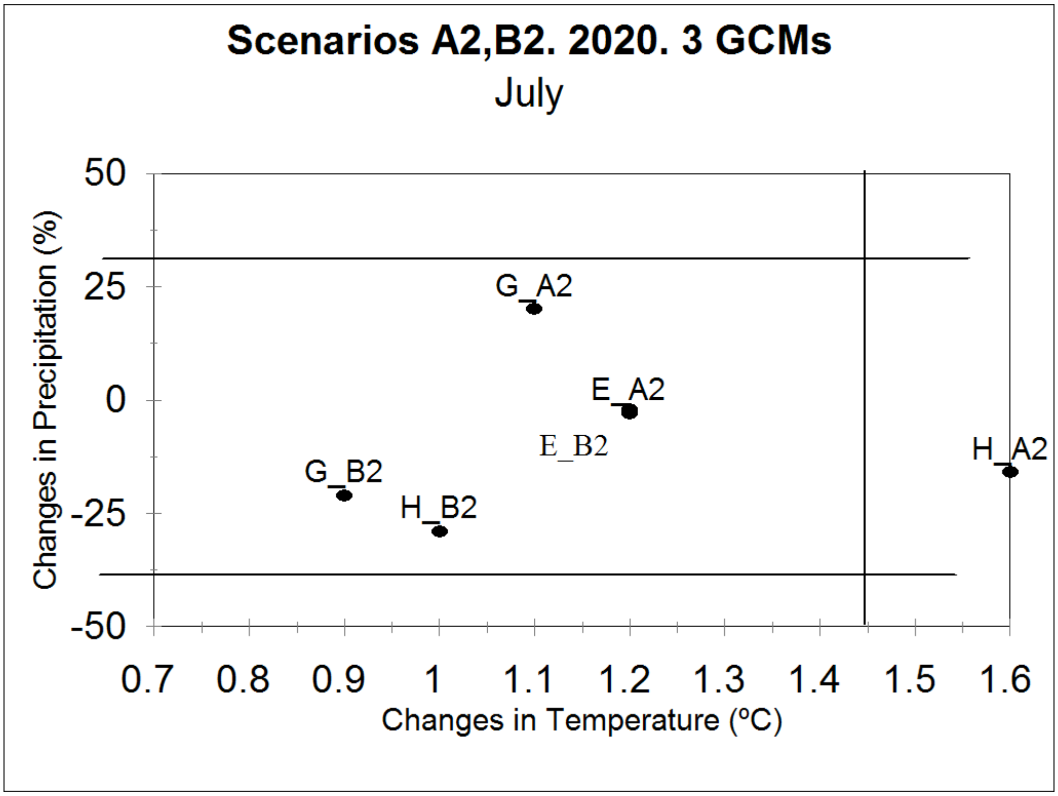


Fig. 2.21: Climatic threat space (outside the rectangle) for coffee production in the central region of Veracruz, considering climate change scenarios. The projected changes are based on the models ECHAM4 (E_A2 and E_B2), GFDL (G_A2 and G_B2), and for the Hadley model (H_A2 and H_B2).

The projected changes from the ECHAM4 (A2 and B2) and GFDL (B2) models could be within the coping range. The projected changes for the Hadley model, in the emission scenario A2 (H_A2, figure2.21) are in the threat space, implying possible important decreases in production, considering the historic impacts and the current climatic threat spaces.

However, if climate variability is considered to follow the distribution of the observed data, then even the scenarios that are within the coping range could represent a climatic threat. As an example, if the ECHAM4 (E_A2 and E_B2) scenarios are considered, which are in the coping range (figure 2.22), instead of having two years (5%) with temperatures over or equal to 30ºC as the observed data show, there could be 4 years (11%) that could exceed that upper limit (figure 2.23). This shows that areas not threatened now could be threatened in the future, so these scenarios should be taken into account for future vulnerability studies.

According to the models' projections for the climatic mean values, a relocation of the observed minimum, lower quartile, median, upper quartile, and maximum values can be performed, providing a scenario of possible changes in climate variability. Each marker in figure 2.22 represents different means and variability in temperature (horizontal lines) and precipitation (vertical lines). The dotted line shows current mean and variability (TO and PO), and all of the other markers are future scenarios, for the emission scenario A2. The box represents the coping range for July (figure 2.22), and it is used to illustrate how, once a variability scenario is provided, relatively small and moderate changes in mean can imply important changes in the probability of adverse conditions for a specific crop. These changes in probability could be interpreted as changes in the viability of a certain crop (or activity) given climate change conditions. It also reveals the possible increase in future vulnerability of the coffee producers to climatic hazards.

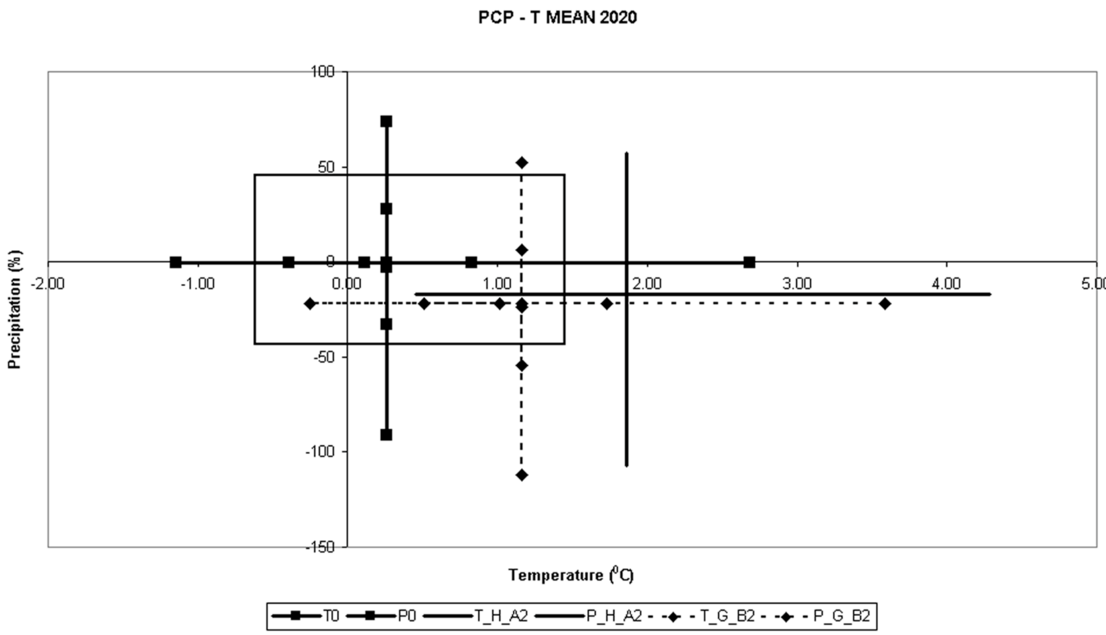


Fig. 2.22: Current mean and variability conditions and climate change scenarios for 2020. The crosses show a mean value and variability for current and for each future scenario of temperature and precipitation. T0 and P0 are current temperature and precipitation conditions and the black box represents the coping range (Figure II.A2.4. 4). The scenarios were constructed using mean temperature (T) and precipitation (Pcp) for the HadCM3 (A2 scenario), and the GFDL (B2 scenario), which project the highest and lowest changes in temperature, respectively (figure 2.20).

These results show the importance to consider possible changes in climate variability within the climate change scenarios. Unfortunately, there is still a lack of adequate impact models to use the multiple combinations that arise from the 5 possible outcomes for each variable depicted in figure 2.22. Impact models that could introduce a probability density function (pdf) for each variable could be useful.

For that purpose, a multi regression analysis was performed (Gay et al, 2004) to introduce in an econometric model the key climatic variables for the case of coffee production. Also, economical variables were consider in that study.

2.4.2 Econometric model

The results obtained with regression equations constructed in previous work (Gay et al., 2004), which relate climate and economic variables with coffee production, show the most important decreases might occur when the projected changes in spring, summer, and winter precipitation are considered. The regression parameters derived are presented in equation 1.

$$P_{coffee} = -35965262 + 2296270(T_{summ}) - 46298.67(T_{summ})^2 + 658.01618(P_{spr}) + 813976.3(T_{win}) - 20318.27(T_{win})^2 - 3549.71(MINWAGE) \quad (1)$$

where

P_{coffee} = projected changes in coffee production,

T_{summ} = mean summer temperature,

T_{win} = mean winter temperature,

P_{spr} = mean spring precipitation, and

MINWAGE = the real minimum wage.

Considering that optimal temperatures for coffee in the summer and winter are 24.8ºC and 20.0ºC, respectively, and that the mean precipitation for spring is ~81 mm, the expected production of coffee in the central region of Veracruz is 549,158.4 tons. Considering that the changes in those variables could be represented by the scenarios for April, July, and January, a decrease of 9% to 13% in coffee production could be expected in the year 2020.

Comparing the observed and modeled production with the later equation (figure 2.23) it can be seen that it is possible to use this econometric model to analyze future impacts on coffee production under climate change conditions.

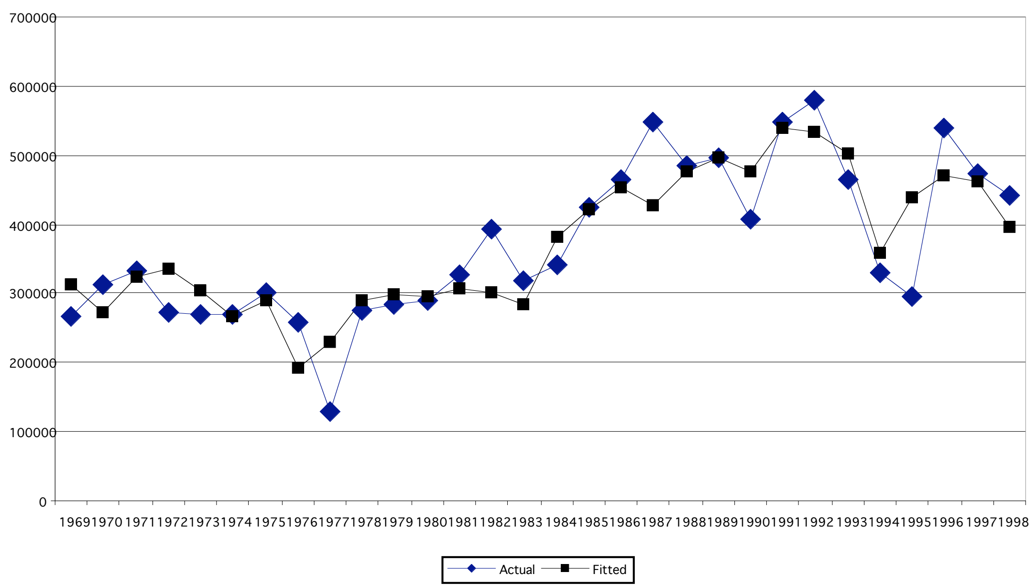


Fig. 2.23: Actual and fitted series for coffee production in Veracruz. (Gay et al, 2006).

2.4.3 Conclusions Veracruz case study

The research developed in Veracruz was quite successful. Several posgraduate students (from climate and social disciplines) are developing or starting their thesis research. New projects have emerged since the AIACC project, so there is a great support to continue the AIACC research.

One issue that is now being consider is to analyzed the changes in climate variability under climate change conditions. Another main issue is the treatment of uncertainties associated to climate change scenarios. For both purposes students with a degree in Statistical Analysis are being incorporated to research with the original climate AIACC team.

Agronomist and Geographers are using the CROPWAT model to specifically analyzed the possible impacts under particular climate change conditions in coffee production. Also, considering that the coffee plantations are imbibed in complex forest ecosystems, studies of environmental services are now being developed, since coffee producers no longer find a good market for their production and are starting to switch to other agricultural activities, such as sugar cane. This fact endanger the future of the forests.

On the other hand, related to the climatic threat spaces, the analyses of regional climatic variability help in defining the current climatic threat. In this sense, climatic threat spaces can be a useful tool for defining "threat" with stakeholders and for communicating risk. The dispersion diagrams for temperature and precipitation illustrate climatic threat to a specific agricultural production and the damages that they could cause to specific crops. The magnitudes of the hazard and of the losses can be used to characterize the vulnerability of agricultural producers. Regional climate change scenarios can be introduced to the climatic threat spaces, and future threats or opportunities can be discussed with key stakeholders in the region.

Even if the changes in the mean values proposed by the outputs of several GCMs appear to be within the coping range, caution should be taken with the behavior of the extreme events in the future. Considering that under climate change conditions, the climate variability will be similar to the observed in current values (as a first approximation), the frequency of extreme climatic events might increase, increasing then the future vulnerability of the system under study.

A limitation of these threat spaces is that they are not for the analysis of extreme events in daily frequency (frosts, heavy rain, for example), since threat spaces are constructed using seasonal means, which can hide the effect of a daily extreme value. However, using other sources, as newspaper articles, interviews, and surveys, along with specific daily climatic studies, this limitation can be overcome.

2.5 Argentina-South of Cordoba Case Study Region

In the case of study for Argentina the current climate is summarized and the climate change, the weather variability and extremes are studied as a base to explore the climate and weather impacts, the socio-economic vulnerability and adaptation in the region.

2.5.1 Data and data sources

Data used for the analysis was based on daily weather values of maximum and minimum temperature and precipitation for four weather stations in the area (Table 2.2). The length of the daily record was from 1961 to 1990 as the baseline period. Also, monthly normal for the period 1961/90 and for 1931/60 were available for the stations in the area and from auxiliary stations in a surrounding region outside the limits of the study area. The auxiliary stations were used to get the continuity of the variables in the plotting procedure.

Station name	Lat. (°, S)	Long. (°, W)	Elevation (masl)	Series length	Data source
Río Cuarto	33° 03′	64° 18′	440	1961-1990	UNRC/NWS
Laboulaye	34° 07′	63° 23′	280	1961-1990	UNRC/NWS
Pilar	31° 41′	63° 53′	338	1961-1990	NWS
Marcos Juarez	32° 41′	62° 06′	115	1961-1990	INTA
Córdoba	31° 24′	64° 11′	425	1961-1990	NWS
Villa Dolores	31° 57′	65° 08′	569	1961-1990	NWS
Villa María del Río Seco	29° 54′	63° 41′	341	1961-1990	NWS
Gral. Pico	35° 42′	63° 45′	145	1961-1990	NWS
Chamical	30° 22′	66° 17′	461	1961-1990	NWS
Chepes	31° 20′	66° 40′	658	1961-1990	NWS
San Luis	33° 16′	66° 21′	713	1961-1990	NWS
Villa Reynolds	33° 44′	65° 23′	486	1961-1990	NWS
Ceres	29° 53′	61° 57′	88	1961-1990	NWS
Rafaela	31° 11′	61° 33′	100	1961-1990	INTA- NWS
Pergamino	33° 56′	60° 33′	65	1961-1990	INTA-NWS
Junín	34° 33′	60° 56′	81	1961-1990	INTA-NWS
Nueve de Julio	35° 27′	60° 53′	76	1961-1990	NWS
Trenque Lauquen	35° 58′	62° 44′	95	1961-1990	NWS
Santiago del Estero	27° 46′	64° 18′	199	1961-1990	NWS

Table 2.2:. Selected locations used in the analysis and their data sources. The first four stations are the analyzed stations in the study region. The rest are the auxiliary stations. (NWS: National Weather Service; masl: meters above sea level)

2.5.2 Characterization of the current climate

2.5.2.1 General circulation

The climate in Argentina is determined by the circulation features of South America. As described by Trewartha (1966), Antarctica, although excessively frigid, has a convex surface profile which facilitates a down slope seaward movement of the cold air almost as rapidly as it forms, so that there is no build-up into well developed cold anticyclones such as the ones generated over sub arctic Eurasia and North America in the winter. As a result the middle and lower latitudes of the Southern Hemisphere are not invaded by cold anticyclonic surges of cold polar air of magnitude and intensity comparable to those of the Northern Hemisphere. South America extends far enough pole wards, and offers sufficiently high terrain barriers, to produce dynamic and thermal effects of a magnitude to disturb greatly the strong zonal circulation. Consequently, the zonal circulation is most disrupted, and a great meridional exchange of air between high and low latitudes occurs. Surges of sea-modified Antarctica air do move northward in the western south Atlantic and penetrate well into the tropics, causing disturbed weather along the east coast of South America and in the interior as well. Such cold-front disturbances provide an important element in the weather.

The fact that the subtropical belt of high pressure is not continuous across South America, but instead there exists a continental corridor between the Pacific and the Atlantic cells, permits a relatively free meridional exchange of tropical and polar air, with remarkable climatic consequences. Satyamurty et al. (1998) states that the regional atmospheric circulation over South America presents many interesting characteristics, such as the Bolivian high, the South America Convergence Zone (SACZ), the Chaco low in summer, and cold frontal invasions into the tropical region known as friagens in winter. The region between the two subtropical anticyclones lies over the continent in the latitudinal belt between 15° and 40° S, and this region is frontogenetic. In this region there is an indication of the presence of a low-level northerly jet below 850 hPa that is responsible for the transport of water vapour and heat to the region of Paraguay and northern Argentina from the Amazon mostly during the summer. The rainfall maxima in Argentina northern of 40 ° S is during the summer (December to February). Most of the region has a dry season during the winter (June to August).

Cold frontal passages are the most common transient weather events over Argentina. The mid-latitude cyclones coming from the Pacific cross the Andes and Argentina, south of 35° S, take an east-south-easterly course in the Atlantic, while the cold front associated with the low pressure center moves north-eastward. As the cold front sweeps the eastern parts of the continent, convective activity is triggered over Argentina. In general, the frontal penetrations are well spread over all seasons in all latitudinal bands. Their convective activity, however, is very low in the winter months, especially in June and July. They are more frequent in the southern latitudinal belt between 35° and 40° S (about nine per month) and less frequent in the northern belt, north of 20° S (about one per month). They are responsible for a large part of the rainfall in northern Argentina. Also, the northern Argentina and especially in the period November-April experience the effects of sudden development of mesoscale convective complexes (MCCs) (Velasco and Fritsch, 1987). The MCCs usually start in the early hours of the day before sunrise and have a short life cycle, less than a day, and providing cloud formation and precipitation occurrences.

2.5.2.2 Temperature and moisture climate conditions

Thermal and water conditions are the main variables in the south of Cordoba area responsible of the agroclimate and crops variability. The incoming solar radiation determines mesothermal conditions during the year, with differentiated winter and summer seasons. Mean annual temperature (figure 2.24) ranges between 17 °C in the north of the area to 16 °C in the south. General climate patterns during the winter are low temperatures and frost occurrences coupled with soil water deficit, showing dry yellow vegetation during this season. However, the climate variability may yield occasionally milder temperatures during the winter coupled with wet conditions of the soils promoting green vegetation and anticipating the development of the crops, changing crop cycles and exposing them to high risk due to frost damage. Temperatures in the Argentine prairies show distinctive effects compared to more continental regions in the world. Mean maximum temperatures in January and July in the area show values about 31 °C and 16.5 ºC, respectively. Mean minimum temperatures for January ranges from 17.5 °C in the north to 16 °C in the south of the area. In July the values are from 4.5 °C to 2.0 °C, respectively (figure 2.25). The annual pattern of the mean temperature variation between summer and winter in the area shows temperatures above 15 ºC, which are effective for vegetation development, from the first decade of October to the second decade of April. The soil temperatures occurrences are favorable for crop seeds germination in average from the end of September to the end of April (Seiler et al., 1995). The mild and short winters, moderate summers and extended length of the growing season allow the normal growth, development and maturity of summer crops such as corn, sunflower, sorghum grain, and soybean, which are extensively cropped in the region. During the winter, temperatures are low enough for winter chilling and satisfactory to mature the adapted cultivars of the cold season crops such as wheat (Pascale and Damario, 1988). In figures 2.26 and 2.27 the maximum and minimum monthly normal temperatures and their patterns of annual variation are shown for the locations studied in the area. Although the quite favorable temperature conditions and the excellent length of the growing season, uncertainties exist and risk is imposed in the region due to inter annual temperature variability causing frost damage. The mean date of the first frost in the north of the area (Pilar) is May 28 and September 1st for the last frost. In the south of the area (Laboulaye) are May 15 and September 12 for the mean date of the first and last frost, respectively. As frosts happening outside of the mean frosting period are the risky ones for vegetation growth, it is important to know the variability of the mean dates of the first and last frost. Calculated standard deviations for the date of first and last frost in Pilar are 18 and 17 days respectively and in Laboulaye 17 and 14 days, respectively. The crop-growing period may be shortened or lengthened by inter annual variations of the weather conditions.

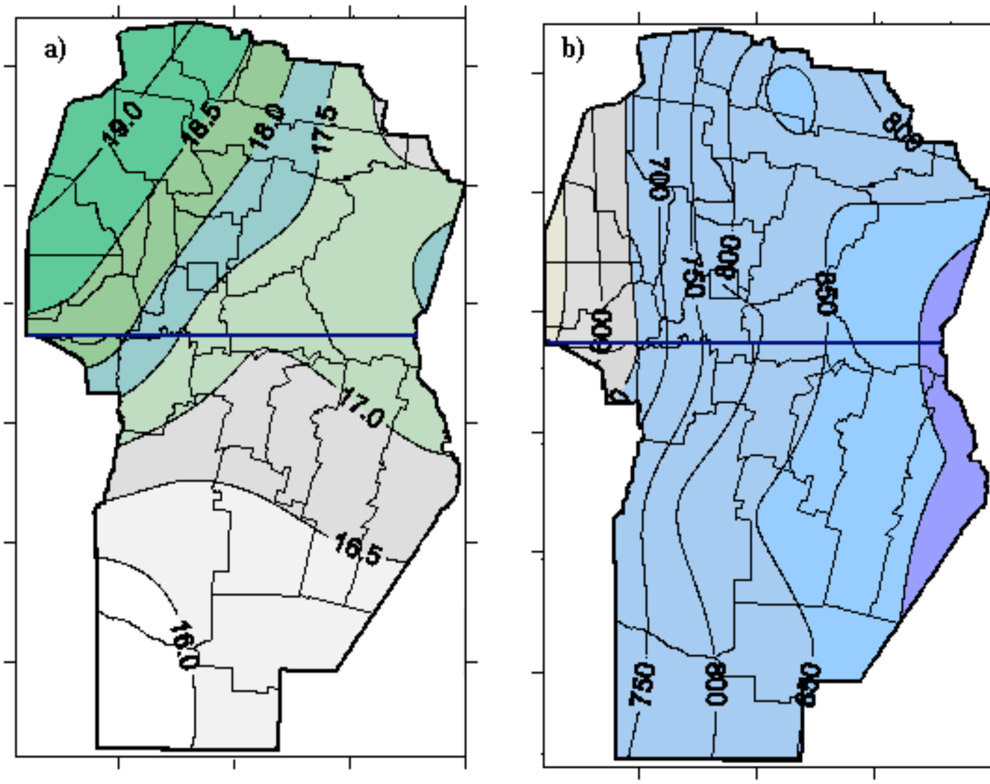


Fig. 2.24: Mean annual temperature (a) and precipitation (b)

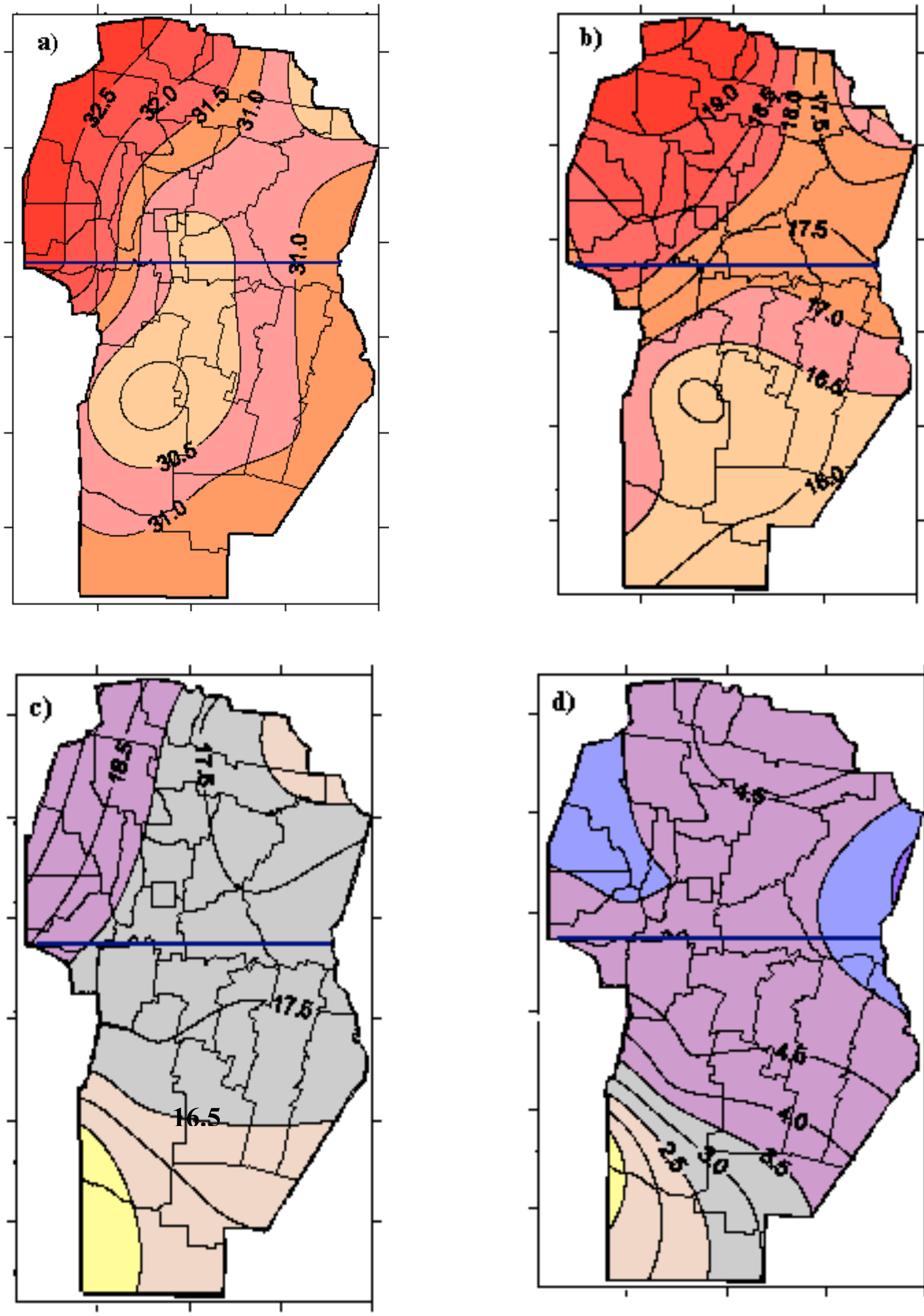
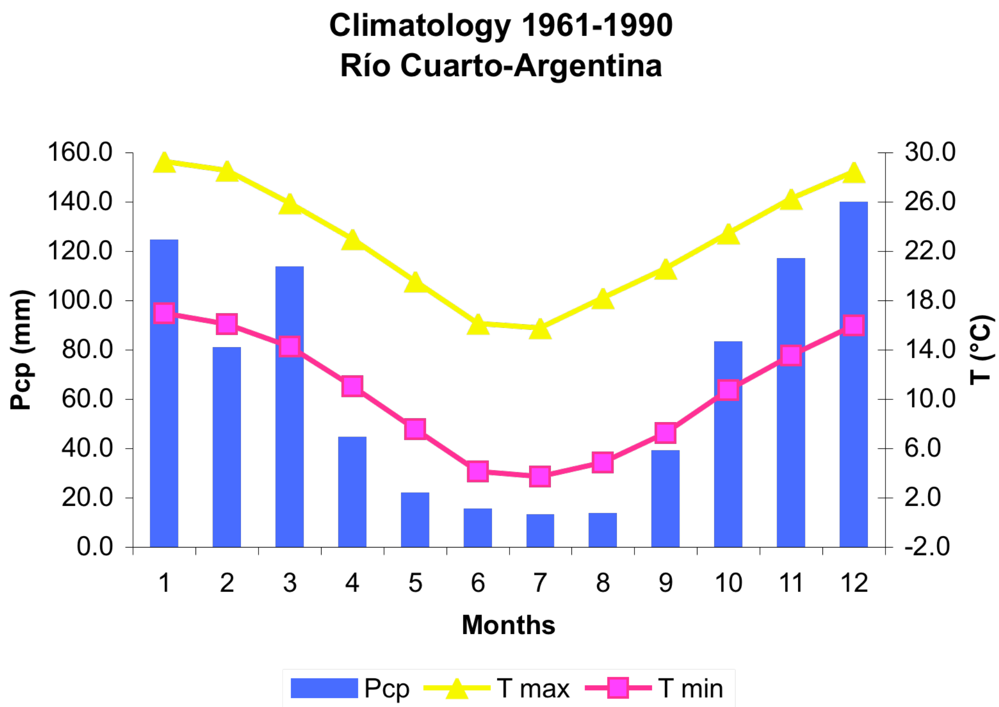


Fig. 2.25: Mean maximum temperature in the area in a) January, b) July and mean minimum in c) January and d) July respectively



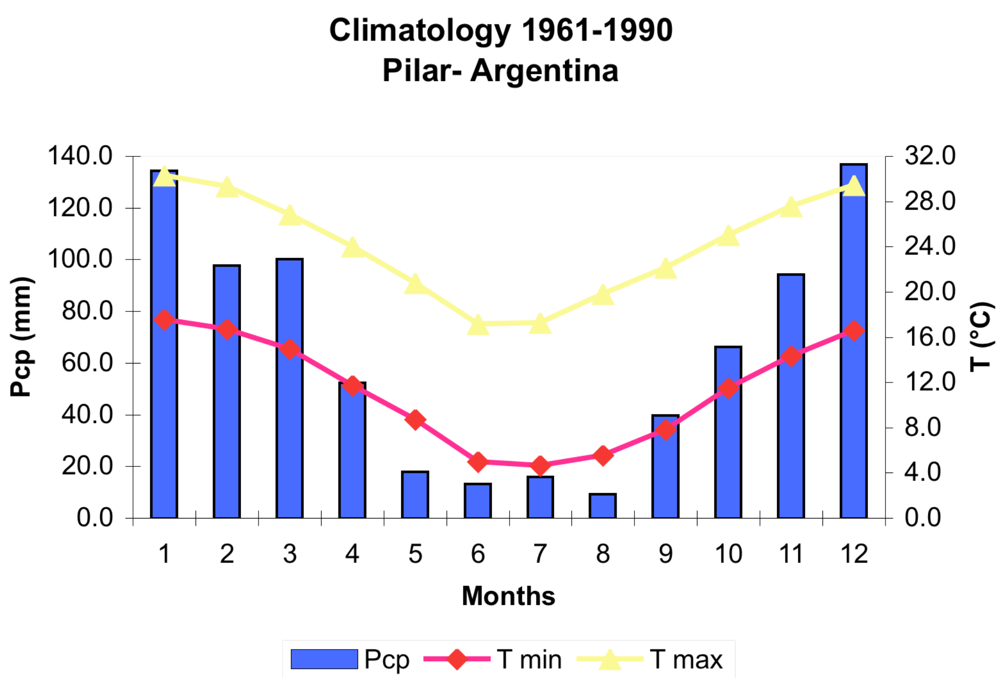
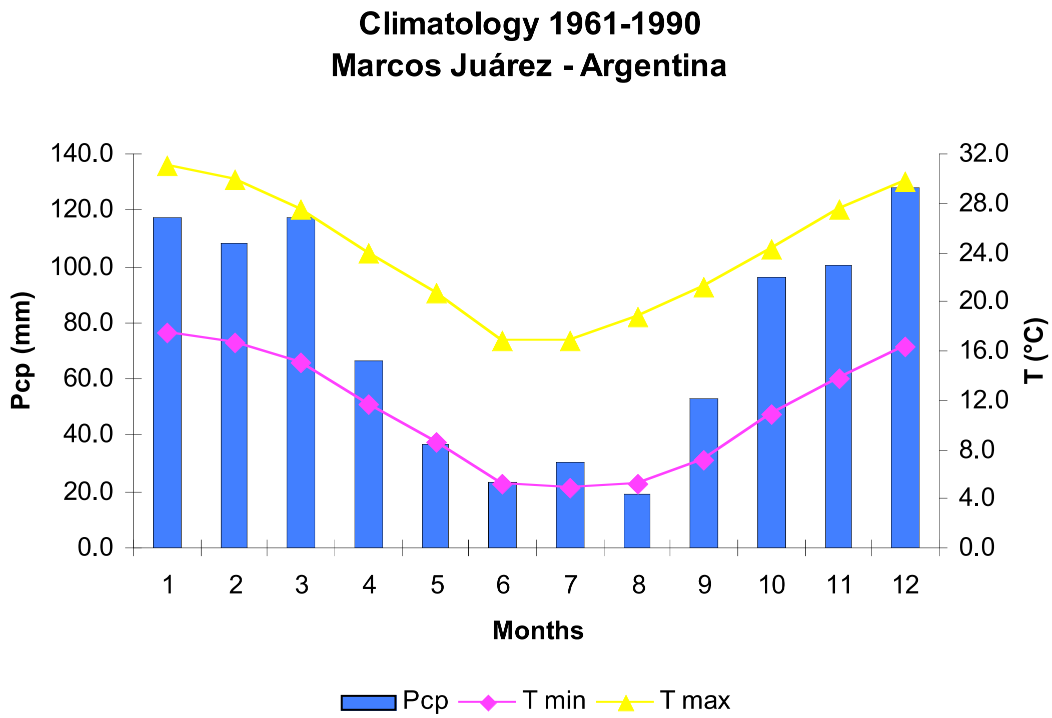


Fig. 2.26: Normal climatic conditions for Río Cuarto and Pilar in Argentina, considering maximum (Tmax), minimum temperatures (Tmin) and precipitation (Pcp).



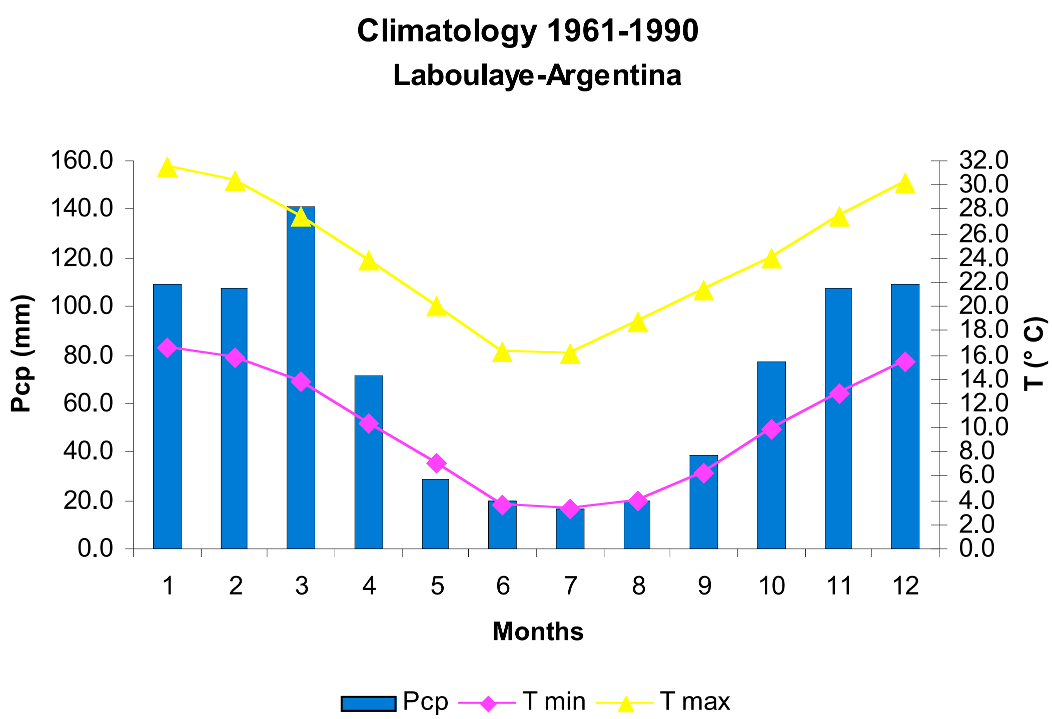


Fig. 2.27: Normal climatic conditions for Marcos Juárez and Laboulaye in Argentina, considering maximum (Tmax), minimum temperatures (Tmin) and precipitation (Pcp).

Local seasonal conditions of maximum and minimum temperatures are presented in figure 2.28 for each of the locations in the area. Each value for a season represents the average of the monthly temperature for the three months associated with that season starting with the one of the beginning of the season (i.e. Spring is the average of September, October and November monthly temperatures). Temperatures for each season appear to be rather conservative over the area since small differences are shown between locations.

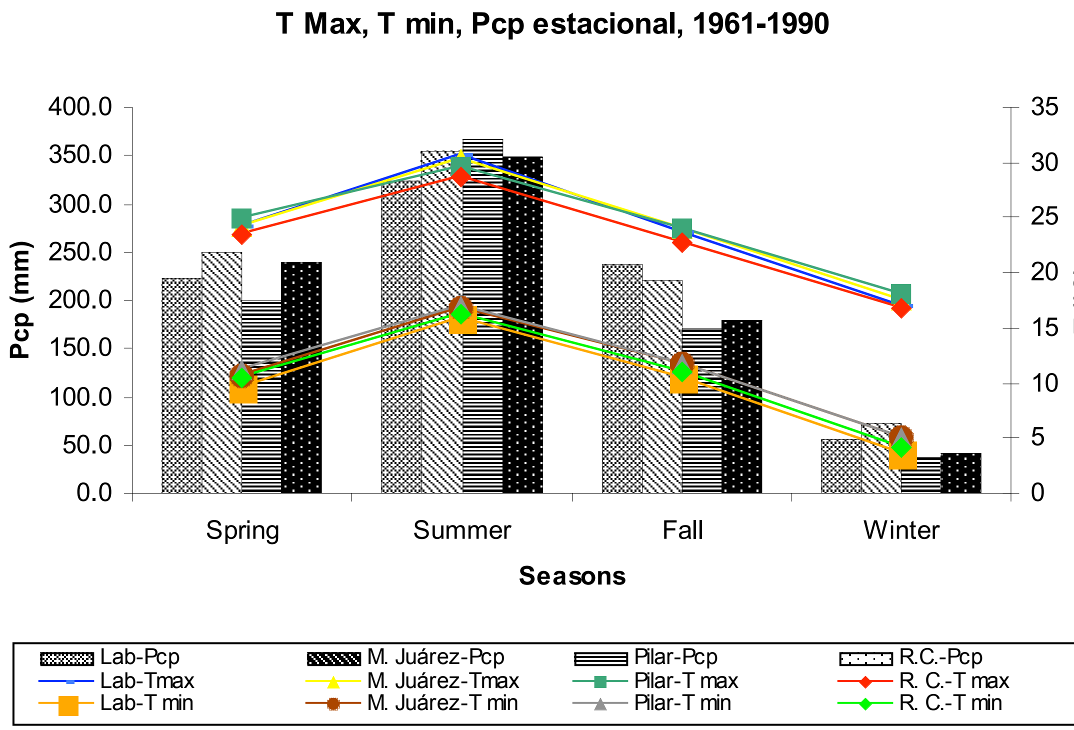


Fig. 2.28: Seasonal values of maximum and minimum temperature and precipitation for the locations analyzed in the area

Providing temperature allows the crops cycle, as in any agricultural region water in the south of Cordoba area is the most limiting factor. Average precipitation during the year ranges from 900 mm in the northeast of the prairies to 700 mm in the west (figure 2.24). Most of the precipitation occurs from September to March. Winter is the driest season (figures 2.26 and 2.27). The climatic water balance for the region indicates a slight water surplus. However, the inter-annual climate variability may produce unbalanced situations anywhere with occasional droughts of different frequency and severity.

Variation of water availability is more noticeable than temperature along the area. Spatial variations let to differentiate at least four sub regions according to the normal annual precipitation: the eastern part, the central, the south west sub region and the mountains area. In the east, the annual precipitation of the department of Marcos Juarez average 900 to 950 mm and even more in the limit with the Santa Fe province. Record annual precipitation for the central area is about 800 mm. In the south west area, annual precipitation decreases to the south and to the west. This variation shows precipitation around 700 mm in the limit with the San Luis and La Pampa provinces. In the subarea of the mountains a gradient is observed as a result of the convection of the air, producing around 700 mm of annual precipitation at the base to about 900 mm in some up the hills areas. The seasonal distribution of the precipitation for the whole area is typical of monsoon (concentrated during the warm period, October to March) (Ravelo and Seiler 1979). In the north and west of the area about 45 of the total annual precipitation falls during the summer months, 22% in the autumn; 28% in the spring and a small proportion (5%) during the winter while in the east and south locations these percentages change to 39%, 26%, 27% and 8% respectively for each season.

The precipitation regime affects the soil water balance in the region and also the recharge of the subsurface reservoir and of the superficial hydrological system, including floods in some prone areas. The northeast areas show a reduced frequency of dry summers. In more than 50% of the years there is no drought during the period December-March. In the western portion of the region the probabilities for the development of water deficiencies and drought during the summer are high. Cultural practices and management becomes the key for reducing risk and for avoiding water shortages during critical crop stages. In the mountains area there are favorable situation for water availability but the spatial variability is very high.

The climate and weather occurrences in the whole area and in the sub regions become even more complex according to the interaction with the soils (depressed areas and flood-prone basin, salty soils, drainage difficulties, etc) and topography variations causing different responses of the environment due to the variation of the efficiency of the precipitation and changes in the environmental potential for production. The weather variability and the variation on the physical resources also change the vulnerability of the agricultural producers and causes strong socio economic impacts either favorable or unfavorable.

2.5.3 Climate change and climate variability analysis

Climate change and climate variability are major factors causing changes in the ecology. The biological responses of the environment to changes in climate are likely to have significant relevance for socio-economic issues such as agriculture, forestry, human health and also to play a role in raising environmental awareness and education on climate change. During the 20th century the increase in temperature was 0.6°C (IPCC, 2001). On the average, the daily minimum air temperature over the land increased by about 0.2°C /decade between 1950 and 1993. In the agricultural areas of Argentina and particularly in the south of the province of Cordoba, climate variability has become a very significant feature of the farming system. In the analysis of the impacts for the study area, Vinocur, et al., (2000, a,b,c; 2001) using experimental data and crop development and yield simulations of peanut and maize demonstrated that an increase in the temperature variability cause a decrease in the mean yield of the crops and also increase the variability of their yields among other changes. De La Casa and Seiler (2003) by comparing ten years mean of climate variables from 1941 to 1990, found climate changes likely to induce changes in the aptness for cattle production in the province of Cordoba – Argentina.

The Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) also reports changes in precipitation. There are indications that precipitation has increased by 0.5% to 1% by decade in the 20th century over most mid and high latitudes of the Northern Hemisphere continents, and an increase of about 0.2% to 0.3% by decade over the tropical land areas (IPCC, 2001). In the province of Córdoba, Ravelo et al., (2002) studying the trend and variability of the precipitation between 1931 and 2000, have found a positive trend of 0.2 to 4 mm by year according to the site of the stations.

2.5.3.1 Temperature and precipitation

Recent analysis of Seiler and Vinocur (2004), comparing 1961/90 versus 1931/60 climatology indicates changes in the seasonal temperature and precipitation in the region. Maximum temperature decreased during the spring (Sep, Oct, Nov) and summer (Dec, Jan, Feb) seasons by 0.5°C and 1°C respectively and did not show changes during the autumn (Mar, Apr, May) and winter (Jun, Jul, Aug) seasons (figure 2.29).

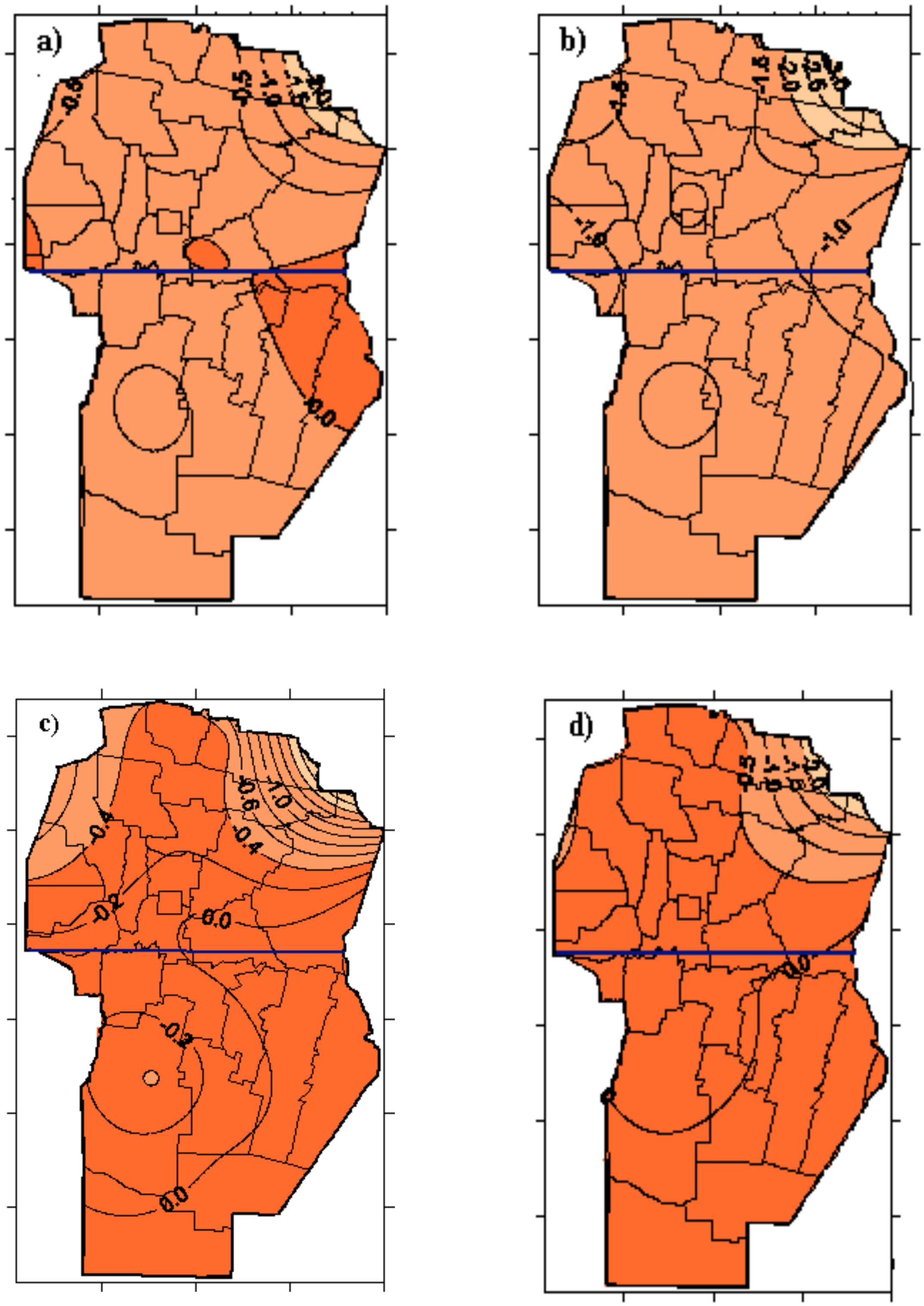


Fig. 2.29: Seasonal changes in the maximum temperatures, a) Spring (Sep, Oct, Nov); b) Summer (Dec, Jan. Feb); c) Autumn (Mar, Apr, May); d) Winter (Jun, Jul, Aug)

Minimum seasonal temperature has shown increasing values in all the seasons (figure 2.30). Higher minimum temperatures from 0.4 °C to 0.9 °C are observed across the region during the spring and up to 0.8 °C of increase during the summer. In the autumn the increase is the most noticeable, up to 0.9 °C to 1.4 °C. Winter is also warmer than the 1931/60 period in 0.2 °C to 0.7 °C.

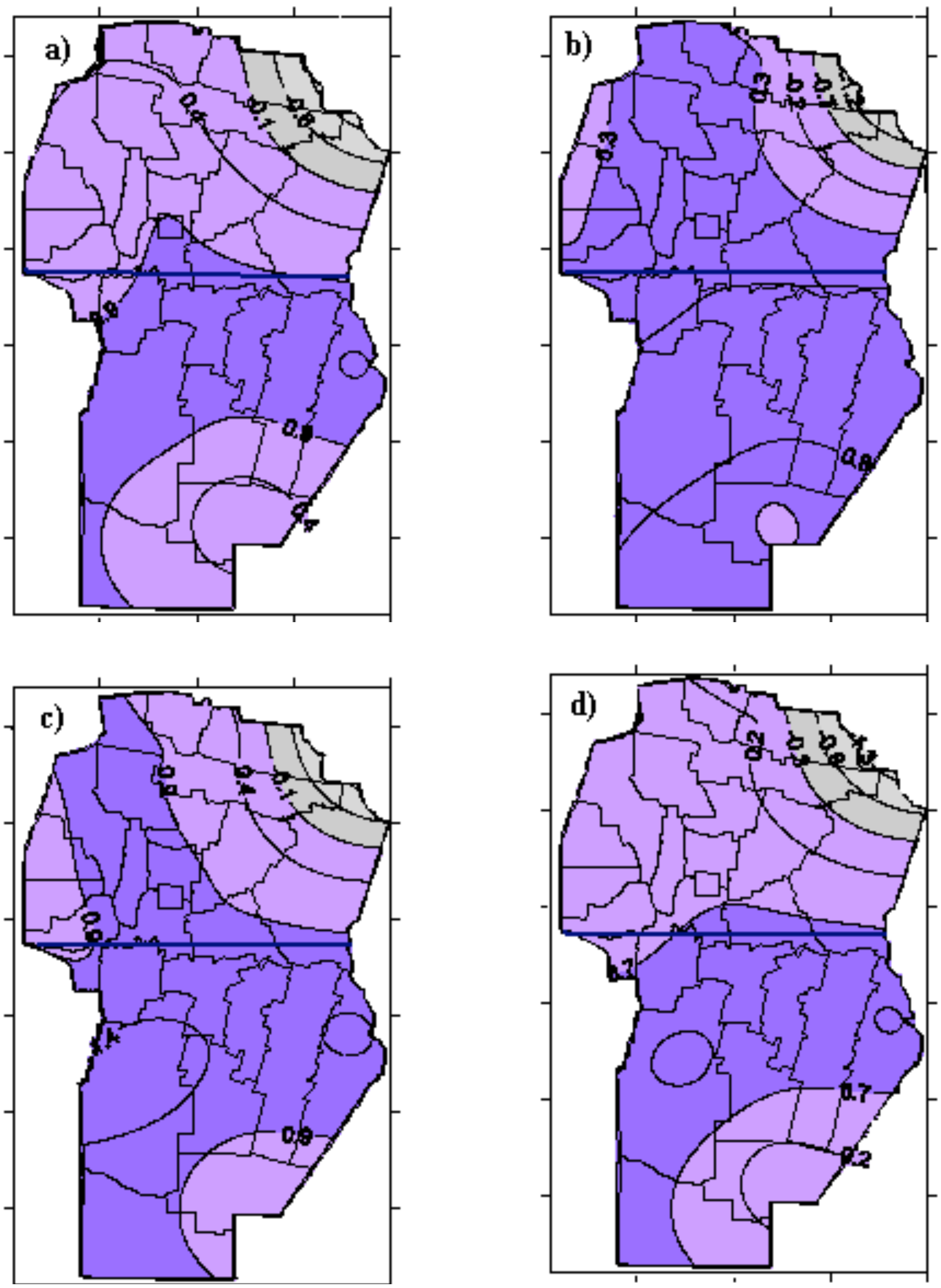


Fig. 2.30: Seasonal changes in the minimum temperatures, a) Spring (Sep, Oct, Nov); b) Summer (Dec, Jan. Feb); c) Autumn (Mar, Apr, May);d) Winter (Jun, Jul,7Aug)

Precipitation shows more significant increases, mainly during the summer and fall seasons (figure 2.31). Spring shows an increase in precipitation in the east and in the south and a decrease in the center of the region while winter indicates a slight increase in the west and south and remains unchanged in the rest of the region. Average precipitation increase during summer reaches more than 15%, while during the fall and spring is about 4%.

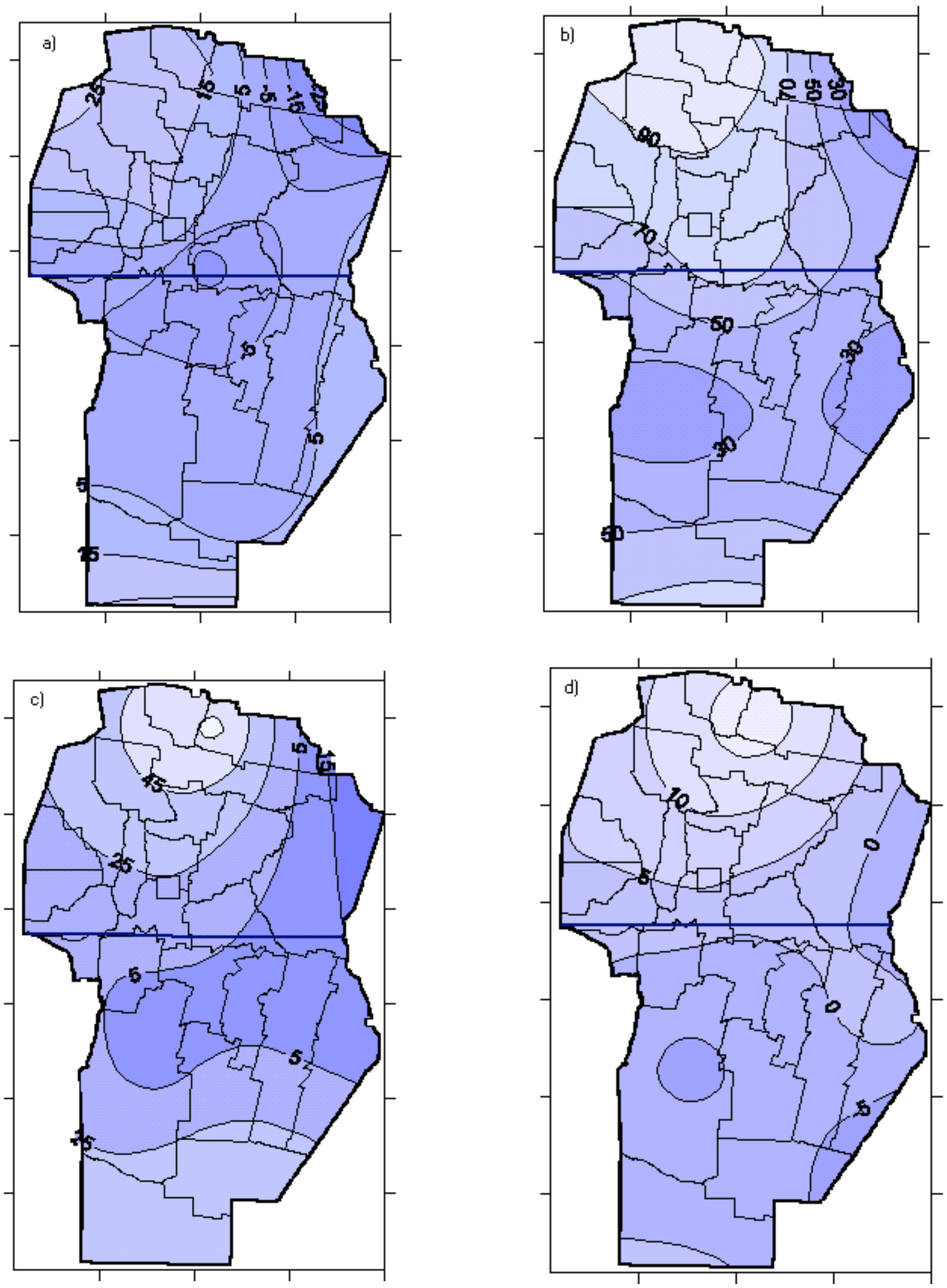


Fig. 2.31: Seasonal changes in the precipitation, a) Spring (Sep, Oct, Nov); b) Summer (Dec, Jan. Feb); Fall (Mar, Apr, May); Winter (Jun, Jul, Aug)

According to Lucero and Rodriguez (1999), in central Argentina, an important positive trend in annual rainfall is produced by fluctuations with timescales larger than 10 years. Atmospheric processes related to ENSO are not contributing significantly to the generation of this trend in annual rainfall. The fluctuation in the province of Cordoba was excited approximately in 1935 with a timescale of about 10 years. Before 1935, annual rainfall had an stationary mean. After that year, mean annual rainfall in this region is increasing at a rate of 5 mm/year.

As climate changes, the main changes in precipitation will likely be in the intensity, frequency, and duration of events, but these characteristics are seldom analyzed in observations or models (Trenberth et al., 2003). It means that prospects are greater for changes in the extremes of floods and droughts than in total precipitation amounts. The year to year variability of the precipitation or the interseasonal variation including the extremes conditions, are very important for agriculture, hydrology, and water resources, yet not been adequately appreciated or addressed in studies of impacts of climate change. As an example of that variability, in figures 2.32 and 2.33 a long series of precipitation (IPCC data), the linear trend and the variability of summer precipitation average of the whole region are shown. Extreme occurrences are indicated just for convention as the cases out of plus/minus one standard deviation.

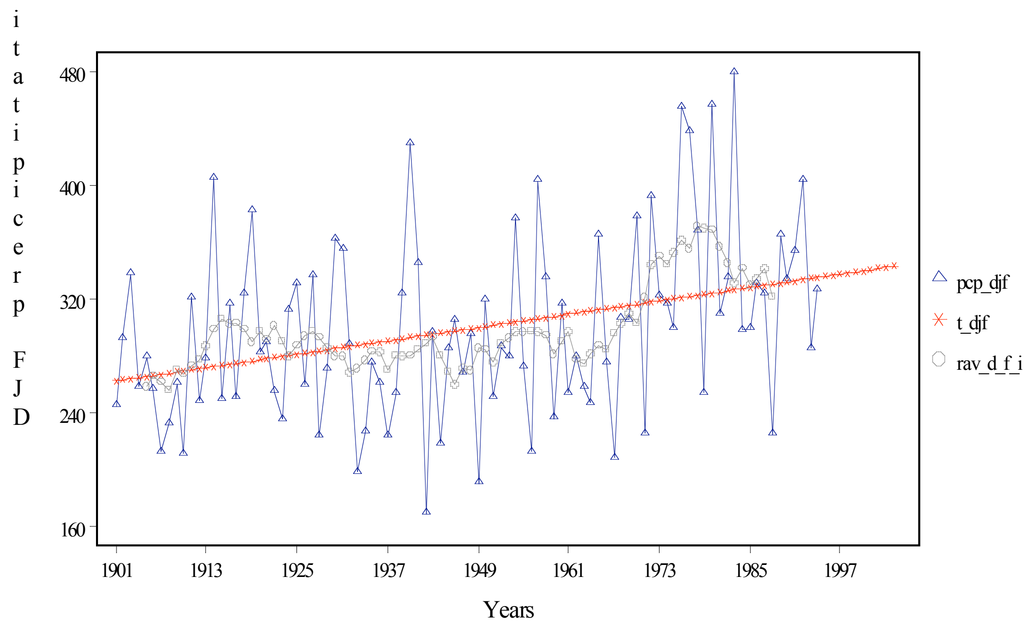


Fig. 2.32: Regional precipitation during the summer (D-J-F) from IPCC data and trend análisis. (Pcp_djf: summer precipitation; t_djf: linear trend; iav_d_f_i: five years moving average)

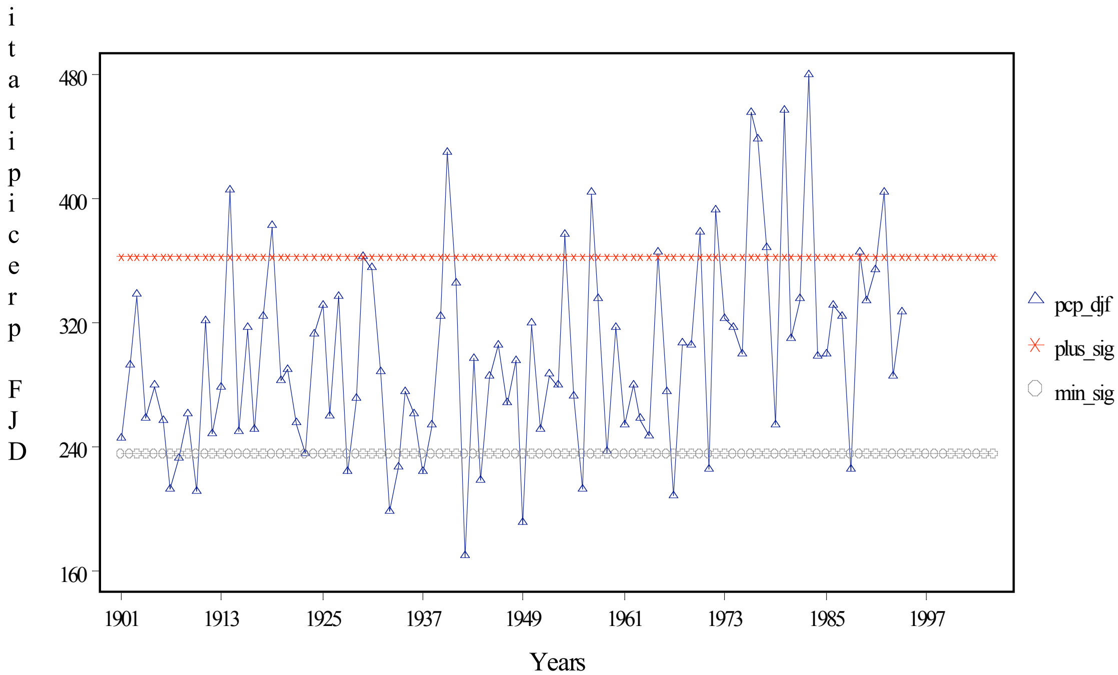


Fig. 2.33: Summer precipitation variability analysis for the Cordoba region from IPCC data series. (pcp_djf: summer precipitation, as the total of Dec, Jan, Feb.; plus_sig, min_sig: plus, minus one standard deviation, respectively)

As measures of the precipitation variability and anomalies, but for the four particular locations studied in the region, the top wettest years for each season and location are presented in tables 2.3 to 2.6

Annual total (calendar year)		Spring season (Sept – Nov)		Summer season (Dec – Feb)		Autumn season (Mar – May)		Winter season (Jun – Aug)	
Year	**mm**	**Year**	**mm**	**Year**	**mm**	**Year**	**mm**	**Year**	**mm**
1981	1181.7	1978	338.0	1978	743.4	1981	379.7	1985	144.6
1978	1141.6	1967	313.5	1979	616.4	1973	316.5	1979	120.3
1977	1091.7	1976	307.8	1981	589.7	1987	286.0	1986	88.9
1979	1065.4	1972	305.9	1983	514.8	1978	272.5	1968	73.9
1984	989.3	1979	296.4	1973	468.9	1975	261.1	1973	64.5
1983	928.4	1964	271.6	1984	444.5	1980	242.2	1969	59.3
1976	894.3	1984	265.2	1977	443.1	1969	225.7	1965	53.0
1973	894.0	1961	252.9	1990	438.5	1961	209.0	1974	49.2
1961	850.1	1981	239.6	1966	411.5	1989	201.0	1975	45.2
1990	811.6	1985	232.5	1987	385.2	1966	196.1	1983	43.2

Table 2.3: Top ten wettest years for calendar year and for the Spring, Summer, Autumn and Winter seasons in Pilar (Cba), 1961-1990. Summer season rains are designated by the year of the month ending the interval.

Annual total (calendar year)		Spring season (Sept – Nov)		Summer season (Dec – Feb)		Autumn season (Mar – May)		Winter season (Jun – Aug)	
Year	**mm**	**Year**	**mm**	**Year**	**mm**	**Year**	**mm**	**Year**	**mm**
1990	1345.0	**1966**	447.0	**1976**	710.0	1980	412.0	**1972**	222.0
1975	1265.0	**1977**	401.0	**1983**	520.0	1974	347.0	1971	169.0
1989	1262.0	1989	389.0	**1977**	513.0	1990	346.0	1990	165.0
1976	1254.0	1971	377.0	1989	499.0	**1986**	325.0	1984	128.0
1977	1178.0	1978	329.0	1975	491.0	**1972**	321.0	**1973**	127.0
1980	1139.0	1975	305.0	1978	456.0	**1977**	314.0	**1970**	105.0
1972	1073.0	**1983**	299.0	1962	451.0	**1963**	280.0	1974	100.0
1961	1039.0	1981	290.0	**1987**	419.0	**1987**	273.0	1975	94.0
1966	1005.0	1961	281.0	**1970**	418.0	1962	247.0	1978	92.0
1983	1002.0	1976	278.0	1981	360.0	**1970**	240.0	1967	91.0

Table 2.4: Top ten wettest years for calendar year and for the Spring, Summer, Autumn and Winter seasons in Marcos Juarez (Cba), 1961-1990.

Annual total (calendar year)		Spring season (Sept – Nov)		Summer season (Dec – Feb)		Autumn season (Mar – May)		Winter season (Jun – Aug)	
Year	**mm**	**Year**	**mm**	**Year**	**mm**	**Year**	**mm**	**Year**	**mm**
1984	1185.0	1967	449.0	1984	600.0	1973	303.0	1985	176.0
1972	1117.0	1961	400.0	1979	537.0	1980	297.0	1979	131.0
1978	1026.0	1978	350.0	1978	461.0	1966	253.0	1968	88.0
1967	972.0	1964	335.0	1973	456.0	1974	251.0	1974	76.0
1961	967.0	1972	317.0	1981	455.0	1975	245.0	1973	59.0
1979	956.0	1963	292.0	1970	428.0	1990	234.0	1962	58.0
1964	913.0	1983	290.0	1985	409.0	1964	230.0	1972	57.0
1966	873.0	1984	279.0	1987	393.0	1967	220.0	1976	52.0
1973	847.0	1982	273.0	1977	390.0	1987	211.0	1977	50.0
1983	834.0	1976	265.0	1969	366.0	1963	206.0	1964	45.0

Table 2.5: Top ten wettest years for calendar year and for the Spring, Summer, Autumn and Winter seasons in Rio Cuarto (Cba), 1961-1990.

Annual total (calendar year) Year	mm	Spring season (Sept – Nov) Year	mm	Summer season (Dec – Feb) Year	mm	Autumn season (Mar – May) Year	mm	Winter season (Jun – Aug) Year	mm
1976	1251.0	1978	398.0	1978	550.0	1966	484.0	1962	137.0
1978	1115.0	1972	340.0	1984	538.0	1990	458.0	1985	135.0
1984	1055.0	1990	324.0	1977	450.0	1975	382.0	1968	121.0
1966	1037.0	1967	321.0	1976	427.0	1980	381.0	1979	117.0
1990	970.0	1970	290.0	1986	405.0	1969	361.0	1973	116.0
1975	934.0	1961	279.0	1982	400.0	1988	352.0	1976	107.0
1969	916.0	1979	276.0	1983	378.0	1964	288.0	1969	90.0
1961	891.0	1976	266.0	1966	353.0	1984	286.0	1989	82.0
1979	890.0	1983	238.0	1975	345.0	1986	266.0	1974	78.0
1985	885.0	1969	226.0	1981	344.0	1987	258.0	1972	74.0

Table 2.6: Top ten wettest years for calendar year and for the Spring, Summer, Autumn and Winter seasons in Laboulaye (Cba), 1961-1990.

2.5.3.2 ENSO impacts

During the cropping season of the summer crops (September-March), corn, soybean, and peanut are the main options in this region. These crops are sensitive not only to the availability of water at planting but also during crop development (December to February), when the water demand is normally the highest of the season (Seiler et al., 1995).

El Niño is one part of a multi-year cycle of the coupled ocean-atmosphere interaction in the tropical Pacific, called El Niño-Southern Oscillation (ENSO) (WMO, 1995) and it has been recognized as one of the controls of the precipitation variability. The ENSO phenomenon involves two extremes phases: a warmer (El Niño) and cold (La Niña) ocean events, that affect atmospheric circulation, disturbing normal pattern of air pressure, tropical rainfall, and winds, leading to changes in the weather around the globe (Ropelewski and Halpert, 1989; NOAA, 1997). Years that do not fall in these extreme phases are referred as Neutral. In the main agricultural area of Argentina warm ENSO events were associated with enhanced likelihood of higher than the median precipitation anomalies during October-February, while lower than the normal precipitation during the same period was typical of cold ENSO events (Messina, et al. 1999; Ropelewski and Halpert, 1989). Seiler and Kogan (2002) working with NOAA-AVHRR indices during particular ENSO events, found significant responses of crops and vegetation to El Niño and La Niña years in the south of Cordoba. Although strong ENSO related precipitation signal over central-eastern Argentina was found for November-January precipitation (Ropelewski and Halpert, 1989; Podesta et al., 1999), Ropelewski and Halpert, (1996) and Tanco and Berri (1996) found the association between rainfall anomalies and the cold phase stronger than for warm events in the region. In the west of that region and particularly in the south of Cordoba little is known about the magnitude of the ENSO signal where precipitation occurrences may be also affected by local factors and processes.

A regional analysis based on four locations (Seiler and Vinocur, 2004) reveals that there is not enough evidence of a clear El Niño signal associated to positive rainfall enhancement during El Niño years, as compared to Neutral years, in the south of Cordoba. These results differ from the findings for central-eastern Argentina (Ropelewski and Halpert,1987, 1989; Podesta et al., 1999), where a strong ENSO-related precipitation signal was found during Nov-Jan. Indeed, as stated by Kane (1999) for other regions in South America, local effects and/or different mechanisms appear to be interfering. However, evidence exists of strong La Niña signal, causing significant diminutions of rainfall associated with most of the analysed rainfall periods in the west of the region, and with **Nov-Dec** rainfall period in the east of the region (Seiler and Vinocur, 2004). Rainfall variability during El Niño events compared to Neutral years was higher in the west, but mostly in Rio Cuarto. Differences in the interannual variability of rainfall during La Niña events compared to Neutral years were found for **Jan-Feb** period in Rio Cuarto and Marcos Juarez. Rio Cuarto also showed differences in the **Jan-Mar** period, and Laboulaye in **Dec-Jan**.

Significant correlation of the Southern Oscillation Index (SOI) with rainfall allows the monthly SOI values to be proposed in the region as a basis for seasonal rainfall predictions. Undoubtedly, future research must be done in the same region to identify other predicting variables besides SOI that may help to improve forecasts. Best correlations were shown between early spring SOI and late spring and summer rainfall periods. For some of the sites in the region, even earlier SOI as the Fall SOI showed significant correlation with **Nov-Dec** and **Nov-Jan** rainfall. For the highest relationships, 41% of the rainfall variability was captured by the SOI value (Seiler and Vinocur, 2004).

2.5.3.3 Extremes events

A. Floods

Floods, like storms or severe droughts, are climate events occurring at variable time frequencies in many areas of the world. Thus, different regions in Argentina are affected by flooding, which, depending on the degree of the event, can significantly alter regional and national economic development. Although it is hard to estimate the damages and costs associated with a flood, there is no doubt that these costs are generally high. They are even higher if social and environmental impacts are added to the economic losses.

The recurrence of the flood phenomenon, mainly in higher risk areas, should highlight the concept that floods are a normal climate feature and their impacts come not only from the direct effect of the phenomenon but also from the vulnerability of the society affected (Wilhite and Hayes, 1998).

The southern part of Cordoba Province is temporarily affected by floods. During the last 25 years three mayor flood episodes have occurred in the region, having impact in the production and in the socio economy of the areas for several years after each episode (figure 2.34). The flooding area corresponds to the poorly drained plains in the south of the region. Floods in this area are caused mainly by excess rainfall in the flood-prone basin and by the overflowing of rivers and streams that drain the runoff. Additional factors, such as soil saturation, volume of runoff, and the physical characteristics of the zone (type of soil, size of the flood zone, topographic relief, control structures, management), also play a significant role in the occurrence of the phenomenon. Despite the significance of the different variables involved, the trend in most climate studies is to focus on rainfall only. Seiler, et al. (2002) have developed an study based on a series of 25 years of rainfall data collected at three locations, one within the flooding basin, Laboulaye, and the other two outside its limits and upstream of the flooding area. Dates marking the beginning of floods in the last 25 years in the area (Laboulaye City Council, personal communication; La Comuna, 1986), corresponded to July 1979, May 1986, and March 1998. The Standardized Precipitation Index (SPI) for different time scale periods were applied for monitoring hydrological conditions and flood risk (figure 2.34). This type of analysis shows its potential for climate risk monitoring into a regional system as part of a comprehensive flood mitigation program.

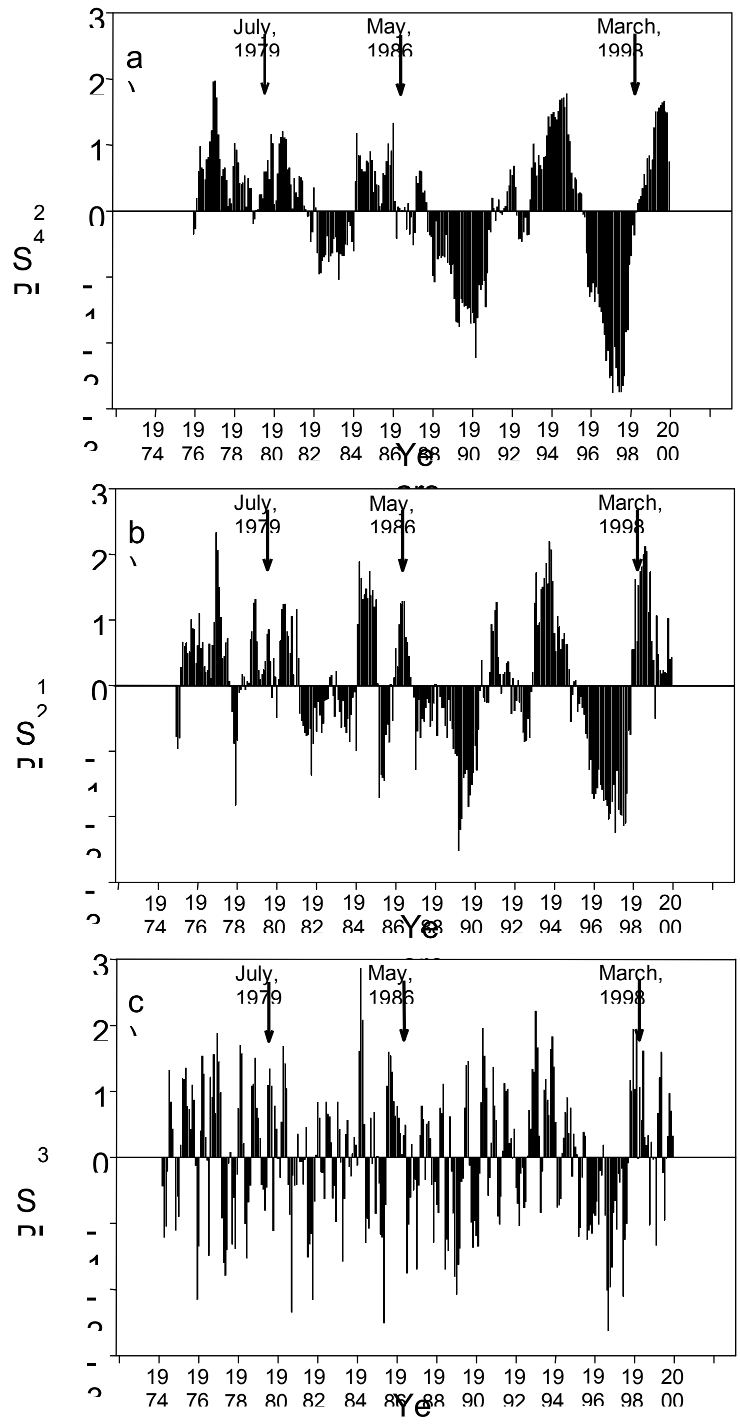


Fig. 2.34: SPI values for Laboulaye calculated from the 1974/99 series for periods of a) 24 months (SPI$_{24}$); b) 12 months (SPI$_{12}$); c) 3 months (SPI$_{3}$), and dates of flood occurrences throughout the series (arrows) Int. J. Climatol. 22: 1365-1376 (2002)

B. Droughts analysis in the region

Among climate hazards, drought is the most damaging phenomenon that occurs every year in some part of the world. Drought is common feature in the agricultural areas of Argentina, including the south of Cordoba. Sensitivity of the agricultural farmers to drought in the region has been reported the highest, compared to flood and hail occurrences (Vinocur et al. 2001; Rivarola et al, 2002). To reduce drought impacts, the main components of a drought preparedness and mitigation plan should include drought monitoring/early warning, assessment of impacts, and response (Wilhite 1993). Timely information about the onset of drought and its extent, intensity, duration, and impacts can limit drought-related losses of life as well as human suffering and reduce damage to the economy and environment (Wilhite, 1993).

Drought indices are valuable tools for drought assessment. In 1993, researchers at Colorado State University developed the Standardized Precipitation Index (SPI) (McKee et al. 1993), suggesting a classification scale (table 2.7) for different drought categories.

SPI values	Drought category
0 to -0.99	Mild droughts
-1.00 to -1.49	Moderate droughts
-1.50 to -1.99	Severe drought
-2.0 of less	Extreme drought

Table 2.7: SPI values and respective drought classifications

One of the major strengths of the SPI is that its capability to show multiple time scales enables it to detect a drought's onset and development (Hayes, et al. 2000). Seiler and Bressan (2002/03) using the SPI for three months periods along the precipitation series made an analysis for the south of Cordoba at the four locations selected for the study, to characterize drought frequency, intensity and duration. Figures 2.35 to 2.38 show the historical conditions during the spring for each of the four location areas of the south of Cordoba region. Droughts duration, peak intensity and also mean intensity can be observed. The SPI analysis also reflects the spatial variability of the drought characteristics along the region and an indication of the risk exposure to the phenomenon.

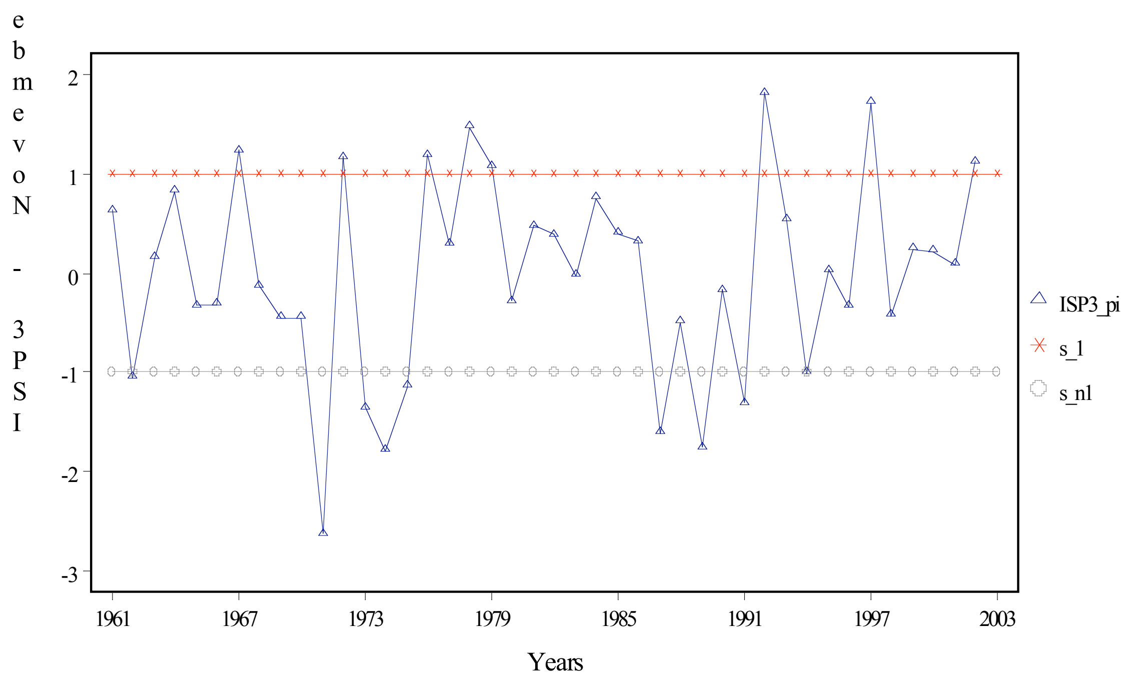


Fig. 2.35: Spring season SPI (three months period ending November) using precipitation values, 1961-2003 for Pilar. (s_1 and s-n1 are plus and minus one standard deviation, respectively)

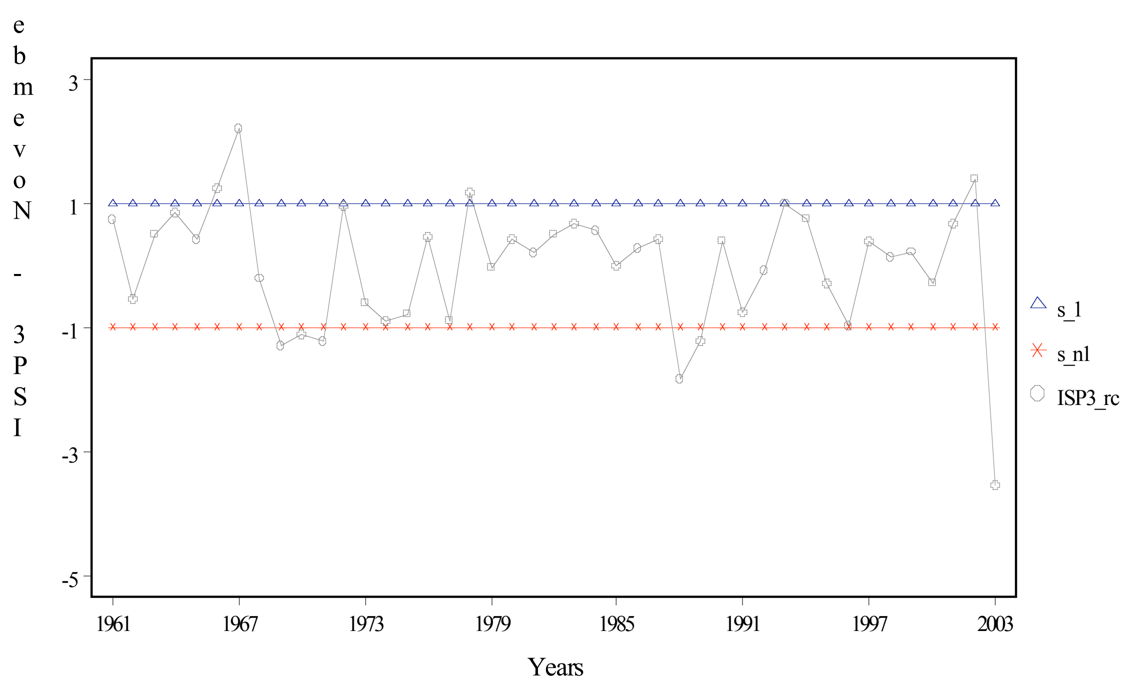


Fig. 2.36: Spring season SPI (three months period ending November) using precipitation values, 1961-2003 for Rio Cuarto. (s_1 and s-n1 are plus and minus one standard deviation, respectively).

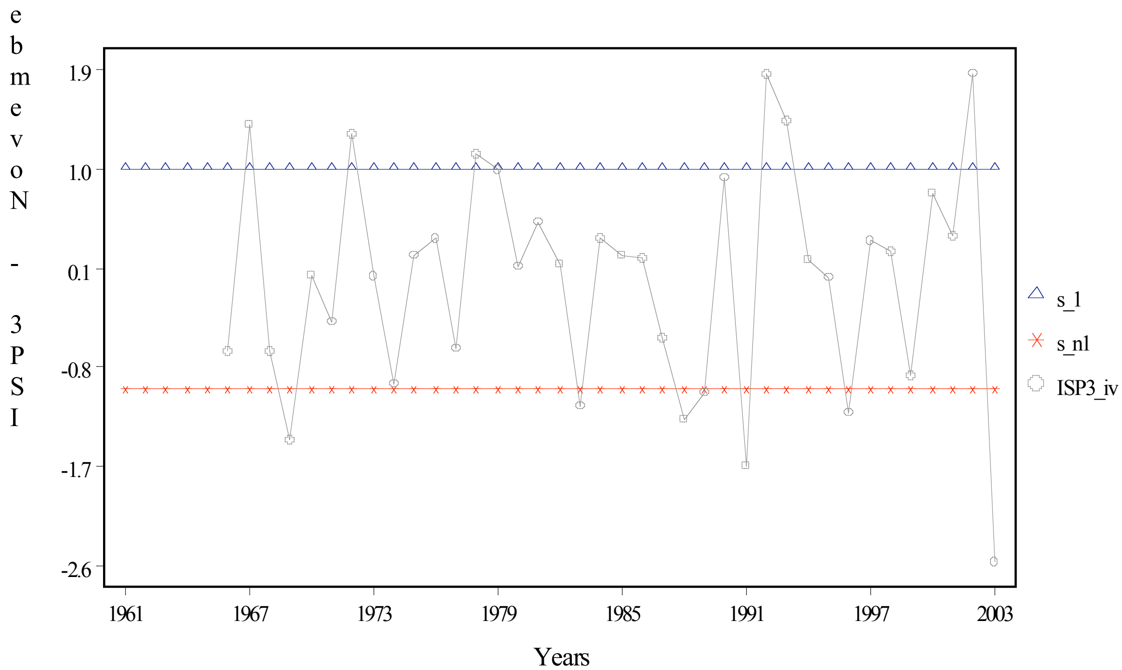


Fig. 2.37: Spring season SPI (three months period ending November) using precipitation values, 1961-2003 for Marcos Juarez. (s_1 and s-n1 are plus and minus one standard deviation, respectively).

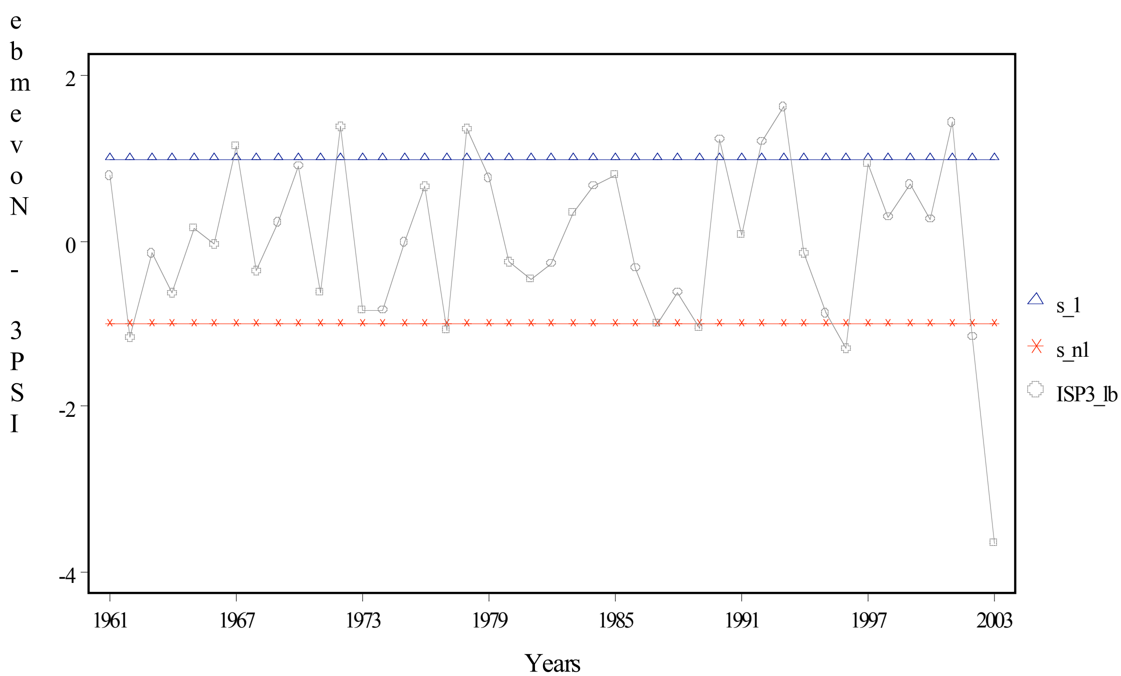


Fig. 2.38: Spring season SPI (three months period ending November) using precipitation values, 1961-2003 for Laboulaye. (s_1 and s-n1 are plus and minus one standard deviation, respectively).

Similar analysis was done during the summer season. Figures 2.39 to 2.42 show historical SPI of three month periods, ending February, reflecting the conditions during December-January and February for each of the locations area. Duration, peak intensity and mean intensity of droughts during the summer may have different impact for the regional agriculture than during the spring since the crops are already planted, and sometimes those impacts may be more devastating for the regional economy.

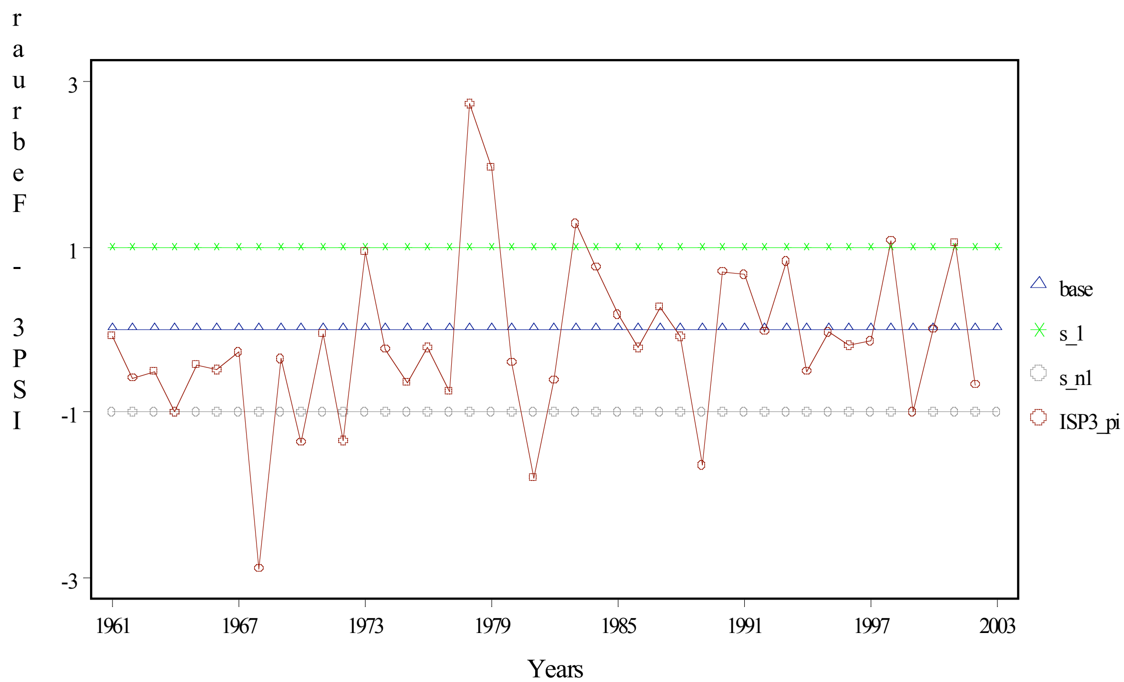


Fig. 2.39: Summer season SPI (three months period ending February) using precipitation values, 1961-2002 for Pilar. (s_1 and s-n1 are plus and minus one standard deviation, respectively)

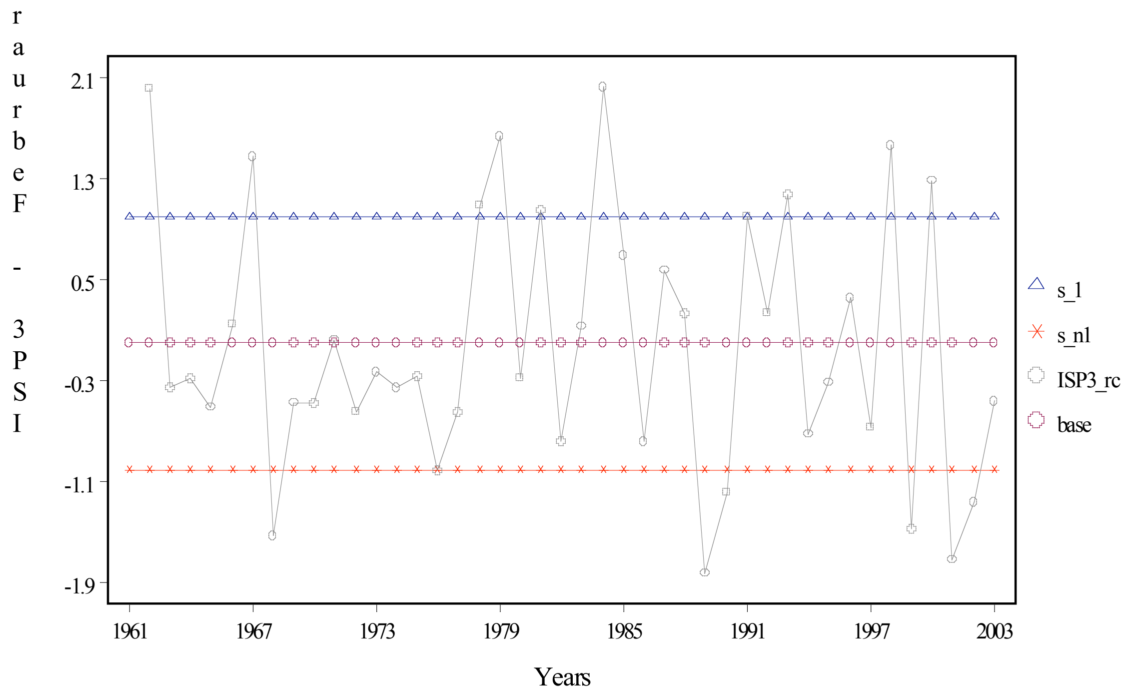


Fig. 2.40: Summer season SPI (three months period ending February) using precipitation values, 1961-2002 for Rio Cuarto (s_1 and s-n1 are plus and minus one standard deviation, respectively)

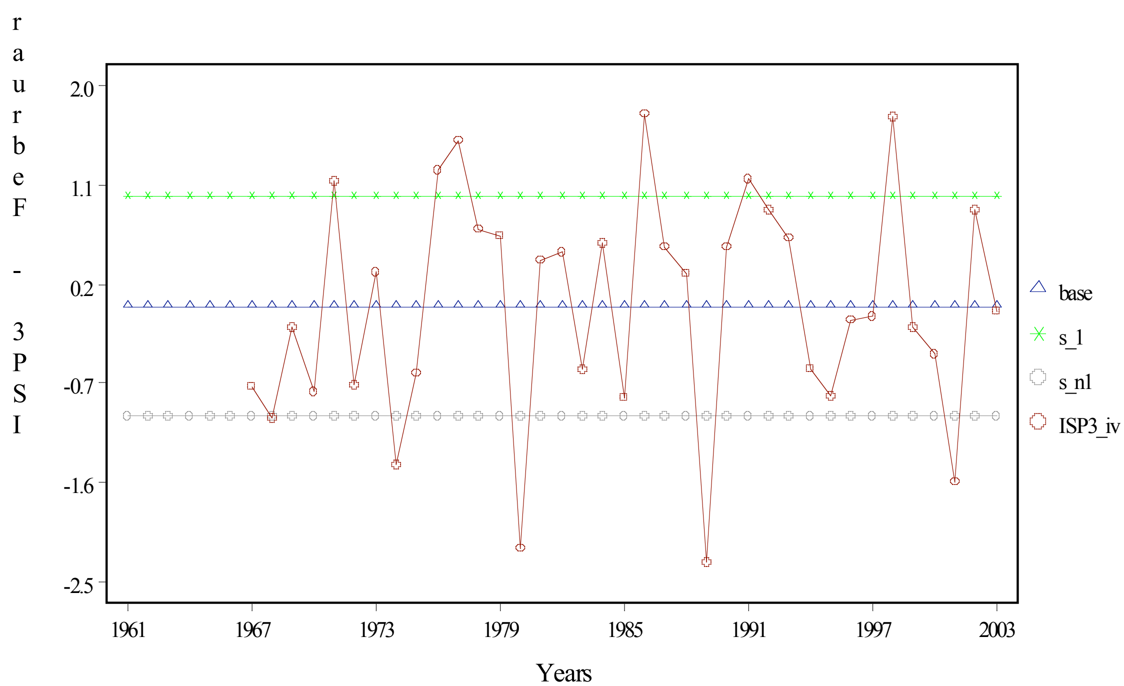


Fig. 2.41: Summer season SPI (three months period ending February) using precipitation values, 1961-2002 for Marcos Juarez. (s_1 and s-n1 are plus and minus one standard deviation, respectively)

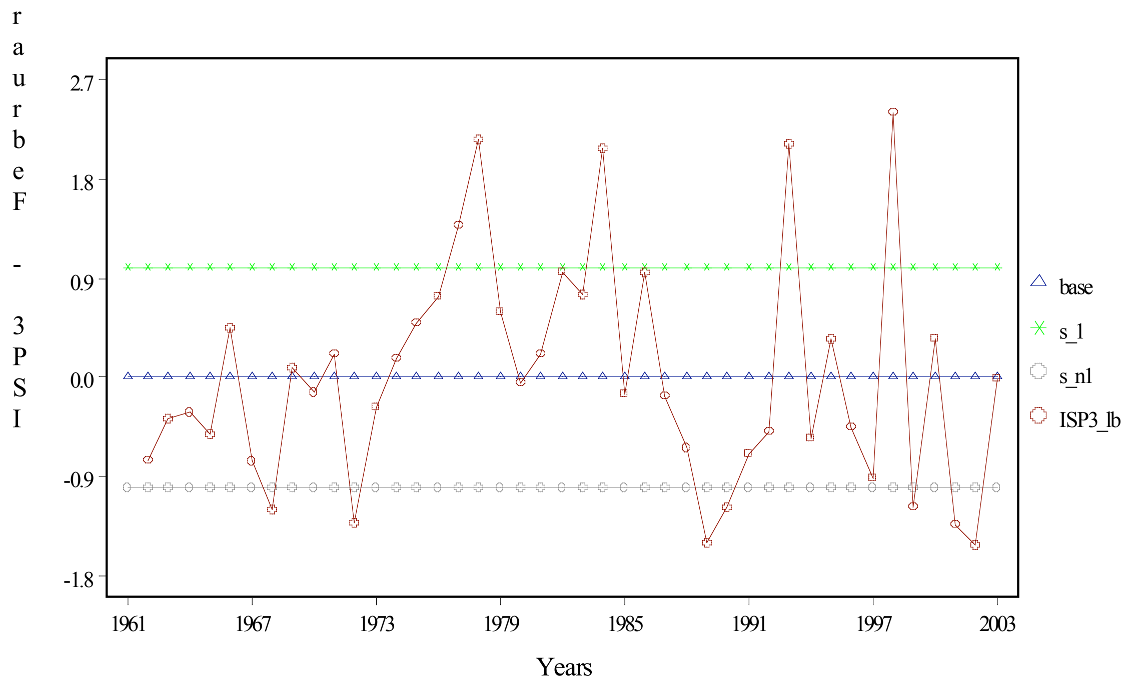


Fig. 2.42: Summer season SPI (three months period ending February) using precipitation values, 1961-2002 for Laboulaye. (s_1 and s-n1 are plus and minus one standard deviation, respectively)

The characterization of drought by the water supply (precipitation) does not define alone the risk to the phenomenon in a given area. The weather variability coupled to the spatial variation of the physical resources show changes in the risk and vulnerability at which farmers are exposed. Rivarola, et al (2004) analyzing the combination of climate variables, mainly water supply by precipitation, with soil types and crops water demands in the region, have defined different levels of risk to drought for the agricultural production. The calculated risk to drought in the region increases from the east to the west and south (figure 2.43).

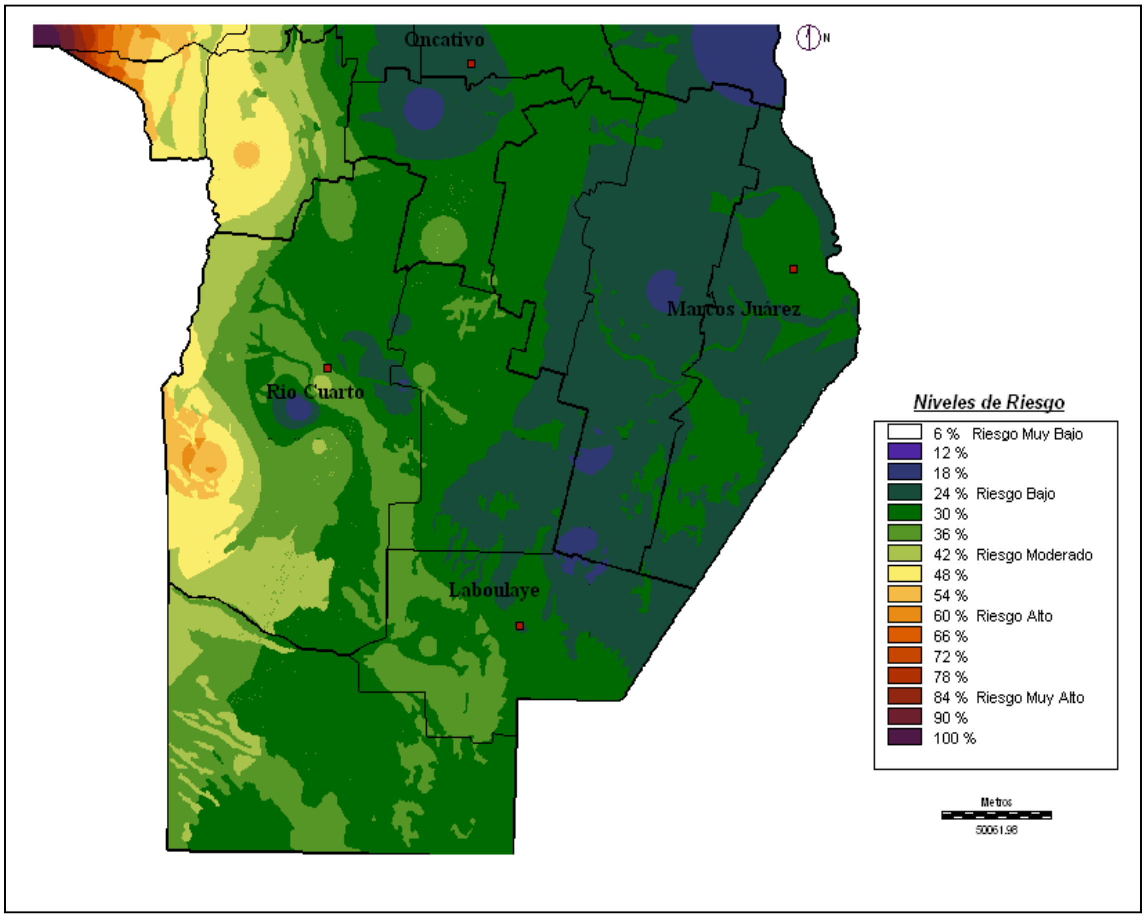


Fig. 2.43: Risk of drought in the southern region of Córdoba, Argentina.

2.5.4 Future climate change scenarios

Climate change scenarios were constructed for 2020 and 2050 using the Model for the Assessment of Greenhouse – gas Induced Climate Change and a Scenario Generator (MAGICC/SCENGEN model, version 4.1) (Wigley and Raper, 2001,2002; Hulme *et al*, 2000). The outputs of three general circulation models (GCMs) were used: EH4TR98, GFDLTR90 and HAD3TR00, under A2 and B2 emission scenarios (IPCC, WGIII, 2000; Nakicenovic, *et al*, 2000).

Almost all the scenarios projected for 2020 an increase in mean temperature for almost all the months of the year, ranging from 0.1°C to 1.1°C, being the months of February, March and October the ones that showed the highest increments. Small diminutions in mean temperature (from 0.1°C to 0.3°C) are projected for May, June and August in some scenarios (E-A2, E-B2 and H-A2) (table 2.8). Projected temperature changes for 2050 also show increments in almost all months (from 0.1°C to 2.4°C) although the increments are higher than in 2020 while January, February and March will likely be the warmest. Possible decreases in mean temperature (from 0.2°C to 0.7°C) are projected for May and August in the scenarios E-A2 and E-B2 (table 2.9).

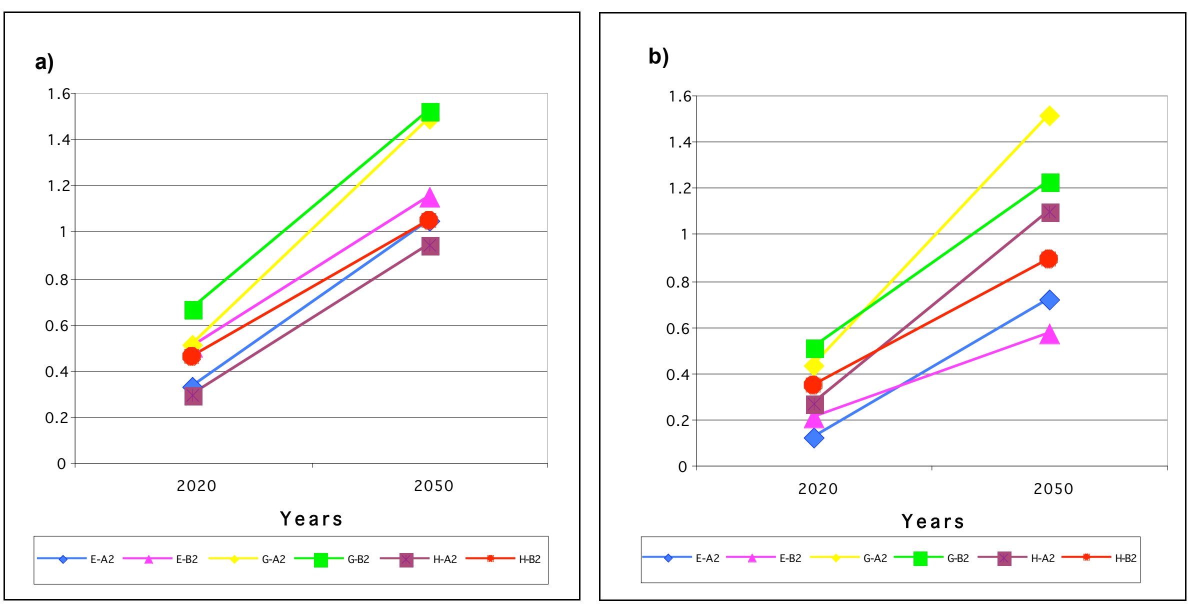
Scenarios	J	F	M	A	May	Jun	Jul	Aug	S	O	N	D
E-A2	1.53	1	1.09	0.73	-0.21	0.2	0.65	-0.68	0	1.43	0.74	1.14
E-B2	1.29	1.46	0.54	0.61	-0.13	0.05	0.55	-0.32	0.18	1.2	0.46	0.73
G-A2	1.35	2.07	2.2	1.53	1.24	1.86	1.92	1.4	1.1	1.8	1.64	1.39
G-B2	1.14	2.37	1.47	1.29	1.1	1.44	1.62	1.43	1.1	1.52	1.22	0.94
H-A2	1.12	0.65	2.14	1.66	0.75	0.42	0.51	1.06	1.43	1.12	0.8	1.49
H-B2	0.94	1.17	1.42	1.4	0.68	0.23	0.43	1.15	1.38	0.94	0.51	1.02

Table 2.8: Projected changes in monthly mean temperature for the southern region of Córdoba, Argentina for 2020, using 3 GCM (E: ECHAM; G: GFDL; H: HADLEY) outputs and two SRES scenarios (A2 and B2).

Scenarios	J	F	M	A	May	Jun	Jul	Aug	S	O	N	D
E-A2	0.33	0.44	0.31	-0.16	-0.17	-0.29	0.06	-0.27	-0.2	0.46	0.08	0.24
E-B2	0.54	0.67	0.24	0.04	-0.07	-0.09	0.19	-0.16	0	0.46	0.15	0.28
G-A2	0.26	0.86	0.74	0.16	0.41	0.37	0.57	0.55	0.23	0.61	0.43	0.34
G-B2	0.47	1.09	0.66	0.34	0.49	0.55	0.67	0.64	0.42	0.61	0.49	0.38
H-A2	0.16	0.3	0.72	0.21	0.21	-0.21	0.01	0.42	0.37	0.34	0.1	0.38
H-B2	0.38	0.54	0.64	0.4	0.3	-0.01	0.13	0.52	0.55	0.35	0.17	0.42

Table 2.9: Projected changes in monthly mean temperature for the southern region of Córdoba, Argentina for 2050, using 3 GCM (E: ECHAM; G: GFDL; H: HADLEY) outputs and two SRES scenarios (A2 and B2).

Seasonal scenarios for mean temperature projected increases in all seasons for 2020 and 2050 with higher values in the spring and summer (figures 2.44 a and b). Only winter E-A2 and E-B2 scenarios show small decreases in mean temperature.



Figs. 2.44 a and b: a). Projected changes in summer temperature for the southern region of Cordoba, Argentina (2020 and 2050), using 3 GCM (G: GFDL; H: Hadley; E: ECHAM) outputs and two SRES scenarios (A2 and B2). B). Idem as a but for spring temperature changes.

The monthly projected changes in precipitation show more variability between scenarios and between months than the temperature changes. Diminutions in precipitation are projected for January and June in all scenarios for 2020, ranging from 1 to 2.3% for January and from 1 to 11.5% for June depending on the model used. Four over six scenarios also show decreases in precipitation for March (0.6 to 3%), July (6 to 8%) and September (1 to 3%) (table 2.10). Scenarios with increases in precipitation are depicted for April, May, August, October, November and December, ranging from 1 to 22.3% depending on the month and scenario considered. February also shows an increase in precipitation in four over six scenarios from 1 to 9% (table 2.10).

Scenarios	J	F	M	A	May	Jun	Jul	Aug	S	O	N	D
E-A2	-1.77	9.45	11.62	22.26	8.31	-0.99	1.81	5.39	-2.33	3.69	12.43	9.02
E-B2	-1.21	8.74	13.74	22.0	6.88	1.24	0.12	2.98	-2.96	5.4	10.61	5.7
G-A2	-2.3	-0.37	-1.59	0.44	1.99	-5.73	-6.4	9.98	-1.15	4.78	0	10.63
G-B2	-1.72	-0.79	0.92	0.82	0.74	-3.36	-7.84	7.43	-1.81	6.46	-1.46	7.27
H-A2	-1.22	1.88	-3.12	15.86	1.9	-11.41	-6.7	0.52	10.68	3.34	4.61	11.01
H-B2	-0.67	1.39	-0.57	15.79	0.66	-8.88	-8.14	-1.75	9.67	5.06	3.01	7.64

Table 2.10: Projected changes in monthly precipitation (%) for the southern region of Córdoba, Argentina for 2020, using 3 GCM (E: ECHAM; G: GFDL; H:HADLEY) outputs and two SRES scenarios (A2 and B2).

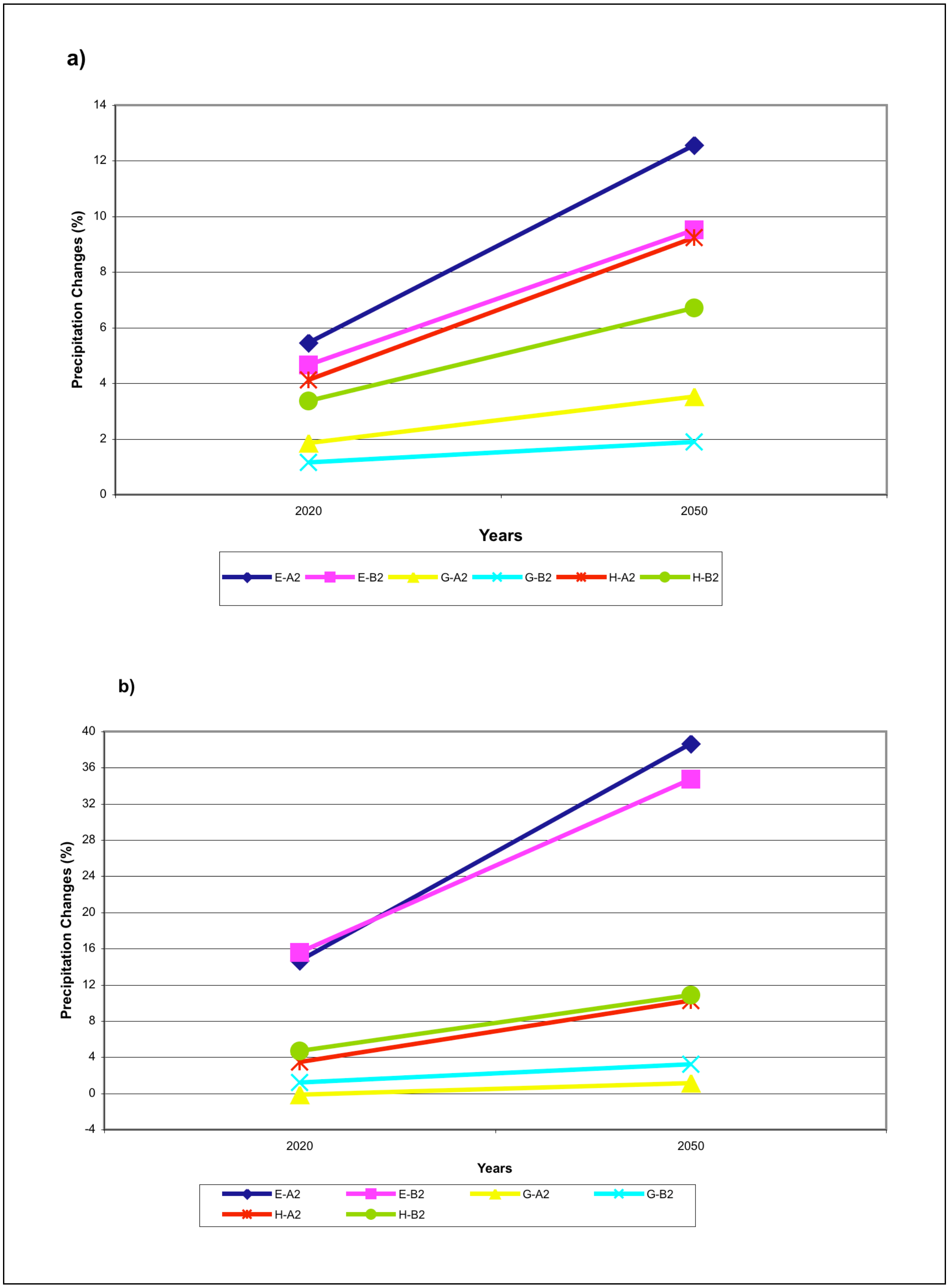
The monthly projected changes in precipitation show more variability between scenarios and between months than the temperature changes. Diminutions in precipitation are projected for January and June in all scenarios for 2020, ranging from 1 to 2.3% for January and from 1 to 11.5% for June depending on the model used. Four over six scenarios also show decreases in precipitation for March (0.6 to 3%), July (6 to 8%) and September (1 to 3%) (table 2.10). Scenarios with increases in precipitation are depicted for April, May, August, October, November and December, ranging from 1 to 22.3% depending on the month and scenario considered. February also shows an increase in precipitation in four over six scenarios from 1 to 9% (table 2.10).

Similar patterns of changes are projected for the year 2050 although they show bigger diminutions or increments than in 2020. It is noticeable the projected increase in the precipitation of April which ranges from 36 to 61% in four over six scenarios and the decreases for June (from 5.5 to 23%) and July (from 6 to 16%) respectively (table 2.11). The projected increases for April precipitation might result in higher risk of floods in the flood prone zone of the study area.

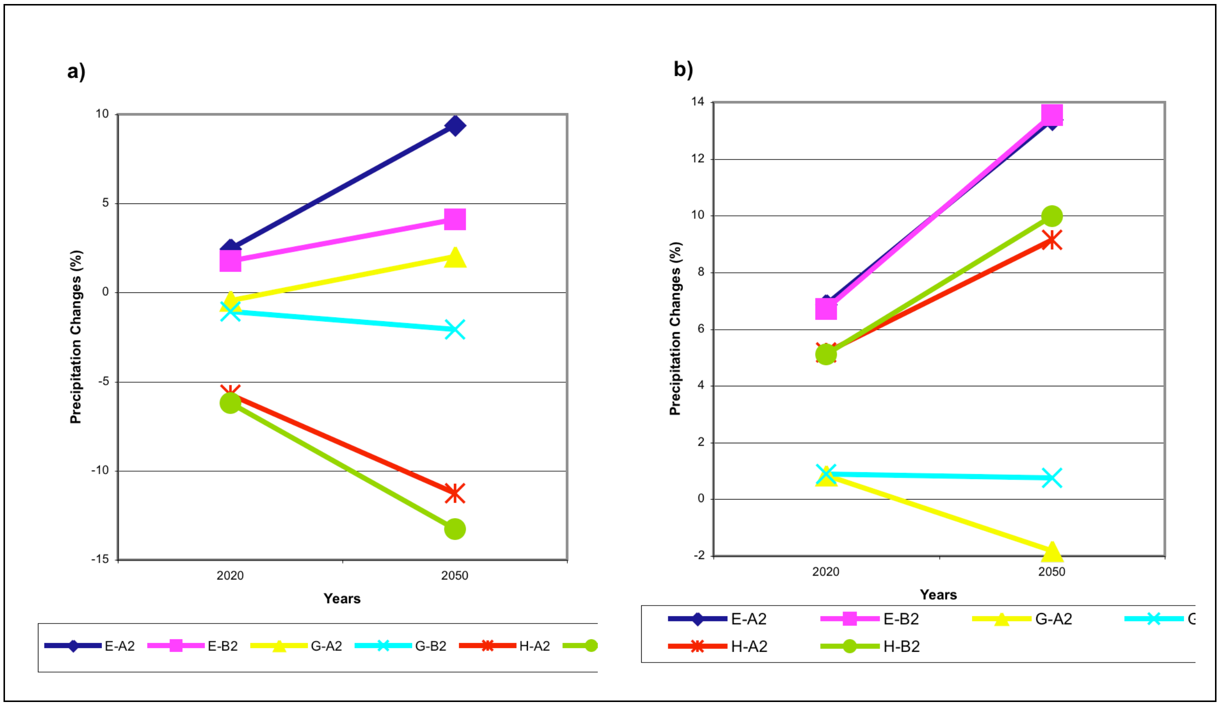
Scenarios	J	F	M	A	May	Jun	Jul	Aug	S	O	N	D
E-A2	-2.71	25.29	28.88	61.29	23.26	3.66	14.52	9.39	-11.0	6.44	27.3	16.93
E-B2	-2.18	19.03	30.6	49.4	15.01	4.46	1.85	4.57	-7.9	11.38	21.4	10
G-A2	-4.04	0.5	-4.45	6.24	7.3	-8.32	-6.18	20.97	-7.99	9.19	-4.7	20.99
G-B2	-3.3	-1.82	2.56	3.08	1.59	-5.61	-15.56	14.32	-5.39	13.69	-5.04	13.42
H-A2	-1.31	6.19	-8.32	45.16	7.08	-22.65	-6.95	-2.9	21.87	5.55	7.55	21.97
H-B2	-1.01	2.96	-0.7	35.83	1.4	-17.67	-16.21	-5.77	19.63	10.63	4.74	14.24

Table 2.11: Projected changes in monthly precipitation (%) for the southern region of Córdoba, Argentina for 2050, using 3 GCM (E: ECHAM; G: GFDL; H: HADLEY) outputs and two SRES scenarios (A2 and B2).

Projected changes in seasonal precipitation indicate increases of different magnitude for the summer, fall and spring depending on the scenario considered being these increments bigger for the year 2050 than for 2020 (figures 2.45 a,b and Figure 2.46 b). Four over six scenarios projected decreases in precipitation for winter ranging from 0.5 to 6% for 2020 and 2 to 13% for 2050 (figure 2.46 a).

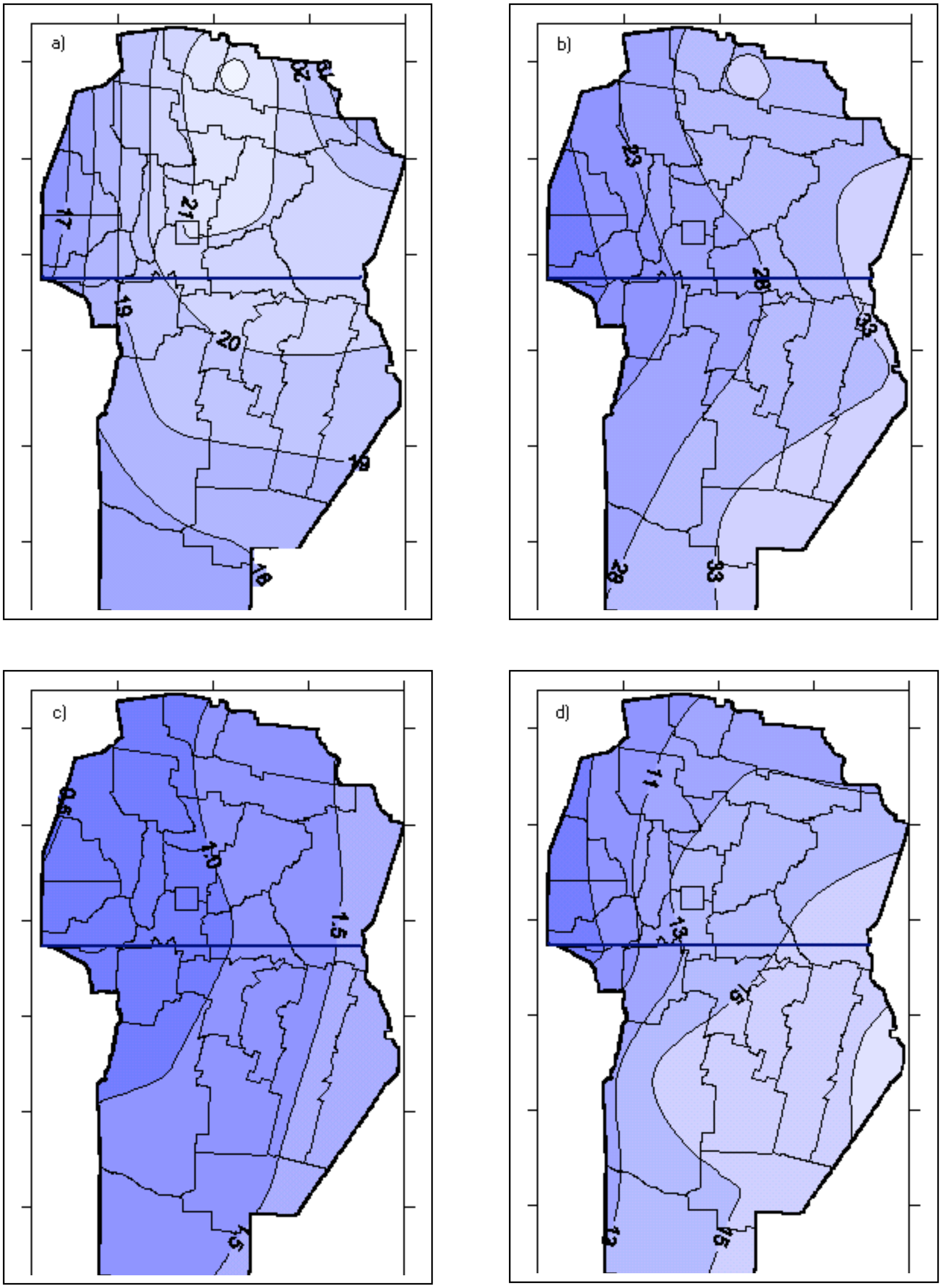


Figs. 2.45 a and b: a). Projected changes in summer precipitation (%) for the southern region of Cordoba, Argentina (2020 and 2050), using 3 GCM (G: GFDL; H: Hadley; E: ECHAM) outputs and two SRES scenarios (A2 and B2). b). Idem for a but for fall precipitation changes.

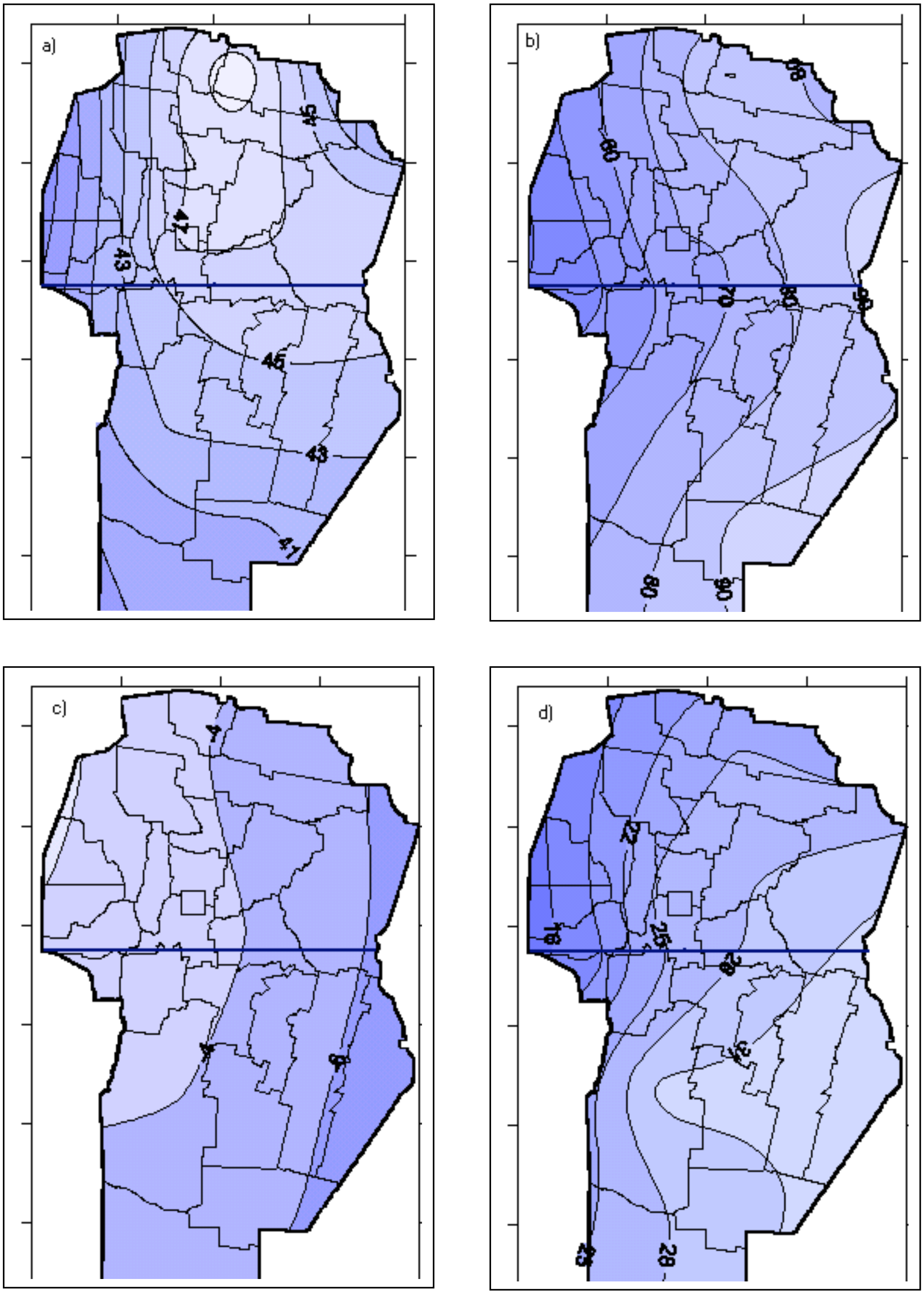


Figs. 2.46 a and b: a). Projected changes in winter precipitation (%) for the southern region of Córdoba, Argentina (2020 and 2050), using 3 GCM (G: GFDL; H: Hadley; E: ECHAM) outputs and two SRES scenarios (A2 and B2). B). Idem for a but for spring precipitation changes.

The spatial distribution of the seasonal precipitation changes in the study area for the ECHAM A2 scenario (the one that projected the highest changes) and for the years 2020 and 2050 are shown in figures 2.47 and 2.48 respectively. Precipitation changes are near 20 mm in the center of the region decreasing to the south of the area in the summer of 2020. Higher increases are expected for the fall (28 mm) while the projections for the spring are around 15 mm. Winter will be the one with lowest benefits, only 1 mm increase in rainfall for 2020 (figure2.47). For 2050 and for the same scenario, higher increases are projected for fall, spring and summer with values above 70 mm, 35 mm and 45 mm for the center of the region and for each season respectively. These changes decrease to the south in summer, and increase to the east in the spring and fall (Figures 2.48 a, b and d). Winter precipitation increments are around 4 mm and increase to the east of the region (Figure 2.48 c).



Figs. 2.47: Seasonal precipitation changes (mm) for the ECHAM A2 scenario for the year 2020. a) Summer, b) Fall, c) Winter, and d) Spring.



Figs. 2.48: Seasonal precipitation changes (mm) for the ECHAM A2 scenario for the year 2050.a) Summer, b) Fall, c) Winter, and d) Spring.

2.5.5 Conclusions

A host of independent observations of meteorological and hydrological variables and records of extreme events indicate that climate change is actually happening. The quantification of change, however, especially on regional and sub regional scales poses a scientific challenge and still carry considerable uncertainty. In addition to natural climate variability, in the south of Cordoba it is perceived increase variability as a consequence of climate change. Fluctuation of the climate during the seasons, the occurrence of anomalous temperature and precipitation, as well as soil moisture availability exert in the region the greatest influence upon both intra and inter annual onset of the crops season and in the consequent crops growth, development and yield.

Changes were observed in the seasonal maximum and minimum temperatures in the region. Maximum temperature has decreased particularly in the spring and summer while increasing values of minimum temperatures are shown during all the seasons. Precipitation also showed changes in time. There is a consistent regional increase in the precipitation during the summer and fall over the entire region with a well defined positive time trend. The spring shows increased precipitation in the east and south and winter in the west and south of the region.

While there is no doubt of the beneficial impacts that the increasing precipitation may cause on the regional agriculture in most of the cases, climate variability and extreme events in the region are the conditions of major uncertainties in the agriculture, at least in the short term. Intra and inter seasonal weather variability is a constant feature in the region causing water deficit or surplus, lower and higher temperatures and alternatively severe droughts, floods and hail damage. Floods events may be exacerbated in the future in the flood prone zone in the south of the region as climate change scenarios indicated an increment in rainfall mainly during summer and fall but with the highest increases during April. Expected rainfall diminutions during the winter may jeopardize the possibility of double cropping although this effect might be ameliorated for the increments expected for the fall. Climate scenarios indicated higher temperatures, which on one hand diminish the risk of frosts but on the other hand will reduce the length of the growing season for the summer crops probably causing yields reductions.

3 Socio Economic Baseline and Institutional Trends

The project took as a premise the fact that the rapid rate of socioeconomic change in Mexico and Argentina, as well as the relatively short-term planning horizon of agricultural producers, makes projecting socioeconomic conditions far into the future problematic. However, we argue that trends in sector and macroeconomic policy of the last 30-50 years, as well as recent changes in the institutional environment, influence present farm-level vulnerability to climate risk through the range of resources farmers have available to them, the sensitivity of their production process to climate impacts, and through the ways in which farmers perceive risk and their expectations of the public sector. In addition, we argue that by understanding the relationship of institutional factors to farm vulnerability, we can identify present development paths and signal the possible implications of those paths for future vulnerability.

We used the period 1980 to the present (2000) as a socioeconomic baseline for the purposes of our study, and, based on the trends and tendencies in public policy, developed qualitative future scenarios (near-term) for evaluating social vulnerability in the case study regions. Because we are interested in longer-term trends in climate averages and climatic variability, we were specifically interested in the implications of policy trends and technology development for the future resilience and sustainability of the farm systems under study. In creating the socioeconomic baseline we were also interested in identifying ways in which policies and practices may have inhibited or be inhibiting effective responses to climatic conditions, and how inequities in resource access may be exacerbating the vulnerability of particular farm groups.

3.1 Activities Conducted

The policy/institutional analyses for each case study were primarily undertaken through the following activities:

- Compilation of time series data from available national and regional databases (Year 1- 2)
- Review of primary and secondary literature on the commodities studied, regional history, agricultural policy and public programs (Year 1, 2 , 3)
- Analysis of regional newspapers for information on trends in policy, farmers' responses, and problems with markets, production and climate impacts (Year 1 – 2)
- Interviews with key stakeholders in each region (i.e., academics, personnel with the national research institutes, agricultural officials, politicians, farmer association representatives, merchants and traders, agricultural service providers, farmers of different scales). These interviews provided information on public policy, program implementation, unpublished agricultural data and perspectives on institutional change and trends (Year 1, 2, 3)
- Workshops in each study region (with: academics, personnel of the national research institutes, agricultural officials, politicians, representatives of farmer associations, merchants and traders, agricultural service providers, farmers of different scales). (Year 2, 3)

3.2 Description of Scientific Methods and Data

3.2.1 Methods

This policy analysis both contributed to and was guided by the farm-level research. We focused on the policies, institutions, and sector economic variables that appear to contribute most to the economic and political uncertainty faced by stakeholders, as revealed in our surveys, workshops and focus groups. Our interviews with the agricultural officials in public agencies and, in Mexico, with water managers in Tamaulipas, also provided information on climatic risk and hazards that affected the priorities of our climatic analyses. Furthermore, in the first and final years of the project's implementation, joint workshops were conducted to facilitate the communication of the project's goals, methods and results among all interested parties, and to encourage the development of participatory fora for improving adaptation capacity.

Through these stakeholder interactions, we identified a series of generic socioeconomic indicators that we considered important for understanding the differential sensitivity and adaptive capacity of farmers in both countries to climatic variability and change. Our project considered that capacity was an essential component of vulnerability, and that capacity could be understood as being characterized by three attributes: flexibility, stability and resource access. In terms of flexibility, we hypothesized that those agricultural systems (or households) characterized by greater diversity (crops, income sources, land use) and by a broad resource endowment (access to water resources, soil quality, financial capital, etc.) would necessarily be more flexible in addressing future uncertainty and surprises, whether climatic or socioeconomic. In terms of stability, we hypothesized that those systems (or households) that are subject to high risk and volatility in prices, climatic conditions, or market opportunities will likely have an unstable livelihood base, and that this instability could translate into an inability to plan ahead, withstand shocks and to accumulate the resources necessary for improving their resilience in the future. Finally, resource access is critical for adaptive capacity. Resource access can be measured in part by the types of goods and services farmers now have and use (i.e., their endowment) and also by what they have available to them in the broader economy and society (entitlements).

This framework and these attributes are further described in chapter 4. However, these attributes were also used as a rough guide in the collection of historical and present day socioeconomic data at the national and state/province scale, to provide the contextual perspective of resource and policy trends and the implications of those trends for social vulnerability at the farm level.

3.2.2 Data and data sources

3.2.2.1 Quantitative data for socioeconomic/institutional analysis

In Mexico we relied on the National Agricultural Census of 1990, statistical annals (*Estadísticas Anuarias*) for Veracruz and Tamaulipas states, the SIACON agriculture and livestock production database of the Federal Agricultural Ministry (SAGARPA) (1980-2003), the National Census of Population and Housing (1990 and 2000), the 1990 National Coffee Census, the 2000 National Coffee Census, the demographic and social indicators of the National Population Council available at the local level, and other data where available.

In Argentina data used was provided by the National Agriculture Census of 1988 (INDEC), Agriculture Statistics for Córdoba of 1999 (SAGyP), The National Census of Population and Housing 1981, 1991, 2001 (INDEC), statistical series on agriculture production and yields from the Agriculture Secretary of Córdoba (SAGyP).

3.2.2.2 Secondary literature and qualitative data

We accessed the wide literature that has been written on agricultural development, agrarian structures and economic trends in each country, as well as commodity-specific literature, as the primary source of information and analysis on the changing context of production in each region. This literature, together with available policy documents from government sources (e.g., Development Plans, program descriptions and regulations) provided the necessary background information to understand the broad-scale socioeconomic processes that have, in the recent past, affected farmers production strategies and resource use. At the local/regional level, we also created a database of climate and non-climate events and tendencies reported through the popular media, resulting in a local socioeconomic time series that we could then correlate with historical climate anomalies and the broader trends observable in socioeconomic and production data.

3.3 Results

3.3.1 General trends in both countries

After WWII "Import Substitution Industrialization"(ISI) phase of development in Latin America, agricultural production in many countries were characterized by heavy-handed involvement of the public sector in the provision of agricultural services and technology (Thorpe 1997). This was particularly the case in countries such as Mexico, where the public sector was involved in everything from the provision of crop insurance, seeds and fertilizer and credit to the transport and commercialization of agricultural products (Appendini 2002). Import restrictions designed to protect the agricultural input industry from external competition tended to limit the range and quality of inputs available to farmers, while marketing parastatals tended to control the distribution of agricultural products and the participation of producers in the global agricultural economy. In Argentina, agriculture policy was highly linked to the results of the ISI. The agricultural sector was a provider of foreign exchange during periods of shortages, and a provider of cheap food and labor, as well as a source of price stability, during periods of expansion in the economic cycle. The only sector program with a vision towards the long-term viability of the sector that was articulated during this period was the creation of the National Institute of Agriculture Technology in 1958. Depending on the international market situation and the economic cycle, tax and credit policy during this period created a demand for agricultural technology (Cuccia, 1983; Sábato, 1980).

The 1990s were a decade of radical change in both macroeconomic and sector policy for many Latin American countries. As a consequence of the debt crisis, countries like Mexico and Argentina were induced to follow a number of policy reforms as to get new financing. At the same time, as globalization started to be the panacea for economic convergence (Fritzche, et al 2004), the economic policy agenda epitomized by the Washington Consensus had profound impacts across the continent as market liberalization; privatization and deregulation reforms were adopted (Bulmer-Thomas 1996).

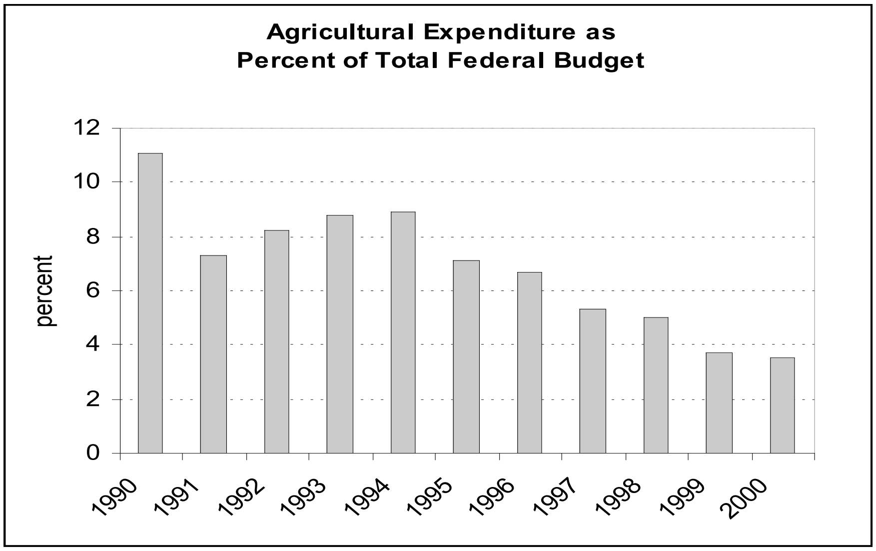
These changes entailed significant restructuring of agricultural production, producing changes in technology, land use and introducing new forms of relationships between farmers and the state. Although in different forms and at different paces, in general Latin American countries in the 1990s (the late 1970's in the case of Argentina) pursued similar policy programs in agriculture involving the opening of agricultural markets and transformation of state involvement in the sector in response to the perceived stagnation of agricultural production in the middle 1980s (de Janvry and Sadoulet 1993; Spoor 2000; Reca and Parellada, 2001). At the farm level, the impacts of these changes have been quite uneven as a function of the existing heterogeneity in the agrarian structure and resource distribution, and thus have had differential effects on social vulnerability to climate impacts.

3.3.2 Mexico

Mexican agricultural policy has historically been bifurcated by the land tenure and organizational status of the farmer. The "social sector" or the *ejidal* sector, incorporates the over 27,000 communities who received land after the 1910 agrarian revolution and who, until the constitutional reform of 1994, had only usufruct rights to their land. The "private" sector is comprised of farmers with *pequeña propiedad* landholding. These farmers have always had titled land and generally have larger landholdings and are more commercially oriented than their *ejidatario* counterparts.

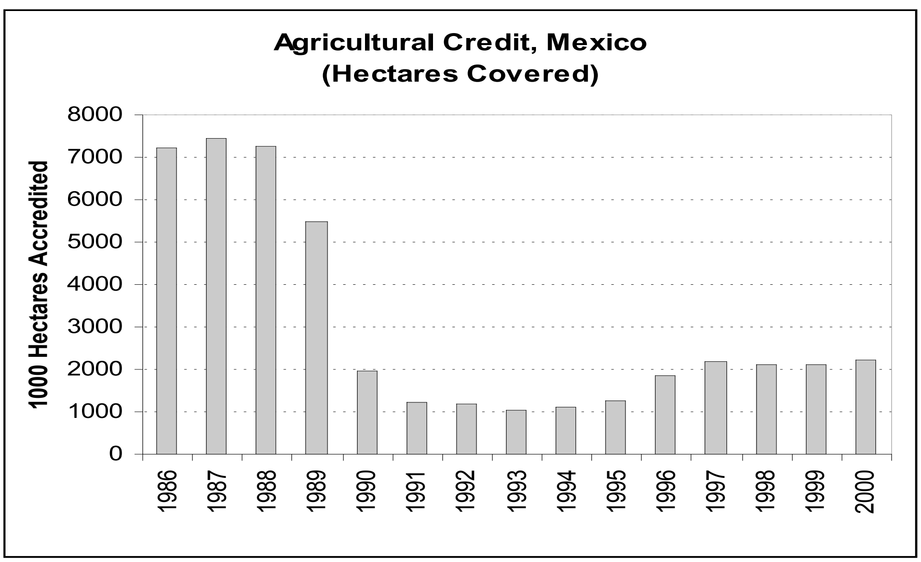
Over the course of the 20th century, the state developed a very close relationship with the *ejidal* sector, a relationship in which the rural population served to ensure the state's legitimacy, and the state ensured *ejido* subsistence through small infusions of resources and the unreliable attention of a variety of state bureaucracies designed specifically to manage the production of the smallholder sector (Gates 1989; Foley 1995; Fox 1995). Larger, commercial producers enjoyed relatively consistent support throughout the 20th century however smallholders were subject to dramatic swings in investment and policy, leaving them both highly vulnerable to economic change and dependent upon the state (Appendini 1992). The federal government established parallel agencies to provide agricultural services and support to the *pequeños propietarios* and *ejidatarios*, thus reinforcing and institutionalizing differences in resource endowments, production technology and commercial orientation (Gates 1989). Despite recent attempts by the government to dismantle the institutional framework for the *ejidatarios* (by granting land titles to ejidatarios and permitting the sale and rental of ejidal land), these historical differences persist and, as Liverman (1990) illustrated, they can have important implications for the sensitivity of particular farm types to climate hazards.

Since the mid 1980s, national agricultural policy has focused on reducing the intervention of the public sector in the provision of agricultural services, technical support and inputs and promoting the integration of farmers into commercial production networks. Federal budgetary expenditure for agriculture was reduced (figure 3.1), and public support for agricultural research and science declined in real terms throughout the 1990s, and only recently (in 2002/2003) has return to 1990 levels (Fox Quesada 2004: Annex Estadística, pg 65). Publicly subsidized credit was also reduced dramatically over the course of the 1990s, effectively excluding smallholders from access to credit for long-term investments (figure 3.2). As a result of market liberalization and the withdrawal of input subsidies, input prices have risen in real terms, while farmers' purchasing power (particularly smallholder grain farmers) has declined (Appendini 2001; Hernández Laos and Velásquez Roa 2003). The combined impact of the reforms of the agricultural sector has been one factor that has induced high and increasing rates of emigration from rural areas, a factor that has been particularly important for labor availability in the coffee sector.



Source: Fox Queseda, V. (2003). *Tercer Informe del Gobierno*. Presidencia de la Republica. Mexico, DF.

Fig. 3.1: Agricultural expenditure as percent of total federal budget



Source: Zedillo, E. (1996) Segundo Informe del Gobierno. *Presidencia de la Republica. Mexico, DF., and Fox Queseda, V. (2003).* Tercer Informe del Gobierno. *Presidencia de la Republica. Mexico, DF.*

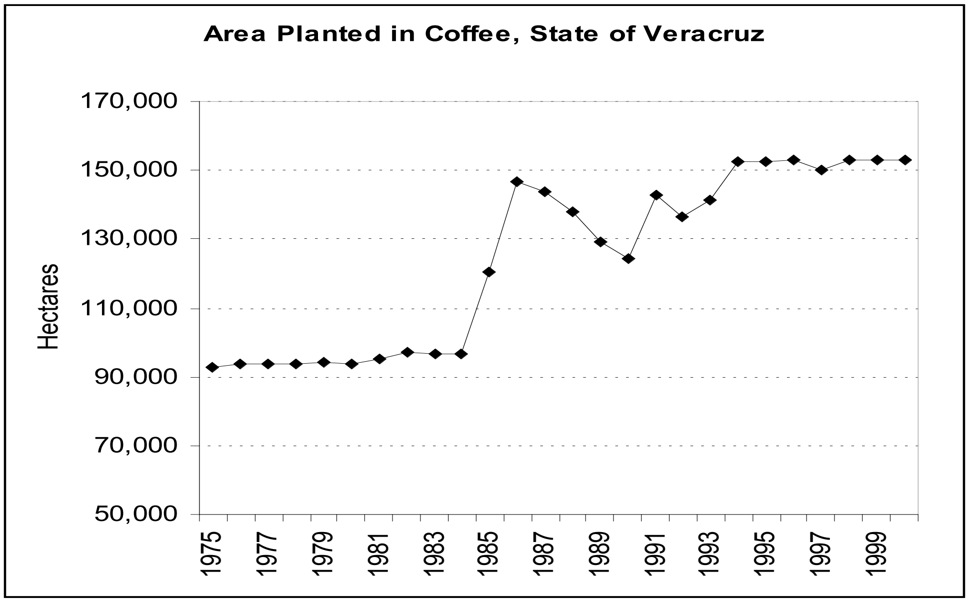
Fig. 3.2: Agricultural credit, Mexico

3.3.2.1 Coffee sector (case study Veracruz)

The changes in national and sector policy that have occurred in Mexico from the mid-1980s to the present are in many ways epitomized by the coffee subsector. In the early 1980s coffee was one of Mexico's principle agricultural exports, representing as much as 35% of the total agricultural export value (Fox Quesada 2004). In 1985, the crop was also one of the sector's most important employers, involving a labor force of over 300,000 (Nolasco 1985). Smallholders (farmers with landholdings between 2 and 3 has) have traditionally represented over 80% of coffee farmers, although rarely contributing more then 30% of the country's coffee harvest.

Beginning in the early part of the 20th century, coffee production, processing and commercialization were also heavily regulated by the public sector through financial and marketing parastatals (Aguirre Saharrea 2003). Internationally beginning in the 1960s, coffee production and prices were controlled through a system of quotas managed by the International Coffee Agreement, to which both coffee producing countries and coffee consuming countries were part (Santoyo Cortés, Díaz Cárdenas et al. 1996).

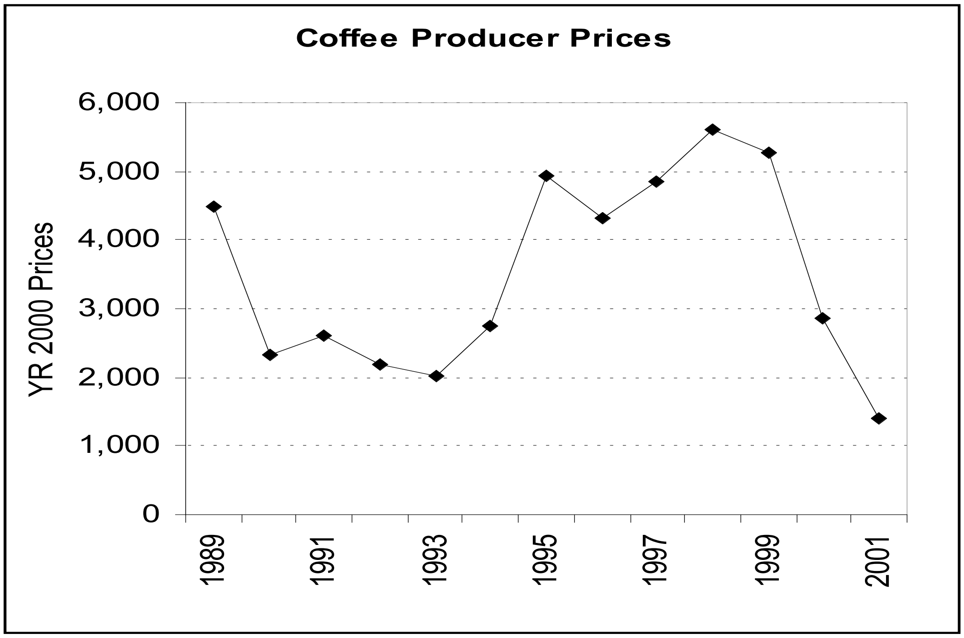
The Mexican government's regulation of the sector was consolidated in 1958 with the creation of INMECAFE, the National Coffee Institute. The production philosophy associated with the Green Revolution in Mexico's grain crops was extended through INMECAFE to the coffee sector and, during the 1970s and early 1980s, the resources of the institute were dedicated to standardizing and increasing coffee production through the diffusion of new coffee varieties produced in INMECAFE nurseries, non-native shade species and the promotion of frequent use of commercial fertilizers (Santoyo Cortés, Díaz Cárdenas et al. 1996). This industrial policy was particularly influential in central Veracruz, where INMECAFE's headquarters were located, where those farmers with landholdings within the altitude range considered ideal for coffee (900 m.a.s.l. to 1200 m.a.s.l.) were encouraged to replace traditional shade trees such as banana with *Inga leptoloba (nombre común chelele, México)* and to plant coffee as a monocrop (Nestel 1995). Many coffee communities abandoned their subsistence crops and alternative cash crops during this period as recommended by INMECAFE in order to secure credit (Hoffman, Blanc-Pamard et al. 1987). Between 1975 and 1985, coffee production expanded by 50% in Mexico and 29% in the state of Veracruz, in many cases replacing maize (a subsistence crop), sugar cane, citrus or other cash crops (figure 3.3). In the *municipios* in which the case studies were conducted, INMECAFE as the principle commercialization channel for Mexico's smallholder coffee farmers, as well as the primary source of credit, technology and extension, a large proportion of Mexico's coffee farmers became heavily dependent on the state apparatus in their production decisions.



Source: SAGARPA, SIACON data base and Estadisticas Anuarias del Estado de Veracruz, INEGI.

Fig. 3.3: Area planted in coffee, Veracruz.

In 1989, following the United States' withdraw, the International Coffee Agreement, which regulated the amount of coffee Mexico commercialized in international markets as well as coffee prices, collapsed (Ponte 2002). Almost immediately following the dissolution of the agreement, excessive quantities of coffee entered international markets, prices increased in volatility, and, with new uncontrolled volumes of coffee entering the market, world coffee prices began a precipitous decline, which has continued to the present (Ponte 2002)(figure 3.4). Climate conditions also had an impact on the stability of the sector at the end of the 1980s. National production declined by 10% as a result of one of the most devastating frosts that have ever affected coffee farmers in Mexico, driving many farmers in the affected regions to seek income from alternative sources and denying thousands of coffee harvesters employment (Martínez Morales 1997).



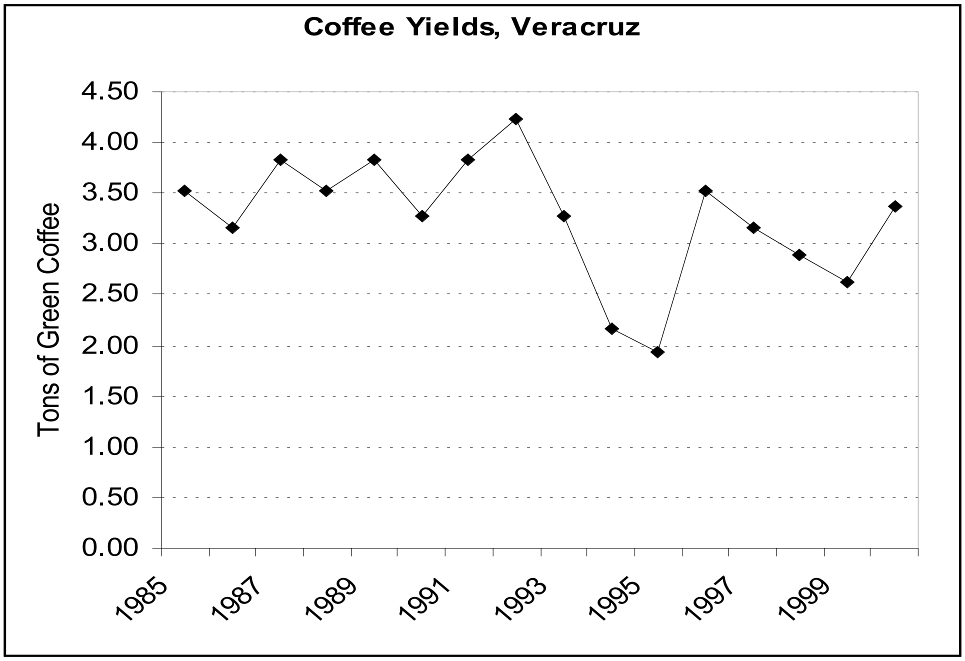
Source: International Coffee Organization

Fig. 3.4: Coffee producer prices.

In the same year, as part of a broad program of national market liberalization, the Mexican government decided to privatise INMECAFE, and began several years of negotiations with coffee farmer organizations concerning the conditions under which the services and infrastructure managed by the institute would be transferred to either producer groups or the private sector (Krippner 1997; Synder 1999). In 1992, INMECAFE was formally dissolved, and along with it, the hundreds of farm credit unions INMECAFE had organized to transfer finances, technology and production. In the early 1990s, the ownership and management of the state-owned coffee processing plants were transferred to farmers' cooperatives and the private sector. A huge number of smallholder producers entered the 1990s with large debts that inhibited them from managing the coffee processing plants successfully (Hernández Navarro and Célis Callejas 1994).

In 1994, after the credit programs of INMECAFE were abolished, farmers were also provided with very small annual loans at no interest through the government's community finance program, PRONASOL (Aguirre Saharrea 2003). Although the credit repayment in this program was generally quite good, the amount of capital offered to farmers was relatively small, preventing any substantial investment in the plantations (Hernández Navarro and Célis Callejas 1994).

Lack of credit and technical support, combined with declining coffee prices, has substantially affected the use of inputs in the sector. Prior to 1990, fertilizer prices were heavily subsidized, and the domestic market was protected through high tariffs and import quotas (Ávila 2001). In 1990, Mexico's fertilizer parastatal was privatized, and fertilizer prices liberated. Domestic fertilizer producers proved to be uncompetitive, and quickly farmers in Mexico faced a market controlled by a transnational fertilizer oligopoly (Ávila 2001). As a consequence, fertilizer prices did not decline after liberalization, and, in combination with plummeting coffee prices, smallholder coffee farmers began to cut back substantially on their input use. As illustration, a national survey of coffee farmers conducted in the early 1980s found that 80% of farmers in Central Veracruz used chemical fertilizers. Fifteen years later, a survey of Veracruz farmers undertaken by the Universidad Veracruzana in 2000 found that only 44% used chemical fertilizers. Not surprisingly, as a result of these changes in the coffee sector, overall productivity fell by over a third between 1989 and 1993 with a corresponding loss in farm income of 70% (Krippner 1997). In Veracruz, coffee yields plummeted from a peak of 4 tons/ ha in 1992 to just over 2.5 tons/ha in 1999 (figure 3.5).



Source: SAGARPA, SIACON database and Estadisticas Anuarias.

Fig. 3.5: Coffee yields, Veracruz.

The lack of investment in coffee has also translated into an increase in pest problems for coffee farmers. In the late 1970s, *la broca* (*Hypothenemus hampei*), a pest that reproduces in the unprocessed coffee berry, was introduced into southeastern Mexico from Central America (Santoyo Cortés, Díaz Cárdenas et al. 1996). By 1994 just over 5,000 has were infected with the pest in Veracruz (Santoyo Cortés, Díaz Cárdenas et al. 1996). According to the coffee census of 2001 36,442 has were infected (ASERCA 2003). Interviews with technical experts on coffee in the Veracruz region suggested that the rapid proliferation of *la broca* is likely a result of the fact that because of poor coffee prices and a lack of labor, many farmers are not harvesting their coffee trees completely and are not investing in traditional maintenance practices, and thus have created ideal conditions for the reproduction of the pest. Some specialists also hypothesized that warmer conditions in the region may also be contributing to the extension of the pest to higher altitudes. Confirming this hypothesis is made complicated by the fact that much of the research results and database of INMECAFE have been distributed among various public and non-governmental institutions, such that locating historical data on pest distribution is now complicated.

Land use is also changing as a result of the collapse in coffee prices. Farmers and agriculture officials interviewed in the region reported that sugar cane, a crop whose price has been artificially elevated by an import tax on fructose, has expanded into land previously planted with coffee. Some fear that this land use change is irreversible, while other experts claim that coffee and sugar cane are planted cyclically in relation to the relative prices of these two crops. Around the communities where the ethnographic work was completed, the regional sugar mill had indeed expanded its area of production. Some coffee orchards around the cities of Coatepec and Xalapa had also been converted into condominiums. Although we were unable to quantify these changes in land use at a regional scale, these changes imply a loss of forest cover, increased albedo in the region and possible increases in water demand.

Since 1992 the federal government has continued to support the coffee sector, although it has tried to limit its interventions to those programs and policies that do not distort the coffee market. Rather than directly intervene in coffee commercialization, the Mexican government today has developed a variety of programs encouraging crop diversification in coffee regions, supporting the costs of production for smallholder producers through a direct per-hectare payment and, most recently, compensating farmers for abysmally low prices with a per-kilo payment for coffee commercialized below what the government is considered a viable price. Unlike past public sector programs, however, these new programs are restricted to economic supports and generally not accompanied by technical assistance or extension services. According to a recent analysis, in 2000 there were 752 extension workers specializing in coffee in the country (up from 0 in 1994), serving 282,000 coffee farmers (ASERCA, 2001). In the Xalapa area, the technical staff with specialization in coffee of the National Institute for Research Forestry, Agriculture and Livestock (INIFAP) field station was cut in half in the 1990s, constraining their capacity to both conduct primary research and provide free extension service to smallholder producers.

For farmers to capture sufficient rent in the coffee markets, they must be able to profit more directly from the stages of coffee processing and commercialization (Martínez Morales 1997). Organization is a critical element in this process. Independently, smallholders who are dependent on intermediaries are unlikely to receive the breadth of information now needed to adapt both to global markets and environmental change. In the absence of public extension support, farmer organizations can facilitate access to information on the availability of public support programs, pest proliferation and pest control, the management of shade, soils, and inter-cropped species and on the impacts of climate variability on coffee quality and yields.

The changes in the structure of the coffee sector have not improved the viability of the local economy. In the *municipios* of central Veracruz, where coffee has traditionally been the main rural economic activity, the proportion of the working population receiving less than two minimum salaries (averaging around 30% in 1990) did not decrease between 1990 and 2000, and in some cases increased. By the mid 1990s, the rural population had declined proportionally to the urban population (table 3.1). With increasing rates of emigration, the population growth of the region has also slowed. Whereas several of the central Veracruz *municipios* had population growth rates of over 3% in 1980, by 1995 these growth rates had slowed in most cases to just over 1%. Although the official rates of migration are low for these *municipios* (ranging between 2 and 4 percent of households receiving remittances at the time of the last National Population Census, 2000), in interviews local officials and rural residents talk of "trucks full of people" leaving the region every month on their way to the United States. This trend is of great importance to coffee farming, given the dependence of farmers on hired and family labor for coffee harvesting. Labor scarcity will affect the capacity of households to make labor-intensive changes to their production practices (e.g., organic production).

Municipio	Urban 1980	Urban 1995	Rural 1980	Rural 1995
Coatepec	67.96	80.00	32.04	20.00
Teocelo	60.99	58.60	39.01	41.40
Coscomatepec	50.18	50.31	49.82	49.13

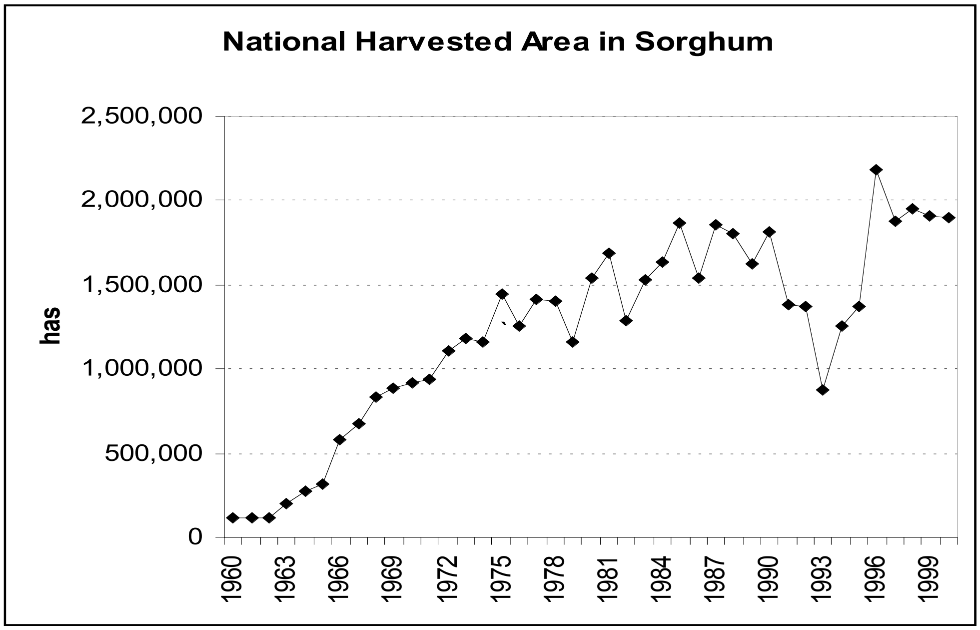
Source: *Anuario Estadístico del Estado de Veracruz*. Editions 1980 and 1995. INEGI, Aguascalientes.

Table 3.1: Percent of population in urban and rural communities

3.3.2.2 Sorghum and Safflower sector (case study González, Tamaulipas)

Tamaulipas is one of Mexico's leading producers of sorghum and safflower (accounting for an average of one third of the national production in sorghum and 14% of safflower production). The two crops are planted as part of a rainfed production system, in which sorghum is planted during the rainy season (June-September) as a summer cycle crop, and safflower is planted following the sorghum harvest using residual soil moisture during the dry season. Sorghum and safflower were actively promoted in Tamaulipas through input, producer price and credit policies and private sector investment in the 1950s, during the Green Revolution in Mexico. Safflower began to take hold in Tamaulipas during the late 1970s. Sorghum was encouraged as a way of integrating Mexican farmers in the animal feed industry as a source of raw material for the United States' and Mexico's growing livestock herds. Both sorghum and safflower are considered particularly suitable for production in Mexico's northern states because of the crops' relatively high tolerance of water stress and heat and relatively low water consumption (Barkin and DeWalt 1988). Subsidies for diesel fuel and irrigation infrastructure in the 1950s and 1960s were particularly important in the growth in area of these crops (Yates 1981). Sorghum expanded at a rate of

8.6% annually and safflower at 7.1% annually between 1965 and 1982 (Barkin and DeWalt 1988)(figure 3.6).

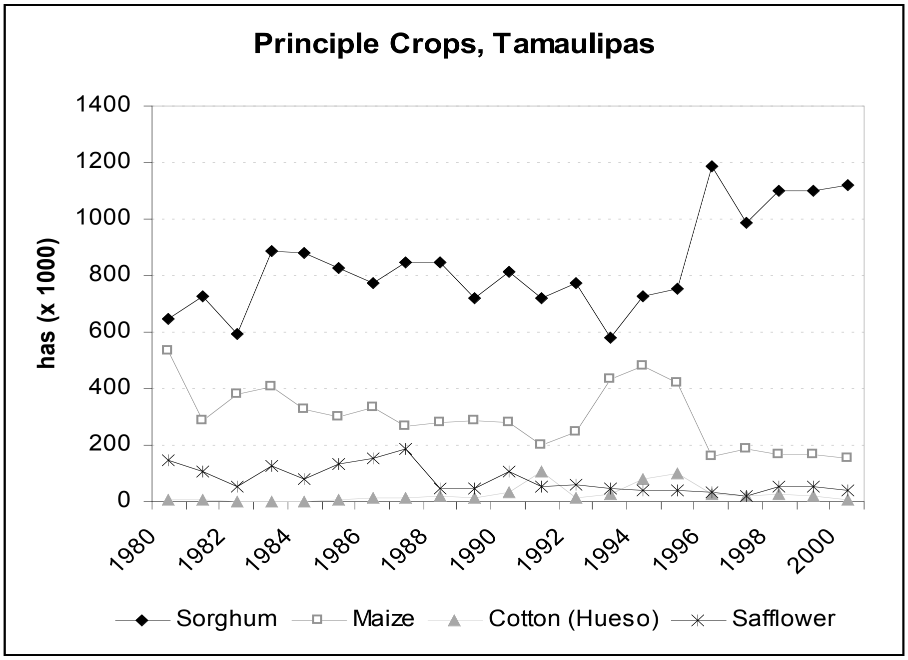


Source: SIACON data base and statistical yearbooks, SAGARPA

Fig. 3.6: National harvested area in sorghum.

The liberalization of agricultural input markets caused production costs to rise rapidly in the 1980s and 1990s, while grain prices have declined significantly (OECD 1997) . These sector trends coincided with a relatively dry decade in northern Mexico and a growing scarcity of water for irrigation, in part due to conflicts over water resources with the United States. As a result sorghum in Tamaulipas –specifically rainfed sorghum, a relatively drought-tolerant crop, and less costly and labor intensive to produce than maize–expanded significantly since Mexico entered NAFTA, despite the fact that after the full liberalization of the sorghum market in 1994, sorghum prices (and grain prices in general) have also declined in real terms. The area under maize, a crop that has traditionally served as an alternative grain for the livestock feed industry, declined as sorghum expanded. This is particularly true for irrigated maize (typically produced for commercial markets rather than subsistence), which has declined by 85%, largely as a result of competition from US imports. Cotton, an important crop in Tamaulipas in the early 1990s has also declined in popularity after repeated losses from flooding, drought and pests (figure 3.7).

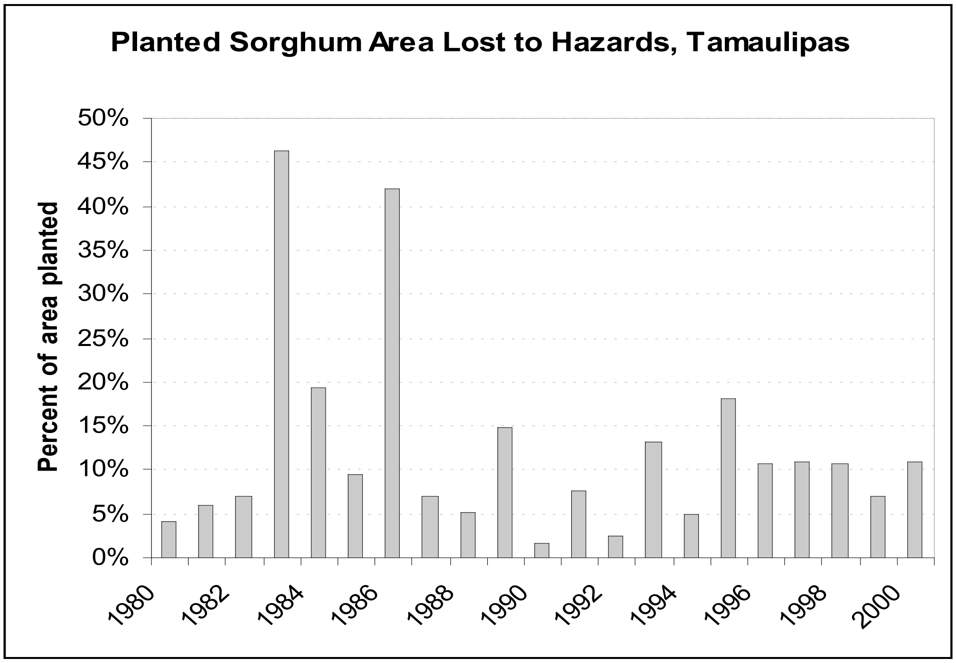
While domestic demand for sorghum should provide stable market conditions for Mexico's sorghum farmers, the competition with U.S. sorghum farmers is stiff, and despite the longer freight distances, US sorghum typically undersells Mexico's crop. Although sorghum is purportedly a hardy crop, sorghum production in Tamaulipas has also been shown to be highly sensitive to climatic variability and pests (ASERCA 1997) (figure 3.8). Locusts have become a significant problem in southern Tamaulipas, specifically in the area of González, requiring action at both the state and federal level in pest control. Sorghum is now being actively discouraged in the more arid northern part of Tamaulipas through a new program of crop conversion (Integrated Program of Sustainable Agriculture and Production Conversion in Areas of Recurrent Hazards, or *Programa Integral de Agricultural Sostenible y Reconversión Productiva en Zonas de Siniestralidad Recurrente, 2003, June*), in response to the state government's observation of a progressive desertification of soils that they believe is associated with sorghum farming under persistent drought conditions in the 1990s. Instead, farmers are being encouraged to plant "buffle grass," a high-yielding pasture grass through a direct payment for each hectare planted.



Source: SAGARPA.

Fig. 3.7: Planted area in principle crops, Tamaulipas.

Interviews with agricultural officials in Tamaulipas confirmed that the crop choices of commercial farmers in Tamaulipas are largely driven by the availability of public sector support programs rather than international market opportunities. Since Mexico's agricultural market have become more open, the government has tried to facilitate farmers' access to markets through a variety of direct payment programs. The most important of these programs is PROCAMPO, which provides farmers with a per/ha payment intended to compensate them for problems in competitiveness and facilitate agricultural investment. Nearly all grain farmers receive these payments. Additional support is offered to farmers on a per/ton basis to help them commercialize their crops. In 2003, participating farmers received approximately US$10/ton for sorghum and US$80/ton for safflower through this program.



Source: SIACON data base, SAGARPA

Fig. 3.8: Planted sorghum area lost to hazards, Tamaulipas.

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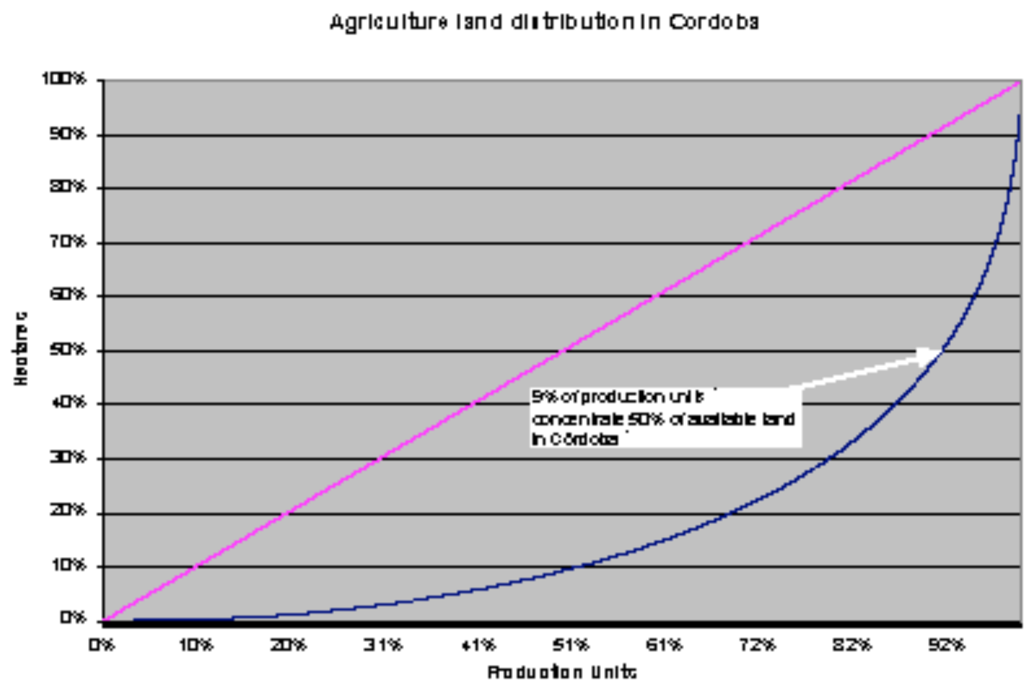
Despite these various support programs available for farmers in the state, the last decade has been particularly difficult for grain farmers. In González, the *municipio* which served as the geographic unit of analysis for the Tamaulipas case study of vulnerability, emigration from rural areas has risen and, as a result, population growth has dropped from 4.8% in 1980 to -0.2% in 2000 (INEGI 2000). According to CONAPO, the National Population Council, the *municipio's* population is projected to continue to decline for several decades into the future. The *municipio* has also not demonstrated significant economic growth or a change in economic structure over the last decades. The proportion of the population working in the primary sector has remained constant at 57% since 1990, and the proportion of the working population earning less than two minimum salaries has actually increased from 33% to 47% over the same period. The population without any formal education has decreased from 28% in 1980 to 18% in 2000, but still remains high. These socioeconomic trends are not auspicious for the pace of human development in the *municipio* and suggest that the *municipio's* dependence on agriculture has contributed to the poor rate of development over the last 20 years.

3.3.3 Argentina

The policy reforms that began in Argentina in the 1970's and intensified in the 1990's affected all aspects of the agriculture sector, including the organization of the production process, agricultural productivity and the agrarian structure. The production process turned into a highly capitalized one with substantial increases in yields. However, the uneven distribution of both processes resulted from the difficulty of an important number of agriculture producers to adjust themselves to the new economic environment. In the case study area, family farmers, who were the basis of the agriculture sector development policy in the past, started to find it difficult to incorporate themselves into the process of productive restructuring required by the new policy and institutional environment. In these conditions, their previous tools for managing market or climate risks became increasingly economically inefficient, and the economic impact of climate variability and its extremes were thus exacerbated. This was, principally the case for those farmers who were unable to meet the capitalization requirements of the reformed sector. To different extents, adverse climatic events (e.g. floods, droughts, frosts) affect the sustainability of agricultural livelihoods and thus have negative repercussions for each region's economies, through impacts on the service and industrial sectors and, socially, in terms of migrations from rural to urban areas and social conflict.



Data source: National Agriculture Census of 2002 (INDEC).

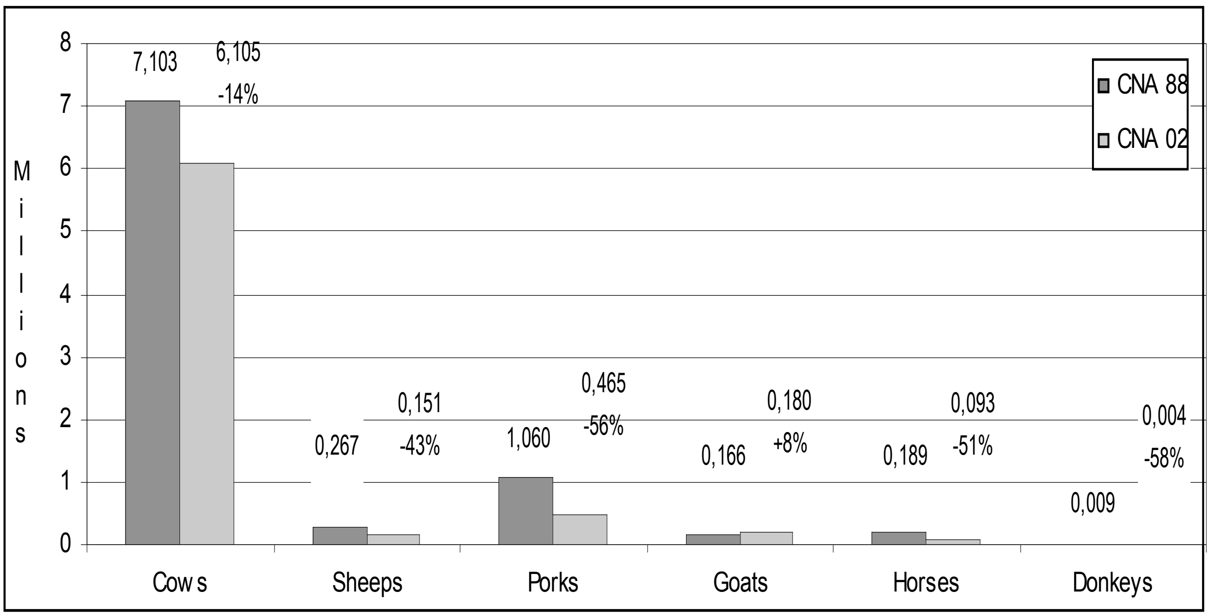
Fig. 3.9: The figure represents agriculture land distribution in Córdoba Province, where 9% of the production units hold 50% of total land available for agriculture.

Prior to the "technological revolution" in the 1960's (Green Revolution), farmers in the Pampas region managed climatic and market risk through highly diversified agricultural strategies with relatively little incorporation of newly developed technology (Sabato,1980). The income of family farmers was sustained through managing land use, thus reducing the high opportunity cost of capital. Cash crop and commercial livestock production was complemented in this region with a variety of subsistence activities, however in general farmers had poor access to educational and health services. By the 1960s, this situation began to change, driven by increased land and labor scarcity resulting from the Import Substitution Industrialization model pursued by the national government.

During the technological revolution of the 1960s, public sector support of farm credit, public financing of the national farm machinery industry, and the availability of seed varieties developed through the National Institute of Agriculture Technology (INTA), facilitated successive waves of technology incorporation by farmers (Obschatko, 1988). With the availability of low cost technologies from the public sector and an explicit tax and credit policy that favored technology use, even small-scale family farmers were able to sustain both their livelihoods and participate in the broader economy. Throughout this period, however, a culture of rural life prevailed, with rural incomes complemented with diversification in on-farm activities such as small-scale meat and dairy production (Cloquel et al, 2003). Mechanization and expansion of agrochemical utilization contributed to the spread of the practice of multiple tillage in one year resulting in the loss of more sustainable agriculture practices (Barsky y Gelman, 2001). However, in general, the increased availability of a diversity of state-subsidized technologies within this institutional framework proved to favor rural households' resilience to climate and market variability (Sabato, 1980).

From 1976 through the 1980s, the agricultural sector was in a period of transition. The liberal economic policies pursued by the military government further facilitated the process of adoption of capital-intensive technologies. In the 1980s, declining grain prices coupled with a decline in the foreign demand for beef (mainly due to increased self-sufficiency and export policies in Europe, the main Argentinean market for beef) and a drop in the real exchange rate, resulted in the decline of cattle production in the Pampas (figure 3.10) and an increased specialization in cash crops as farmers aimed to maximize income per hectare. In general, the economic sustainability of the family farm depended on their capacity to incorporate new technologies and practices aimed to increase productivity, a process facilitated by INTA. Nevertheless, the trend towards greater specialization on cash crops also made the sector more sensitive to climatic variability and other external shocks, thus intensifying the demand for financial mechanisms of risk reduction (insurance and farmers' financial reserves).

During this period there were also rising concerns over the environmental consequences of the structural changes in the sector. For example, the diffusion of soybean production allowed for double cropping and the abandonment of mixed (livestock and crop) production, coinciding with increasing concerns over soil deterioration and degradation (Barsky y Gelman 2001; Moscatelli and Pazos 2000). The use of more capital intensive technologies also led to increased rates of rural-urban migration. Family farm households moved to towns looking for diversifying their incomes through different activities (Cloquel, et al. 2003).



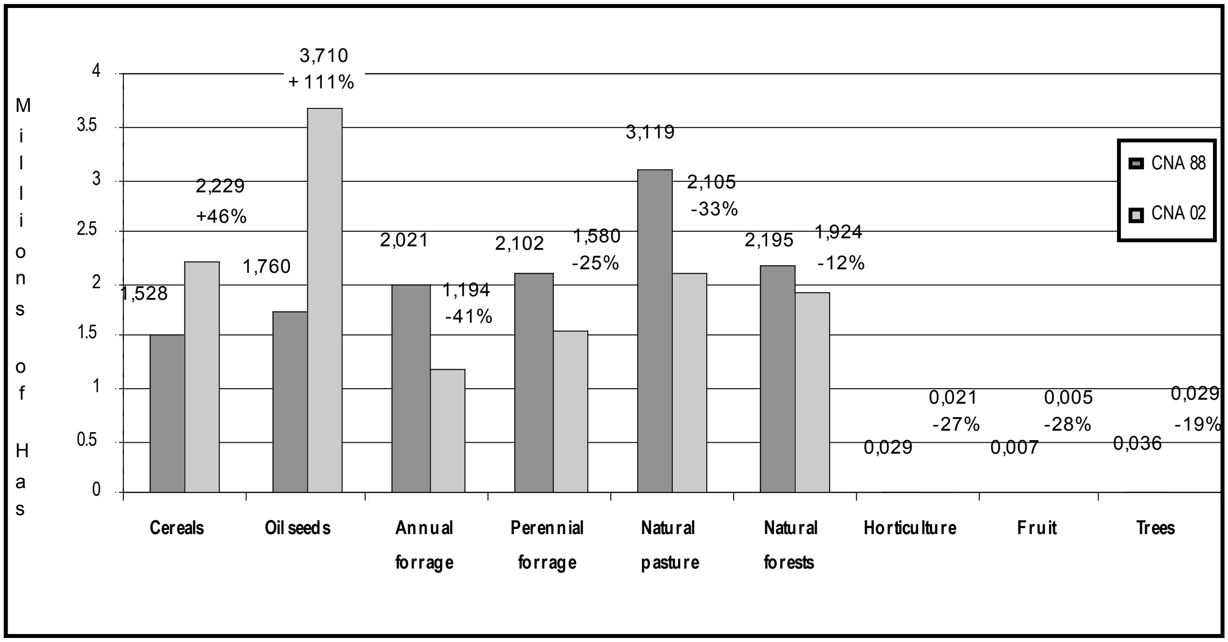
Data source: NAC 1988 and 2002 (INDEC)

Fig. 3.10: Evolution of livestock. Córdoba Province.

A series of macro-economic reforms were initiated in the beginning of the 1990's, principally as a result of negotiations with international financial institutions associated with the debt crisis. At the same time the failure of the ISI strategy supported an argument for economic recovery through export oriented production, increased competition, greater international integration to increase foreign trade (specially among MERCOSUR countries) and a reduction in direct support for agriculture in the public sector.

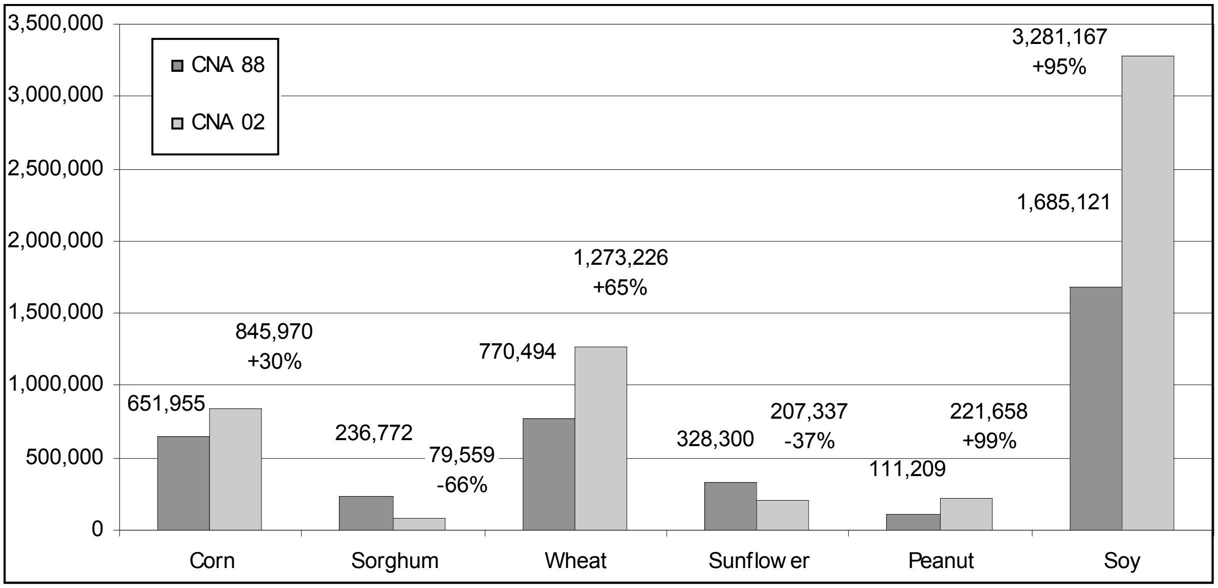
Although the search for higher farm-level productivity has been a constant since the 1960s, the policy framework established in the 1990s has made increasing productivity particularly challenging for some sectors of the farm population. Through the deregulation of sector activities, the liberalization of input and output markets and the withdrawal of state intervention, the government aimed to improve the efficiency and competitiveness of agriculture production. Many of the policy objectives at the sector level were reached, specifically, augmenting efficiency and reducing costs of services directly related to agriculture production (Obschatko, 1993), the same as for increasing sector production.

This process combined with a greater use of input technologies and commercial input packages (e.g., "genetically modified soy seeds"), facilitated the growing participation of multinational agribusiness in the sector. Agriculture land allotted to GM soy notably increased during the 1990s (figures 3.11 and 3.12), replacing other crops and constituting one of the foundations of the agrarian change in the region, although for some researchers, soybean production has allowed the survival of some small family farmers. No-tillage farming has increased in coverage and is now being used in almost a 90% of main crops (wheat and soybeans). However, the use of agro chemicals has also increased considerably as part of the "technological package" including pesticides, fungicides, fertilizers and mainly, herbicides.



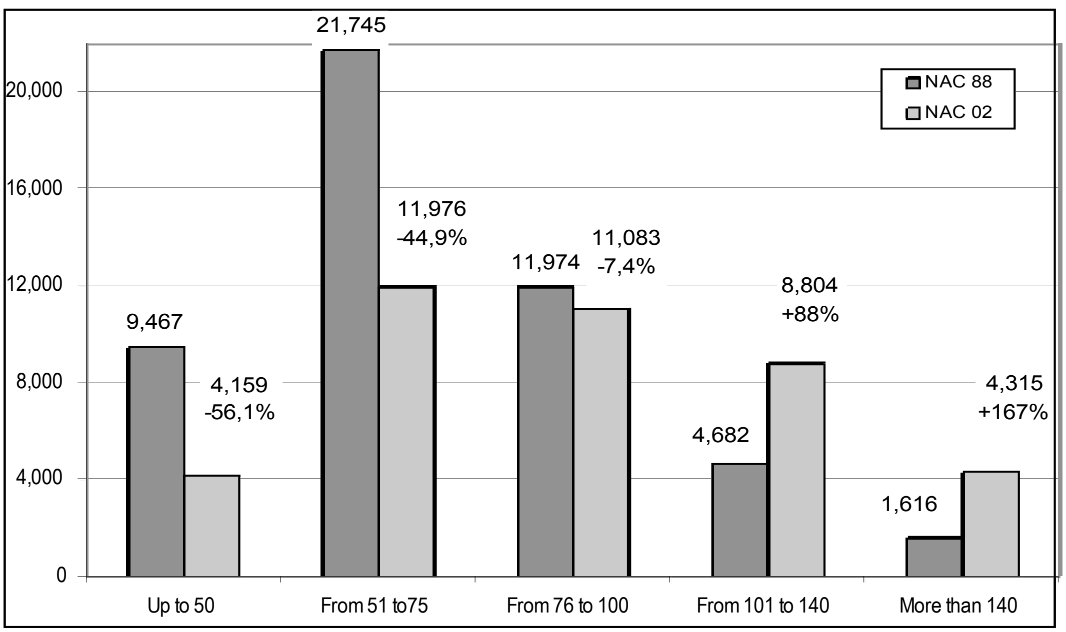
Data source: NAC 1988 and 2002 (INDEC)

Fig. 3.11: Evolution of agriculture. Córdoba Province.



Data source: NAC 1988 and 2002 (INDEC)

Fig. 3.12: Planted area of main crops. Córdoba Province.



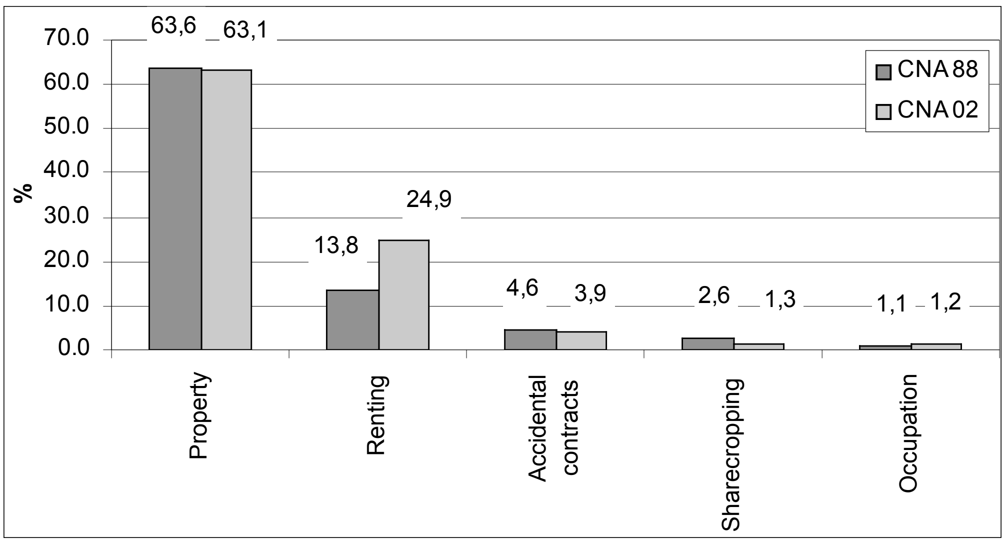
Data source: NAC 1988 and 2002 (INDEC)

Fig. 3.13: Number of tractors by power. Córdoba Province.

The technological change required and the type of available technologies (figure 3.13) for enhancing competitiveness together with a 50% decline in agriculture income purchasing power since the beginning of the 1990s (as measured by the relation between the Agriculture Retail Price Index and the Cost of Living Index) has not only pushed farmers towards more specialized production but also

resulted in land concentration. A family farm that in 1983 needed 39 hectares for an annual minimal net income of 12,000 US dollars, required 344 hectares in 1993 (Peretti, 1999). Economies of scale contributed to the already skewed income distribution. Between the 1988 and 2002 National Agricultural Censuses, 35% of small and medium size farmers abandoned agriculture activities in Córdoba (INDEC, 2002). Another strategy was to rent the land, however, the cost of renting also began to increase as a consequence of competition with new forms of production organizations and agents (food processors, foreign capital and agents from outside agriculture) (figure 3.14). And, on the whole process more marginal land has been incorporated into cash crop production.

In general, restructuring of agriculture production implied an increasing debt burden for small and medium size farmers, given the high real cost of credit and the farmers' lack of collaterals. In many cases these farmers had no access to private credit (e.g., through input suppliers or banks). Integration within MERCOSUR countries also implied greater competition in poultry, pork and dairy production and decreasing prices for these products, leading to the abandonment of more diversified agricultural strategies and contributing to the further specialization in cash crop production.



Data source: NAC 1988 and 2002 (INDEC)

Fig. 3.14: Land tenure regime. Córdoba Province.

Despite the strong tendency towards soybean mono-cropping, most of smallholders, especially in marginal areas, continue to plant a diversity of crops and to keep cattle, although under more intensive practices. According to interviews with farmers in the region, they continue with these strategies to maintain soil conditions and to diminish climate risk. However, despite observable diversification, most specialists consider that the proportion of land under soybean cultivation is so significant that it is not possible to consider the small scale livestock and agricultural strategies of these farmers as diversification.

Independent of the degree of diversification in the region, the prevalence of new technologies favoring intensive production imply increasing rates of nutrients extraction, leading over time to increased fertilization requirements thus rising production costs and the consequent fall in producers' economic margins. Recent research carried in the region by de Prada et al. (2004) concluded that relatively low rates of erosion are having high immediate on-site impacts, even without the consideration of future land productivity and the consequent loss in social welfare.

Changes in the agrarian structure have also resulted in important changes in labor and demographic aspects of the sector. Over the course of the 1990s, the permanent labor force within farms has diminished by 39%. Family labor in agriculture decreased 40% in the same period. Less than half of farms are now not employing a permanent labor force and main production activities are now contracted through service suppliers. For example, 50% of harvesting activities, 25% of planting activities and 20% of crop maintenance is now contracted through service providers. This has contributed to continued migration from rural to urban areas (table 3. 2).

Population	1895	1914	1947	1960	1970	1980	1991	2001
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Urban	37.4	52.7	62.2	72.0	79.0	82.8	88.4	89.3
Rural	62.6	47.3	37.8	28.0	21.0	17.2	11.6	10.7

Source: National Census on Population and Housing (INDEC)

Table 3. 2: Evolution rural urban population. Argentina (Percentages)

As a conclusion, the structural reforms have yielded positive results in terms of production and productivity; however have increased the exposure of farmers to volatile domestic policies and international markets. The reforms have also resulted in a strong dependence on external marketed inputs and technology and an uneven distribution of best practices and technologies. Socially, there has been a strong process of concentration in land tenure through renting or selling and a growing risk that farmers who have rented will not re-enter the sector as producers. This process has also heightened the dependence of farm families on income outside agriculture. Finally, the technological changes that have taken place has produced a worrisome process of soil deterioration aggravated by mono-cropping and cultivation on marginal land and increased levels of pollution due to agrochemicals use, growing environmental concerns not only for farmers but for the whole communities they belong to.

3.4 Possible Socioeconomic Future Scenarios

The institutional analysis presented above provides the basis for the development of qualitative future socioeconomic scenarios for each country. One such regional scenario, roughly equivalent to the "A2" socioeconomic scenario of the IPCC for incorporation in models of climate change, would be a continuation of current policy trends, with the likely result of further land concentration, the continued expansion of mono-cropping, and the continued economic stress for the small family farm. This scenario would likely lead to increased rates of rural emigration and thus increases in urban populations, as well as a smaller role of agriculture in national employment. The farmers would most likely to exit the agriculture sector in this scenario may not necessarily be the ones practicing the most climate sensitive strategies, but rather those that have been unable to adapt to the new economic context of production. This scenario has environmental implications at a local and regional level that could – and likely would – feedback into the production of vulnerability at the scale of the farm-enterprise.

Another scenario – equivalent to the "B2" scenario of the IPCC -- is possible, although less probable. In Argentina, greater concern over the environmental impacts of large-scale monocrop agriculture might encourage the development of new regulations and technologies to conserve fragile lands, and enable more diversified land use. This would potentially revive livelihood opportunities for small-scale family farms and, potentially, provide benefits for the local rural economy. In Mexico, although the promotion of pasture as an alternative to sorghum may, in the long run, also produce unconsidered environmental consequences (particularly because the promoted pasture is buffle grass, an invasive plant that has become very controversial in the Sonoran Desert), such a policy might provide those farmers practicing mixed grain/livestock farming with the resources they need to adjust to new opportunities. For coffee farmers to be competitive, one option is for them to market their coffee in gourmet and ecological "niche" markets. The growth of shade coffee and organic production could have substantial ecological and economic benefits for the central Veracruz region. One of the benefits of globalization is that it can also facilitate the generalization of new approaches that can improve the resilience of production--such as low-tillage farming, rainwater harvesting for irrigation and improved management of organic manures—by spreading information about these techniques and linking producers to consumers who are increasingly interested in the production process. Public support for the formation of farm associations and producer groups would be a key element in such a scenario.

3.5 Conclusions

The specific institutional context and agricultural histories in Argentina and Mexico are quite different. Mexico, unlike Argentina, has a bifurcated agricultural sector which was institutionalised by the land distribution process after the agrarian revolution of 1910. The public sector in Mexico has historically played a far more direct role in farmers' decision and production strategies through subsidies for particular crops and inputs and through producer price controls and trade restrictions. However, in Argentina, the impact of the ISI model of development also favored particular forms of production and circumscribed farm strategies, albeit in a more indirect fashion. Thus in both cases, the process of market liberalization, deregulation, privatisation has represented "shocks" to different segments of the agricultural sector in each country, which, in turn, have affected resource access and distribution. These changes in access to inputs, credit, technical assistance, insurance and other agricultural technologies have altered the ways in which some parts of the rural population previously managed climatic and economic stress. The types of production processes now encouraged by these policies – typically more capital-intensive and more commercially oriented – have put some farmers at an economic disadvantage, thus challenging their ability to manage new economic and climatic shocks or extreme events in the sector.

Furthermore, there are some indications that the types of land use changes occurring in the regions of study (e.g., soybean mono cropping; shifts in land use between livestock and soybean in Argentina, coffee and sugarcane in Coatepec, or sorghum and buffle grass) may have unexpected future ecological and economic consequences, particularly if the expansion of these crops results in a more homogeneous landscape than what is observed at present. Erosion and other forms of soil degradation are of particular concern in relation to the possibility of rising temperatures and drought risk. In all the case studies, problems with pest infestations may well be linked to changes in local climate patterns, although this was not an issue addressed in our study. The control of these pests is made more difficult by declining prices for coffee, sorghum and other grains and the limited economic margins of smallholder producers.

In short, the case studies illustrate that the social and environmental impacts of national economic and sector reforms not only can increase the sensitivity of farm units to climate impacts but also reduce the capacity of farmers to reduce their vulnerability. These impacts are experienced at the level of the individual farm unit, but also have consequences for the rural landscape and economies.

4 Social Vulnerability and Climate Impacts

The vulnerability analysis took as its premise that the vulnerability of agricultural populations to climatic conditions cannot be solely understood through the quantification of biophysical impacts. The degree to which climatic events affect an agricultural system depends on a wide variety of factors, including (among other things) the types of crops or livestock produced, the scale of the operation, the farm's orientation towards commercial or subsistence purposes, the quality of the natural resource base and specific human variables — education, risk tolerance, age — of the farm's managers. Vulnerability is also mediated by institutional factors: the rules, norms and policies that govern land tenure, markets, financial capital and insurance, support programs and technology development and distribution. Finally, the term "social vulnerability" implies an analysis that addresses issues of equity, resource distribution, and differential susceptibility to harm. This implicitly means that the vulnerability assessment should address these aspects, and the implications of local decisions and actions for both the specific welfare of vulnerable populations as well as for the broader society.

4.1 Activities Conducted

- Stakeholder workshops to present the project and generate stakeholder interest and commitment to project activities and outcomes (Year 1 - 2)
- Interviews with stakeholders concerning history of climate impacts, trends in resource distribution and access, regional sensitivity to climate and economic shocks: agricultural officials at the local and regional level; water managers; local government officials; agricultural service providers (credit, public programs, technology); commodity traders; producer association representatives; non-governmental organization representatives; academics and, particularly, farmers (Year 1, 2, 3)
- In-depth interviews with farmers to assess risk perception (Argentina, Year 1, 2)
- Participatory interviews (Focus groups and round-table discussions) to assess perceptions of climate and economic impacts, past climate events and other shocks to local production, trends in land use, agricultural calendars and decision-making (Year 2).
- Indicator selection and survey design and testing (Year 1, 2)
- Farm-level surveys to assess sensitivity and capacity at farm level (Year 1, 2)
- Survey data analysis and vulnerability index development (Year 2 – 3)
- Results dissemination, discussion of interventions to enhance adaptive capacity and validation with stakeholder groups (Year 2 and 3)

4.2 Description of Scientific Methods and Data

4.2.1 Theoretical framework

The unit of analysis for our vulnerability assessment was the farm operation or household. We have compared farmers' production strategies across farm systems – comparing small scale, export-oriented coffee producers in Veracruz to large-scale irrigated farmers in Tamaulipas, and both these systems to the diversified grain-livestock producers in Córdoba Province, Argentina. Following a political-ecology approach, our research considered both the physical environment and social environment as dynamic, evolving and highly uncertain contexts in which farmers are making strategic decisions about their livelihoods (Scoones 1999).

The participation of farm stakeholders in our research design and implementation was critical. We did not assume that any particular set of adaptation options or management strategies are available to farmers. Instead, as part of our vulnerability analysis, we have worked directly with farmers to determine what "choice set" for adaptation they perceive is currently available to them and how these choices are currently being affected by their specific capacities, as well as by broader social, political and economic change.

Our project had the ambition of contributing to the process of sustainable development in the study regions through our analysis of vulnerability. This objective was pursued through understanding the links between the strategies farmers are using to address structural changes in the economy and implications of those responses for their livelihoods, resource base and thus their sensitivity to climate impacts. International agencies such as the Department for International Development and the Food and Agriculture Organization (FAO, 1995), have defined sustainable systems, whether livelihoods, communities or national economies, as those that are able to cope with or recover from external shock or stress, while maintaining or improving its resource base. Thus, if agricultural populations are vulnerable to climate risks in the sense that they cannot cope with adverse climatic events, or lack appropriate mechanisms for doing so, the outcome might be a situation of vulnerability that undermines the resource base therefore sustainability in the medium and long term. A lack of adaptive capacity in agriculture may be indicative of a more general lack of sustainability of the system. If losses due to climatic events are repeated over time and aggregated across an entire sector (given that in the tropics, climate scenarios suggest greater variability and more intense extreme events), one can expect that such impacts will contribute negatively to the capacity of the system to maintain productivity and to assure stable or improving rural livelihoods.

Given the evidence that farmers of annual crops tend to make their production decisions and develop strategies more in response to inter-annual variability than to climate change (Brklachich, McNabb et al. 1997; Chiotti, Johnston et al. 1997; Smit and Skinner 2002), we focused on the sensitivity and capacity of farmers in relation to past and present extreme events. The analysis based on the current process of decision-making at the farm-level aimed at understanding how farmers are responding to multiple stresses and the constraints and opportunities they face in their responses. We identified the factors that affect agricultural adaptive capacity in the interest of proposing interventions not only to reduce vulnerability but also to enhance the system's sustainability.

This sustainability/vulnerability process is presented schematically in figure 4.1. In the figure the red line represents the "level" of sustainability of the unit of analysis; in our case, the agricultural household. At any given moment in time, this "level" of sustainability incorporates the accumulated past experiences of the household and the implications of that experience for present decisions and strategies. The social, environmental, or economic outcomes of these strategies in turn affect the future level of sustainability of the unit of analysis (household). This process is influenced by a number of factors, represented in the diagram by the series of boxes below (representing the micro-context of decision-making) and above (representing the global or exogenous context of decision-making) the red line. The boxes in dark yellow represent the factors affecting the decision-making at the household-level. The light yellow area above the red line represents the broader economic, institutional and environmental context of decision-making over which the individual household has little direct influence or control. These macro and micro factors affect households via sustainability attributes specific to the particular unit of analysis (illustrated in generic terms by the red boxes and as described by Masera and López-Ridaura 2000).

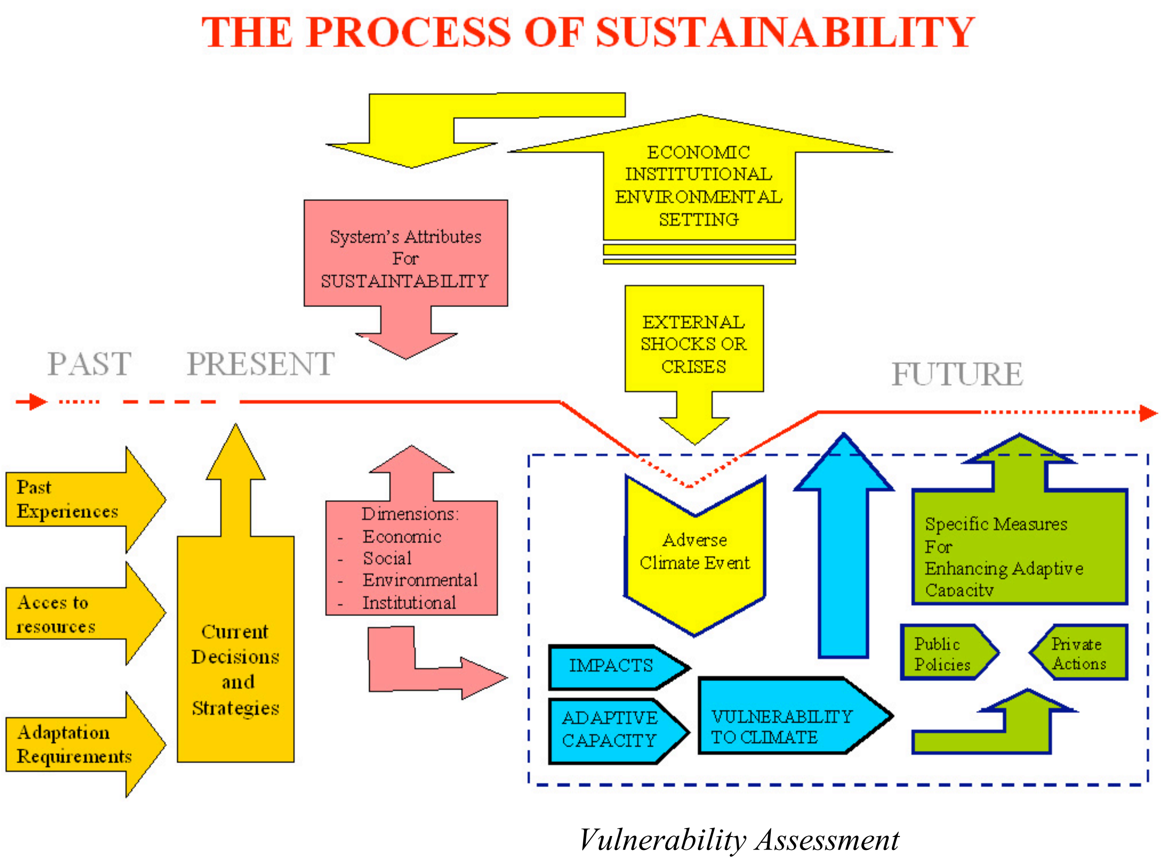


Fig. 4.1: The sustainability and vulnerability of agricultural systems

The light yellow area is also a source of exogenous stressors that can affect the unit of analysis at any point in time, including adverse climate events. The dotted line in the lower right hand corner represents the scope of analysis of this project in which climate events and their impacts on the households are emphasized over other stressors in the sustainability analysis. The implications of the climate events for the vulnerability of the households are determined by the sensitivity of the system and its capacity to adapt. The resulting vulnerability of the system can have an important impact on the level of sustainability of the household, as well as on the broader production system to which it belongs, thus affecting the future trajectory of its development. Interventions, either on behalf of public or private actors, to either reduce the sensitivity of the system or improve the capacities of households to adapt can counter-act this impact on sustainability and thus also influence the system's future development.

4.2.2 The vulnerability function

The project conceived vulnerability as a function of *sensitivity* (S) on a system generated by the characteristics of a system in relation to different climatic events; and, *adaptive capacity* (AC), or the ability of a system to cope with, recover from and adjust to changing climatic conditions and extreme events. We explicitly recognized that vulnerability is spatially and socially differentiated. In other words, sensitivity and adaptive capacity are related specifically to the type of climatic threat affecting a population, the type of farmer or farm system affected, the location of production or livelihood activity (Bohle et. al, 1994). It is also important to clarify if one is assessing the adaptive capacity of the agricultural productive unit or, as in the case of this project, also the livelihood strategy that rests on it. Formally, we expressed vulnerability as a function of both variables as follows:

$$ {}_{j}^{i}V_{k}^{c} = F \left\lfloor {}_{j}^{i}S_{k};\ {}_{j}^{i}AC_{k}^{c} \right\rfloor $$

where:

i = 1, 2,...,n represents different climatic events that can have a negative impacts.

j = 1, 2,..,m and represents different type of producers.

k = 1,2,...,w and represents particular geographical zones to be considered.

c = whether an agricultural productive unit or an agricultural producer's livelihood strategy.

In order to operationalize this analytical framework, our project drew from the MESMIS framework (Masera and López-Ridaura 2000) and on recent research on social vulnerability in central Mexico. However, we used the MESMIS method not to measure each farmer or community's absolute vulnerability but rather as an operational tool to compare the distribution and relative degree of capacities and the differences in sensitivity across the populations of the study region. We used the AMOEBA diagrams to highlight the features that most inhibit the development of adaptation capacity, and thus as tools in discussions of policy reform and interventions to improve adaptation capacity, as well as to discuss difference in vulnerability with farmers.

The appropriate variables that best represented the attributes of vulnerability for each case study were determined through consultations both with sector experts and with different classes of farmers. These variables were associated with a series of generic attributes that we developed from the theoretical literature (Table IIC.1). The data used to construct these indicators was acquired through a representative survey of farm households in each of the case studies.

The evaluation of vulnerability in each case study permitted the consideration of possible interventions to enhance capacity of vulnerable populations. These interventions also took into consideration what farmers are already doing to adjust to climatic risk, the constraints they face in this process (including their perceptions of climate risks), and how their strategies are supported or inhibited by changes in agricultural policy and programs.

4.2.3 Surveys

A similar survey instrument was used in each case study to collect data on the selected indicators to enhance the possibility of comparison. In each case study, the survey data were grouped according to their relation to the proposed indicators of vulnerability. Thus, for example, education levels and farm experience were associated with the human resources necessary for adaptive capacity while past experience with climate impacts and pest problems were associated with sensitivity. The indicators of sensitivity were not an objective measure of impacts, but rather represented farmers' perceptions of how climate and non-climate affect their production and livelihood strategies. The specific variables measured in each case differed according to the structural characteristics of the agricultural sector in each case study. The survey design and implementation is described in detail as related to each case study in the following section. The household survey data in all case studies were coded, tabulated and analyzed using statistical software (SPSS).

For two of the case studies (Argentina and Tamaulipas) aggregated indices for sensitivity and adaptive capacity were created from the survey data. The methodology used to create the indices differed in the two case studies and is described in the following sections. In both case studies the indices were created through a process involving the assignment of weights to each indicator according to the importance of the indicator for either adaptive capacity or sensitivity. These indices were then combined to comparatively classify the farmers in each region according to their relative degree of vulnerability.

In the Veracruz case study, the small sample size and community focus of the study allowed for a more qualitative analysis of vulnerability. No aggregate index of vulnerability was developed, but rather the sample was classified according to the structural characteristics of the farm households, and the differential capacities and sensitivities of these farm classes were then illustrated.

INDICATORS	VARIABLES (MEXICO)	VARIABLES (ARGENTINA)
Human Resources	Age, education, size of household, employment of household members, sex of head of household	Age, education, size of household, employment of household members, place of residency
Material Resources	Landholding size, equipment ownership, input use, transport ownership, irrigation, production, yields, land tenure, access to rented land, livestock	Landholding size, equipment ownership, input use, transport ownership, production, yields, land tenure, access to rented land, livestock, soil quality
Social Resources	Use of technical assistance, source of technical assistance, participation in agricultural organizations	Use of technical assistance, source of technical assistance participation in agricultural organizations
Financial Resources	Credit use and source, insurance use, access to government subsidies and economic support	Credit use, personal finances, marketing strategy
Management Capacity/Diversity	Crops planted, types of land use, income sources, subsistence production, commercialization channels, livestock management, time dedicated to production	Crops planted, land use, income sources, subsistence production, commercialization channels, land rental and sale, livestock management
Previous Risk Mitigation Actions	Climate information use, changes in land use, changes in production strategies, year of adoption of irrigation	Number of geographically dispersed farm plots, climate information use, insurance, changes in crop and cattle management, irrigation
Climate information	Type of climate information used, source, purpose; information needs	Type of climate information used, source, purpose; information needs
Climate impacts	Crop losses in year prior to survey, memory of past climate impacts, past impacts on livestock, month of greatest risk, ranking of crops most sensitive to climate impacts, frequency of pest and disease problems, type of pest problem, month of infestation, perception of climate change	Impacts on cash crops: event, frequency, and area affected and type of damage Impacts on livestock: event, frequency, and area affected and type of damage Impacts on infrastructure: event, frequency, and area affected and type of damage
Economic strategies	Presence of out-migration, destination of migrants, reception of remittances, change in income over last five years, land sales and agricultural abandonment, % of land rented to others	*Included in indicators of management capacity*
Public institutions	Perception of recent change in sector policy, perceived responsibility for resolving climate vulnerability	Perception of recent change in sector policy, perceived responsibility for resolving climate vulnerability
Decision-making	Reasons for participation in agricultural organizations, reasons for contracting insurance, reasons for use of climate information, principle factors driving crop choices	Reasons for participation in agricultural organizations, reasons for contracting insurance, reasons for use of climate information, principle factors driving crop choices

Table 4.1: Data collected in the survey

4.2.4 Focus groups

Group discussions were held with farmers in all three case studies. In Argentina, farmers were invited to participate in round-table discussions in which they were able to articulate their perspective on a variety of issues and trends in the sector, including climate impacts. In Veracruz, the support of experts in the National Institute for Forestry, Agriculture and Livestock Research (INIFAP) enabled the use of participatory methodology (Participatory Rural Appraisal) to gain the perspectives of farmers in two communities over climate variability, impacts and socioeconomic trends. In Tamaulipas, workshops were held in which farmers were able to comment on various aspects of the production process which were affecting their livelihood outcomes. In general, the group discussions in all cases allowed the identification of a set of political-economic and economic factors ("structuring factors") that have, over the last decade, facilitated and/or prevented farmers' realization of their adaptation capacity. The focus groups also provided a realistic depiction of the actual range of adaptation choices available during recent periods of climatic uncertainty and institutional change, and how these choices varied between different farm systems, and different farmers. By revisiting farmers' production and livelihood choices in the years succeeding key climate events (e.g., changes in labor allocation on and off-farm, changes in crop, changes in water use, etc.), we were able to explore with farmers the motivating and constraining factors behind these decisions.

4.2.5 Interviews

In-depth interviews with selected farmers were used to triangulate focus group findings and provide additional information necessary for the elaboration of accurate and measurable indicators. An interview protocol was used in each case study to guide the interview process (described in each case study below). In the Argentina case study, the interest of a student pursuing her master's degree allowed for a detailed analysis of farmers' risk perceptions using primarily data collected in in-depth interviews. Although the other case studies did not benefit from the same in-depth study of perception, complementary risk perception data was collected in the group interviews.

4.3 Methodology Specific to Case Studies

4.3.1 Argentina

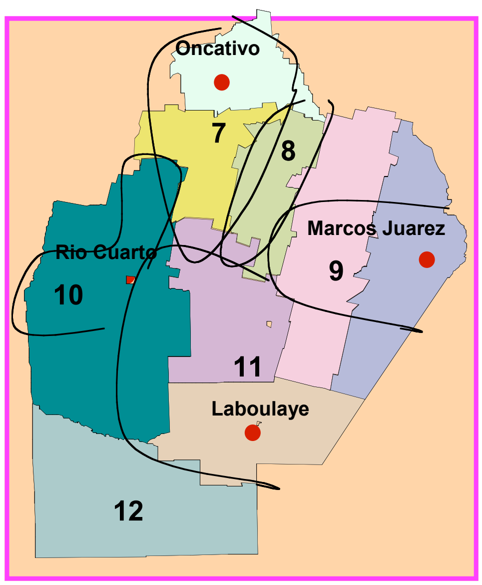
4.3.1.1 Methodology for case study sites and survey sample size determination

The whole Córdoba province is about 16.532.100 hectares and 83% of it is devoted to agriculture activities. The South of Córdoba region comprehends 6 of the 13 different agro ecologic zones (AEZ) of the Province (figure 4.2). Main agriculture systems in each zone within the region are depicted in table 4.2

Zone	Agriculture system	Farms		Area		Average size per farm
		No.	%	has.	%	
AEZ 7	Cash crop	1,166	42.9	396,681	43.3	340.2
	Cash crop/ Livestock	350	12.9	157,922	17.2	451.2
AEZ 8	Dairy/ Livestock	303	25.1	112,030	23.4	369.7
	Bovine livestock	164	13.6	47,460	9.9	289.4
AEZ 9	Cash crop	837	36.6	234,407	28.7	280.1
	Cash crop/ Livestock	357	15.6	145,951	17.9	408.8
AEZ 10	Cash crop/ Livestock	464	31.0	208,628	35.4	449.6
	Livestock –Cash crop	306	20.5	105,580	17.9	345.0
AEZ 11	Livestock	641	25.4	284,962	20.4	444.6
	Cash crop/ Livestock	509	20.2	425,165	30.4	835.3
AEZ 12	Livestock	533	39.8	337,776	34.5	633.7
	Cash crop/ Livestock	328	24.5	286,876	29.3	874.6

Table 4.2: Representative agriculture systems by zone

Source: Peretti, et al "Monitoreo Económico de los Sistemas Productivos Predominantes de Córdoba" Data 1999.



On the right: Departmental units (in different colors); selected localities (survey's base); and, different agro-ecologic Zones (9 Humid east; 8 Semi arid / sub humid central; 11 Semi arid / sub humid south; 7 Semi arid central; 10 Semi arid central-west; 12 Semi arid south). For a more detailed characterization of AEZ, see Ministerio de Economía, Secretaría de Agricutura, Ganadería, Pesca y Alimentación e Instituto de Tecnología agropecuaria (2001).

Fig. 4.2: Selected case study: South of Córdoba province.

The sample size was determined with the consideration that there is no single variable that measures vulnerability. Thus, it was considered appropriate to use maximum variance as the population parameter (π = 0,5). For a confidence level of 95% (Z = 1,96), an error of 6.3 % was estimated for a sample size of 240, which was a workable size according to the available resources for the survey.

$$n = \frac{z^2 \pi \left(1 - \pi\right)}{e^2}$$

Four localities were chosen in which to implement the survey (Laboulaye, Río Cuarto, Marcos Juárez and Oncativo). The sample size for each of them was stratified in terms of the most representative types of agriculture units in each locality.

In addition to the survey, eighteen interviews were conducted with farmers of a wide range of age, educational level, type of agriculture system and landholding size and distributed among the four study sites. The interview was divided into 5 thematic lines as follows (Maurutto, 2004):

1. Climate risk perception and consciousness on vulnerability
2. Experiences, feelings and constructions towards climate
3. Decision-making
4. Past and current adaptation measures
5. Appreciations and demands on public policy

These interviews were coded, the content analyzed through progressive steps and used as a complement to the survey analysis.

4.3.1.2 Sensitivity Index

The survey data provided information on the main climate events affecting each crop planted, the frequency of adverse events (*freq*), percentage of area affected (*affa*) and type of damage experienced (*typd*). Each response has been given a value, representing (0) no impact; (1) low impact; (2) medium impact; (3) high impact.

$$R1g = \left(freq * affa * typd\right)$$

For each crop, these values were weighted by the proportion of agriculture producers concerned with each particular event within their group (n_e/N_g)and by the area dedicated to that particular crop in proportion to the total worked area by each farmer (*%aded*), including the crop area lost to hazards (differences between planted and harvested area, *%nhara*).

$$R2g = \left(R1g * \left(\frac{n_e}{N_g} \right) * \left(\%aded\right) * \left(\%nhara\right) \right)$$

Impacts on livestock production and on infrastructure were also incorporated to the Sensitivity Index with the same methodology. Then to get a measure of sensitivity for a whole locality, each group was weighted by the number of farmers within each group(N_g) in relationship to the total number of farmers surveyed in that locality and summed (N_L).

$$SWig = S\left[R2g * \left(\frac{N_g}{N_L}\right)\right]$$

4.3.1.3 Adaptive Capacity Index

Adaptive Capacity Indices were obtained after weighting indicators through consultation with farmers. The indicators were grouped into four categories: material resources; human resources; management capacity and adaptations. The farmers then determined the importance for adaptive capacity of every indicator within each category, and then the relative importance of the categories themselves. The procedure to get these weights was to obtain a value for each of the categories and indicators in terms of the order of importance given by the farmers. Second, these values were indexed using the maximum value given to a group and then by the maximum value given to an indicator. This process resulted in the following weights: a) Physical and Material Resources Group (1); Variables: Worked Area (0.72); Machinery (0.58); Good Soil Quality (0.90); Yields (0.76); Net Income (0.96); b) Human and Social Resources Group (0.505); Variables: Use of Public Technical Assistance (0.38); Use of Private Technical Assistance (0.36); Participation in Organizations (0.34); Education (0.34); Experience (0.49); c) Management Capacity Group (0.634); Variables: Renting Land (0.44); Buying/Selling Land (0.30); Incorporating Livestock Activities (0.40); Crop Diversity (0.63); Economic Diversity (0.56); and, d) Adaptations (0.634); Variables: Number of Geographically Dispersed Land Units (0.39); Changing Agriculture Practices (0.45); Changing Livestock Practices (0.32); Use of Any Type of Climate Information (0.51); and Climatic Risk Insurance (0.50).

4.3.1.4 Classification of farmers' group by vulnerability

The values for adaptive capacity and sensitivity for each group of farmer, which characterizes a particular farm system within a specific locality, were mapped to compare the relative vulnerability of each group. All farmer groups were then assigned to vulnerability classes (High, Medium, and Low) according to dispersion criteria (defining three ranges from average values of both indeces).

The average values for each of these indicators corresponding to each vulnerability class were then graphed on an AMEOBA diagram to visualize the indicators contributing most to the differences in vulnerability in the surveyed population.

4.3.2 Mexico

4.3.2.1 Veracruz

The Veracruz case study was conducted in parallel with an Inter American Institute for Global Change Research small grant project entitled "Adapting to Market Shocks and Climatic Variability in Mesoamerica: The Coffee Crisis in Mexico, Guatemala, and Honduras" (P.I., Dr. E. Castellanos, Universidad de Valle de Guatemala). The Veracruz case study used an ethnographic and participatory approach similar to that used in Honduras and Guatemala, while pursuing the livelihood approach used in Argentina and Tamaulipas. The case studies of the project were thus comparable in terms of general trends and processes leading to vulnerability and inhibiting/enhancing adaptive capacity, although some of the specific methods and tools used to assess vulnerability were different in each case.

Two communities were chosen from the list of coffee producing communities in central Veracruz in the 1992 national coffee census. After grouping the communities in the central Veracruz region according to altitude ranges, the communities were randomly chosen. Thirty surveys were implemented in each community by three different enumerators in the month of March, using the same survey instrument as was used in Honduras and Guatemala. The resulting sample is not statistically representative of the communities, however the surveys were complemented by a variety of participatory rural appraisal methodologies and the purpose of the surveys was to understand qualitatively the types of strategies and constraints households face (rather than the precise proportion of households implementing each strategy). The households were randomly selected for the survey using a "probability proportional to size" sample, in which a map of each community was divided into segments of random size and in each segment one household was selected by the enumerator for the survey (Bernard 1994).

A two-step cluster analysis in SPSS (permitting the classification of both categorical and numeric data) was run on those variables in the data base associated with the three attributes of sensitivity and adaptive capacity (*flexibility, stability and resource access)* in order to identify two livelihood groups. Variables relating to impacts (climate, market, pest) experienced and adaptations undertaken (land use change, change in production system or practice) were excluded from the classification. The survey data was then analyzed descriptively, stratified by these two livelihood groups, to assess qualitatively and quantitatively (via non-parametric tests) differences in adaptive capacity according to differences in resource use and access. Using the resulting group membership as a variable, the group membership was correlated with adaptations taken (e.g., the variables largely excluded from the classification above).

Several group interviews in each community were organized with the help of an expert in participatory methodology from the Xalapa office of the National Institute for Forest, Agriculture and Livestock Research (INIFAP). In these workshops, farmers drew maps of their communities, identifying spatial differences in resources and land use; prepared a seasonal calendar describing primary production activities and when particular climate events were expected to occur; timelines of changes in land use, producer prices, and public institutions; and a chronology of historical climate events and their impacts on the community. The workshops concluded with a discussion of the expectations of the farmers of future climate conditions, production conditions and the community's development.

Semi-structured interviews were also conducted with larger coffee farmers, coffee exporters, academics, politicians and representatives of government agencies working in the sector. These interviews followed a protocol that addressed both concrete information needs of the project (e.g., descriptions of public programs in the sector, the specific activities and responsibilities of particular actors) as well as the perception of the interviewee over the drop in coffee prices, the importance of climate factors for coffee production, and the responses of the interviewee, his/her organization and other actors to the situation. Aside from providing alternative perspectives over the importance of climate and other factors in coffee production decision-making, these interviews allowed for the triangulation of the ethnographic data collected at the local level, and the identification of the trends or patterns observed at the local level that might be generalized more broadly over the region.

4.3.2.2 González, Tamaulipas

A cluster sample of 234 randomly selected households was surveyed during the summer of 2003 in González (Mexico), incorporating both communal farmers and private landholders. A recent census of farmers in González does not exist. The population universe for this study was thus based on the list of producers enrolled in the government program PROCAMPO, which covers an estimated 80% of the farm population in the *municipio*. A digital version of the PROCAMPO database for the *municipio* was not available at the time of the survey, so a paper copy was entered into an excel database. This process entailed a certain amount of "cleaning" for the repetition or misspelling of names. Thus there was some uncertainty in the final population size, but for the purposes of this study, a universe of 3277 farm households was used, of which 20% were estimated to be *pequeños propietarios* and the remainder *ejidatarios*. The sample size of 240 resulted in sample with a confidence level greater than 90%. The sample was stratified by tenure (*ejidal* or *pequeña propiedad*), resulting in a final sample in which 18% were *pequeños propietarios* and the remainder *ejidatarios* (problems in contacting *pequeños propietarios* resulted in the somewhat lower than desired proportion of farmers of this tenure type). In addition to the private farmers, the surveys were implemented in seven communities (all *ejidos*) that together accounted for over 30% of the PROCAMPO population and were spatially dispersed in the *municipio*, in proportion to the relative population sizes of each of these communities. These communities were: Lopez Rayón, Graciano Sanchez, Centauro, Santa Fe, Nicolas Bravo, Ruíz Cortinez and San Pedro. Two of these communities were located in the irrigation district of Las Animas in the southern part of the *municipio*.

The survey data was analyzed descriptively in SPSS and Excel to assess general characteristics of the farm population, as well as to determine the primary climatic events that were of concern to the population, the impacts of these events and the coping strategies of the farmers. The sample was also classified into farm livelihood systems according to the threshold criteria of the source of 66% of total household income. This data was then presented in the region and validated with stakeholders in the spring of 2004.

Index values for sensitivity, adaptive capacity and vulnerability were created for 181 cases in the sample that had no missing values for the variables of interest. For this analysis, adaptive capacity was measured in five attributes: human resources, material resources, financial resources, information access and use, and economic and agricultural diversity. Similarly, the sensitivity index was created through two attributes: the sensitivity of the production system and sensitivity of the farm livelihood. Specific variables from the survey were then associated with each of these attributes (Table IIC 3, Table IIC 4, below). The variables in all cases were transformed into a homogenous scale [0-1] according to value functions defined specific to each variable.

Saaty's (1980) Analytical Hierarchy Process (AHP) was then used to assign weights for each variable and each attribute. This process involves developing a hierarchy structure and undertaking a series of pair-wise comparisons of the variables defining each attribute using a cardinal scale, and then between the different attributes defining adaptive capacity and those defining sensitivity. Matrix algebra is used to determine final weights for each attribute. The process of pair-wise comparisons can be done in a collective participatory fashion by stakeholders (who may assign cardinal values based on their personal experience) or by a group of experts (who may assign cardinal values based on their technical and theoretical knowledge). The latter was done in the González case, although the resulting weights were qualitatively validated in interviews with farmers in the spring of 2005.

This process allowed for the calculation of aggregate scores for each attribute. According to the AHP, the attribute scores were combined through a weighted linear combination to create the values of a single multivariate indicator of adaptive capacity and a single multivariate indicator of sensitivity. These two indicators were then combined through Fuzzy Logic to create an overall measure of vulnerability. Fuzzy Logic is a formal mathematical theory for addressing uncertainty in decision making. It involves defining fuzzy sets corresponding to linguistic variables such as "high vulnerability" or "moderate vulnerability." The degree (the membership value) to which any particular value belongs to each fuzzy set is determined in a scale [0,1]. For example, a particular households' value for "adaptive capacity" may have a membership value of 0.7 to moderate vulnerability and 0.3 to high vulnerability, indicating that set membership can be uncertain. The resulting membership values of the fuzzy sets for each of the two indices (sensitivity and adaptive capacity) are combined through a procedure known as fuzzy addition in order to determine the final solution space in which the household's membership in a particular vulnerability set is determined (Bojórquez-Tapia et al., 2002). Each household was categorized according to its values for sensitivity and adaptive capacity in one of three vulnerability categories (Low, Moderate and High). The vulnerability classes were then mapped onto AMEOBA diagrams to illustrate the different roles particular attributes of adaptive capacity and sensitivity in distinguishing the vulnerability of the farm households.

In addition, approximately 10 interviews were conducted with farmers, technical specialists (e.g., INIFAP, CAN, SAGARPA), farm association leaders (CNC), and public agency representatives (BANRURAL, FIRA) in order to provide a qualitative perspective on climate impacts and responses, the decision-making process, development trends in the region, resource availability and intervention options (some of the interviewees were interviewed more than once).

4.4 Results

4.4.1 Argentina: The South of Córdoba, Argentina (SC)

4.4.1.1 Description of the case study region

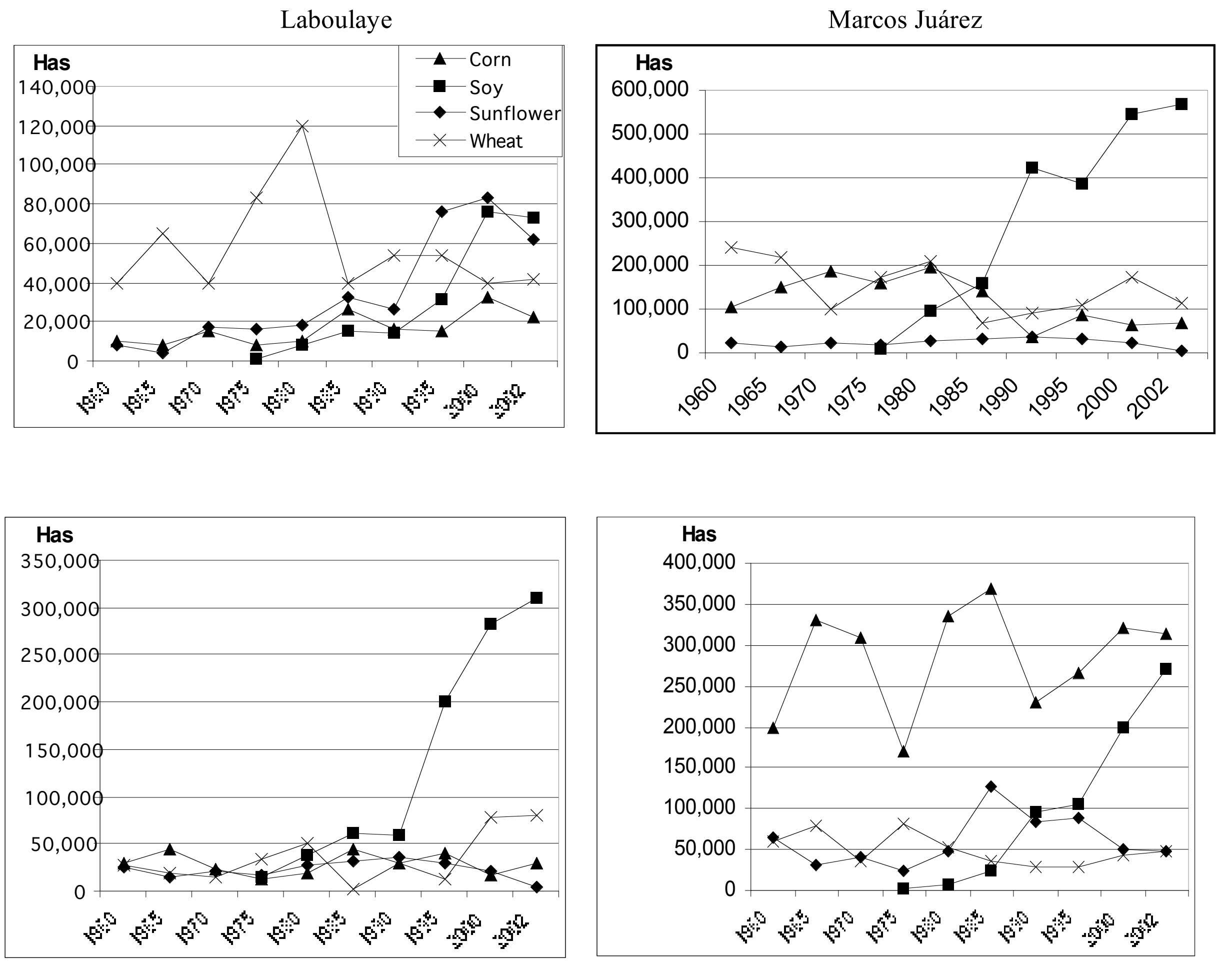
The region has a total population of 917,842 inhabitants, 30% of total population in Córdoba province (NPC, 2001). In the SC, 33% of the population corresponds to rural population (which includes small towns of less than 2,000) a value that is higher than the value for the whole Province, however equally declining. Agricultural production in the area is mainly rainfed, although some farmers have incorporated groundwater irrigation systems. Most of farmers manage two harvests annually: wheat and other fodder crops in winter (facilitated by the fact that soils do not freeze), and soybean, maize, sorghum and to a lesser extent sunflower (among other less important cash crops) in summer. This is an area historically characterized by a mix system of cash crops and livestock, however declining relative prices for beef has resulted in a reduction in herd size in the last decades. Similar declines have been noted in pork, lamb and poultry industry, which prior to the MERCOSUR trade agreement were complementary activities within the farm.

Reflecting the same trends that have been noted at the Provincial level (chapter 3), the SC shows a declining number of production units (table 4.3). The highest reduction in farm units (between 30 and 55%) characterizes those small and medium size units ranging from 50 to 500 hectares, while larger production units have increased in number. Coinciding with macroeconomic policy reforms, viability of small and medium size production units has been threatened through drastic changes in relative prices and confronted with external competition, not only because of market liberalization but also foreign capital directly involved in agriculture production. Similarly, trends towards mono cropping specialization are apparent in the SC, where soybean production has expanded (figure 4.3)

Department	Farms 1988	Farms 2002	Var. farms '02-'88 (%)	Has/farm in 1988	Has/farm in 2002	Var has/farm '02-'88 (%)
Gral Roca	1,556	1,188	-23.7	764	886	16.0
Gral San Martín	1,485	785	-47.1	286	442	54.5
Juárez Celman	1,653	962	-41.8	446	776	74.0
Marcos Juárez	3,421	2,077	-39.3	269	401	49.1
Pte. R. S. Peña	1,350	961	-28.8	580	631	8.8
Río Cuarto	4,58	2,984	-34.8	372	492	32.3
Río Segundo	1,998	1,422	-28.8	237	349	47.3
Tercero Arriba	1,892	1,116	-41.0	259	392	51.4
Unión	2,909	1,804	-38.0	328	506	54.3
Total	20,844	13,299	-36.2			

Note: Being the reduction for the whole province 34,1 % the South of Córdoba appears as the more affected region.

Table 4.3: Variation in number of farms: South of Córdoba



Source: Secretaría Agricultura y Ganadería de la Provincia de Córdoba.

Fig. 4.3: Evolution of planted area for main cash crops in selected departments in the South of Córdoba.

4.4.1.2 Survey data

From the survey sample 16 farmers groups were identified (Table 4.4) in terms of land use and landholding size for the four selected localities within SC region. Differences on landholding size represent those above and below of each system correspondent average value in each locality. It is worth to note that because of the survey sample, some of the farmers groups hold few cases and this may be distorting some of the results.

Locality	System	No. of farms	Average Size	Max	Min
Laboulaye	Cash Crop	6	506.7	1200	120
	Mixed Small	20	435.5	800	120
	Mixed Large	8	2029.5	3600	900
	Livestock	13	426.3	1270	50
Marcos Juárez	Cash crop small	13	359.8	700	65
	Cash crop large	6	1615.0	2100	1150
	Mixed Small	16	329.4	520	30
	Mixed Large	11	921.1	1600	600
	Livestock	4	482.5	900	130
Oncativo	Cash crop small	38	214.9	380	50
	Cash crop large	23	709.7	1800	420
	Mixed	7	691.0	1100	320
Río Cuarto	Cash crop small	10	420.1	900	22
	Cash crop large	6	2155.0	4200	980
	Mixed Small	28	356.4	800	80
	Mixed Large	12	1883.3	5500	900

Source: Survey Data

Table 4.4: Farmers' grouping by land use and landholding size for the four selected localities

The survey data confirmed the tendency towards increasing cash crop production and soybean mono cropping and the presence of different landholding sizes within the selected production systems as shown in table 4.5.

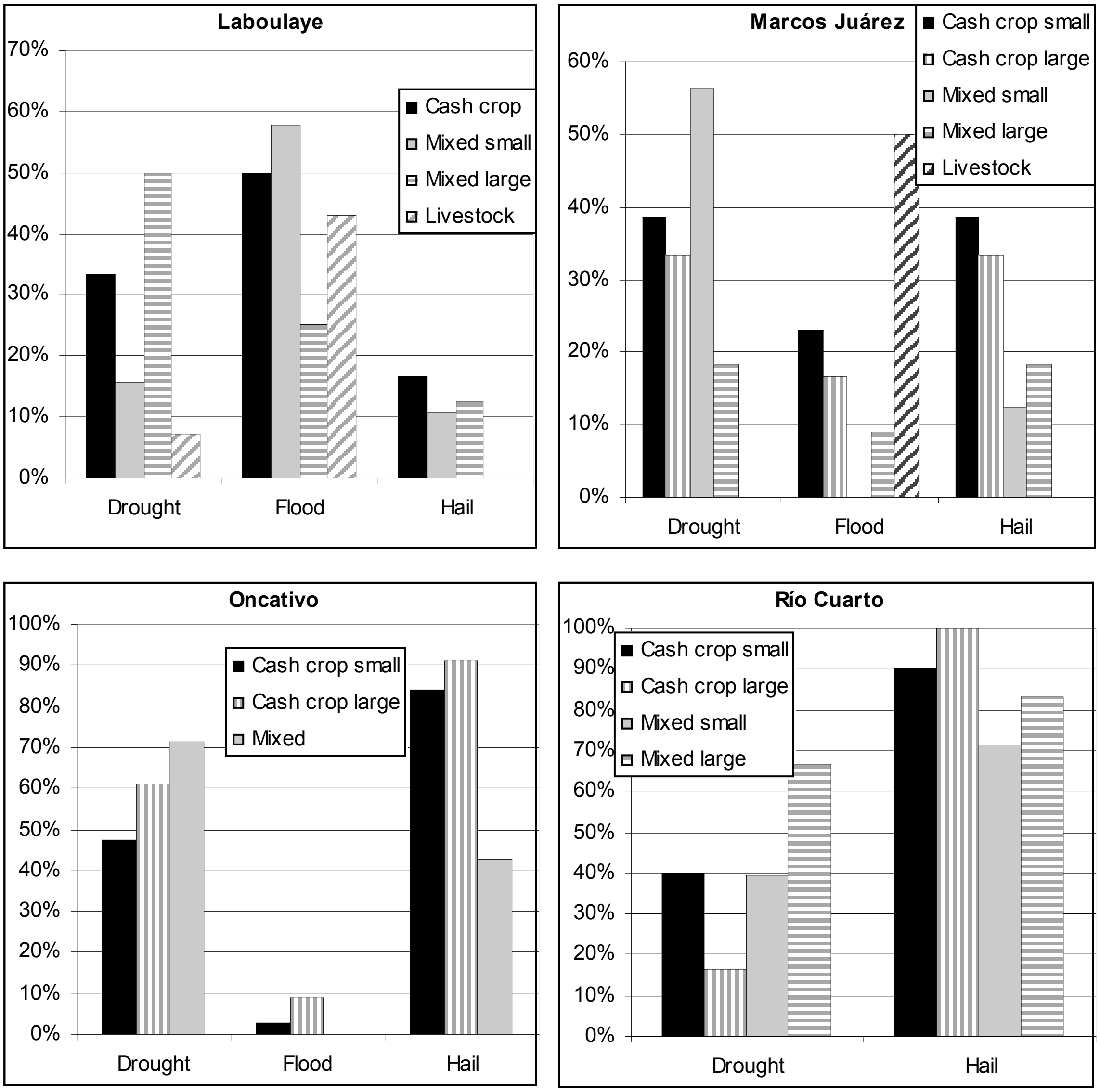
Locality	Number of farms	Average	Area with cash crops	Area with soybean
Laboulaye	47	713.3	39.0%	82.8%
Marcos Juárez	50	634.0	70.9%	76.8%
Oncativo	72	439.7	93.9%	69.6%
Río Cuarto	58	871.7	70.7%	53.0%

Source: Survey Data

Table 4.5: Average landholding size and percentage of land dedicated to cash crops and soybeans by locality

Of the total surveyed farm units resulted that 95% of them belongs to a familiar type of ownership, the rest to some other type of juridical form as stock company (3,5%). Farm management is 94% in the hands of farm owners and 81% of them dedicates completely to the agricultural activity. Average age of farm managers is 52 years old and educational levels are characterized by 35% with completed primary school; 24% has completed secondary school; and, 20% has complete or incomplete University education.

Concerns about different climatic adversities vary not only by locality, but also among different production systems (figure 4.4)



Source: Survey Data

Fig. 4.4: Level of concern on main adverse climate impacts and events by agriculture systems and localities.

4.4.1.3 Sensitivity

Climate Sensitivity indicators for each of the farmers group were obtained from the results of a specific question given to the farmers during the survey and allowed us to have a highly acceptable notion on agriculture producers' sensitivity to different adverse climate events. Farmers' perceptions on their sensitivity and the correspondent obtained indicators are consistent with the climatic characteristics (see chapter 2) both for the whole analyzed region and for the sub areas in which the former was divided, as stated earlier in this chapter.

In table 4.6 it is possible to observe that for the whole SC the most worrisome impact from a climate event is drought, followed by hail storms and to a lesser extent flood. As flood prone areas are situated in some sub areas of SC, it was expected that the flood sensitivity indicator for the whole region to be low.

Analyzing by locality, it is the Laboulaye area, which has the highest value of sensitivity and this is the most affected area with floods. Oncativo is the second most affected locality because drought and hail sensitivity indicators are the highest in SC, even it is not affected by flood. A particular combination of soil and precipitation deficits makes Oncativo and Río Cuarto the most affected sub areas in terms of droughts both belonging to the semi arid Pampas. Marcos Juárez has the lowest sensitivity indicator, result that was expected since this area belongs to the humid Pampas, a low risky area in terms of climate and soil characteristics, however with some flood risk in particular zones.

	Marcos Juárez	Oncativo	Laboulaye	Río Cuarto	Total region
Flood	0.11	0	2.29	0	0.52
Drought	0.63	1.56	0.73	1.08	1.05
Hail	0.31	1.48	0.18	1.61	0.97
Total events	1.06	3.10	3.20	2.69	

Note: These values only include farmers' perceptions on impacts on cash crops.

Table 4.6: Sensitivity Indicators by locality and climate events

Sensitivity indices in terms of production systems are shown in table 4.7, and they were obtained through a Sensitivity Matrix (see 4.3.1.2, this chapter) where farmers' answers were tabulated and weighted as indicated early in this section. It is important to keep in mind that indicators' values reflect the sensitivity that farmers perceive in relation to what extent their activities are negatively affected by climate, including impacts on cash crops, livestock and infrastructure.

Locality	Group	Cropping	Livestock	Infrastructure	Total
Marcos Juárez	Crop small	**1.68**			**1.68**
	Crop large	**0.61**			**0.61**
	Mixed small	**1.38**			**1.38**
	Mixed large	**0.68**			**0.68**
	Livestock		**0.75**		**0.75**
	All (weighted)	**1.06**	**0.06**		**1.12**
Oncativo	Crop small	**3.01**		**0.05**	**3.06**
	Crop large	**3.30**			**3.30**
	Mixed	**3.00**			**3.00**
	All (weighted)	**3.10**		**0.03**	**3.13**
Laboulaye	Crop	**1.27**			**1.27**
	Mixed small	**4.36**		**0.85**	**5.21**
	Mixed large	**4.92**		**0.75**	**5.67**
	Livestock		**1.35**	**0.54**	**1.89**
	All (weighted)	**3.20**	**0.37**	**0.64**	**4.21**
Río Cuarto	Crop small	**1.08**			**1.08**
	Crop large	**3.05**			**3.05**
	Mixed small	**3.42**		**0.07**	**3.49**
	Mixed large	**2.08**		**0.18**	**2.26**
	All (weighted)	**2.69**		**0.07**	**2.76**

Table 4.7: Total sensitivity of agriculture producers by group including cash crop, livestock and infrastructure.

There are some regularities among particular production systems and localities, which is coherent with the previous discussion. An exception is made for cash crop producers in the Laboulaye area. This area is characterized by the prevalence of livestock and mixed (cash crop and livestock) production systems. Cash croppers, generally soybean producers, are renting the land thus selecting high quality soils that are less prone to flooding. Livestock production is a less profitable activity nowadays and tends to take place in marginal cropping areas, more susceptible to floods not only in Laboulaye but also in some parts areas of Marcos Juárez. Main damages on livestock production mentioned by farmers were reduced forage and less calf number among others.

It is also worth to highlight that mixed production units do not show impact on livestock which can be the result of the high proportion of land devoted to cash crops.

Indicators on infrastructure mainly refer to flood impacts, however in less flood prone areas strong wind and hail storms were also mentioned. The final values for *sensitivity indices* are shown in table 4.9.

4.4.1.4 Adaptive capacity

Indicators on adaptive capacity were obtained for the 16 farmers groups and each of the indicators represents one or more variables from the survey data. These indicators aimed to identify main resources available for farmers to respond to stress and uncertainty. These resources for adaptation include physical/financial, social/human resources as well as measures on management capacity and adaptations already incorporated by the farm units.

Some representative variables differentiating and characterizing each group within each locality, and used to obtain indicators are shown in Table 4.8.

a) Marcos Juárez

Capacity Attribute	Variable	Cash crop small	Cash crop large	Mixed small	Mixed large	Livestock
Social/Human Resources	Potential experience (yrs.)[a]	41.9	31.8	48.1	38.9	30.0
	Education (yrs.)[a]	10.3	12.5	10.4	9.3	9.0
Material Resources	Landholding size (has.)[a]	359.8	1615	329.4	921.1	482.5
	Machinery Index[a]	1.9	2.3	1.7	2.2	0.5
	Gross Margin (Arg $) (Income)[a]	319,983	1,353,383	132,820	466,201	0
Management Capacity	Rented land (as % of worked area)[b]	42.8	51.2	32.3	31.1	16.4
Financial Resources	Other sources of income [d](% of cases)	7.7	0	12.5	0	0
	Hail Insurance (% of cases)	84	83	62	91	0
Information	Official Technical assistance [a]	38.46	33.33	12.5	1.93	27.27
	Consults climate information [c](% of cases)	69.2	66.7	62.5	72.7	75.0
Diversity	Number of crops[a]	2.62	3.0	1.88	2.64	0
	% of hectares dedicated to cash crops[a]	97.8	100.0	59.8	65.4	0

b) Oncativo

Capacity Attribute	Variable	Cash crop small	Cash crop large	Mixed
Social/Human Resources	Potential experience (yrs.)[a]	37.2	31.3	32.0
	Education (yrs.)[a]	8.5	9.5	8.6
Material Resources	Landholding size (has.)[a]	215	710	691
	Machinery Index [a]	2.0	2.6	1.7
	Gross Margin (Arg $) (Income)[a]	82,129	189,143	4,838
Management Capacity	Rented land (as % of worked area)[b]	48.5	50.7	52.8
Financial Resources	Other sources of income [d] (% of cases)	18.4	0.0	14.3
	Hail Insurance (% of cases)	68.4	65.2	42.9
Information	Official Technical assistance[a]	28.95	52.17	14.28
	Consults climate information [c](% of cases)	81.6	91.3	71.4
Diversity	Number of crops[a]	2.21	2.61	3.29
	% of hectares dedicated to cash crops[a]	99.7	99.0	58.2

c) Río Cuarto

Capacity Attribute	Variable	Cash crop small	Cash crop large	Mixed small	Mixed large
Social/Human Resources	Potential experience (yrs.)[a]	28.9	26.2	33.1	32.6
	Education (yrs.)[a]	12.7	14.2	10.9	12.4
Material Resources	Landholding size (has.)[a]	420	2,155	356	1,883
	Machinery Index [a]	1.9	2.3	2.2	2.3
	Gross Margin (Arg $) (Income)[a]	165,570	426,862	38,961	309,550
Management Capacity	Rented land (as % of worked area)[b]	13.1	77.0	27.3	30.0
Financial Resources	Other sources of income [d] (% of cases)	40.0	16.7	25.0	25.0
	Hail Insurance (% of cases)	90.0	83.3	50.0	50.0
Information	Official Technical assistance[a]	30	16.7	21.4	0
	Consults climate information [c](% of cases)	90.0	83.3	92.9	100.0
Diversity	Number of crops[a]	2.2	2.67	2.36	2.83
	% of hectares dedicated to cash crops[a]	94.6	99.5	62.6	67.1

d) Laboulaye

Capacity Attribute	Variable	Cash-crop	Mixed large	Mixed small	Livestock
Social/Human Resources	Potential experience (yrs.)[a]	32	37	40	47
	Education (yrs.)[a]	11.7	12.25	8.9	7.3
Material Resources	Landholding size (has.)[a]	506	2,030	435	426
	Machinery Index[a]	1.3	2.3	1.3	0.6
	Gross Margin(Arg $)(Income)[a]	207,000	807,000	66,000	-
Management Capacity	Rented land (as % of worked area)[b]	66.6	38.9	29.1	32.6
Financial Resources	Other sources of income[d] (% of cases)	17	12	25	54
	Hail Insurance (% of cases)	33	70	40	7
Information	Official Technical assistance	0	25	40	30
	Consults climate Information[c](% of cases)	83	50	100	84
Diversity	Number of crops[a]	1.83	3	2.05	0.15
	(% of hectares dedicated to cash crops)[a]	100	61.7	36.7	0

Survey Data, 2003.

[a] Survey group´s average

[b] Weighted survey group´s average

[c] Reception of any kind of climate information

[d] Other sources of income refers only to the same or greater amount of money from other activities but agriculture.

Table 4.8: Selected Adaptive Capacity Indicators and variables, by group in each locality

An adaptive capacity index was then created from those weighted indicators, through a process that involved a summation of the average values of the weighted indicators for each farm group (see this chapter, 4.3.1.3.) (table 4.9).

In general, adaptive capacity indices were higher for those larger landholding sizes, as weighted by the proper farmers, since economies of scale in commercial agriculture production allows for the availability of financial resources as to cope with different type of stresses. The availability of own machinery is also higher for these farmers who can afford for them giving them more flexibility for changing planting, fertilizing or harvesting dates depending on weather conditions. Higher adaptive capacity of farmers are not related to specific production systems, whether cash crop or mixed, cash crop/livestock, however for the latest, more than 50% of land devoted to cash crop seems to be determining the indices values. During the last decades, relative prices cash crop/livestock made one of the main production activities in the region (cattle rising) uneconomic. These farm groupings with higher adaptive capacity indices are the few in number of groups (35%) and farmers involved (20%) in terms of the whole surveyed population, and can represent 50% of farmers in the AEZ9; but not more than 20% and 10% of farmers in AEZ10 and AEZ11, respectively. For Oncativo area, there are no farming groups with high adaptive capacity indices, and the type of surveyed farmers represent more than 55% of farmers in the AEZ7.

As a whole, the sixteen analysed groups do not show other specific particularities driving the value of their adaptive capacity indices, despite the fact of being heterogeneous.

4.4.1.5 Vulnerability

Neither sensitivity nor adaptive capacity alone determines vulnerability, but rather it is the combination of the farm's sensitivity to climate and its capacity to manage its impact that determines its vulnerability. For this study, the overall vulnerability of each farm group was assessed qualitatively, by comparing the aggregate scores for the sensitivity and adaptive capacity indices (table 4.9 and figure 4.5) (see, 4.3.1.3, this chapter) and by comparing the farm groups according to the variables considered most important in determining capacity together with overall sensitivity.

Locality	Group	ID Sys.	Sensitivity	Adaptive capacity
Marcos Juárez	Crop small	CSMJ	1.68	8.84
	Crop large	CLMJ	0.61	14.97
	Mixed small	MSMJ	1.38	7.19
	Mixed large	MLMJ	0.68	9.86
	Livestock	LMJ	0.75	3.77
Oncativo	Crop small	CSO	3.06	7.10
	Crop large	CLO	3.30	8.50
	Mixed	MO	3.00	6.95
Laboulaye	Crop	CL	1.27	6.22
	Mixed small	MSL	5.21	7.11
	Mixed large	MLL	5.67	12.43
	Livestock	LL	1.89	6.30
Río Cuarto	Crop small	CSRC	1.08	8.57
	Crop large	CLRC	3.05	10.53
	Mixed small	MSRC	3.49	6.86
	Mixed large	MLRC	2.26	10.35

Table 4.9: Sensitivity and Adaptive Capacity Indices

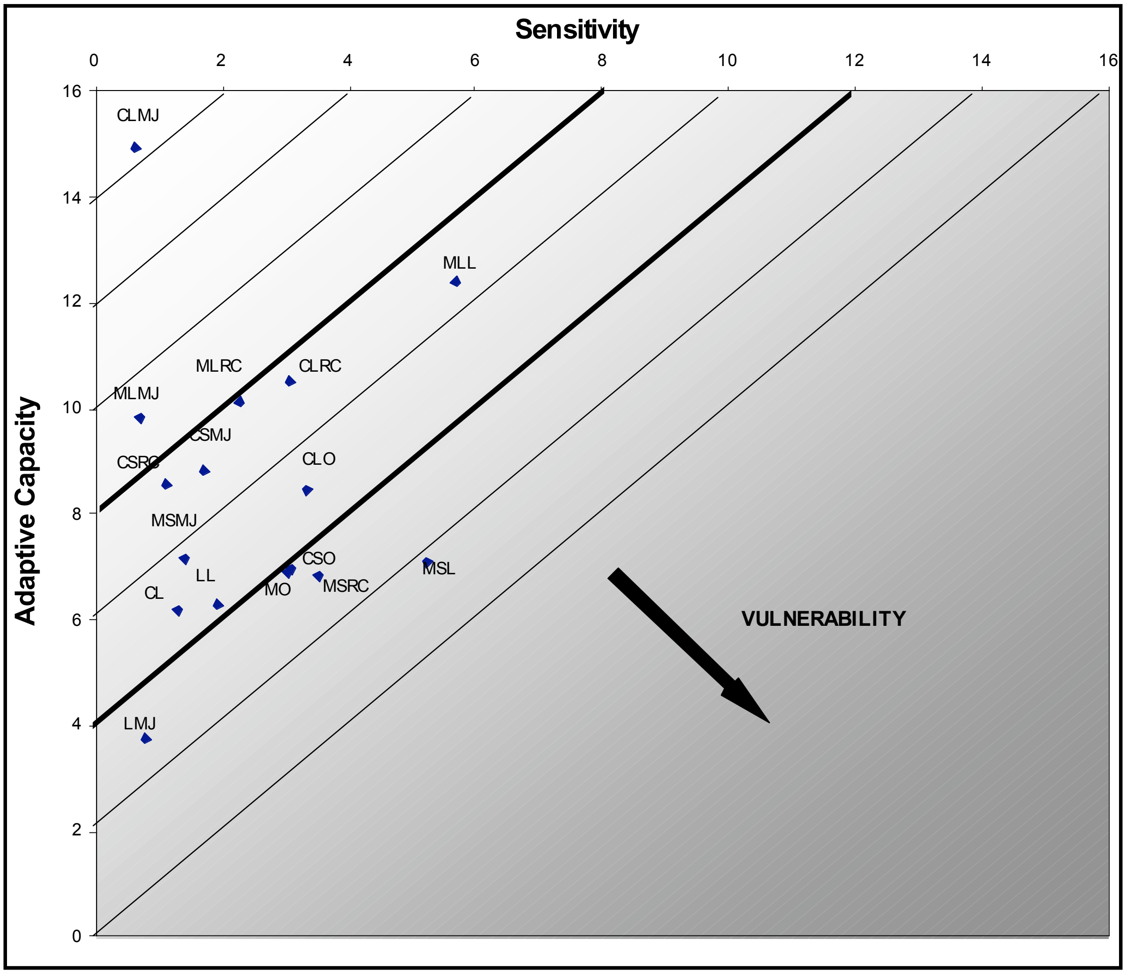


Fig. 4.5: South of Córdoba studied groups positioning in terms of vulnerability levels

From the mapping of the sixteen farm groups, three levels of vulnerability (high, moderate, low) were defined for explanation purposes. For determining vulnerability levels dispersion criteria from the average values of both indices were used, and constant indifference curves were supposed, however, what the figure is showing is consistent with the qualitative analysis.

Thus, within the *low vulnerability class*, only two farmers' groupings can be distinguished, representing only 13% of the surveyed farmers. Both groups are in Marcos Juárez area where climatic risks are lower, belonging to the humid pampas, less exposed to hail storms and few flooding problems, these are the groups with the lowest sensitivity indices. They are also large landholdings, with good quality soils, which contract hail insurance in most of cases, and they are among those with the highest adaptive capacity indices (figure 4.6).

The *high vulnerability class* is represented by five of the sixteen defined groups and represents 43% of surveyed farmers. Distributed in different AEZ, they are exposed to floods (those in Marcos Juárez and Laboulaye areas), hold the highest sensitivity to hail storms (Río Cuarto and Oncativo areas), or highly exposed to drought (Oncativo area). These are in general small landholdings with soil problems due to salinisation for flooding or degradation as a consequence of mono cropping (specially peanuts during the last two decades), and because of that they do not have the possibility of ceding their land for renting. Some of them only rely on cattle rising activities. Even some of them could manage to increase their worked area through renting, this practice put them into a more risky position when facing climate adversities since they are engaged with the payment. In general their livelihood depends on other sources of income, which are higher than that of agriculture.

The *moderate vulnerability class*, representing half of the surveyed population, shows different combinations of agricultural systems, sensitivity (due to different climatic exposure) and, adaptive capacity (landholding size, soil quality, management of the farm) that reflect climate variability incidence on farmers' livelihoods in the studied region. Even vulnerability levels (as measured in this study) do not represent absolute positioning in terms of climate vulnerability, this type of assessment allows for the identification and prioritization of required adaptation measures to directly or indirectly lessen climate impacts or to enhance farmers' adaptive capacity to cope with climate through managing more structural constraints. However, before doing this, more individual perceptions on climate risks and on adaptation alternatives should also be assessed.

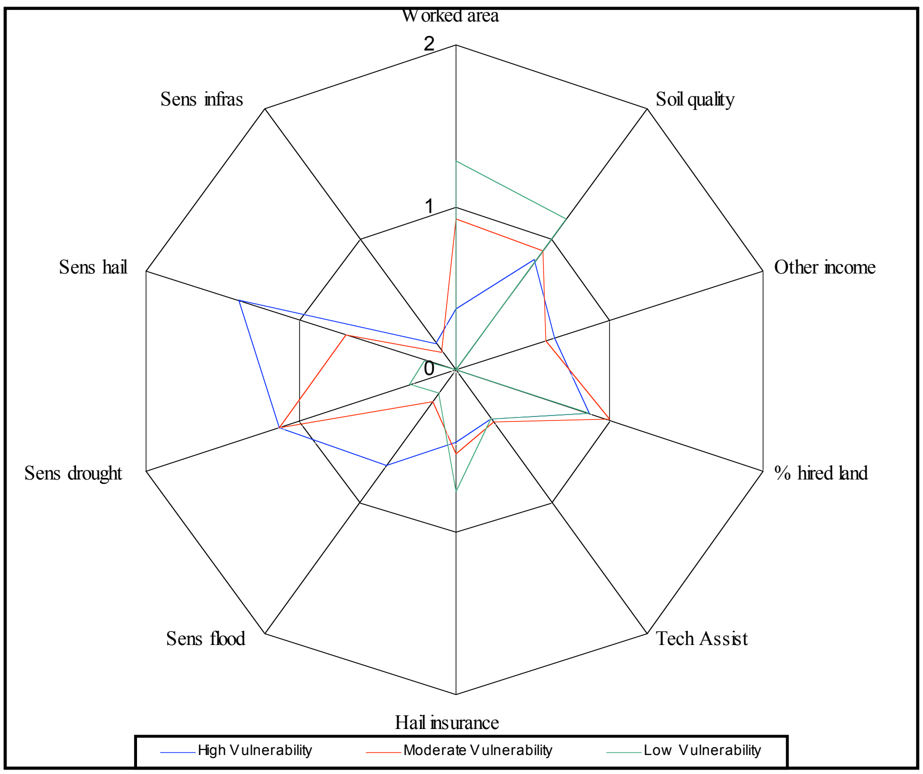


Fig. 4.6: Vulnerability classes

4.4.1.6 Farmers' adjustments

The structure of the agricultural sector in the SC is highly heterogeneous and their vulnerability to climate differs according to exposure, the nature of their production activities, their soil conditions and use, their material assets, landholding size and income, as well as according to the specific climate adaptations they are able or have the will to incorporate. Moreover, their response to risk entails not only particularities in their objective characteristics but also their perception of risk and their acceptation of that risk (Maurutto, 2004). Their perceptions in turn incorporate subjective considerations such as their personal history and culture, knowledge and experience.

During in-depth interviews, in addition to various agronomic adjustments, farmers mentioned climate risk insurance and irrigation as the main preventive measures against hail storms and droughts. They also use a highly controversial mechanism under the Agricultural Emergency Law (Law 22.913, 1983) to publicly declare their losses. As a collective form to strengthen adaptive capacity in general and to reduce impacts from adverse climate events in particular, some farmers also mentioned the importance of participating in different types of producers associations.

From survey information, most common agronomic adaptations incorporated in response to climate were adjusting planting dates (36 % of total surveyed farmers); spatially distributing risk through geographically separated plots (52 %); changing crops (12%); accumulating commodities as an economic reserve (85 %); maintaining a livestock herd (70 %) since "*cows are not being killed by ice stones, they are a kind of insurance, when a hail storm comes I have cows*". These strategies were not always mentioned as responses to climate conditions, but rather general changes in production strategies for economic reasons.

Commercial hail insurance is one of the more specific strategies adopted by farmers in relation to one of the main climate concerns in the region, hail storms. However, the use of insurance is not uniform. In the survey, only 65% of farmers reported having contracted insurance, and, of these, 53% contracted insurance annually. Another type of insurance, "climate risk insurance" is still not much used in the region. Farmers commented that "*it is very expensive*" and "*not well implemented*" even when there was a "pilot plan for subsidizing" it at the Provincial level (Secretaría de Agricultura y Ganadería de Córdoba, 2003).

The frequency in contracting insurance depends on each farmer and his experience; some of them contract insurance "*every year, unless because of drought the crop prospects are poor and it is not convenient*". For others they "*seldom contract insurance because insurance is just a business, they [the insurance companies] are anxious to be paid but after the damage they take a long time to pay and this leaves no time to re plant*". For this reason, a few years ago the collective action of a group of farmers resulted in the "Seguro Solidario." The participating farmers commit to contributing a certain amount of money to a collective fund in order to cope with climatic events. This local insurance mechanism was not widespread over the studied area, and the extent to which all participants can benefit from it depends largely on the degree of impacts. However, it is now being promoted at the provincial level and as a pilot experience.

The other climate event negatively affecting agriculture production in the region is drought. Irrigation is an obvious technical support for drought risk mitigation, but the benefit of an irrigation system is diminished by its cost, making irrigation a less viable alternative for smaller farmers. As farmers reported, "*we have analyzed the possibility of incorporating irrigation but its cost is enormous*" and "*against drought, irrigation [is an option], but it is very expensive, a costly alternative*". Only 1% of farmers in the region count on irrigation systems.

The Agriculture Emergency Law is a governmental support available at the sector level with the objective of diminishing impacts from climatic, telluric, biological or physical and unforeseeable or inevitable in character events. It allows farmers to access benefits like delaying fiscal obligations, acquiring tax extensions or exemptions, accessing credit, and special considerations regarding transportation, among other benefits. However, farmers have generally viewed this mechanism negatively: " *If you can cope by yourself it will be better. After a while everything comes together and at the end you still have to pay and it was just another great amount of papers*" or "*It is very difficult for a farmer if he is not within a cooperative or an association.*"

In contrast, participating in farmers' organizations or associations with other farmers is considered to be highly positive, necessary, useful and powerful. "*Every organization procures common interests; the more the people involved the more powerful*". However interviews revealed that the advantages and benefits of organization depend on the personal experience and the attitude of its members. Other interviewees suggested that participation in agricultural organizations is often simply a temporary response to periods of difficulty: "*People do not trust [organizations] anymore and because of the economic situation has improved since the devaluation of the peso, they believe institutions are not necessary anymore.*"

The perspectives of farmers articulated through the interviews concurred with the results of the more objective dimension assessed through the survey: only 50% of farmers participate in organizations, the rest allude to them as being not useful (13%); to have had bad experiences (12%); lack of interest (27%); or organizations lack of capacity (39%).

Aside from formal mechanisms such as insurance to reduce climate risk, adaptation is also facilitated through the use of climate information whether from the media, farmers' empirical observations of natural indicators used as forms of climate forecasts, or their personal experiences with climate as transmitted through their family or collective histories. For example, ancient practices like the "cabañuelas" ("*the 12 days calendar, which consists in the observation of the first twelve days of the year, and climate in each of them would correspond with the characteristics that the twelve month of the year will take*") were inherited from the Mediterranean world (Katz, 1997). But, for some farmers, these practices do not invalidate scientific information, and they thus use both.

However, despite the apparent importance of climate in farmers strategies, when asked directly about their decision-making process, farmers declared that their main production decisions were based on market signals, soil condition and the availability of working capital. Thus, although farmers reported being familiar with a variety of sources of climate information and reported consulting this information daily, the role of this information in the decision making process was minimal: "*I watch TV, listen to the radio, and that's all,*" or "*after receiving the information, I base my decisions in terms of the amount of land and working capital I have available*". Moreover, the farmers appeared to have no confidence in technical or scientific forecasts, based on their experience with this information: "*We manage climate information, it is interesting, but you cannot base your decisions on them, their likelihood is of the 50%: 50% rains 50% does not*".

Prices, crop rotation, habits are main factors for planning, climate considerations are constraint to short term decisions like planting or harvesting dates, which is paradoxical as climate is considered the most important factor of agriculture production "agriculture production depends on climate, 90% is climate"*. But for farmers, climate is the variable that cannot be controlled. Casualty, fatality, fortune or luck are recurrently mentioned to explain discontinuous and unforeseeable climate phenomena* "it is a matter of luck, I had six good years, but this year I suffered hail storms twice, good luck cannot be that long".

Specifically, climate change is perceived as a normal and well-known phenomenon, but it is closer to the theoretical concept of variability than scientifically understood climate change "*the climate is always changing, they are cycles*". Inquiring about the causes of these changes, farmers refer to soil degradation, impacts from increasing use of agrochemicals, the increasing mono-cropping of soybeans more than climate change "*we are putting many things to the soil it has to go out from somewhere*". Some farmers have accessed dispersed information on climate change and have combined this information with alarmist opinions from the media, although many believe the impacts will not occur locally: "*I heard some areas are going to disappear under the water*"; "*….in some countries will happen, there in the US….*"

As a result of recent changes in macroeconomic and sector policy, farmers were increasingly aware that any action necessary to resolve local problems such as repeated climate impacts would require local action rather than interventions from the national government. Expressions like "*the hand of the State is present, but against us*"; "*there is no agriculture policy*"; "*the Provincial government still has some compassion for us, but the National government is killing us*" show the feeling of lack of support or protection from the national government, and fundamentally, concern over the burden of export taxes. More recently the farmers' dissatisfaction with the lack of government interventions has been ameliorated by the devaluation of the peso and the high prices of soybeans. Nevertheless, should conditions change, the climate threat would rise in importance: "*We are being favored by a high exchange rate and high prices of soybeans, but we also have very high export taxes, which is a not very noticeable situation because of good harvests, but this year because of hail storms and droughts the real situation will begin to be felt.*" However, both factors, state interventions and climate, are considered unpredictable by farmers; "*if government does what it likes, the climate will be even more fickle*" "*it is easiest to know what is going to happen with climate, than to know what is the State going to do for us*" (Mauruto et al, 2003).

4.4.1.7 Enhancing adaptive capacities

Although most farmers argue that their problems can be solved through increasing credit availability and diminishing export taxes, it is clear that under the current policy environment these types of measures will not find support, at least at national level.

According to the indicators of climate sensitivity created for the region the climate event with the most negative impact in the studied region is drought, followed by hail storms and floods. Evidence and projection on climate change for the region is towards increasing temperature and rainfall, however climate variability would also increase thus maintaining the need for alternatives to cope with droughts, specifically for less endowed farmers.

The same projections on climate averages make necessary to focus on floods, an impact that affects not only individual farmers (flooding, soil saltiness, plant diseases, road destruction) but also whole communities and towns that become directly or indirectly affected, economically and in terms of social conflicts (rural-rural; rural-urban). The following are the main specific adaptation alternatives for the region derived from sensitivity and adaptive capacity analysis.

Supplementary irrigation technologies imply an important fixed capital investment that can affect financial capacity of the firm therefore affecting the availability of working capital. Support for this option thus will require public interventions (tax incentives or interest rates subsidy) to overcome lack of private banking credit. Moreover, despite the existing knowledge regarding supplementary irrigation within National Institute of Agricultural Technology (INTA), farmers still lack experience with irrigation and will need further training the same as for analysis on the potential capacity of regional surface and groundwater as sources of irrigation supplies.

The proportion of farmers contracting hail insurance in the region is quite important, demonstrating that it is already a common coping strategy in the region. The government could further facilitate insurance use by supervising the completion of contract obligations as well as by providing information and subsidizing insurance for small and medium-size farmers. The lack of guaranty and high insurance premiums are the principle problems for smallholder farmers. To date, the primary interventions of the government in insurance have been restricted to limited subsidies of insurance premiums and the declaration of an Agriculture Emergency when an event affects an important geographical area.

Although farmers' concerns over flood risk are concentrated geographically, the farmers affected by flood illustrated the highest indices of sensitivity in the whole studied region. Interventions to support flood risk management in this region could entail infrastructure works, such as additional drainage or containment structures, the diversion of excess water, and road construction as well as improved re-zoning of crops and improvements in land use practices. The magnitude of the required investments necessarily entails support from either the national or provincial government such that local policy can concentrate on smaller works or maintenance, efforts that also have an important impact on the cost of flooding for farmers.

Farmers agree that the fact that the technology available is mainly accessible through commercial channels explains in part the wide gap in productivity levels and thus the potential for climate adaptation among producers in the region. Public sector support for technology and research and development is thus one way to increase the likelihood of adaptation for those farmers who have difficulty accessing commercial technology. Public intervention in research and development, however, is limited by the high cost of investment, the need for institutional coordination and the lack of participation of farmers in producer associations to help articulate their technology demand.

Support for improved access and use of climate, market and technological information is crucial for the sector to respond rapidly to economic and environmental change. To achieve this goal, it is of utmost importance to build a network to systemize the available information and thus enable it to reach producers. Conflict and lack of coordination between the relevant sources of information and agencies responsible for dissemination is a primary obstacle. However, it is the less endowed farmers (often the most vulnerable to climate impacts) who benefit most from any increase in the availability of free information.

4.4.1.8 Conclusions

Evidence of climate change in the region, increasing temperatures and precipitation, have positively operated on crop production (as described in chapter 2), contributing to expand more profitable crops within the current market situation. However, new lands were put into production in higher physical risk areas (drought, floods, higher climate variability) and livestock production is being abandoned. Thus, pushing specialized agriculture to areas with greater physical restrictions, resulting in higher production risks, more prone to natural resources degradation, and higher sensitivity to climate variability. All of which makes expectations on current levels of vulnerability in the region to increase, further affecting less endowed farmers livelihoods, who may leave agriculture production at the time exacerbating land concentration processes in the region, unless conscious efforts towards reducing impacts from climate variability and change are motorized from the proper region.

4.4.2 Coatepec Veracruz, coffee sector

4.4.2.1 Description of the case study

Central Veracruz — a region incorporating some twelve different *municipios*, including the busy commercial city of Xalapa—has traditionally led the state's coffee production, contributing approximately 25% of total production. In the 1970s and 1980s, coffee was one of the primary drivers of both the local economy. Coffee farms in this region are quite small, averaging approximately 2 hectares.

The two communities selected for the case study were Vaquería and Ursulo Galván, both *ejidos.* Vaquería is a small community of approximately 80 households located at approximately 800 m above sea level, at the lower margin of the altitude most apt for coffee production. Ursulo Galván is a community of approximately 300 households located at 1200m above sea level, an altitude considered ideal for highland production. According to the National Population Census of 2000, farmers in both communities had similar levels of education (approximately 20% of adults had secondary school education) and income (over 70% of the population received less than two minimum salaries). Both communities had been producing coffee for several generations, although at different intensities. With an average of two hectares of land, the farmers in both communities were similar in scale as most coffee farmers in the state. According to the survey, the vast majority (over 95%) sold the unprocessed coffee berry through intermediaries, and thus was facing the full impact of the low coffee prices.

4.4.2.2 Survey analysis

The survey illustrated that farmers perceive the current problem with coffee prices to be far more problematic than climate in their livelihoods and production decisions (figure 4.7). The impact of the collapse in coffee prices was uniformly severe across the sample, resulting in important drops in income and contraction in household expenditures on basic goods (clothing, food, school supplies, and medicine). The lack of profitability in coffee was also leading to a reduction in investment in coffee, reduction in input use and labor dedicated to the crop. Nearly two thirds of the sample (63%) reported labor shortages, reflecting the growing rates of emigration not only within the communities but also in the broader region of Central Veracruz (this trend confirmed qualitatively through interviews with agricultural officials and experts in migration). The average age of the farmers interviewed also was relatively high – 52 years – within the sample of the 60 households. This suggests that the motivation of these farmers to improve the resource base on which they depend and to boost their coffee production will depend in part in their perspective of the future viability of coffee and agriculture in the region as a whole (this issue was addressed in the focus groups, see section below).

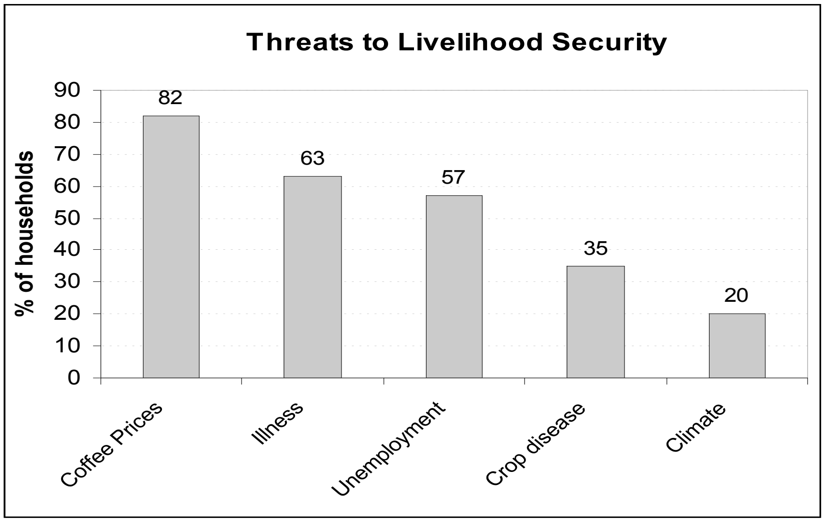


Fig. 4.7: Treats to livelihood security.

These results do not necessarily mean that climate does not have an important impact on coffee yields in the two communities, or that climate events have not affected production in the past, but rather from the farmers' perspective, climate impacts and climate change are secondary concerns compared to other more immediate stressors. Indeed, the types of climate events that farmers reported affecting their production coincided with what would be expected from the climate patterns and general trends in the region (see chapter 2) (figure 4.8). Half of the farmers surveyed had observed climate changes manifested in rising temperatures and an increased frequency of drought. Lack of rain and low prices together were also the more frequent explanations for the losses farmers reported experiencing in 2002 **(**table 4.10**)**.

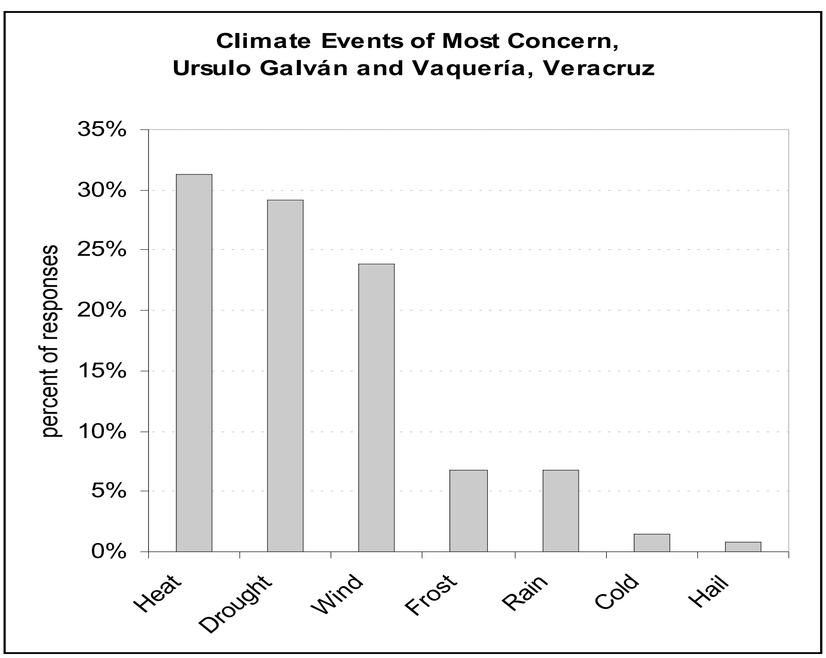


Fig. 4.8: Climate events of most concern. Source: Household Survey

[illegible]	[illegible]	2	[illegible]	6	6
	[illegible]	[illegible]			
	h	1	9	[illegible]	
	[illegible]	4	8	[illegible]	
	[illegible]	[illegible]			
	l	[illegible]			
	[illegible]	3	[illegible]	5	
	[illegible]	5			
[illegible]		[illegible]			
[illegible]		[illegible]			

Source: Household Survey.

Table 4.10: Reasons for loss of coffee harvest in 2002. Note: Farmers reported more than one cause of loss, thus total frequency measures total responses, not households.

Just under half (47%) of the farmers surveyed recalled particular climatic events in the distant and recent past that had negatively affected their coffee yields. Among the most frequently remembered events were a seven-month drought in 1988, the severe frost of 1989; heavy winds (nortes) and drought in 1997; hail, drought and disease outbreaks in 1998; drought, disease and cold weather in 2000; frost and heavy rains in 2001; and drought in 2002. The fact that farmers tended to recall more events in the recent past is alone not a reliable indicator of the incidence or frequency of climatic events, given the fallibility of distant memory. The farmers' recall of recent drought events (in the period 1997 to 2002), the frost of 1989 and the impact of pest outbreaks all coincide with both the observed trends in the climatic records, the newspaper reports and the information collected in interviews with regional experts.

4.4.2.3 Focus Groups/ Participatory Appraisal

An expert in participatory rural appraisal from the Xalapa office of INIFAP helped coordinate and design the workshop activities. These activities involved 1) a mapping exercise in which the community mapped the location of different areas of production and described differences in climate impacts and production in the different locations (figure 4.9); 2) the development of an agricultural calendar in which production activities were plotted as well as periods where the probability of climate events were most likely (figure 4.10); 3) timelines demonstrating changes in land use, coffee prices, and public policy ; 4) a chronology of climate events and their impacts on the community and the community's response and 5) a discussion over the future impacts of climate on the community.

The process of elaborating the agricultural calendars revealed that the farmers have, in many cases, ceased undertaking many activities because of labor shortages, lack of finance or lack of motivation because of the poor coffee prices. For example, few farmers are replacing the older coffee trees in their plantations. The farmers commented that during the period of IMECAFE's interventions, there was a lot of pressure to maintain their own tree nurseries but for the last few years they have dropped that activity. The calendar also illustrated distinct phases of production corresponding to climatic conditions. For example, seed germination and planting are associated with the onset of the summer rains. The farmers also commented that in previous years they would plant new coffee trees in June, but more recently that have postponed planting until September, apparently because of changes in the timing and distribution of rainfall in the region. Disease impacts are most felt in the period of the mid-summer drought, or the *canicula*, while dry periods have the greatest impact on coffee in the month of April and May.

The farmers in both communities did not remember many climate events that had affected their plantations in the past. In Vaquería, the farmers were more conscious of impacts on their maize crops than on their coffee plantations. They remembered a hail storm in 1972, a prolonged drought in 1988, an infestation of a maize pest in 1998, and the proliferation of *la broca* in their coffee orchards in 2000. In none of these events did they receive support from the public agencies for their losses, with the exception of the infestation of the *la broca* in which they participated in a public sector campaign to eradicate the pest. They reported that the campaign was ineffective. The farmers remembered that during the period that IMECAFE was most active, their yields were generally quite high and they suffered few impacts. In Ursulo Galván, the farmers remembered only 5 events (one frost in 1977/78, a hail storm in 1972, one *norte* in the winter of 1982-83 and two droughts during 1994 and 1996) that had affected their harvests since 1960s and, of these, only three had severely affected their harvests. To cope with the losses experienced in the 1970s and 1980s, the women set out to sell a variety of other agricultural products they harvested locally (oranges, maize, lemon, bananas etc) and the men worked as day laborers. The farmers of Ursula Galván explained that they no longer have the diversity of production to cope with climate impacts in the same manner.

The discussion over historical tendencies in production, prices and land use revealed the strong historical influence of IMECAFE. In Ursula Galván, the farmers had, over the course of the 1980s, ceased to plant sugar cane, maize, beans, citrus crops and bananas and dedicated their land to a coffee monoculture with introduced shade species. The explained that currently banana trees are the only remaining alternative crops from that period and that today coffee is what occupies 100% of their planted area, although 50% of their plantations are currently abandoned because of the poor prices. In Vaquería, as in Ursula Galván, the 1980s was a decade of coffee expansion. In the 1940s, the community was dedicated to the production of sugar cane and it was in the 1980s that they became primarily coffee farmers. However the farmers of Vaquería never completely abandoned their maize crops nor their sugar plantations. With the help of INMECAFE, the area under coffee expanded to occupy 50% of their fields. Recently, in the last half of the 1990s, they have converted some of their coffee fields to sugar cane. If prices continue to decline in coffee, the farmers indicated that they will plant more sugar cane given the present high demand for sugar cane in local markets. However the farmers also reported that they would never completely abandon coffee because "it is good to have a bit of everything."

In both communities, farmers recalled significant variability in coffee prices and consistently reported that the prices have been particularly bad since 1997-1998. They also recalled that prices were quite good in the mid-1990s because of a frost in Brazil, after having collapsed in the late 1980s. They were not optimistic about adjusting to the changes in prices. Some considered that the prices would rise once again, others commented that there was little support available for alternative crops appropriate to the climate conditions of their communities, and that some of the alternatives that been tried (macadamia, lemon, tomato) had failed because of lack of market opportunities and commercialization problems. Migration and economic diversification were more common coping strategies.

In both communities, the farmers in general perceived the future as "very sad." They collectively expressed a lack of empowerment over their future economic and agricultural development. They were not so much concerned with climate change but rather deforestation, erosion and the consequences of these processes for their production conditions. They expected increased heat waves and a reduction in water availability from the changes in climate conditions resulting from deforestation. They also felt that without government assistance their capacity to manage changes in the coffee market and environment was limited. They noted that the emigration of youth from the villages and the lack of interest in the youth in agriculture did not bode well for the future production of coffee in the region, particularly given the high demand of labor in coffee harvesting. This was particularly a problem in Vaquería where the farmers reported that approximately 50 individuals of the community were now in the United States, and that the rate of emigration had increased considerably since 1997. Despite this pessimistic outlook, they did not suggest that they were prepared to abandon their coffee plantations completely, but rather would hold out and hope for improved prices and public supports in the future.

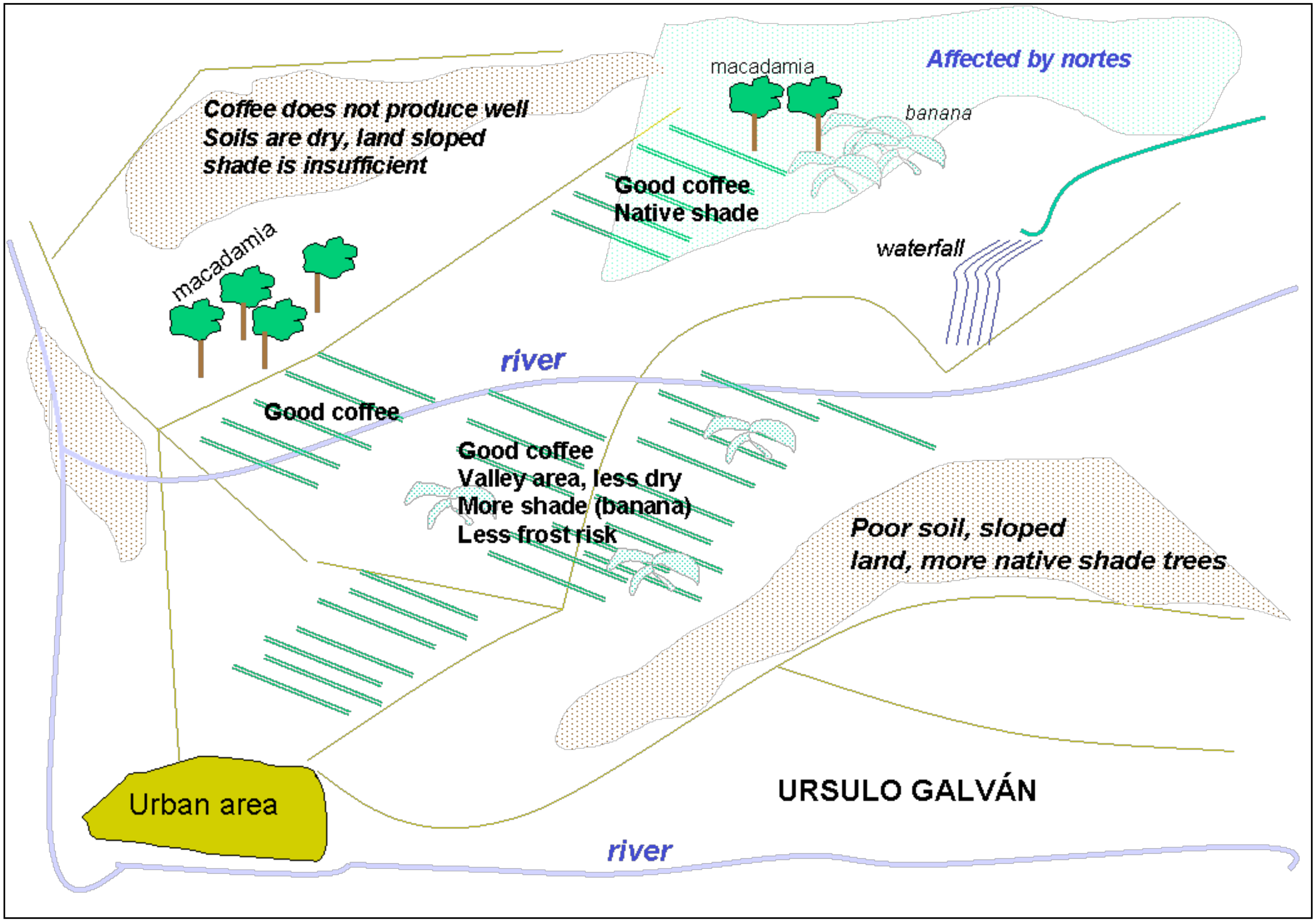


Fig. 4.9: Map drawn by farmers of Ursulo Galván.

ACTIVIDADES	E	F	M	A	M	J	J	A	S	O	N	D
Semillero												
Preparación de la tierra (limpia, abono)			X									
Riego de semilla para germinación			X									
Tapa de hoja de plátano (calentamiento para germinación)			X									
Germinación (soldadito)					X							
Pesetilla (dos hojitas)					x	X	X					
Naranjillo						X	X					
Preparación de tierra para llenar los bolsas								X				
Actividades para preparación de vivero (posteo, alambre, techo de hoja de plátano)						X	X	X				
Se arranca nara njillo y se pasa a la bolsa. Selecciona la planta. Se fertiliza (2 -3 veces al año)								X	X			
Vivero: Un año en bolsa								X YR1				
Labores de la finca									X 2			
Acarreo de la planta, hoyar					x	x	X	X				
Sembrada (<3 meses) *si hay lluvias buenos						x*		X	X			
Fertilizada (+1 mes de siembra)						x	x		X	X		
Limpias (2 x por año)			X	X					X	X		
Cosecha (4 cortes max., 2 buenos, 2 regulares)	X	X	x								X	
Clima												
Lluvias					ll	LL	Ll	ll	LL			
Canícula							C	C				
Lluvias intensas (una vez al mes, y 1st viernes de marzo)			LI	li	li							
Nortes	n	n										
Granizadas			g	g	g							
Heladas												
Secas				s	s		T	T				
Floración		f	F	f								
Siniestros												
Nortes y vientos (un vez cada 10 años)	N											
Granizada			G	G								
Lluvia (no afecta mucho)					LL	LL						

Fig. 4.10: Agricultural calendar, Ursulo Galván.

4.4.2.4 Sensitivity and adaptive capacity

The two-step cluster analysis on the sample of 60 households identified two livelihood groups (the cluster analysis included those variables relating to production, material assets, income sources and human resources, but variables measuring impacts and adaptations and coping strategies were excluded). The majority of households (90%) in Ursulo Galván were classified in Group 2, while the households of Vaquería were classified almost equally in Group 1 and Group 2 (46.7% and 53.3% respectively). Group 1 had 17 households, while Group 2 had 43. Given that the variables included in the cluster analysis were also those used to create indicators of adaptive capacity, it is not surprising that the two groups were distinguished by significant differences in capacity. Group 1 was associated with more land, more education, more animals, and greater participation in agricultural and compensation support programs, more participation in organizations, and more access to finance. Interestingly, this group was also associated with greater participation in the government welfare program "Oportunidades," a federally funded program of income support which is supposedly targeted to the most disadvantaged households in rural areas.

Non-parametric tests (Chi-square, ANOVA) revealed that the values of the indicators that measured impact – either of climate events (e.g., number of climate events remembered, number of climate events of concern to household, % of household who suffered climate losses in 2002), or of prices and markets (cuts in household expenditure, perception of risk to multiple stresses, change in income, change in harvest or crop sales, plan to migrate in future) – were similar in the two groups. In part, this suggests certain homogeneity in exposure to both market and climate impacts, and in part, the general homogeneity in the production systems of the two communities.

The indicators of adaptive capacity and sensitivity were transformed into a uniform scale representing the percent of households in each group associated with each indicator. These diagrams clearly illustrate the similar nature of impacts across the sample but the distinct capacities in the two groups (figures 4.11 and figure 4.12). In the case of impacts, the most significant difference between the two groups is in the greater degree to which the recent changes in the coffee market have reduced the investment of Group 2 in their coffee plantations, which may have to do with the degree to which the households depend on coffee as their primary activity.

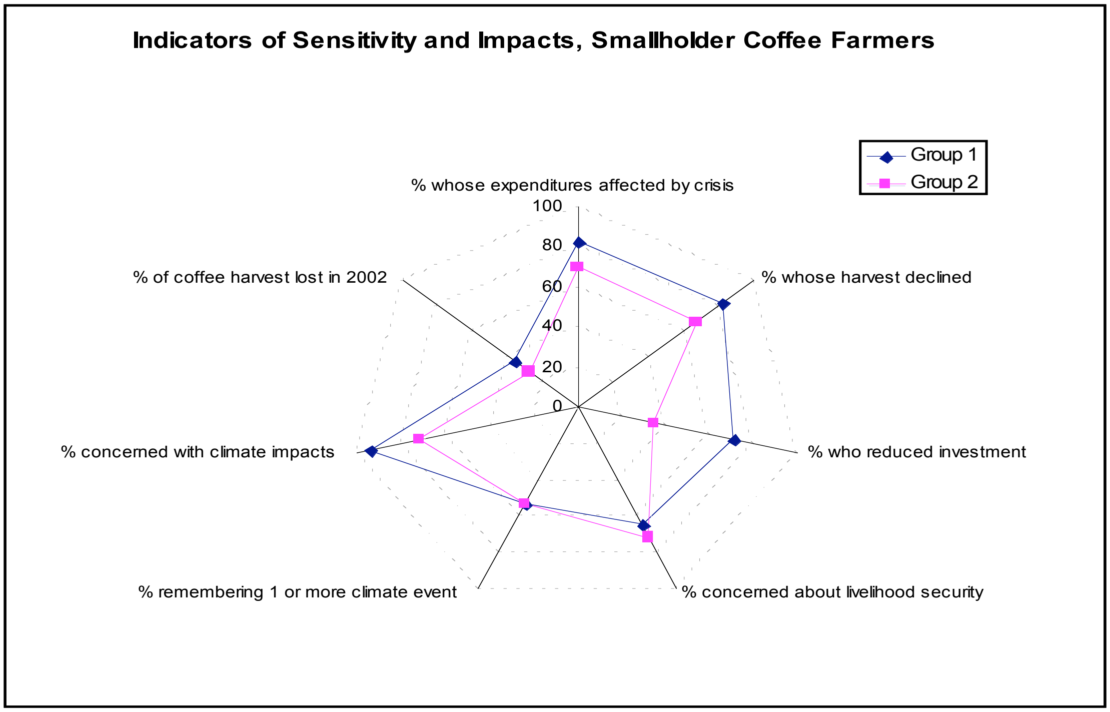


Fig. 4.11: Indicators of impacts and sensitivity of coffee farmers

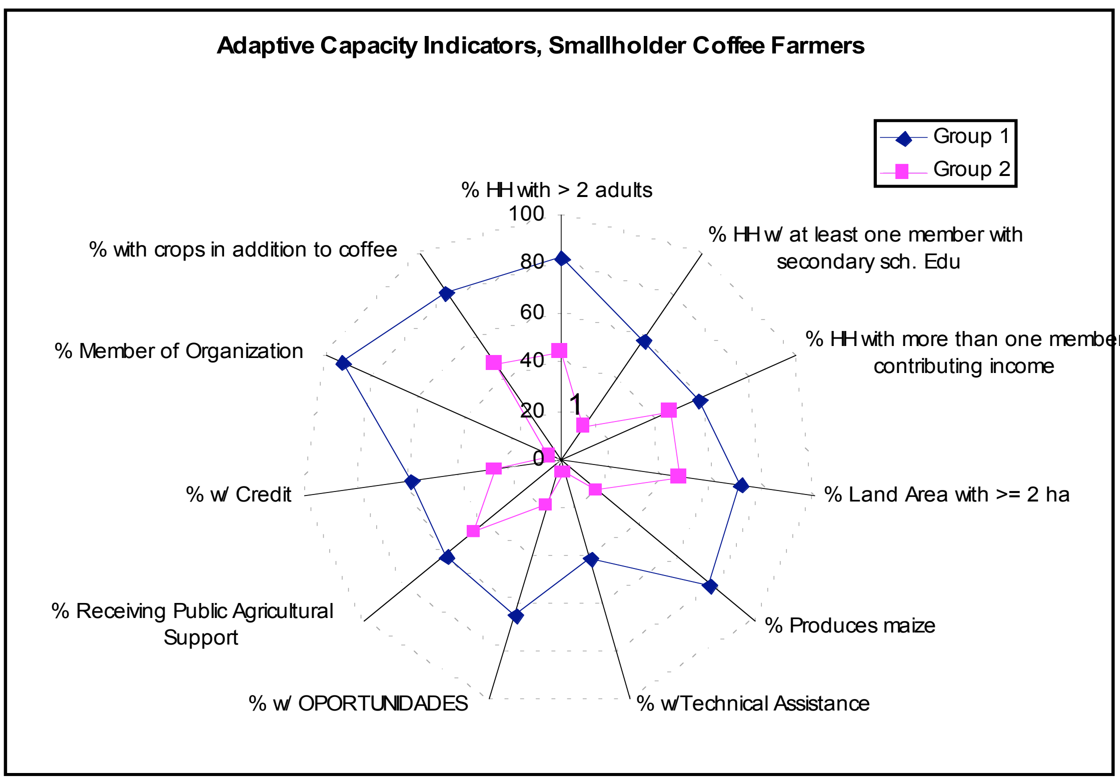


Fig. 4.12: Adaptive capacity, smallholder coffee farmers.

4.4.2.5 Validation of the adaptive capacity indicators

The indicators of adaptive capacity were correlated (via Chi.-square analysis) individually with indicators of farmers' responses to the coffee crisis in order to validate these indicators as measures of adaptive capacity. The adaptations that farmers in the samples had engaged in were related to planting alternative crops (in some cases, this meant returning to planting crops that were planted previously in the region such as sugar cane, citrus or maize); changing the mix of crops or crop variety; increase in planted area or an increase in investment.

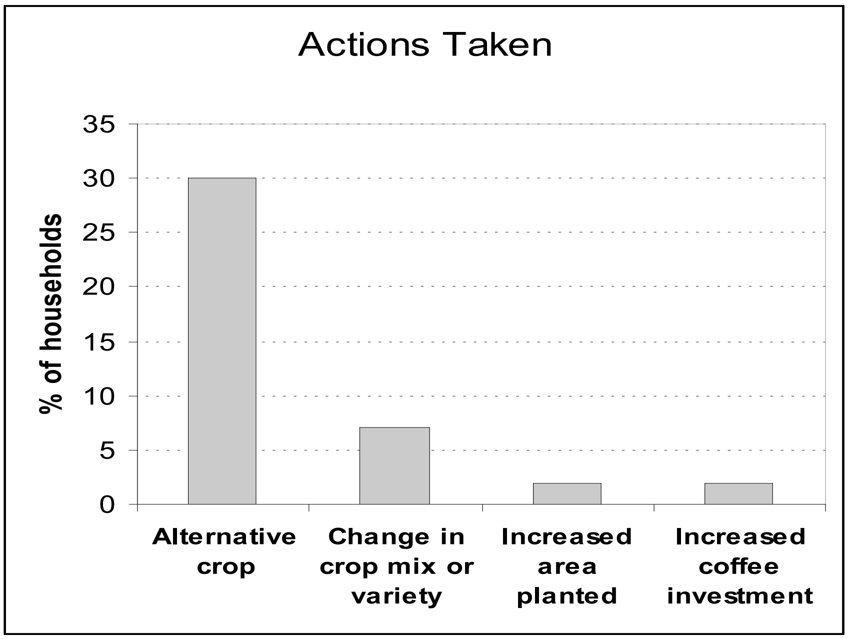


Fig. 4.13: Actions taken by farmers in response to the combined impact of climate events and the coffee crisis

Of all the adaptive capacity indicators, those with a significant relationship (*$p < .01$*) to one or more of the adaptations taken were:

- Use of technical assistance
- Member of agricultural organization
- Participation in agricultural support programs

This result confirms the findings from the participatory activities of the continued importance of government intervention in farmers' production strategies and the growing importance of farm organization for access to information on government support programs and markets. Over two thirds of the 60 households surveyed did not participate in agricultural organizations, expressing considerable distrust over the management of these organizations at the local level. However, the nature of the structural changes in the coffee market suggests that without organization at the local level, farmers will have a difficult in accessing the information and technology necessary to adapt. This lesson is important for adaptation to climate change, given that despite evidence that climatic conditions have changed in the Veracruz region, few farmers perceived significant changes in the local climate and were thus not likely to make any agronomic changes without access to information and technology through formal channels. This is important in the context of neoliberal reforms in Mexico, given that access to these types of resources has been severely constrained by the withdrawal of the public sector from service provision.

Agricultural organizations are now the primary way of access to information and services for smallholders, yet the data illustrates substantial distrust of these organizations, and the majority of surveyed households are not members of any organization.

In contrast, large-scale *pequeña propietarios* interviewed in the region were not necessarily members of agricultural associations (although many were) but were able to independently access information on markets, prices and public sector support relatively easily. These farmers tended to have anywhere between 20 and 100 hectares, and tended to have higher education levels than their smallholder counterparts. In times of high coffee prices, these farmers served as intermediaries for the smallholder sector, not only purchasing their harvests but also employing smallholder coffee households for coffee harvesting. However, in the recent period of declining prices and increased competition, many larger farmers had stopped purchasing from their smallholder neighbors in order to maintain control over the quality of their production and ensure that they could market all of their harvest. These larger farmers were not only diversifying into alternative crops to survive the downturn in the global coffee market, but also investing in organic production and/or certifying their harvests for gourmet coffee markets and vertically integrating into coffee processing and retail activities. These farmers were not only distinguished by the scale of their production but by their relative independence from the public sector.

4.4.2.6 Conclusions

The case study in Veracruz illustrated the importance of the historical involvement of INMECAFE and the crisis in the coffee market in the production decisions and livelihoods of smallholder coffee farmers, the evolution of their coping strategies and thus their vulnerability. The heavy-handed role played by the public sector in the 1970s and 1980s has made the transition to a free-market economy all the more difficult for farmers in central Veracruz. With the support of INMECAFE in the 1980s, many of these farmers had become producers of coffee mono-crops and had abandoned their traditional risk mitigation strategies of crop diversification. Today the farmers perceive the problem of poor prices and lack of government support as their primary concerns; climate variability and change are secondary issues, and many farmers (as well as experts in the region) do not believe climate is an issue of any concern for coffee. The fact that yields have declined substantially in the region as a result of a reduction of investment in coffee maintenance, increased problems with pests and poor prices also mean that the additional impact of climate on coffee yields may not be perceived by farmers. The fact that smallholder coffee farmers are an aging population – with average ages in the 50s– suggests that farmers may also lack the personal incentive to make substantial changes in their production strategies, whether in relation to climate or market risks. The focus groups revealed that the farmers in the two communities still maintain high expectations that the public sector will resolve the economic difficulties they face and provide appropriate solutions to the crisis. This implies that most smallholder farmers in these communities would also expect the public sector to take the lead in any adaptation to climate change.

4.4.3 Tamaulipas

4.4.3.1 Description of the case study region

The *municipio* of González is located in the southern extension of the north-eastern state of Tamaulipas, Mexico. In contrast to the northern *municipios* of Tamaulipas, González has few factories or assembly plants and is primarily agricultural, with 28% of land in crops, and 24% in pasture. The *municipio's* 3491 km^2 is also relatively flat (averaging 56 meters above sea level), which facilitates mechanized agriculture and contributes to the relatively uniform climatic conditions. In the year 2000 51% of the population was rural, living in localities of less than 2500 people, and 44% of the economically active population was dedicated to agriculture. It is a relatively poor *municipio*, with 47% of its economically active population earning less than two minimum salaries (INEGI 2000). Although 87% of adults are literate, over a third has not completed primary school.

As in other *municipios* in Mexico, the cultivated area in González is divided between private farmers (*pequeños propietarios)*, farming 70% of agricultural land and smaller-scale communal farmers (*ejidatarios*) who farm approximately 30% of the municipio's land. Several of the *municipio's* ejidos were incorporated into irrigation districts along the Tamesi and Guayalejo Rivers, and this has provided them with the opportunity to plant irrigated vegetables, grains and fruit trees. The remainder of the *municipio* specializes in the crops for which Tamaulipas is most known: sorghum, maize, safflower and soy. Sorghum was introduced in the region in the 1950s and 1960s to supply the United States' and Mexico's growing livestock industry and to address what was perceived as Tamaulipas' drought vulnerability (Barkin and DeWalt 1988) (see also chapter 3).

Sorghum is known as a crop that is particularly resilient to water stress, and partly for this reason was the crop of choice for rainfed farmers exposed to repeated drought in the 1990s. Ironically, given the initial marketing of sorghum as a drought-tolerant crop, sorghum is now being actively discouraged in the more arid northern part of Tamaulipas, in response to the government's observation of a progressive desertification of soils that they believe is associated with sorghum farming under persistent drought conditions in the 1990s (ASERCA 1997). A new incentive program, consisting of a direct payment for farmers planting pasture or an alternative crop to sorghum may, in the near future, cause a shift in production away from sorghum and into forage and livestock production (see also chapter 3).

4.4.3.2 Survey data

The survey data revealed that mono-cropping sorghum and safflower is the norm in the *municipio*. Of those farmers who plant a summer-cycle crop, 82% plant sorghum, 23% plant maize and less than 10% plan other crops. In winter, under rainfed conditions, 70% of farmers plant safflower, 13% plant sorghum and 9% plant maize. A significant proportion of the sample (41.5%) does not typically plant in winter or does not plant in summer (23.5%). A surprisingly high number of households (51 households, or 21%) reported not planting in both cycles. All of these households were *ejidatarios*, and the majority had less than 20 hectares of land. The majority of these households were renting some or all of their land, and/or dedicating land to (uncultivated) pasture for livestock.

	Ejidatarios (n= 193)	**Pequeña Propiedad (n = 37)**
Average total Area	21.50 has (std dev. 20)	289.34 has (std dev. 660)
% cultivated in crops	60% (std. dev. 42)	82% (std. dev. 28)
% in pasture	26% (std. dev. 39)	13% (std. dev. 23)
% forested	13% (std. dev. 27)	7% (std. dev. 19)

Table 4.11: Land use in González

In the survey, the respondents estimated the proportion of their total income coming from different sources. These data allowed for a classification of the farm households in to livelihood systems, as defined by Ellis (e.g., income sources representing > = 66% of total income; Ellis 2000). This classification revealed that non-farm activities play an important role in livelihood strategies for both private and *ejidal* farmers in the *municipio* (figure 4.14). In general, *ejidal* farmers appear to depend more on livestock, while private farmers are by far the most dependent on crop production as their exclusive source of income (47% vs. 12%). Although interviews revealed that livestock is of increasing importance to smallholders (in face of declining or volatile grain prices and problems in water availability), 41% of households surveyed reported that they owned no livestock at all.

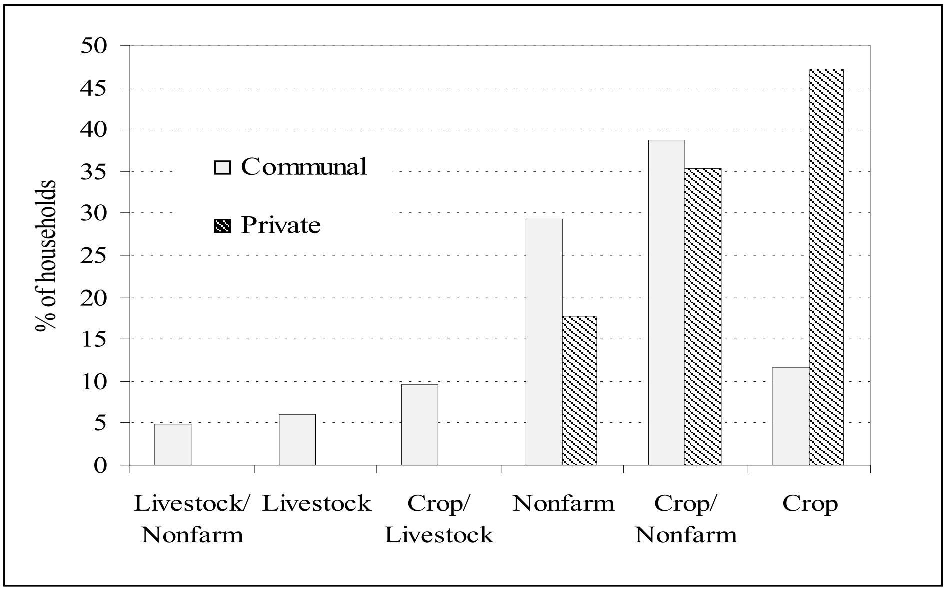


Fig. 4.14: Farm systems in Gonzalez

Farmers in González were particularly concerned with the impact of drought and high temperatures on their crops. Over 86% of households reported that drought, or lack of rainfall during the growing season, was the type of climate event that had historically most affected their production. The respondents recalled the years 2000 to 2002 as the worst for production in terms of climate conditions (undoubtedly reflecting in part the strength of recent memory). Drought and high temperatures were the most common cause of climate problems in 2001, 2002, 2003 although impacts from hurricanes in the Golf and excessive rainfall were also mentioned in each of these years. Newspaper reports show, for example, that in 2001 agricultural drought was experienced in April, affecting sorghum, but that in September, excessive rainfall had also destroyed crops. Impacts from Hurricane Keith were frequently mentioned in 2000 (this was an event that occurred in October of 2000 and destroyed much of the grain harvest in the region, resulting in a state declaration of emergency). The months of July and August (the *canícula*) were most frequently mentioned as the months of with the greatest frequency of climate impacts.

Of all their crops, sorghum was reported to be the most sensitive to the impact of drought and high temperatures by 48% of households, followed by maize (22%) and safflower (14%). These results reflect in part the dominance of these crops in the *municipio* (farmers are likely to report the crop that they plant most frequently as the most sensitive, particularly if they do not plant other crops). However, interviews with farmers in the *municipio* in which farmers ranked crops according to their sensitivity to water stress confirmed the general perception that sorghum was one of the more sensitive crops that one could plant. Farmers ranked beans and maize as the most sensitive, followed by soybeans and sorghum and then pasture and safflower. However, in the growing season prior to the survey (2002-2003), the respondents reported the most extensive losses in beans and pasture. In the winter cycle of 2002-2003, in some communities farmers reported losses in safflower and sorghum of nearly 80% (San Pedro and Lopez Rayón), while losses reported in pasture were all 50% or more of the planted area (these losses were primarily a result of lack of rain and high temperatures). In the summer cycle of 2002, the most extensive losses were reported in beans and pasture (> 50% of planted area) (figure 4.15). Thus it is clear that despite the general perception that pasture is less sensitive to climate impacts than other crops, this was not the case in 2002-2003.

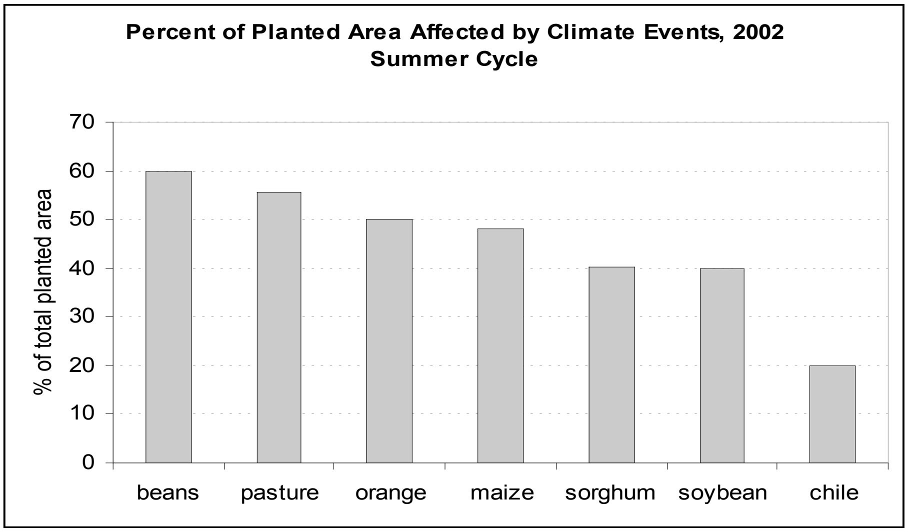


Fig. 4.15: Percent of planted area affected by climate events, 2002 summer cycle

Aside from climate impacts, the farmers surveyed also reported a high incidence of pest problems, particularly in sorghum. The most frequent pests mentioned were *langosta* (locust), *gusano cogollero* (Spodoptera frugiperda), *mosca midge* (Contarinia sorghicola). Nearly one quarter of pequeña propietario farmers reported problems with pests, compared to 5% to 15% of ejidatarios. The months of greatest pest incidence were the months of July and August (locust and Spodoptera frugiperda) coinciding with the *canícula,* and September and October for Contarinia sorghicola, coinciding with the resumption of rainfall in those months.

4.4.3.3 Adaptive capacity

Of the reduced sample of 181 farm households used to analyze vulnerability in González, 34 cases were private farmers and 147 were communal farmers. Indicators were developed to measure adaptive capacity from the variables of the survey, and, through the AHP, weights were assigned to each indicator and each indicator group. Table 4.12 shows that the two groups of farmers (private and ejidal) were distinguished in capacities not only in terms of landholding size, but also in terms of education, age, and access to key resources such as credit and insurance.

Capacity Attribute *with weight*[1]	Variable	Private	Communal
Human capital	Age of farmer (yrs)	46	52
w = .068	Education (yrs)	4.6	3.2
	Adults with primary school education	1.5	2.15
Material resources	Landholding size (ha)	332	23
w =.232	Animal units	30	10
	Tractor ownership	91%	31%
	Irrigation	15%	37%
Financial resources	Credit	44%	15%
w=.414	Insurance	21%	7%
Information	Technical assistance	27%	27%
w=.107	Consults climate information	53%	70%
Diversity	Number of crops	2.2	1.5
w=.179	Income from agriculture	90%	69%

Table 4.12: Selected Adaptive Capacity Indicators and variables, private and communal farmers

In general, the average values for the private farmer groups suggested higher adaptive capacity. The private farmers were more educated, younger (and thus hypothetically more likely to be receptive to new technologies and ideas), and had far more land with which to experiment with alternative crops or with which to generate income. A higher percent of private farmers reported having received credit and insurance, and were far more likely to have the mechanical equipment necessary for production. These physical and financial resources could give these farmers more flexibility to respond to unexpected challenges in the future – whether from market shocks or climatic events.

The communal farmers, however, reported far greater income diversification (as measured by their dependence on agricultural income), were more likely to have access to irrigation, and, despite lower education levels, were more likely to consult climate information (weather forecasts) in their agricultural activities. Should income diversification indicate greater flexibility and resilience in face of climate impacts on agricultural production and livelihoods (Ellis 2000), the communal farmers might be in a better position to deal with climatic shocks than farmers more exclusively dependent on agriculture for their income. Yet the value of diversification in part depends on future scenarios for Mexico's agricultural development. With small landholdings, agricultural credit and public support programs are generally more available for farmers who have specialized in one or two commercial crops. Should a crop insurance market develop for farmers, less diversified farmers may also be better able to cope with climatic hazards despite their dependence on crop income. Given the ambiguity of the role of diversification in adaptive capacity, this attribute was not weighted as high as financial and material resources in the creation of the adaptive capacity index.

4.4.3.4 Sensitivity

In terms of both indirect (e.g., impact on livelihoods) and direct (e.g, impact on crop yields) sensitivity to climatic hazards both the *ejidatarios* and the private farmers were similar (table 4.12). In part the similarity of the data on past losses to hazards, variability in yields and losses experienced in 2002-2003 collected in the survey may reflect the relative homogeneity of the study region in terms of exposure to climatic hazards. Soils in the *municipio* are primarily vertisols with high contents of clay, and these soils tend to cake under both excessive humidity and drought conditions. Surprisingly, although private farmers tended to recall more damaging climate events in the past than communal farmers, the communal farmers were more inclined to believe that the climate is changing (table 4.13). The *ejidatarios* also reported less frequent problems with pests and crop diseases. The final important difference between the two farm groups was the farmers' income dependence on crop production.

	Private	Communal
Climate Sensitivity ***w* = .5**		
Average number of past climate events remembered *w = .176*	2.0	1.6
Average number of pests that frequently affect crops and livestock *w = .135*	2.4	1.7
Average % area affected by hazards, summer 2002 *w = .037*	35%	45%
% of farmers who think climate is changing *w = .023*	71%	92%
Livelihood Sensitivity ***w* = .5**		
% of households dependent on intermediaries for commercialization *w = .232*	56.8%	38.1%
% of households with emigrants *w = .037*	35%	55.4%
% of farmers reporting loss in income 1998-2003 *w = .071*	32.4%	35.4%
Dependency of household on crop income *w = .16*	60%	37%

Note: Two additional indicators were created to measure climate sensitivity. These indicators measured the perceived (by respondent) sensitivity of the principle crop produced by the household in the winter and summer crop cycle to climate. The ranking of crop sensitivity was based on: the degree of loss reported in 2002/2003 for each crop; the difference in "good" and "poor" yields for each crop as reported by households in the survey and the interviews with farmers in the region regarding the relative sensitivity of each crop to drought and high temperatures.

Table 4.13: Selected measures of sensitivity to climate hazards

4.4.3.5 Vulnerability

Each of the variables associated with adaptive capacity and sensitivity were transformed into a 0 to 1 scale, and weighted through the Analytical Hierarchy Process. This process produced two indicators for each household with values between 0 and 1 representing "absence of adaptive capacity" and "degree of sensitivity". The average score for "absence of adaptive capacity" was predictably higher for the *ejidatarios* than for the private farmers (0.696 vs 0.594), reflecting the long history of unequal access to services and resources between the two groups. However, the opposite was true for sensitivity. Average sensitivity scores were 0.383 for *ejidatarios vs.* 0.510 for private farmers. The higher sensitivity scores for private farmers can be attributed to the sensitivity they reported in the survey to crop pests and diseases, as well as their dependence on crop income (table 4.13, above).

To analyze the overall vulnerability of the households, the values for the sensitivity and adaptive capacity indicators were combined through Fuzzy Logic, and the resulting values were used to assign each household to one of three vulnerability classes (low, moderate, high). In the overall sample, 56.9% of households were classified as moderately vulnerable, 39.2% as highly vulnerable and only 3.9% in the low vulnerability class. In comparison with the *ejidatarios*, a higher percentage of private farmers was associated with the low vulnerability category. However, private tenure farmers were also proportionally more represented in the high vulnerability class suggesting that the land tenure classes alone are not good predictors of vulnerability.

By plotting the transformed values of the variables that were used to construct the indices for adaptive capacity and sensitivity on AMOEBA diagrams, one can see that for the communal farmers, access to financial resources (credit and insurance) and technical assistance are what primarily distinguishes the households in the high and low vulnerability classes (figures 4.16 and 4.17). The communal farmers are surprisingly similar in terms of their sensitivity to climate impacts. Financial resources also appear to play an important role in distinguishing the low vulnerability households from the high vulnerability households among the private farmers. The vulnerability classes of the private landholders were also more stratified in terms of their sensitivity, particularly in terms of the number of adverse climate events the farmers recalled having had affected their production and in terms of the variety of pest and crop disease problems they faced.

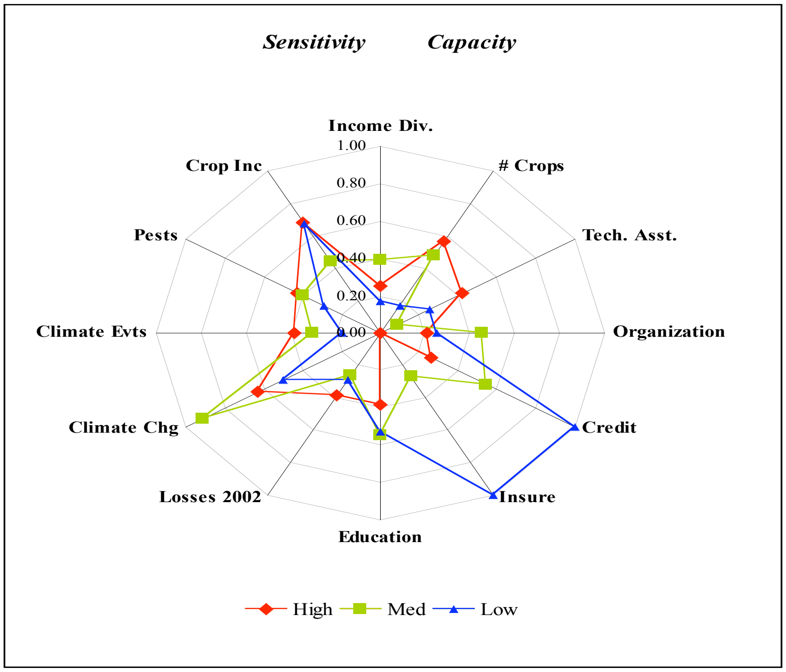


Fig. 4.16: Vulnerability classes, private farmers

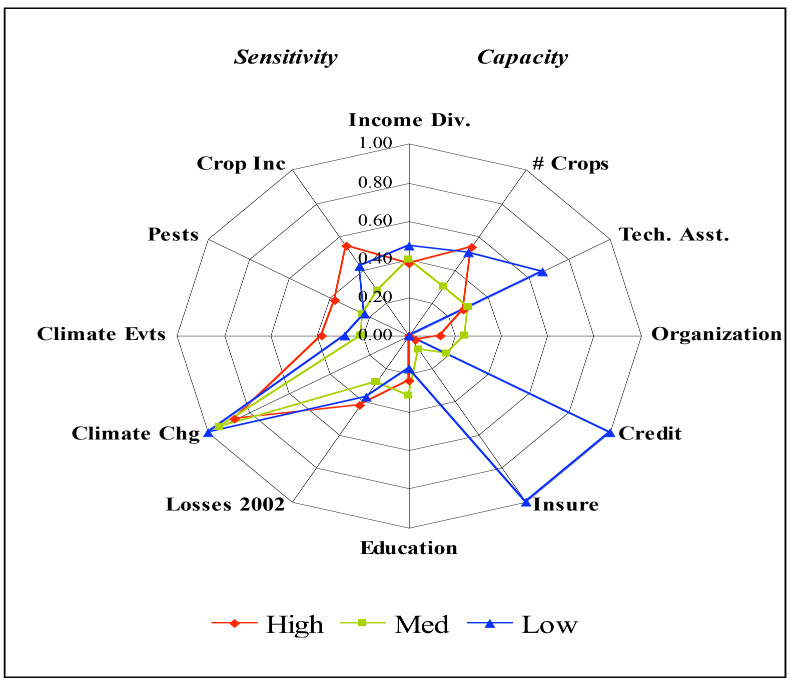


Fig. 4.17: Vulnerability classes, communal farmers

4.4.3.6 Farmers' adjustments

Our evaluation of adaptive capacity was not only in relation to the particular resources farmers owned or had access to, but also in relation to what actions farmers reported having taken in response to the challenges they faced (coping strategies and more structural changes in production) and the ways in which farmers prioritized climate factors in their decision-making. In terms of decision-making, the survey revealed that climate factors – particularly the onset of the rainy season -- were reported to be determinant in the crop choice decisions for nearly a third of the farmers' surveyed. Farmers wait to plant until the first rains have arrived, and then chose their crop accordingly. Yet interviews with both farmers and agricultural officials revealed that inter-annual adjustments in crop choice according to observed climate patterns often have limited economic effectiveness given the lack of crop diversity in *municipio* and the consequence that local markets become saturated when farmers all decide to pursue similar strategies. (For example, one official commented, *"If everyone is planting sorghum as a response to the lack of rain, there are problems with commercialization because of so much of the same harvest."*)

An additional third of the farmers surveyed cited the availability of government support for particular crops as determinant in their crop choices, illustrating the continued importance of government intervention in farm strategies. Surprisingly, despite the liberalization of markets, crop prices appeared to have relatively little influence (< 10%) on farmers' seasonal crop choices. The importance of government support—particularly crop-specific subsidies (e.g., a per-hectare payment to plant cotton or pasture; or a per-ton payment to subsidize the commercialization of safflower) in farmers' decisions and annual crop strategies was confirmed in interviews undertaken in the region with public officials.

In terms of the specific actions that farmers reported making as a response to, or means of coping with climate risk and other challenges (prices and markets), we considered farmers' use of climate information; specific strategies implemented to address inter-annual variability; and more generic adjustments farmers had made in their production strategies. These adjustments are listed in table 4.14.

A majority of the farmers surveyed reported using climate information of some kind (68%), principally in their decision about the timing of planting and crop choice. The most frequent type of information was daily climate information (68%) and weather forecasts (26.5%), and the most frequent source of information was the television (48.5%) or radio (33.2%). There were a variety of reasons for why 32% of farmers surveyed did *not* use climate information in their production decisions. For a substantial proportion of these farmers (39%), the reason related to a lack of access, lack of means, a lack of knowledge about climate information availability and interpretation (table 4.15)

Strategy	% of Responses
Climate-Specific Strategies*	75.0%
Change planting date	16.1%
Change crop	10.3%
Change livestock breed	7.6%
Change seed variety	4.0%
Other	12.5%
Multiple strategies	25.8%
Generic Adjustments**	44.3%
Change in crop	25.2%
Land rental	20.4%
Modification of infrastructure (irrigation)	15.5%
Change to livestock	10.7%
Change in soil management	10.7%
Change in irrigation area	35.5%
Use of climate information	68.4%
Use of insurance	9.0%

Table 4.14: Adjustments and changes in production strategies

*Coded replies to: "What have you done to protect your production from climate hazards?"

**Coded replies to: "In the last five years, have you made any important changes in your production strategy?"

Do not need it	21.4
Lack access	14.3
Lack time	12.5
Lack the means	12.5
Manage risk through adjusting planting date	10.7
Do not know where to get it	7.1
Do no know how to consult it	5.4
Other	16.1

Table 4.15: Reasons for why farmers do not use climate information (Percent of Responses)

To support investment in new crops, as well as to improve the reliability of the harvests of traditional grain crops, some farmers with sufficient capital are now constructing small earthen dams to capture rainwater for additional irrigation. This is reflected in the 15.5% of farmers who reported "modifying infrastructure" as part of a "generic adaptation" in table 4.14 above. It is also reflected in the fact that many of the farmers reporting having access to irrigation acquired irrigation in the mid to late 1990s. Forty-two percent of farmers with irrigation initiated irrigated planting as part of the irrigation district in the late 1970s, but since then a few farmers (principally those with private tenure) have continued to independently contract irrigation through the construction of private earthen dams. These dams fill with rainfall during the rainy season, and are used for auxiliary irrigation during dry spells. Interviews with some *ejidatarios* who had constructed dams revealed that there was a lot of skepticism about the effectiveness of the dams. Many farmers believed that if there was insufficient rain for their crops, there would also be insufficient water in the dams and thus the investment would be futile.

Despite the minimal participation in the program, an increasing number of farmers were investing in livestock both as a response to repeated crop losses and problems in commercializing their harvests, in part supported by a government program called "Program of Incentives for Livestock Productivity" or PROGAN. Livestock appeared to be an activity most associated with smallholder *ejidatarios*, who dedicated proportionally more land to livestock activities, and reported on average proportionally greater income from livestock than was reported by *pequeños propietarios* (14% vs. 5%). Of those households with livestock, 39.6% reported increasing their herds since 1995, principally through livestock breeding, although 7.5% increased their herds by "initiating livestock raising activities." It is important to note that 15.8% of households with livestock reported *diminishing* their herds, primarily because of economic difficulties or livestock disease and pests.

The final action recorded in the survey was migration. From the motivations for migration reported in the survey, it appears that migration is (at least initially) more of a means by which households cope with economic stress rather than an adaptation to environmental or economic change. The primary destination of migrants from the surveyed households was the United States (72%) and the primary reason for migration was economic hardship (71%). The frequency of migrations was greater in 1993, 1995, 1996, and 1999-2001.

There are always multiple factors driving migration, however according to newspaper reports, 1993 was a year of excessive rainfall, damaging much of the maize crop in southern Tamaulipas. This was also an ENSO warm event year. 1995 was a year of drought, in which the state's secretary of agriculture reported problems in compensating farmers and generating sufficient alternative employment opportunities. 1996 was reported to be the worst drought in two decades and then again in 1999 the government declares a state emergency given prolonged drought impacts. These events are likely to have contributed to the impulse of out-migration reported by the surveyed households.

4.4.3.7 Enhancing adaptive capacities

The AMOEBA diagrams (figures 4.16 and 4.17, above) indicate that the greatest differences in adaptive capacity between vulnerability classes are in indicators of "information" (technical assistance, farm organization) and financial resources (credit and insurance). These results indicate that interventions (either from the public or private sector) could be developed to enhance capacities in these areas.

Enhancing farmers' use of information – either climatic, technological or market related – is challenged by the relatively low education levels of the population of González and the absence of extension services (either private or public). The survey revealed that the vast majority of farmers lacked technical assistance and less than a quarter (20.9%) reported being members of agricultural organizations where they could conceivably acquire information on public and private agricultural services and opportunities, as well as lobby for program changes to meet their common goals.

As in the Veracruz case study, farm organizations could be a means by which capacities could be enhanced, through facilitating farmers' access to information and agricultural services, particularly in the current era of reduced public sector investment and intervention. Of the 20% of the sample who reported being members of a farm organization, the majority (61%) joined their organization after 1998, and reported that the primary benefit was commercial.

Farm-level organization is difficult to facilitate, but some public sector organizations (for example, Fidecomisos Instituidos en Relación con la Agricultura or FIRA of the Bank of Mexico, or Fundación Produce) and non-governmental organizations have been working to organize farmers into commercial production units for some time and facilitating credit and insurance to such groups, and it is these organizations that may be instrumental in capacity building for adaptation. The obstacles are significant, however. Of the farmers who were not part of any agricultural organization, 38.7% reported that they lacked information about organizations, 27% reported that they were not interested in organizations, and 13.5% said they did not have time to participate.

The public sector is also promoting some programs to help farmers manage both climate and market risk, including crop insurance and contract farming (Yarrington Ruvalcaba, 2004). Very few (9%) of the surveyed farmers had crop insurance. The majority of these farmers were *pequeños propietarios*, although also a handful of *ejidatarios* in the irrigation district also had insurance. Lack of affordability, lack of information and general distrust were cited as reasons for not having contracted insurance by those farmers who lacked insurance. In the 1980s *ejidatarios* were obligated to purchase insurance from a government parastatal (first ANAGASA and then AGROASEMEX) with the loans they received from the public agricultural bank, BANRURAL. Newspaper reports from this period confirm the prominent role that these insurance payments played in climate impact compensation programs. Repeated difficulty in receiving insurance payments, however, left farmers distrustful of insurance initiatives, and the recent declining value of their harvests has provide little incentive for purchasing insurance, which now is acquired through private commercial banks.

The state government is also now promoting diversification into non-traditional crops and livestock as a possible strategy for addressing both environmental challenges to production as well as the lack of commercial opportunities in grain farming. Some of the alternatives being promoted – *agave* and aloe for example – are particularly well suited to drier and warmer climates. However, relatively few small scale farmers are experimenting with such alternative, non-traditional crops as *agave* (for tequila production), aloe, tree-crops for timber, vegetables or pasture. Some of the smaller-scale farmers interviewed argued that the government's support was insufficient, and that investment necessary for planting alternative crops on a commercial basis was prohibitive. Much of the land planted with *agave* and aloe, for example, was reportedly rented from *ejidatarios* by investors from outside of the region. The *ejidatarios* perceived that the small-scale of their production and the variable quality of their products were important obstacles to getting credit and commercializing their harvests.

Through a national program of crop conversion (PIASRE, or *Programa Integral de Agricultura Sostenible y Reconversión Productiva en Zonas de Sinestralidad Recurrente*) the planting of buffle grass is now being encouraged through direct per hectare payments to sorghum farmers and investment in infrastructure (Yarrington Ruvalcaba, 2004). In the Rural Development District of González (a territory that includes the neighboring *municipios* of Altamirano and Mante) the area under planted pasture increased by 63% between 1999 and 2002, although only a handful of farmers reported receiving support through the crop conversion program in the survey administered in the *municipio* of González in 2003.

Not all experts interviewed agreed with a livestock-pasture strategy as the most appropriate response to a perceived increased frequency of drought. One agricultural official commented, "Those that have livestock have been the most affected by drought in recent years. Because of a lack of pasture they have had to cull animals and sell them at very low prices. Some have had to buy sorghum from neighbors to feed their cattle. The problem is made worse because live cattle are entering from the United States with the liberalization of the cattle market. This is driving local prices down." Some farmers interviewed concurred that having cattle could be a liability should drought affect the productivity of pasture and thus require purchasing hay or grain. In fact, the survey revealed that farmers who had planted pasture reported some of the highest losses to drought in 2002, and many sold cattle as a result.

Despite the general decline in public sector investment and support for agriculture over the 1990s (Appendini, 2001; Cornelius & Myhre, 1998), it was clear that the farmers of the *municipio* still perceive an important role for the public sector in taking the lead in responding to climate change and resent the recent absence of government support for finance, technical assistance and research. When asked who should take the responsibility for responding to climate change, 30% of respondents placed primary responsibility on the federal government, 23% on the state government and 27% on themselves, the farmers. Although this response suggests an attitude of divided responsibility, when asked what actions should be taken, common replies were "more government support" "economic incentives" or other such public-sector actions, reflecting the expectation that for substantial change to occur in the agricultural sector it would need to be subsidized by the public sector.

4.4.3.8 Conclusion

In summary, farmers in the region have perceived some changes in the local climate and are, in general, sensitive to seasonal climatic conditions in their production decisions. Their primary inter-annual strategies for addressing climate risk are through adjustments in their planting dates and through crop choice, although the latter adjustment is relatively narrow given the limited number of crops commonly planted in the region. Almost half the farmers surveyed have implemented a change in their production and/or livelihood strategy, including changing crops, changing from crops to livestock, investing in irrigation infrastructure, and renting out their landholdings.

Surprisingly, the farmers classified as "highly vulnerable" were not exclusively *ejidatarios* but rather a mix of tenure types. These were generally farmers whose income was primarily agricultural (thus enhancing their sensitivity to climate impacts), reported frequent pest and climate problems, yet who lacked formal financial and technical resources to mitigate risk. Low-vulnerability households were those that were either crop-specialists but who had ample access to credit, technical assistance and insurance and reported low sensitivity (primarily private tenure farmers) or those had diversified economically and agriculturally, and also had access to financial and technical resources (*ejidatarios*).

The government's promotion of alternative cash crops with low water consumption is inhibited by problems in finance, commercialization and access to information. There are, however, evidences of more significant adaptations to the combined problem of recurrent drought and economic stress. Earthen dams to capture rainwater for auxiliary irrigation and the conversion of agriculture to livestock are increasingly popular adaptations, particularly in the context of public sector support for pasture and livestock production. Formal risk management mechanisms such as insurance have met with significant skepticism, in part because of farmers' previous experience with insurance as well as because of the declining value of traditional crops in González.

4.5 Discussion

Despite the differences in the agricultural histories and structure of farming in the two countries, the case studies reveal important similarities. First, the drivers of vulnerability are similar. In the context of neoliberalism, farmers in both regions are feeling renewed pressure to specialize in one or two commercially viable commodities, and the bias in policy is in favor of larger-scale more entrepreneurial farm units, putting the smallholder farm system at a disadvantage. In Mexico the continued important presence of government incentive programs for planting specific crops – first sorghum, now pasture in Gonzalez; or coffee and now macadamia or sugar cane in Coatepec – also is a factor in encouraging particular land uses. In Argentina, the process is occurring at the scale of the macro-economy, through reform in tax laws and the regulation of the exchange rate, but with a similar result. Large-scale export-oriented producers are expanding soybean production onto land that formerly was dedicated to mixed farming practices, while family farmers are struggling to make ends meet in an increasingly competitive environment.

The importance of agricultural diversification in climate risk mitigation may also be diminishing in face of the changing technologies and markets of each region, which encourage farmers to accept a higher climate risk whenever these risks are coupled with higher economics returns. However, specializing in cash crops in order to take advantage of current market opportunities entails higher production costs and as a result, some households have been forced by debt and economic hardship to rent out their land or abandon agriculture altogether. For these vary reasons, we observed a high rate of land rental in both the Cordoba and Gonzalez case studies, and, in Coatepec, the abandonment of coffee plantations.

These processes have various implications. First, the expansion of monocrop systems not only makes the individual household or farm unit more sensitive to any impact (climatic, market, pest) on its sole agricultural activity, but also monocropping can have environmental implications that make the broader region more susceptible to climate extremes and economic volatility. This is best illustrated in the Cordoba case study, where soybean expansion is increasing rates of soil erosion, although similar process are evident in Gonzalez where intensive sorghum farming has also apparently exhausted soils. Second, in replacing diversified production systems, monocrop systems demand that farmers develop alternative means of risk mitigation that are market-based (e.g. insurance). This also entails risks and costs that some farmers, in entering into the newly liberalized commercial markets, are unable to assume.

Given that many farmers find that they lack the capacity to mitigate the risks involved with adopting the more specialized production system, diversification remains a viable – and perhaps necessary -- risk reduction strategy for farmers operating on the economic margin. For this reason, in all three case studies, the households that have had a more difficult time responding to the demands of the new agricultural economy tend to mitigate their sensitivity to impacts through a more diversified production system or economic base while those that have adopted the more specialized production system address their vulnerability through acquiring the specific resources that improve their capacity to recover from and adapt to stress. The most vulnerable strategies are associated with those farm households that attempt to adopt a specialized production system without the formal mechanisms to buffer their household economy from external shocks.

4.6 Conclusions

The approach to vulnerability described above deviates from the more typical frame of climate vulnerability assessment, which considers vulnerability as primarily a function of anticipated impacts exclusively from climate events or change after adaptation to these changes on a given economic or biological system. The social vulnerability approach described above uses livelihoods as the unit of analysis and frames these livelihoods in a political-economic context. Where an impact assessment can illustrate the sensitivity of a particular commodity (coffee, sorghum, soy) to climatic stimuli, and an evaluation of adaptation options may illustrate the efficiency or cost effectiveness of one technical option over another, these types of assessments do not address the fundamental social and *political* nature of vulnerability: That there exists some segments of the farm population whose ways of earning a living are more susceptible to harm from climatic events and change not only because of differences in their exposure to hazards, but also because of their position in the broader society, because of the resources they own and the resources they have access to, and because of the history and trends in economic development that have provided them with specific opportunities and constraints.

This approach also illustrates the important influence of past macroeconomic and sector policy in the present structure of livelihoods and vulnerabilities in the three case studies. In general, the neoliberal reforms adopted in both countries during the last decades have affected not only the possibilities for development of an important number of agriculture producers, but also the communities they belong to. Macroeconomic policies aimed at generally increasing production and competitiveness of the economy, and thus also agriculture, have had a heterogeneous effect on the sector's performance, with consequent mixed social and economic impacts on entire communities. This means that policy decisions taken today — whether in a very local context, or at the provincial or national level — will likely have important implications for future vulnerability. The populations that are vulnerable today, if no action is taken, may well not be subjects of a vulnerability analysis in the future. Moreover, "business as usual" development paths will undoubtedly create new vulnerable populations as a result of the unintended environmental and social externalities of development.

Our intention was thus to evaluate adaptive capacities in each case study specific to the institutional context of decision-making, in order to produce results relevant not only to the vulnerable populations but also to politicians, technical experts and others involved in policy development. The interventions discussed above in each case study are thus not generic interventions applicable in every context but rather responses to the observed deficiencies in particular resources that appeared to give some households an advantage in managing risk in the particular institutional and socioeconomic context of production.

Similarly, the adaptive capacities of the farm units in all three case studies are not exclusively related to the technologies, practices or resources that directly help households buffer climate impacts but rather the complex combination of livelihood resources that also enable households to improve their standard of living and the quality of their resource base while confronting not only climatic risk but the variety of other stressors affecting their livelihoods. For adaptation to occur to these multiple stressors, there will be a need for increased collaboration between farmers, producer associations, the private and public sector.

We have shown through the three case studies that although it is possible theoretically to isolate climate impacts and the responses of households to those impacts from the variety of other environmental, economic and institutional stressors affecting a household, the households themselves in making strategic decisions about risk weigh all of these stressors simultaneously. This means that for some households, climate will represent a relatively minor factor in their decision-making process, according to the households' greater concern over the impact of other stressors—e.g., market volatility, changes in input availability, commercialization problems—on their livelihood outcomes. This does not mean that for these households climate impacts are negligible or insignificant, but rather that the household does not have the flexibility, given the other constraints and stressors to which it is responding (according to its prioritization of risks and perception of consequences), to invest in climate-specific adaptations. However, interventions to enhance capacity—whether from the public or private sector – can and should address these other constraints and limitations on the decision-making process with the aim of improving the generic degree of capacity to adapt of the vulnerable populations.

Our ambition was not to create a generic quantitative model of vulnerability to determine the absolute degree of vulnerability of any particular population or household. Rather, the approach involved the development of heuristic tools that are sufficiently flexible to allow for the use of different indicators in the development of multivariate vulnerability indices, yet sufficiently structured to enable a discussion of the similar processes and consequences contributing to and resulting from the vulnerabilities in each case study. The interpretation of the vulnerability indices also depended as much on the quantitative analysis of the surveys as on the qualitative data collected in interviews, participatory activities and the review of primary and secondary literature (described in chapter 3 as well as this chapter).

The case studies also illustrate that vulnerability is a relative concept, and thus circumscribed by a reference population (e.g., within a household, community, province or country). A vulnerability assessment is thus relevant in relation to the governance and/or decision-making unit of that reference population. In our study, the reference populations were: the *municipio* of González; the Coatepec coffee production district in central Veracruz; and the Center-South of Córdoba Province. Within country and between-country comparisons of agricultural vulnerability are made difficult by the important differences in geography, production, economy, and the institutional and policy context affecting particular crops. The fact that the decision-making units and governance structures also tend to be distinct in case study research makes comparisons of vulnerability across case studies relatively meaningless. For this reason we found little utility comparing the relative values or levels of vulnerability of the Argentina and Mexico cases.

However, our project identified other viable axes of comparison. First, in each country similar global and national institutional trends are contributing to the vulnerability of particular sub-populations of the agricultural sectors. Second, in all three cases, the sensitivity of farm groups to climate impacts is a product not only of changes in the nature of climate hazards (frequency, duration, intensity), but also a product of the types of livelihood strategies farmers are pursuing in relation to these broader scale socioeconomic and institutional trends. Thus, for example, farmers taking advantage of opportunities in soybean cultivation or organic coffee production are also altering their sensitivities to climatic hazards.

5 Capacity Building Outcomes and Remaining Needs

5.1 Workshops, Courses and Students

5.1.1 Workshops

Investigators and students participated in AIACC workshops and other national and international meetings to attain knowledge and experience. Following is the list of meetings attended:

AIACC Global Kick-off Meeting, 11-15 February 2002, Nairobi, Kenya. Participants from the Project: Cecilia Conde (CO-PI), Marta Vinocur (CO-PI) and Patricia Romero Lankao (CO-PI)

AIACC Project Development Workshop: Development and Application of Scenarios in Impacts, Vulnerability and Adaptation Assessments, 15-26 April 2002, Norwich, UK. Participants from the Project: Cecilia Conde (CO-PI), Marta Vinocur (CO-PI)

AIACC Project Development Workshop: Climate Change Vulnerability and Adaptation, 3-14 June 2002, Trieste, Italy. Participants from the Project: Hallie Eakin (CO-PI), Marta Vinocur (CO-PI), Patricia Romero Lankao (CO-PI) and Mónica Wehbe (CO-PI).

First Bi-national Workshop Mexico-Argentina: 17 – 21 May 2002, UNAM, Mexico. Attended this workshop: PI and CO-PIs: México. Carlos Gay, Cecilia Conde, Hallie Eakin, Patricia Romero. Argentina: Roberto Seiler, Marta Vinocur, Ana Geymonat. Invited Researchers: Adalberto Tejeda (Veracruz, Mexico), Lourdes Villers (UNAM, México), Ismael Aguilar (Nuevo León, México), Maria Carmen Lemos (Brazil), Luz Dary Yepes (Colombia). Students: Cristian Daniel Santos (Argentina); Beatriz Palma, Gerardo Utrera, Genaro Martínez, Miguel A. Hernández, Leticia Cuellar (Veracruz), Juan López, Angélica Rosas (UAM, México), Raquel Araujo (UNAM, México).

Second Bi-national Workshop Mexico-Argentina: 21-23 May 2003, UNRC, Río Cuarto, Argentina. Attended this workshop: CO-PIs: México. Cecilia Conde and Hallie Eakin. Argentina: Roberto Seiler, Marta Vinocur, Ana Geymonat and Mónica Wehbe. Invited Researchers: Dr. Alejandro Leon (Development-Univ. de Chile, Chile), Dr. Mario Cantú (Geology- UNRC, Argentina), Mg. Gustavo Busso (Economy-UNRC, Argentina). Students: Cristian Daniel Santos, María Cecilia Maurutto, Andrea del Valle Rivarola, Gastón Chiessa, María Eugenia Kehoe (Argentina). Stakeholders: Oncativo and Laboulaye city Majors, one representative of each one of the following institutions: INTA (Scientific and Extension National Institution), Sociedad Rural (farmer organization), AIASC (Agricultural Engineers Association) and two farmers from different areas participated in a Focus Group meeting organized during this Workshop.

First AIACC Regional Workshop for Latin America and Caribbean: 27-30 May, San José, Costa Rica. Participants from the Project: Carlos Gay (PI), Mónica Wehbe and Marta Vinocur (Co-PI).

Third Bi-national Workshop Mexico-Argentina: 17 – 21 May 2004, UNAM, Mexico. Attended this workshop: PI and CO-PIs: México. Carlos Gay, Cecilia Conde, Hallie Eakin; Argentina: Roberto Seiler, Marta Vinocur and Mónica Wehbe.

Second AIACC Regional Workshop for Latin America and Caribbean: 24-27 August 2004, Buenos Aires, Argentina. Participants from the Project: Hallie Eakin, Cecilia Conde, Roberto Seiler, Mónica Wehbe and Marta Vinocur (Co-PI).

AIACC Bellagio Vulnerability Synthesis Workshop: March 7-12, 2005, Bellagio, Italy. Participants from the project: Cecilia Conde, Hallie Eakin and Mónica Wehbe.

Fourth Bi-national Workshop Mexico-Argentina: 8-18 June 2005, UNAM, Mexico. Attended this workshop: PI and CO-PIs: México. Carlos Gay, Cecilia Conde, Hallie Eakin; Argentina: Roberto Seiler, Marta Vinocur and Mónica Wehbe.

AIACC Adaptation Synthesis Workshop: 12-17 September 2005, Naivasha, Kenya. Participants from the project: Roberto Seiler and Mónica Wehbe.

5.1.2 Courses

a. Courses for students

b. Other courses

5.1.3 Students

Thirteen students in Mexico were involved in the AIACC project: three students have graduated during the project, four are finishing or waiting for exam dates, six are developing their thesis currently. They are all related to climate variability and change, and or its impacts on crop production. No social science's students agreed to develop their thesis within the Mexican project.

A special case is Sergio Saldaña who is developing the project *Reducing Economic and Financial Vulnerability from Natural Disasters in Mexico: Poverty, Agriculture and Development issues.* Cecilia Conde is his external mentor.

In Veracruz, for the climatic component of the project, students from the University completed or started their thesis: two bachelor students (meteorology) finished their thesis, one master students (geography) also completed her thesis and will start her PhD with us (two more master students used the climate change scenarios proposed by the AIACC team), and two students started their PhD thesis (geography). Dr. Adalberto Tejeda, Dr. Carlos Gay and Dr. Cecilia Conde were or are their tutors. All of them, have related their results to the possible impacts of climate variability and climate change in Veracruz. In UNAM, one master student (geography) and one bachelor student (biology) have completed their thesis. This is very relevant for capacity building, since there is a "critical mass" of young scientist in the state and in UNAM that will develop further research in the region, and be part of a network that will collaborate in one ongoing project and that will submit future research projects.

For Tamaulipas, one geography student completed his social service and is now writing his bachelor thesis, similar to one bachelor student in biology. One PhD student (geography) will complete her PhD thesis in the next year. No students in Tamaulipas developed their thesis during this AIACC project. Dr. Gerardo Sánchez and researchers in UNAM have agreed to include two students in one ongoing project and to submit another project to create an stronger research team in the region.

No researchers in the social areas (such as Dr. Tejeda and Dr. Sánchez) were involved in the AIACC project. No students from these areas were involved in the research team with the academic compromise of a thesis. They participated in collecting field work (surveys, interviews) or capturing data in worksheets, but were not interested in developing further research with us. This deficiency will be corrected in future projects.

In Argentina, the Project supported the development of highly qualified students who made their thesis in different aspects of the project. Cecilia Maurutto (Socio cultural aspects of farmers) and Andrea del Valle Rivarola (agroclimatic vulnerability to droughts) are in the final stage (writing phase) of their Master Thesis in Regional Development Master Program of the UNRC, Argentina. Cristian Santos is also in the writing stage, although he will not be finishing this year, of his Master thesis (climate change policy and institutional changes) in the Science, Technology and Society Program of the UNQ, Argentina. Gaston Chiesa obtained his degree of Licenciate in Economy (UNRC) with his thesis on regional economic chains. Dana Lucero will become a Licenciate in geography with her thesis on the history of extreme events in the region. Around seven undergraduate y graduate students with different backgrounds (economists, social workers, agronomists, geographers, etc.) made meaningful contributions to the project by creating and completing the project database, surveying farmers and other stakeholders, collecting and processing information from different sources, participating in field work activities, etc.

5.2 General Capacity Building Accomplishments

This project was designed to initiate, in the regions of study, a process in which issues of climatic change, variability and extreme events are given new consideration in the development of sector policy. This was accomplished through raising awareness among appropriate sector agencies and stakeholders of the importance of these issues through outreach efforts, and motivating support for the contributions of scientific research in decision-making. Not only our project reinforced the development of innovative research methodology and interdisciplinary collaboration in the region's academic institutions, but also we have been evaluating the particular factors that make each region vulnerable, and providing the forum for a dialogue on how this vulnerability can be reduced through adaptive strategies. Building the regional capacity to sustain this dialogue in the academic community is a critical component of this project.

Our project used expertise in climatology, agrometeorology, rural development, political science, economics and geography, and the involvement of the societal actors integrating the knowledge from different scientific disciplines and knowledge from non-scientific sources to carry on the complex research. Through this transdisciplinarity research, the mutual learning and knowledge of all participants was enhanced.

During the project students and researchers learned new models and methods and also developed new methodology. These activities resulted in increased individual and project capacities. Examples are the development of social vulnerability and adaptive capacity indexes, geographic information systems for the different research areas, etc.

Institutional capacity building was strengthening through the collaboration between different researches groups of Mexico and Argentina. Two of these groups are in the University of Río Cuarto, one devoted to agricultural meteorology at the School of Agronomy and the other devoted to rural development in the Instituto de Desarrollo Regional (Regional Development Institute) at the School of Economy.

5.3 Remaining Capacity Needs

The involvement of different stakeholders (farmers, farmers'organizations, grain dealers, city major, city council, etc.) and the mass media support to the activities of the project resulted in a broad diffusion of climate variability and climate change issues in the region creating a fertile and collaborative environment for the development of the project. Continuous reinforcement of these relationships (through workshops, conferences, brochure, booklets, web site, etc) is required to improve current adaptive capacities and enhance future adaptation to climate variability and change in the region.

6 National Communications, Science-Policy Linkages and Stakeholder Engagement

6.1 National Communication

For the Mexican case study, Carlos Gay and Cecilia Conde are currently involved in the research team that will elaborate the Third National Communication.

In Argentina, the activities of the Second National Communication to the UNFCC were assigned to consultants, scientific groups or institutions according to an open bid and selection was done based on scientific merits. We are not participating in the Second National Communication as the center of Argentine (our research region) was not included in that assessment for the Argentina Government.

6.2 Contribution to UNFCC activities

Marta Vinocur attended the COP-10 in Buenos Aires invited to the side events that AIACC organized in that meeting. Mónica Wehbe participated in the COP- 11 in Montreal.

6.3 IPCC

Cecilia Conde and Carlos Gay are Coordinator Lead Author (CLA) or Lead Author (LA) in the Fourth Assessment Report for the IPCC.

Carlos Gay (CLA). **Chapter 13**. IPCC WGII Fourth Assessment Report (AR4). First Drafting Meeting. Vienna International Centre (VIC). Viena, Austria. September, 20 - 23, 2004. Second Drafting Meeting. Cairns, Australia. March, 14 al 17, 2005.

Cecilia Conde. (LA). **Chapter 2**. IPCC WGII Fourth Assessment Report (AR4). First Drafting Meeting. Vienna International Centre (VIC). Viena, Austria. September, 20 - 23, 2004. Second Drafting Meeting. Cairns, Australia. March, 14 al 17, 2005.

Cecilia Conde. LA. **Chapter 17**. IPCC WGII Fourth Assessment Report (AR4). First Drafting Meeting. Vienna International Centre (VIC). Viena, Austria. September, 20 - 23, 2004. Second Drafting Meeting. Cairns, Australia. March, 14 al 17, 2005

In Argentina, M. Vinocur and M.Wehbe are expert reviewers of the Fourth Assessment Report for the IPCC

6.4 Stakeholder Engagement

In all three case studies the project investigators established contacts with local representatives of agricultural organizations, officials with the state and federal government working on water and agriculture issues in the regions of study and directly with farmers. Some of these contacts resulted in subsequent active participation in some elements of the project as (e.g., INIFAP-Campo Experimental Xalapa, Majors of the selected cities, etc.), while other contacts remained primarily passive recipients of information about the project. These stakeholders were contacted initially by the project team for one-on-one interviews. These interviews were designed to present the purpose of the study and initiated an exchange of information on how climate impacts and variability is perceived and experienced, and the issues of greatest concern to the stakeholders consulted.

The primary contacts made were with the following organizations:

Argentina:

- Instituto Nacional de Investigaciones Agropecuarias (INTA), Estación Experimental (EEA) Marcos Juárez y Manfredi, Unidades de Extensión Río Cuarto y Laboulaye

- City Majors of Laboulaye, Oncativo, Marcos Juárez y Río Cuarto
- Sociedad Rural de Río Cuarto y Laboulaye
- Secretaría de Agricultura, Ganadería y Alimentos de la Provincia de Córdoba
- Secretaría de Agricultura, Ganadería, Pesca y Alimentos de la Nación
- Farmers of Laboulaye, Oncativo, Marcos Juárez y Río Cuarto
- Federación Agraria Argentina
- Asociación de Cooperativas Argentinas

Mexico:

- Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias (INIFAP). Campo Experimental, Xalapa
- Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias (INIFAP). Campo Experimental, Altamira
- Secretaria de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación (SAGARPA). Delegación, oficina Xalapa.
- Secretaria de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación (SAGARPA). Delegación, oficina Tampico.
- Secretaria de Desarrollo Rural, Tamaulipas, Tampico
- FIRA (office Tampico)
- Districto de Desarrollo Rural, González (CADER González)
- Comisión Nacional Forestal (CONAFOR). Delgación Xalapa.
- Consejo Veracruzano de Café (COVERCAFE). Xalapa.
- Instituto Veracruzano para el Desarrollo Rural (INVEDER)
- Comisión Nacional de Agua (C.N.A., o CONAGUA)
- Consejo Regional de Café de Coatepec
- Asociación Agrícola de Coatepec
- Unión Agrícola Regional del Sur de Tamaulipas
- Farmers of:
    - Vaquería, Coatepec, Ver.
    - Ursulo Galván, Xico, Ver.
    - Municipio of González
    - Delegación Estatal de Jornaleros Agrícolas, Xalapa

The interviewee was then invited to attend the project launching workshops held in each case study region. In several cases the project initiated a collaboration with a particular organization (e.g., the staff of the DDR González, CONAGUA Tampico, and INIFAP Xalapa) in which information and expertise was exchanged, and/or the organization facilitated some aspect of the project (e.g., workshops with farmers). This collaboration improved the project by orienting the project research towards those aspects of climate variability that were of most important to the farmers. The interviews also revealed useful information on past climate impacts on production and farmers' responses, the relationship of public policy to farmers´ experience of climate hazards and the effect of public sector intervention on coping strategies. Regional workshops were designed to facilitate a dialogue between the project and stakeholders and to keep the communities informed of the project's progress. Informational pamphlets were distributed in these meetings with the project contact information and preliminary results.

With some stakeholders we managed an effective collaboration in which representatives actively participated in specific activities of the project. The office of INIFAP in Xalapa, Veracruz, for example, provided climate and geographic data to the team and an expert on participatory rural appraisal from this office facilitated two workshops with farmers in the region. Although it is unclear if the project has yet influenced INIFAP's operations, the collaboration resulted in a new project proposal that has been submitted to the Inter American Institute for Global Change Research. The staff of CONAGUA became key supporters of the application of the model WEAP in Tamaulipas and have expressed an interest in making use of the results.

In Argentina sstakeholders' workshops were done in the selected cities. First, we contacted the Mayor of each city and during an appointed meeting; we explained the objectives and scope of the project and some background information about climate variability and change. The objective of this initial meeting was to interest him in the project to finally get his full collaboration and engagement in the proposed workshop and further activities. We got an impressive support from the Mayor and it was the Press Office of each city (in three over four cases) who contacted the selected workshops' participants and did all the event diffusion.

After obtaining the city representatives support we organized four stakeholders 'meetings, one in each selected city. A letter of invitation and an informative brochure (specially developed for this meeting) were personally handled to each participant. The high level of engagement and communication attained with the key groups during these meetings will allow us to gain a better understanding of the problems faced by the stakeholders and to focus our research strategies.

a. September 5th 2002, *Oncativo*: The meeting was attended for 60 people; forty six were previously invited and the others contacted the City Press Office requesting an invitation. Attendants were: the city Mayor (Mr. Osvaldo Rubén Vottero), representatives of insurance companies and banks, city and provincial council, National Agrotechnological Institute (INTA), regional officials of agricultural secretaries (national and province level), farmers'organizations (AACREA, Cambio Rural, Sociedad Rural, Federación Agraria, Agricultural Cooperatives), agricultural schools, grain dealers, etc. After the presentation, an open exchange of questions demonstrated the participant's interest in the project and their willingness to collaborate with us.

b. October 3rd 2002, *Marcos Juárez*; In this city, the stakeholder's meeting was attended by 35 people, with the same typology as the Oncativo meeting (City Council Head: Mr. Javier Ignacio Vidal). Although there were fewer attendants, the final opinion and question exchange was more fruitful and challenging than in our first meeting.

c. October 31st 2002, Laboulaye (City Major: Dr. Néstor Garimanno): Twenty eight of over forty invited stakeholders participated in this meeting, belonging to similar institutions as in the other two cities although we got less attendants from the policy sector. A political meeting with the Province Governor just before ours may explain this difference. Recurrent floods characterized this area and make it more prone to agricultural and civil damages. The great interest in the scope and objectives of the project and the willingness to further collaboration may reflect the particular situation they faced.

d. December 18th 2002, Río Cuarto: In this case, the workshop was convoked by the Head of the University of Río Cuarto and the AIACC team. A heavy storm happened around the time of the meeting, diminishing the prospective audience to 20 people. Nevertheless, similar interest and engagement in the project proposed activities were attained.

A Focus Group Meeting named *Vulnerability and Adaptation: a vision from the social actors*, was organized during the second Binational Workshop held in May 22th in Río Cuarto in May 2003. The objectives were to recognize the impacts of climate variability and change as determinant factors of the vulnerability in the agricultural, economic and social sectors, analyze the complexity and multivariate aspects of the vulnerability in those sectors, stressed the importance of an integrated approach to address these issues and the necessity of a permanent compromise of the social actors in the proposition, analysis and evaluation of adaptation strategies. A personal letter of invitation and five questions to guide the discussion were handled to each participant before the meeting. Two cities (Oncativo and Laboulaye) Majors, one representative of each one of the following institutions: INTA (Scientific and Extension National Institution), Sociedad Rural (farmer organization), AIASC (Agricultural Engineers Association) and two farmers from different areas were invited. The Mexican and Argentinean project researchers, graduate and undergraduate students from the project and other invited researchers also participated in an open discussion following the meeting. It was a fruitful experience that helps us to consolidate our vision and focus our perceptions of the vulnerability and adaptation aspects of those society sectors and also strengthen the link between the university and the community which we are investigating.

Final Stakeholders Workshops were done in the selected cities during 2004 and 2005 with the aim of presenting and validating the project results on the assessment of biophysical impact and adaptive capacity. Meetings usually started with openings words from the Major of each city, continued with the explanation of climate trends, climate change impacts, sensitivity analysis and adaptive capacity issues presented by projects Co-Pi and ended with a reception offered to all participants. Before the end of each meeting three participative activities were proposed which were related to agriculture producers' past experiences on adaptive activities for coping with adverse climate years, to farmers' perceptions and valuation of different resources for adaptation and an open answer question on adaptation responses to the last cropping season, which was particularly dry in this region; expectations for the next winter cropping period and issues related to the decision-making process. Meetings were attended by most of the farmers surveyed the year before, City Mayor, regional representatives of the Argentinean Agrarian Federation (FAA), the Road Consortium and other institutions.

In both countries not all of these efforts to engage stakeholders were equally successful. For stakeholder engagement to be more successful in future projects, the team concluded that:

- There should be a constant physical presence of researchers in study region
- Key stakeholders should be incorporated into project preparation and design *before funding*
- Climate change is not an institutional priority for many stakeholders, the issue must be framed according to their interests
- It is difficult for researchers to work with stakeholders at distinct scales of decision-making
- Stakeholders´ perceptions of the project can be influenced by how the project is presented, where and by whom
- Effort should be made to present project and engage with stakeholders within the organizational structures that exist in the region (e.g., council meetings, municipal or agricultural development committees, farmer assemblies).

    a. Dissemination material of the project

    b. Informative brochures of the project were disseminated between participants of the stakeholders meetings, farmers' organizations and public institutions.

    c. Different materials containing project results (book and booklet) directed to the different stakeholders and to the general public are being elaborated in both countries and will be available soon.

7 Outputs of the Project

7.1 Peer Reviewed Publications

- **Papers**

Rivarola A.del V., M.G. Vinocur y R.A.Seiler. 2002/03. Uso y demanda de información agrometeorológica en el sector agropecuario del centro de Argentina. *Revista Argentina de Agrometeorología* (RADA), **2**(2): 143-149. (Spanish)

Seiler, R. A. y L. Bressán. 2002/03. Evaluación y seguimiento de las condiciones de humedad del suelo en Córdoba mediante el indice estandarizado de precipitación. *Revista Argentina de Agrometeorología* (RADA) **2**(2): 187-192. (Spanish)

Eakin, H. 2003. The Social Vulnerability of Irrigated Vegetable Farming Households in Central Puebla. Journal of Environment & Development, 12(4): 414-429.

Rivarola, A, R., Seiler, y M. Vinocur. 2003/2004. Vulnerabilidad y adaptación de los productores agropecuarios al cambio y a la variabilidad climática: el uso de la información agrometeorológica. Revista Reflexiones Geograficas 11: 109-120. (Spanish)

Eakin, H. and M.C. Lemos. 2006. Adaptation and the state: Latin America and the challenge of capacity-building under globalization. Global Environmental Change 16:7-18

- **Book Chapters**

Cecilia Conde and Hallie Eakin. 2003. Adaptation to Climatic Variability and Change in Tlaxcala, Mexico. 2003. Chapter in: *Climate Change, Adaptive Capacity and Development*, J. Smith, R. Klein, S-Huq. (editors). Imperial College Press, London. 241-259.

Gay, C., F. Estrada, C. Conde, H. Eakin. 2004. Impactos Potenciales del Cambio Climático en la Agricultura: Escenarios de Producción de Café para el 2050 en Veracruz, México. *El Clima, entre el Mar y la Montaña.* García Cordón et al (editores). 651-660.

Cecilia Conde, Kate Lonsdale. 2005. Engaging Stakeholders in the Adaptation Process. Technical Paper No.2. Adaptation Policy Frameworks for Climate Change: Developing Strategies, Policies and Measure. Lim et al (editor). UNDP- GEF National Communications Support Programme. Cambridge University Press. 47-66.

Conde, C., R.M. Ferrer, C. Gay, R. Araujo. 2004. Impactos del Cambio Climático en la Agricultura en México. En: *Cambio Climático: Una Visión desde México*. Martínez, J., A. Fernández (compiladores). 227-238

7.2 Other Outputs

- **Thesis**

Conde, Cecilia. 2003. Climate Change and Climate Variability. Two Study Cases in Mexico. PhD Thesis. Earth Sciences. UNAM. 222 pp. (spanish).

Utrera, Gerardo. 2004. Bioclimatic effects of climate change. Bachelor thesis completed. Universidad Veracruzana (UV). 86 pp. (spanish).

Maurutto, Cecilia. 2006. Vulnerabilidad y Cambio Climático: aspectos socio culturales de los productores agropecuarios del centro sur de la provincia de Córdoba. Master Thesis. UNRC (in review)

Rivarola, Andrea del Valle. 2006. Vulnerabilidad agroclimática a las sequías en la región sur de Córdoba. Master Thesis. UNRC (in review).

- **Reports**

  Royce, F., J.W. Jones. *Extending ISP III Findings and Methodologies: Agricultural Applications to Climate Forecast Information in Mexico and Argentina*. Final Report to the IAI. January, 9, 2003. (*collaboration between AIACC – Mexico and the University of Florida*).

- **Proceedings**

  More than 20 presentations were done in different meetings around the world by PI, Co-PI and students that participated in the project

- **AIACC Working papers**

  Wehbe, M., R. Seiler, M Vinocur, H.Eakin, C. Santos and M. Civitaresi. 2005. Social Methods for Assessing Agricultural Producers' Vulnerability to Climate Variability and Change based on the Notion of Sustainability. Working Paper N° 19

- **Bellagio Vulnerability Synthesis and Naivasha Adaptation Syntesis**

  Cecilia Conde, Hallie Eakin, Carlos Gay, Roberto Seiler, Marta Vinocur y Mónica Wehbe are co-authors of three papers accepted in the Vulnerability and Adaptation books that AIACC will be publishing in the near future.

- **Papers in review**

  Eakin, H., C. Tucker and E. Castellanos (*in review*) "Responding to the coffee crisis: A pilot study of farmers' adaptations in Mexico, Guatemala and Honduras." The Geographical Journal.

8 Policy Implications and Future Directions

On regional basis, the project results have launched future research (bachelor, master and PhD students are still developing their thesis following the methods proposed by this project). This issue has provided the basis for changes in the bachelor and postgraduate courses given in the two universities involved in Mexico (Universidad Veracruzana and Universidad Autónoma de Tamaulipas) and in the Universidad Nacional de Río Cuarto in Argentina.

Several ongoing projects will be used to continue with this project efforts. One of the projects is now being supported by the Minister of Environment (SEMARNAT) and by UNAM. The new features in that project are mainly supported in the Adaptation Policy Framework (APF, Lim, 2005). Particularly, it considers: a) the scope of the project is guided by stakeholders' needs, b) policy makers are involved and will monitor the possible achievements c) focus groups and workshops are programmed and decided with the key stakeholders, d) new methods for climate scenarios (i.e downscaling) are being developed and are part of the thesis stated above, e) all students (from climate and social areas) have to participate and present their research to key stakeholders and include that feedback in their thesis.

Two specific projects have been submitted (one approved) to be developed in Tamaulipas and Veracruz. The first one, (Sánchez, et al, 2005) will address water current and future availability in the southern region of Tamaulipas and possible adaptation measures, using climate change scenarios to project future conditions and involving the regional decision makers.

The second project (Castro et al, 2005; accepted), will be developed in the central region of Veracruz, and will focus on analysing and developing "environmental services" as a possible source of adaptation. Also, forests sources and sinks of CO2 will be studied, as part of a larger project for carbon sequestration. Finally, the results of this AIACC project will be included in the Mexican Third National Communication to the UNFCCC.

The development of the Project in Argentina helped on a regional base, to increase the conscious about the climate change and climate variability and their impacts and to create the consciousness at institutional level. The capacity building, the trained researchers and the graduate students (some of them finishing their thesis) brought the topic of climate changes, vulnerability and adaptation to the centre of the scenario making the UNRC (Universidad de Río Cuarto) a reference institution for other institutions, organizations or individuals on that matter in the region. In the School of Agronomy in the UNRC, a course on climate change, vulnerability and adaptation was incorporated in the curricula of the senior under graduated students.

A couple of new interdisciplinary research projects are being discussed and designed to be submitted for funding during the present year to continue with the lessons learned from this AIACC Project. Further studies on climate, physical and socioeconomic climatic impacts, adaptation assessments and costs will be included. Discussion have been initiated with researchers from two universities out of this Project study region but from nearby provinces to develop a network for permanent research, knowledge exchange and adaptation practises and experiences, or influence in policies on the topics of this Project. New research pathways are being undertaken through the collaboration with different stakeholders associations..

In addition the debate installed in the society through the Project outcomes resulted in an increment of the solicitudes to the government for the design of new infrastructure to deal with floods in the south of the area. New policies and regulations should be developed to face increasing environmental risks in the area; the outputs of this Project will be of technical support to develop and instrument these measures.

9 References

Aguirre Saharrea, F. (N.D.). El Café de México. 2003.

Appendini, K. (1992). Los campesinos maiceros en el contexto de la política de liberalizacion y contrareforma agraria. XVII International congress of the Latin American Studies Association, Los Angeles.

Appendini, K. (2001). De la Milpa a los Tortibonos: La Resturcturación de la Política Alimentaria en México. México, DF, Colegio de México.

ASERCA (1997). El sorgo mexicano: entre la autosuficiencia y la dependencia externa. Claridades Agropecuarias. 46: 3-13.

ASERCA (2003). Padron Nacional Cafetalero 2001: Estados Productores de Café. Mexico DF, ASERCA.

Ávila, J. A. (2001). "El mercado de los fertilizantes en México: Situación actual y perspectivas." Problemas del Desarrollo 32(127): 189-207.

Barkin, D. and B. R. DeWalt (1988). "Sorghum and the Mexican Food Crisis." Latin American Research Review 23(3): 30-59.

Bernard, H. R. (1994). Research Methods in Anthropology. Walnut Creek, CA: AltaMira Press.

Bojórquez-Tapia, L.A., L. Juárez, G. Cruz-Bello (2002). "Integrating Fuzzy Logic, Optimization and GIS for Ecological Impact Assessments." Environmental Management 30 (3): 418-433.

Bravo, J.L., C. Gay, C. Conde, F. Estrada. 2006. Probabilistic description of rains and ENSO phenomenon in a coffee farm area in Veracruz, México. Atmosfera, 19(2): 49-74.

Brelmer-Thomas, V. (1987). The Political Economy of Central America since 1920. Cambridge, Cambridge University Press.

Brklachich, M., D. McNabb, et al. (1997). Adaptability of agriculture systems to global climate change: a Renfrew County, Ontario, Canada Pilot Study. Agricultural restructuring and sustainability: a geographical perspective. B. Ilbery, Q. Chiotti and T. Rickard. Oxon and New York, CAB International: 185-200.

Castro, T., C. Conde, A. Monterroso, G. Rosales. Los Servicios Ambientales De La Subregión Central Del Estado De Veracruz Ante El Cambio Y La Variabilidad Climáticos. Posibles Propuestas De Adaptación. Proyect supported by UNAM.

Chiotti, Q., T. Johnston, et al, 1997. Agricultural response to climate change. A preliminary investigation of farm-level adaptation in South Alberta. Agricultural Restructuring and Sustainability. T. Rickard. Oxon and New York, CAB International: 201-218.

Comisión Nacional del Agua, CNA (2004). Estadísticas del Agua en México. Edición 2004. Sistema Unificado de Información Básica del Agua (SUIBA). México, D.F.

Conde, C., M. Vinocur, C. Gay, R. Seiler. 2006. Climatic Threat Spaces as a Tool to Assess Current and Future Climatic Risk in Mexico and Argentina. Two Case Studies. Vulnerability to Climate Change in the Developing World. AIACC Working Paper No. 30. http://www.aiaccproject.org/working_papers/working_papers.html.

Conde, C., R. Ferrer, C. Gay, V. Magaña, J.L: Pérez, T. Morales, S. Orozco. 1999. "El Niño y la Agricultura". In: Los Impactos de El Niño en México. Víctor Magaña. México (editor). 103 - 135.

Conde, C., D. Liverman, M. Flores, R. Ferrer, R. Araujo, E. Betancourt, G. Villarreal, C.Gay. 1997. Vulnerability of rainfed maize crops in Mexico to climate change. Climate Research. 9: 17 - 23.

Cornelius, W., & Myhre, D. (Eds.). (1998). The Transformation of Rural Mexico: Reforming the ejido sector. San Diego: Center for U.S. - Mexico Studies.

De La Casa, A., and R. A. Seiler. 2003. Respuesta de la aptitud ganadera a la variabilidad climática en la provincia de Córdoba. Rev. Arg. Prod.Animal, 23 (3-4): 187-200.

de Janvry, A. and E. Sadoulet (1993). "Market, State, and Civil Organizations in Latin America Beyond the Debt Crisis: The Context for Rural Development." World Development 21(4): 659-674.

De La Casa, A., and R. A. Seiler. 2003. Respuesta de la aptitud ganadera a la variabilidad climática en la provincia de Córdoba. Rev. Arg. Prod.Animal, 23 (3-4): 187-200

Ellis, F. (2000). Rural Livelihoods and Diversity in Developing Countries. Oxford: Oxford University Press.

FAO. 1998. Crop and Water Assessment Tool, CROPWAT. User's Guide. Land and Water Development Division. Food and Agriculture Organization of the United Nations (FAO). Rome, Italy.

Foley, M. (1995). "Privatizing the countryside: The Mexican peasant movement and neoliberal reform." Latin American Research Review 22(1): 59-76.

Fox, J. (1995). "Governance and rural development in Mexico: State intervention and public accountability." The Journal of Development Studies 32(1): 1-30.

Fox Quesada, V. (2004). Cuarto Informe del Gobierno. Mexico, D.F., Presidencia de la Republica.

Gates, M. (1989). "Codifying marginality: The evolution of Mexican agricultural policy and its impact on the peasantry." Journal of Latin American studies 20: 277-311.

Gay, C., F., Estrada, C. Conde, H. Eakin, L. Villers. 2006. Potential impacts of climate change on agriculture: A case of study of coffee production in Veracruz, Mexico. Climate Change (in press).

Gay, C. et al. (Mexico Country Studies Project Team). 1995a. Mexico: emissions inventory, mitigation scenarios, and vulnerability and adaptation. In C. Ramos-Mane, R. Benioff (ed.) Interim Report on Climate Change Country Studies, ed. US Country Studies Program. Available at http:// www. gcrio.org/CSP/IR/IRmexico.html.

Gay, C, L.G. Ruiz, M. Imaz, C. Conde, B. Mar. (eds.). 1996. Memorias del Segundo Taller de "Estudio de País: México". México Ante el Cambio Climático. Cuernavaca, Morelos 8 a 11 mayo, 1995.

Gerencia Regional Golfo Norte, GRGN-CNA (2004). Padrón de Usuarios de Aguas Subterráneas en la Cuenca del Río Guayalejo-Tamesí. Reporte Interno. Cd. Victoria, Tamaulipas.

Haces, Miguel A. (1999). Balance Hídrico en la Conurbación Tampico-Madero-Altamira: Bases para Determinar la Necesidad de Depuración de Aguas Residuales. Tesina. UAT. Mayo 1999. Tampico, Tamaulipas.

Hayes, M., Svoboda, M. and d. A. Wilhite, 2000. Monitoring Drought using the Standardized Precipitation Index. In D.A. Wilhite (ed.), Drought - Volume I– A global Assessment. Routeledge Hazards and Disasters Series. Routledge, Taylor & Franciss Group- London and New York, pp. 168-180.

Hernández Laos, E. and J. Velásquez Roa (2003). Globalización, desigualdad y pobreza: Lecciones de la experiencia mexicana. México D.F., Universidad Autónoma Metropolitana.

Hoffman, O., C. Blanc-Pamard, et al. (1987). Paisaje y Sociedad en un Ejido Veracruzano (Xico). Xalapa, Ver., Instituto Nacional de Invetigaciones Sobre Recursos Bioticos.

Hulme, M., Wigley, T.M.L., Barrow, E.M., Raper, S.C.B., Centella, A., Smith, S.J. and Chipanshi, A.C., 2000: *Using a Climate Scenario Generator for Vulnerability and Adaptation Assessments: MAGICC and SCENGEN Version 2.4 Workbook*. Climatic Research Unit, Norwich UK, 52 pp.

Hulme, M. and O. Brown. 1998. Portraying climate scenario uncertainties in relation to tolerable regional climate change. *Clim. Res*. 10:1–14.

INEGI (2000). XII Censo General de Población y Vivienda, 2000. Aguascalientes, INEGI.

IPCC, WGII (Intergovernanmental Panel on Climate Change Working Group II). 2001a. Climate Change 2001: Impacts, Adaptation and Vulnerability. J. J. McCarthy, O. F. Canziani, N. A. Leary, F. J. Dokken, K.S. White (eds.). Cambridge University Press. 1032 pp.

IPCC, WGI (Intergovernanmental Panel on Climate Change, Working Group I). 2001b. Summary for Policy Makers. A Report of Working Group I of the Intergovernmental Panel of Climate Change. Cambridge University Press. 20 pp.

IPCC. 2000. Escenarios de Emisiones. *Resumen para Responsables de Políticas. Informe Especial del Grupo de Trabajo III del IPCC*. Publicado por el IPCC, 27 págs. Available in: http://www.ipcc.ch/pub/sres-s.pdf

IPCC. 2001. Climate change 2001, The scientific basis. Houghton, et al., Eds., Cambridge University Press. Cambridge, United Kingdom. 881 pp.

Kane, R.P., 1999: Rainfall extremes in some selected parts of central and south America: ENSO and other relationships re-examined. *Int.J.Climatol*., 19, 423-455

Krippner, G. (1997). "The Politics of Privatization in Rural Mexico." Politics and Society **25**(1): 4 - 34.

La Red. Social Studies Network for Disaster Prevention in Latin America. Accessed 20/11/04 at http://www.desinventar.org/desinventar.html

Lucero, A. O. and N. Rodriguez. 1999. Relationship between interdecadal fluctuations in annual rainfall amount and annual rainfall trend in a southern mid-latitudes region of Argentina. Atmospheric Res. 52: 177-193.

Liverman, D. (1990). "Drought impacts in Mexico: Climate, agriculture, technology and land tenure in Sonora and Puebla." Annals of the Association of American Geographers 80: 49-72.

Magaña, V., C. Conde, O. Sánchez, C. Gay. 1997. Assessment of current and future regional climate scenarios. Climate Research. 9: 107 - 114.

Magaña, V. (editor). 1999. Los Impactos de El Niño en México .México. UNAM, IAI; SG. 228 pp. http://ccaunam.atmosfcu.unam.mx/cambio/nino.htm.

Masera, O., López-Ridaura (eds). 2000. Sustentabilidad y Sistemas Campesinos. Cinco Experiencias de Evaluación en el México Rural. México. D.F.

Martínez Morales, A. C. (1997). El Proceso Cafetalero Mexicano. Ciudad de México, Universidad Nacional Autónoma de México.

Messina, C.D., J.W. Hansen, and A.J. Hall, 1999: Land allocation conditioned on El Niño –Southern Oscillation phases in the Pampas of Argentina. Agric. Sys., 60, 197-212

McKee, T. B., Doesken, N. J. and J. Kleist, 1993. The relationship of drought frequency and duration to time scales. Proceedings of the Eighth Conference on Applied Climatology. Boston, MA: American Meteorological Society.

Nakicenovic, N., J. Alcamo, G. Davis, B.de Vries, J. Fenhann, S. Gaffin, K. Gregory, A. Grübler, T.Y. Jung, T. Ktram, E.L. La Rovere, L. Michaelis, S. Mori, T. Morita, W. Pepper, H. Pitcher, L. Price, K. Raihi, A. Roehrl, H. Rogner, A. Sankovski, M. Schlesinger, P. Shukla, S. Smith, R. Swart, S. van Rooijen, N. Victor, and Z. Dadi. 2000. Emissions Scenarios. A Special Report of Working Group III of the IPCC. Cambridge University Press, Cambridge, UK and New York,

Nestel, D. (1995). "Coffee in Mexico: international market, agricultural landscape and ecology." Ecological Economics **15**: 165-178.

Nakicenovic, N., J. Alcamo, G. Davis, B.de Vries, J. Fenhann, S. Gaffin, K. Gregory, A. Grübler, T.Y. Jung, T. Ktram, E.L. La Rovere, L. Michaelis, S. Mori, T. Morita, W. Pepper, H. Pitcher, L. Price, K. Raihi, A. Roehrl, H. Rogner, A. Sankovski, M. Schlesinger, P. Shukla, S. Smith, R. Swart, S. van Rooijen, N. Victor, and Z. Dadi. 2000. *Emissions Scenarios. A Special Report of Working Group III of the IPCC.* Cambridge University Press, Cambridge, UK and New York, USA, 599 pp.

NOAA (Nacional Oceanic and Atmospheric Administration), 1997: Climate conditions associated with the 1997-1998 El Niño: Impact and outlook. Special climate summary 97/3, 13 Nov. Washington, DC.

Nolasco, M. (1985). Café y Sociedad en México. México, D.F., Centro de Ecodesarrollo.

O'Brian, K.L., R.M. Leichenko. 2000. Double Exposure: assessing the impacts of climate change within the context of economic globalization. Global Environ. Change. Elsevier Science. 10: 221- 232.

OECD (1997). Review of Agricultural Polices in Mexico. Paris, OECD.

Palma, B- 2005. Generación de Escenarios de Cambio Climático para la Zona Centro del Estado de Veracruz. México. Tesis para obtener el grado de Maestría en Geografía. UNAM. 134 pp.

Parry, M. 2002. Scenarios for climate impacts and adaptation assessment. *Global Envirnon. Change*. 12:149–153.

Pascale, A. J. y E. A. Damario. 1988. Características Agroclimáticas de la Región Pampeana, Revista Facultad de Agronomía-UBA, 9**,** 1- 2, 41-64

Podestá, G.P., C.D. Messina, M.O.Grondona, and G.O. Magrin, 1999: Associations between grain crop yields in central-eastern Argentina and El Niño-Southern Oscillations. *J. Appl. Meteorol*., 38, 1488-1498

Ponte, S. (2002). "The 'Latte Revolution'? Regulation, markets and consumption in the global coffee chain." World Development **30**(7): 1099-1122.

Ravelo, A. C. y R. A. Seiler. 1978/79. Agroclima de la provincia de Córdoba: Expectativa de precipitación en el curso del año. Rev. de Inv. Agrop. (RIA), INTA. XIV (3):15-36.

Ravelo, A. C., R. O. Irastorza y L. E. Luque. 2002. Variabilidad de la tendencia en series pluviométricas de la provincia de Córdoba (Argentina). Rev. Arg. de Agrometeorología, 2(1): 69-74.

Rivarola, A.del V., M.G. Vinocur, y R.A.Seiler. 2002/03. Uso y demanda de información agrometeorológica en el sector agropecuario del centro de Argentina. Revista Argentina de Agrometeorología (RADA), 2 (2): 143-149.

Rivarola, A. del V., R. Seiler y M. Vinocur**.** 2004. Vulnerabilidad agroclimática a las sequías en el sur de la provincia de Córdoba. X Reunión Argentina y IV Reunión Latinoamericana de Agrometeorología**,** 13-15 de Octubre de 2004, Mar del Plata, Argentina. CD.

Ropelewski, C.F., and M.S. Halpert, 1989: Precipitation patterns associated with the high index phase of the Southern Oscillation. *J.Climate*, 2, 268-284

Ropelewski, C.F., and M.S. Halpert, 1996: Quantifying Southern Oscillation-precipitation relationships. *J.Climate*, 9,1043-1059

Santoyo Cortés, V. H., S. Díaz Cárdenas, et al. (1996). Sistema Agroindustrial Café en México. Chapingo, CIESTAAM.

Saaty, T.L. (1980) The Analytical Hierarchy Process. New York, McGraw Hill.

Sánchez, G., R. Vargas, C. Conde. Case Study: Municipality of Gonzalez, Tamaulipas, Mexico. Final AIACC report.

Sánchez, G., M.A. Medina, C. Conde. 2005b. Submitted to CONACY – SEMARNAT.

Scoones, I. (1998). Sustainable Rural Livelihoods: A Framework for Analysis. IDS Working Paper.

Seiler, R. A., Fabricius, R., Rotondo, V. y M. Vinocur., 1995. Agroclimatología de Río Cuarto-1974/93, Vol. I. UNRC. 68 pgs.

Seiler, R. A. and F. Kogan. 2002. Monitoring ENSO cycles and their impacts on crops in Argentina from NOAA-AVHRR satellite data. Adv. in Space Res. 30 (11) : 2489-2493.

Seiler, R. A. y L. Bressan. 2002/03. Evaluación y seguimiento de las condiciones de humedad del suelo en Córdoba mediante el indice estandarizado de precipitación. Rev. Arg. de Agrometeorología, 2 (2): 187-192.

Seiler, R. A., M. Hayes and L. Bressan. 2002. Using the standardized precipitation index for flood risk monitoring. Int. Journal of Climatology, 22: 1365-1376.

Seiler, R. A. Y M. G. Vinocur. 2004. ENSO events, rainfall variability and the potential of SOI for the seasonal precipitation predictions in the south of Cordoba-Argentina. 14th Conference on Applied Climatology. Americal Meteorological Society, 84th Annual Meeting, 11-15 Jan, 2004. Seatle, WA. (JP1.10 extended abstract). http://ams.confex.com/ams/pdfpapers/71002.pdf

Seiler, R.A., and M.G. Vinocur. 2004. Climate changes during the last century in the south of Córdoba, Argentina. Scientific Report of PICTO project. Unpublished.

Satyamurty, P., C. Nobre and P. L. Silva Dias. 1998. South América. In Meteorology of the Southern Hemisphere, D. Karoly and D. G. Vincent (Eds.). Am. Met. Society. 410 pp.

Smit, B., M.W., Skinner. 2002. Adaptation options in agriculture to climate change. A typology. Mitigation and Adaptation Strategies for Global Change. 7: 85-114.

Stockholm Environment Institute-Boston (2001). WEAP: Water Evaluation And Planning System. User Guide for WEAP21. SEI-Boston, Tellus Institute, Boston, MA.

Spoor, M. (2000). Two decades of adjustment and agricultural development in Latin America and the Caribbean, CEPAL: 30.

Thorpe, A. (1997). Structural adjustment and the agrarian sector in Latin America. The 'Market Panacea': Agrarian Transformation in Developing Countries and Former Socialist Economies. M. Spoor. London, Intermediate Technology Publications.

Tanco, R., and G. Berri, 1996: Acerca del fenómeno El Niño sobre la precipitación en la Pampa húmeda Argentina. 319-320. Proc.VII Congreso Argentino y VII Congreso Latinoamericano e Ibérico de Meteorología, 2-6 Sept., 1996, Buenos Aires, Argentina

Trenberth, K. E., A. Dai, R. M. Rasmussen and D. B. Parsons, 2003. The changing character of precipitation. BAMS, 84 (9): 1205-1217.

Yarrington Ruvalcaba, T. (2004). V Informe de Gobierno 1999-2004 Tamaulipas. Ciudad Victoria: Gobierno del Estado de Tamaulipas.

Yates, P. L. (1981). Mexico's agricultural dilemma. Tucson, The University of Arizona Press.

Velasco, I. and J. M. Fritsch, 1987. Mesoscale convective complexes in the Americas. J. Geophys. Res., 92:9591-9613.

Vinocur, M.G.,R. A. Seiler, y L.O. Mearns. 2000a. Forecasting the impact of climate variability on peanut crop production in Argentina. International Forum on Climate Prediction, Agriculture and Development, Palisades, New York, USA. 26 al 29 de Abril de 2000. Pag.: 189-195. International Research Institute for Climate Prediction (IRI) Publications IRI-CW/00/1. ISBN 0-9705907-0-9

Vinocur, M.G.,R. A. Seiler, y L.O. Mearns 2000b. Predicting maize yield responses to climate variability in Córdoba, Argentina. Abstracts International Scientific Meeting on Detection and Modelling of Recent Climate Change and its Effects on a Regional Scale, Tarragona, Spain. May 29-31, 2000. Pág. 137.

Vinocur, M.G.,R. A. Seiler, y L.O. Mearns. 2000c. A simulation study of maize crop responses to climate variability in Córdoba, Argentina. Annual Meetings Abstracts, ASA, CSSA y SSSA, November 5-9, 2000 Minneapolis, Minnesota. Pag. 27.

Vinocur, M.G.,R. A. Seiler, y L.O. Mearns. 2001. Respuestas del cultivo de maní a distintos escenarios climáticos. Revista Argentina de Agrometeorología (RADA), 1 (2): 71-76. ISSN 1666-017X

Vinocur, M.G, A. Rivarola y R. A. Seiler. 2001. Current status and future uses of the climate information in the agricultural system of central Argentina. 2001 Open Meeting of the Human Dimensions of Global Environmental Change Research Community, Río de Janeiro, Brasil, 6-8 de Octubre de 2001. Available in: http://sedac.ciesin.columbia.edu /openmeeting/ downloads.html.

Wilhite, D. A., 1993. The Enigma of Drought, in D. A. Whilhite (ed.), Drought Assessment, Management and Planning: Theory and Case Studies, Boston, MA: Kluwer Academic Publishers, pp. 3-15

Wilhite D A, Hayes M. J. 1998. Drought Planning in the United States: Status and Future Directions. In: The Arid Frontier, H. J. Bruins and H. Lithwick, eds., Kluwer Academic Publishers Group.

Wigley, T.M.L. and Raper, S.C.B., 2001: Interpretation of high projections for global-mean warming. Science 293, 451–454.

Wigley, T.M.L. and Raper, S.C.B., 2002: Reasons for larger warming projections in the IPCC Third Assessment Report. Journal of Climate 15, 2945–2952.

Wilks, D. 1995. Statistical methods in atmospheric sciences. An introduction. International Geophysics Series. Vol. 59. San Diego, CA: Academic Press, pp. 21–27.

WMO (World Meteorological Organization), 1995: The global climate system review: Climate system monitoring, June 1991-November 1993. WMO No. 819-150.

Ziervogel, G., A. Nyong, B. Osman, C. Conde, S. Cortés and T. Downing. 2005. Climate Variability and Change Implications for Household Food Security. Vulnerability to Climate Change in the Developing World. (accepted)

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