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Fighting climate change:
Human solidarity in a divided world

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I. Background

In context of climate change, the Fourth Assessment Report of Working Group II of the Intergovernmental Panel on Climate Change (IPCC, WGII, 2007) stated that "increases in the frequency of droughts and floods are projected to affect local production negatively, especially in subsistence sectors at low latitudes". Particularly, the IPCC projected –with high confidence- a decreasing productivity of some important crops in Latin American, as well as livestock production to decline, given the salinisation and desertification of agricultural land, which will lead to "adverse consequences for food security". Also, changes in precipitation patterns and important decreases in glaciers are projected to significantly affect water availability for human basic needs, including agriculture and energy generation. Even though some countries have made major efforts to adapt, "the effectiveness of these efforts is outweighed by: lack of basic information, observation and monitoring systems; lack of capacity building and appropriate political, institutional and technological frameworks; low income; and settlements in vulnerable areas, among others." (IPCC, WGII, 2007).

Several studies performed by the Economic Commission for Latin America and the Caribbean (ECLAC, 2003)[1] show that floods, landslides, hurricanes and droughts are the major hydrometeorological threats in the region. Even the number of human deaths caused by those events have decreased, the number of affected population increased dramatically. Other studies (Zapata, 2006) show that the cost of those disasters have sum around 250 billion usd for the period 1972 to 2005, and are estimated to be near 50 billion usd from 2000 to 2010. These figures show that it is urgent to "adopt, as part of the development policies and to achieve the millennium goals, those measures that mitigate the vulnerability to increasing and multiple threats" (Zapata, 2006).

Living conditions and livelihoods opportunities for million of people will be in danger in Latin America (Stern, 2006). Some scenarios under climate change conditions project that maize production by 2055 will drop by around 15% on average (Stern, 2006). This possibility will endanger the subsistence and food security of the majority of the rural population in the region.

Considering agricultural activities –which be the basic issue in this paper -, it is then highly probable that the crops yields will diminish significantly in climate change conditions for most of the countries in Latin America, and probably pests will expand their territory and soil degradation processes will continue to increase.

Latin America is highly diverse, considering not only its climatic conditions –which allow a huge biodiversity –, but also considering the socio-economic and cultural characteristics.

[1] Turn to: http://www.eclac.cl/

Regardless of that fact, the majority of their inhabitants have the consciousness of belonging to a shared region. Regarding its highly political, institutional and technological diversity, it will be quite difficult to embrace all the recent efforts to address the recent research done in all the Latin American countries related to vulnerability and adaptation of agricultural activities to climate variability and change. In addition, recent studies have shown that similar extreme climatic events do not render similar impacts even in the same study sites. This paper, thus, focuses on the different new approaches that have been developed at household and community level in regions in, basically, Mexico and Argentina. Several case studies developed at household level are then presented to illustrate what other factors or stressors might enhance climate risks or, on the contrary, can increase adaptive capacity to climate variability and change. Along with natural hazard exposure, the role of agricultural weakness and capacity building is discussed in order to obtain a picture of potential effects that extreme climate events can trigger if they continue to increase frequency and severity. This paper highlights the impacts of climate extremes on emigration, impoverishment and food security, and warns about those cases exceeding both private and public capacity to respond.

Study cases presented along this paper possesses three key elements: a) they have been conducted by an interdisciplinary research team; b) stakeholders involvement to define climatic threats and elements defining current adaptive capacity and vulnerability; and c) adaptation to current and future climate as the main concept and target of the projects.

In order to illustrate how social vulnerability to climate variability and change can be address and how adaptive capacity could be enhanced, this paper bases on a comparative study between two study cases developed in Mexico and Argentina: *Integrated Assessment of Social Vulnerability and Adaptation to Climate Variability and Change Among Farmers in Mexico and Argentina.* The production systems analyzed are small-scale export-oriented (Veracruz, Mexico and Córdoba, Argentina) and large-scale highly diversified (Tamaulipas, Mexico and Córdoba, Argentina). This project is one of the twenty four AIACC projects (Assessments of Impacts and Adaptations to Climate Change[2]). These projects are part of a global initiative developed in collaboration with the IPCC and funded by the Global Environment Facility to advance scientific understanding of climate change vulnerabilities and adaptation options in developing countries. In Latin America, five AIACC projects were developed, that included regional studies in Central America (Guatemala, Belize, Honduras, Nicaragua, El Salvador, Costa Rica and Panama), Argentina, Uruguay and Mexico.

Another interesting initiative is the project: *Capacity Building for Stage II Adaptation to Climate Change in Central America, Mexico and Cuba*, where eight Latin American countries (Guatemala, El Salvador, Costa Rica, Panamá, Honduras, Nicaragua, México and Cuba) were involved and was supported by the United Nations Development Program (UNDP). Mexico developed its research considering the agriculture, forest ecosystems as well as water resources in the state of Tlaxcala. For the agricultural study, the farmers' involvement in the project made it possible to launch several adaptive measures to climate variability and change in Mexico.

[2] www.aiaccproject.gov

Finally, the vulnerability assessment in Chiapas here included was carried out by one of the authors in different communities by relating the disasters caused by climatic extreme events and their impact in economic losses and increase in poverty. That project is part of the *Advanced Institute of Vulnerability to Global Environmental Change*, sponsored by START in partnership with the International Institute fro Applied Systems Analysis (IIASA) and the International Human Dimensions Program (IHDP).

In these study cases, the research focuses on farmers' strategies to adapt not only to climatic events, but also to economical trends toward "privatization and decentralization of agricultural and water institutions, new price regimes for inputs, products and services and increased resource competition", and "how policy can better address climatic risk to facilitate adaptation" (Gay et al, 2006a, Wehbe et al, 2005, Eakin, et al, 2006). In the Tlaxcalan case study, it was possible to develop explicit support to several adaptation option chosen by farmers that participated in the project (Conde et al, 2006a), so that experience is described here in depth. In all of those studies, the lack of access to resources (or inequity) will be addressed as a major factor that increases vulnerability to climate variability and change.

II. Recent Extreme climatic events in Mexico and Argentina.

Droughts, floods, heat waves, frosts, hail and other climate extreme events have significantly affected agricultural activities in human history. The limited capacity to forecast those events, to communicate "useful" forecasts, but also to cope with them, determines not only the agricultural output, but, most important, the farmers' livelihoods and, in developing countries, even put at risk their food security.

However, important losses have occurred even when climate conditions have been favorable, or similar climatic events have caused very different impacts, suggesting that other stressors are also determinant in the agricultural activities (O'Brian and Leichenko, 2000). Defining and determining the weight of those stressors can support the strategies to increase adaptive capacity and to reduce vulnerability to climate variability and change.

One of the main issues increasing vulnerability to extreme climate events in Latin America is the acute poverty. By 2005 (CEPAL, 2006), 28.9% of its population (209 million people) lived in poverty conditions, and 15.4% (81 million) where extremely poor.

Though being poor does not necessarily imply being vulnerable, but poverty makes individuals relatively more vulnerable to a given hazard. People worldwide living in adverse economic conditions is less able to invest in all items, including those to manage risk and increase disasters protection. Developing countries have historically been more severely damaged compared to developed countries (Benson and Clay 2000). On the one hand, total economic losses tend to be higher in rich countries in absolute terms, but compared to economy value, losses are much higher in developing countries (Saldaña 2006a). A given natural hazard with identical intensity can hit in different degree two distinct countries. Differences in civil protection system, health facilities and public financial ability (i.e. for reconstruction) make countries to absorb hazards differently. As Cannon (1994) points out, what turns a natural hazard into a disaster is not simply a question of money, but also of economic and political system. The way countries structure societies determine that a similar hazard lead to very different impacts among societies.

In Latin America, El Niño/Southern Oscillation (ENSO) is the most important source of climate variability and has caused the largest economic and social impacts. Strong ENSO events have modified climate conditions and impacted severely, mostly, the rainfed agriculture. In the case of Mexico, changes in rainfall patterns are observed during the strong El Niño events (1982-183, 1997-1998) and, for instance, during the strong 1988 – 1999 La Niña event. Almost in all the Mexican territory severe summer droughts have affected the agricultural activities during strong El Niño events (Magaña *et al*, 1999, Conde et al, 1999), leading, for example, to an economic loss of almost 1.5 billion USD during the 1997-1998 event. In Argentina, El Niño events are associated with enhanced likelihood of higher than the median precipitation anomalies during October-February along the main agricultural area, while lower than the normal precipitation during the same period was typical of cold ENSO events (Messina, *et al*. 1999; Ropelewski and Halpert, 1989).

In the study case of Argentina, farmers identified floods, droughts, and hailstorms as the most important events affecting their activities, of which floods caused comparatively more damages (Riverola et al, 2002; Seiler et al, 2002; Seiler and Vinocur, 2004). For example, five of the ten wettest years since 1980 occurred during El Niño years in Córdoba, and also severe droughts were recorded in 1988-1989 (La Niña year) and important losses in maize yields occurred during 1986-1987 (El Niño year).

During the last 25 years three mayor flood episodes have occurred in the study region in Argentina. It has brought clear production drops as well as remaining socioeconomic damages lasting for years in the affected areas. The flooding area corresponds to the poorly drained plains in the south of the region.

In addition to natural climate variability, in the south of Cordoba (Argentina) it is perceived increase variability possibly 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 (Gay et al, 2006. AIACC final report).

Droughts and floods have been documented in the Mexican history (La Red, 2004) as the source of serious losses in different sectors, particularly among poor regions. They have affected livelihoods and even caused a number of human fatalities. Veracruz, Chiapas and Tamaulipas have been three of the most affected states from extreme events since 1970 (Briones, 2006; Saldaña, 2006; see box 1).

Box 1. Disasters and Economic Losses in Mexico.

Over the past three decades, "natural" disasters in Mexico have increased both frequency and economic cost (see chart below). However, most damages have been due to weather-related (hydro-meteorological) disasters, responsible for nearly 80% of economic losses over the period 1980-2005 (see Table 1). It has led to particularly stress rural livelihoods as the most affected economic sector tends to be the agriculture.

Macroeconomic analyses tend to ignore crucial impacts of natural disasters on the economy. Though the agricultural sector in Mexico is small sector in GDP terms (4%, compared to 68% from services, 28% from industry –INEGI 2007), but this sector employs over 20% of Mexican population, and constitutes the livelihood to 68% of the population living in extreme and moderate poverty in rural areas (WB 2002). Moreover, the Mexican agriculture is highly vulnerable to droughts given current high levels of rainfed agriculture, which exceeds 80% of cultivated area.

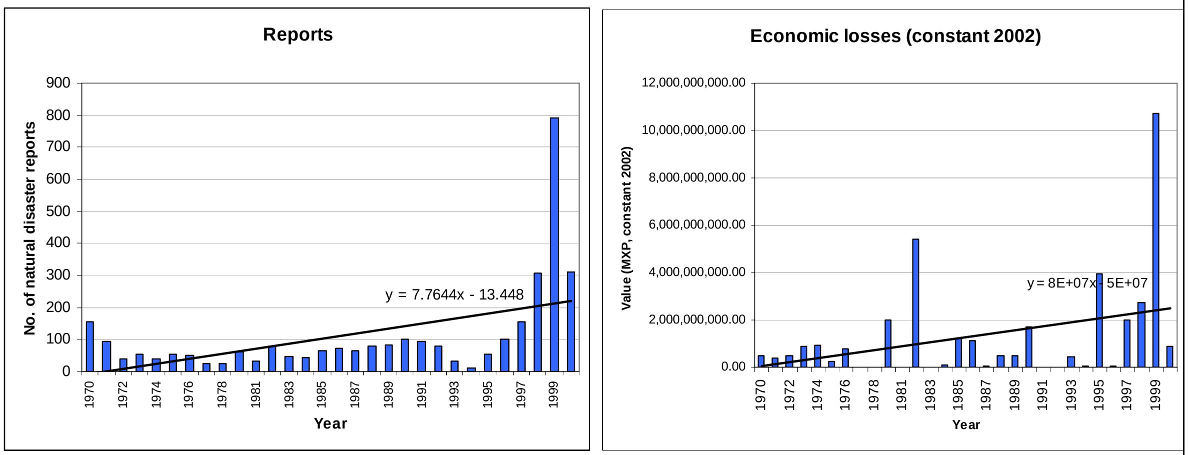


Figure 1. Frequency and economic losses from natural disasters in Mexico (1970-2000)
Data source: La Red (2003), SEGOB (2003) and CENAPRED (2002)

The 82 major weather-related events that have struck between 1980 and 2002 have damaged mostly agriculture disrupting rural incomes. Every time a hurricane strikes, at least 70% of total damages are located in agriculture (Saldaña 2006). Thanks to reports from La Red (2004), we know that natural disasters affectation in agriculture over the past 35 years has affected mostly assets of poor and extreme poor farmers in the South of the country.

Table 1: Losses from disasters in Mexico 1980-2005 (Losses in current USD mill)

Disaster type	Direct losses	Indirect losses	Total losses	As % of total
Weather	21,887	145	22,032	79
Geologic	4,044	517	4,561	16
Human	1,150	134	1,284	5
Total	27,081	796	27,877	100

With data from Guy Carpenter (2006), SEGOB (2003) and CENAPRED (2001)

To assess the relative importance of climatic events, even on non ENSO years, in Mexico and in Argentina, a method based on “climatic threat spaces” has been applied (Conde, 2003; Conde et al, 2006b). This tool was used to determine which climatic variables have played major role when important agricultural losses have occurred, but also, to visualize in which years other stressors should be considered as more important than climatic conditions. These climatic threat spaces were also applied to the study case in Tlaxcala, where proved being useful as well.

Climatic threat spaces 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). However, the focus for climatic threat spaces is on current climate anomalies, which make use of a standard deviation or the interquartile range of the two variables to decide which years could be classified as normal and which as critical. This tool is then used to assess the historical interactions between society and climate hazards (Jones and Boer, 2005).

The one standard deviation criterion (Gay et al., 2004) is currently used by the Mexican Ministry of Agriculture to provide economic support to farmers affected by extreme climatic events (*contingencias climatológicas*). On the other hand, 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" (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 that distribution (25% in each tail) in which extreme values occur.

The quartile range for the climatic variables is considered as a first approximation for the limits of the coping range for agricultural activities. Optimal conditions for a specific crop can be described in the threat space to help determine whether the region provides optimal or near-optimal conditions or whether the climatic circumstances represent an important threat for that particular production. The coping range's boundaries, which were defined initially in terms of statistical measures, could then be redefined in terms of the climatic requirements for the specific crop, that determine hypothetical critical thresholds for the crop under study. Beyond the coping range, "the damages or losses are no longer tolerable and an identifiable group is said to be vulnerable" (Jones and Boer, 2005).

This tool has been used in the AIACC project and the study in Tlaxcala to integrate the interdisciplinary team and to discuss with key stakeholders the climatic events that have severely impacted the agricultural production. So, does the visualization tool of critical years help to know who got affected? What capacity they had to react to those conditions? To answer these questions, focus groups, in-depth interviews with regional experts, and newspaper articles (La Red, 2003) were used.

An important share of this research's data relies on *DesInventar*. *DesInventar,* developed by La Red (2004), is a conceptual and methodological development about disasters of any magnitude and about local, regional and national surrounding diversity". It facilitates the analysis and representation in space and time of hazards, vulnerabilities and risks in a retrospective and prospective way, for applications in risk management". These inventories are available for 17 Latin American Countries.

Box 2. Example of Climatic Threat Spaces to assess possible adverse climatic events.

Agriculture is an important economic activity in the state of Veracruz, Mexico, generating 7.9% of the state's gross domestic product (GDP) and providing jobs to 31.7% of the state's labor force (Gay et al., 2006b). Veracruz is the second largest coffee producer in the country. 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.

The region under study is situated in the central region of the state, with high altitudes where coffee production can be developed in almost optimal conditions, and it contributes about 90% of the total production of coffee in the state.

The temperature and precipitation anomalies, shown in figures 2, are related to the possible climatic risks for coffee production. Statistical analysis (Gay et al, 2006b) showed that temperature is the most relevant climatic factor, followed by spring precipitation.

Critical years for coffee production were detected during focus groups, regional experts' judgment and by newspaper articles (La Red, 2004). For instance, in 1983 and 1998, severe droughts led to loosing almost 20% of the coffee production. An interesting feature in figures 2 is that the lowest minimum temperature values were found in the 1960s and 1970s, while the highest values in the 1980s and 1990s.

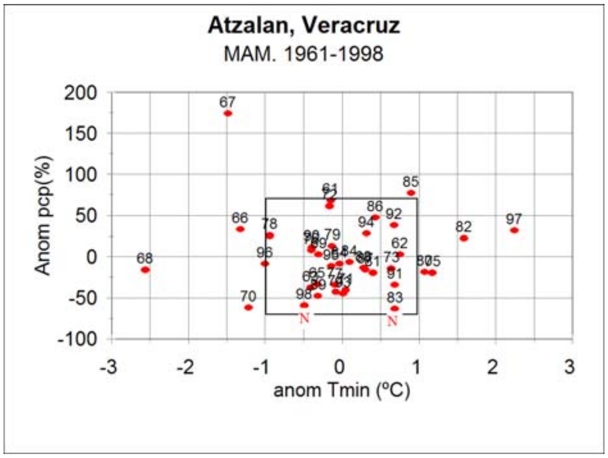


Figure 2a. Threat space for Atzalan, Veracruz in spring (MAM). Dots relate anomalies for minimum temperature (Tmin ºC) and precipitation (%), labeled with the last two digits of the year they occurred. The rectangle represents the quartile range (1961–1990) for those variables in this season. **N** represents strong El Niño years. Years with greater anomalies lie outside the rectangle.

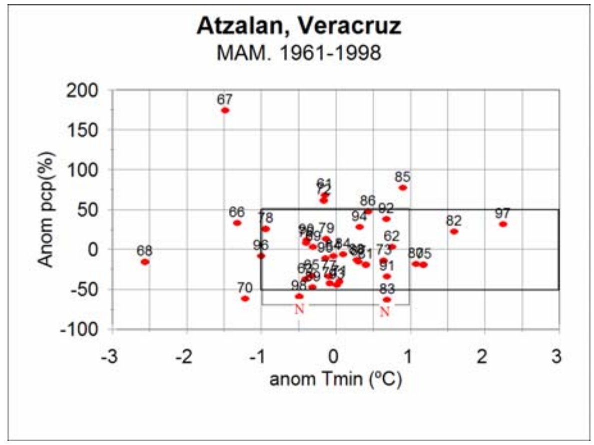


Figure 2b. Climatic threat space for coffee during spring (MAM) in Atzalan Veracruz, considering the minimum temperature and precipitation requirements of the coffee plant. The square box represents the initial coping range proposed. Climatic anomalies outside the rectangle are considered to be risky for coffee production.

III. Sensitivity and Adaptive Capacity.

Coping capacity can be defined as the ability of a unit to respond to a harm occurrence as well as to avoid its potential affectation, whereas adaptive capacity is the ability of a unit to gradually transform its structure, functioning or organization to survive under hazards threatening its existence (Kelly and Adger 2000). After persistent or major natural disasters, coping and adaptive capacity of the most vulnerable economic units is taken to the limit, as discussed for the cases of Mexico and Argentina along this section.

At national level, governments have developed several policies to aid farmers to cope with climate extreme events. In Mexico, the federal government has very developed and varied public instruments to reduce disaster risk. For instance, subsidy to crop insurance premia is available by means of several instruments. *Fondos*, for example, are mutual arrangements of farmers to manage self-insurance, where the government acts as insurer of last resort; rebuilding of public assets is possible by the federal fund FONDEN; mitigation works can be undertaken by the federal-state shared fund FOPREDEN; and FAPRACC is a fund designed for rebuilding, mitigation and insurance to the poorest farmers. Nevertheless, where are failing these instruments?

Subsidies to crop insurance *premia* have only been relevant to farmers in 10% of Mexico's cultivated area during the 90s, whereas during the 80s the subsidy reached 40% of the area.

From its part, FAPRACC offers catastrophic insurance to subsistence farmers, but few state governments have contracted it so far, concentrating its expenditure in aid for reconstruction to farmers and leaving exposure to natural hazards unchanged. In general, expenditure in mitigation works has been minor. Despite its sophisticated design, there is a relatively low resources allocation in disaster prevention measures, and disbursements to deal with losses have not brought clear contributions to vulnerability reduction of the poor over the past two decades. There is a widespread recognition among governmental officials responsible for social programs about the relevance of integrating a disaster reduction strategy to meet overall goals of poverty reduction strategies. However, the main operative challenge for their implementation seems to consist in combining risk and vulnerability analysis at municipal level. As risk identification and vulnerability analysis at municipal level are the main legal requirements to apply for financial resources to carry on mitigation works and insurance, the success of the disasters vulnerability strategy in the country depends on promotion from the municipal authority at a large extent.

Box 3. The case of Chiapas, Mexico (I): Sensitivity and Adaptive Capacity.

Roughly speaking, the South of the country suffers of high floods frequency, whereas the North of droughts and of an ongoing desertification process.

Mexico can be hit at the same time by two independent cyclones, namely from the North Atlantic and the North Pacific. Affected population in Mexico is usually subsistence farmers without access to credit, low crop insurance coverage, and work small farms.

Both poverty and losses from climatic extreme events tend to cluster in the South of the country. The economic dependence on agricultural activities in the South is far above the national mean, amplifying the negative effects from extreme events given the comparatively higher sensitivity of agriculture to climatic conditions.

Most social indicators of the southern state of Chiapas are much lower than elsewhere in the country. Mean incomes in Chiapas are half of the Mexican mean, so that over two thirds of its total population is poor –compared with 47% of the national population (WB 2003). No surprise, thus, that while the national mean of population without school attendance in 2005 reached 8%, in this state it exceeded 20% (INEGI 2007); infant mortality rate is 30 per 1,000 children under 5 years old, around 1.5 times the rate in Sri Lanka, Bosnia, or Belize. Despite producing just 15% of state GDP, Chiapas' agricultural sector employs 43% of workforce (INEGI 2007, Caballero 2003). It contributes to explain why poverty in, especially, rural areas in Chiapas reaches 86% -compared with 74% in Mexico-, and net emigration continues to grow (Wodon et al 2003 and WB 2002).

Chiapas reports the highest agricultural losses due to climatic events over the past three decades. In September 1998, floods and landslides strike severely this state. The 2005 hurricane season was particularly dramatic, hitting practically the same region again but causing economic losses three-fold higher than those of 1998.

Along with recurrent natural hazards, current economic policy has contributed to stress agricultural livelihoods at national level and, given its prevailing agricultural structure, the trade liberalization in the agricultural sector has been particularly biased against the South. Low prices of agricultural goods in Mexico's main trade partners –most likely due to high subsidies-, has resulted in higher agricultural imports, pressing downwards agricultural domestic prices in the country. Rural incomes tend thus to decrease to those farmers without possibilities to either increase productive yield or to enlarge cropping area, as the case of subsistence farming (ECLAC 2003, 2001, WB1994). It is leading to reduce subsistence farmers' ability to create a financial pool to face hazards their activities imply, drawing a vicious circle of low coping capacity, low savings, lack of climate adaptive instruments (i.e. crop insurance, reserve fund), and higher disasters vulnerability.

In order to asses the strategy for risk and vulnerability reduction in Mexico, a survey was undertaken in the state of Chiapas (Saldaña 2006b). The selected communities are Cacahoatan, Escuintla and Cintalapa, located on the coast of Chiapas, in the region known as *Soconusco*. This region is located at the Pacific Ocean coast, bordering Guatemala, and is the gate of Mexico to Central America. According to the Mexican National Council of Population, these three surveyed communities are classified as highly marginalized (CONAPO 2004). Also, only 13% and 17% of the interviewed has access to irrigation and credit granting, respectively. Historically, the region has been highly affected by heavy rains, winds, hurricanes and landslides. Interviewees evaluated the relevance of set of disaster financing sources by scoring them from 1 to 5, where 1 means irrelevant and 5 very important. *Relatives in the community* is the most important post-disaster financing source, receiving the highest summed score (332), followed by *governmental aid* (270) and *neighbor solidarity* (266). Less important was the *sell of property* (207); *governmental fund* (173); the *sell of land* (170), and *community loans* (161). The importance of relatives living in the same community and aid from the government underlines the high dependence on ex-post financial instruments –thus the challenge to implement prevention measures. The four types of available insurance –private, public, *Fondos* and subsidized- were ranked at low bottom.

A farm-level analysis was developed in Mexico and Argentina, implementing focus groups, workshops, interviews and survey data. A set of indicators were used to measure key elements of a farmers' adaptative capacity. These indicators were derived from the farmers' descriptions of the primary "structuring factors" in the development of their coping strategies. The table below provides a an example of those indicators (Eakin, 2002;Wehbe, 2005; Gay et al, 2006a).

Table 3. Examples of attributes and indicators.

Adaptation attributes	Possible Indicators
System Flexibility	Number of crops planted; degree of livestock integration
	% of total income from non-farm sources; classification of type of household occupations
Livelihood Stability	% of production costs from purchased inputs; variability in input and product prices; % of harvest formally marketed; destination of products
	Total household income and inter-annual variability in income; % of total income from agriculture; material possessions and assets
	% harvest lost to hazards; variability of yields; sensitivity of yields to rainfall/ temperature variability;
Equity (access to resources)	% of farmers with irrigation access; costs of water use; land distribution; number of farmers with land
	% of farmers with insurance, formal credit, technical assistance; subsidies as % of production costs
	% of income from welfare subsidies; participation of farmers in government programs
	Migration from farm households; land and equipment sales; rural infrastructure investment

The household level survey in each region was applied with the objectives of collecting data on the selected indicators (i.e., household resources, income, hazard impacts, production practices etc.), and determining the relative importance of climate in relation to other factors (e.g., market prices, food security, resource availability, etc.) in key production decisions (timing of planting, crop choice, land and input use). Although some of the specific variables measured in each case differed, an effort was made to use a similar survey instrument in both Argentina and Mexico in order to have comparable indicators of vulnerability and adaptive capacity. A total of 234 farm households were surveyed for the study cases in México. In Córdoba, during 2003/2004, 240 farmers were surveyed within four selected communities (the latter represent four different agro-ecological zones) and were distributed in terms of the total number of farmers in each community.

Box 4. Sensitivity and Adaptive Capacity. Veracruz Case study. (AIACC final report, Eakin et al, 2006).

Two communities for the case study in Veracruz were selected: Vaquería and Ursulo *Galván*.. These communities have approximately 80 and 300 households, respectively, and are located at an altitude considered ideal for highland production. The survey illustrated that farmers perceive the current problem of the collapse of coffee prices to be far more problematic than climate in their livelihoods and production decisions.

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. However, variables measuring impacts and adaptations and coping strategies were excluded. 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. 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. 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).

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 (figure 3). In the case of impacts, the most significant difference between the two groups consists of the greater reduction in the reinvestment levels of Group 2 as response to recent adverse changes in the coffee market. It seems to be closely related with the degree to which the households depend on coffee as their primary activity.

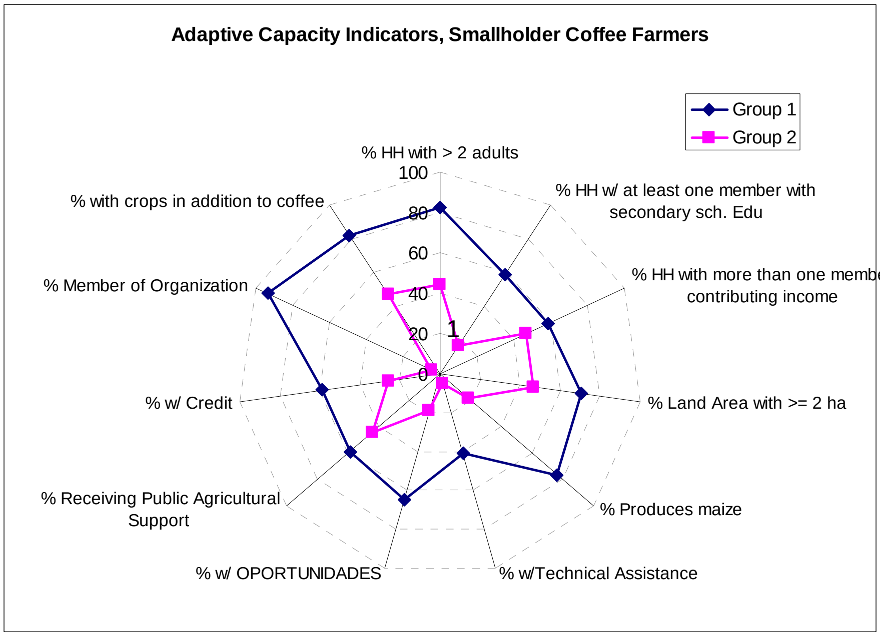


Figure 3. Adaptive capacity Indicators.

IV. Vulnerability to Climate Variability and Change.

Vulnerability has not an unique meaning for different research communities (Downing and Downing and Pathwardhan, 2005; O'Brian et al, 2004). The studies described here decided their frameworks in terms of the questions being asked and the answers that were needed by the key stakeholders involved in the projects.

The IPCC Fourth Assessment Report (IPCC, WGII, 2007) recover the definitions stated in its Third Assessment, and considers that vulnerability is "the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity".

Fieldwork was a key element in the four study cases discussed in this paper. Surveys, workshops and focus groups were conducted to involve farmers in the project at different levels of participation (Conde and Lonsdale, 2005). Interviews in depth with key policy makers were also conducted to gather information on climatic hazards that had affected the agricultural activities in the regions under study.

Box 5. Crop insurance coverage: lessons to learn inside Latin-America

As an adaptation measure, risk-sharing in the form of crop insurance in Latin-America presents still a number of challenges to face. Low coverage and insufficient penetration tend to be the most remarkable, whose causes vary widely among countries. Whereas Uruguay experiences high coverage even without governmental subsidy, insured cropland in Chile is increasing thanks to discriminatory subsidies combined with the participation of private insurers. By contrast, Mexico continues to maintain low coverage even despite governmental subsidies and the facilities conceded to private insurers. From its part, Argentina presents both low coverage as well as the absence of governmental subsidy.

Uruguay

So far, Uruguayan government does not provide any subsidy to crop insurance. However, insurance coverage in this country is greater than in most subsidized agricultural schemes in the world. Since the 1970s, self-insurance (*autoseguro agricola*) has been an intensively employed instrument. It consists of a shared-risk pool funded by farmer's arrangements. This instrument covers especially hail risk of mainly winter crops. Unlike the rest of Latin-American countries, the increasing natural disasters occurrence experienced over the 1980s in Uruguay led to the emergence of a number of private crop insurance companies, leaving behind the state monopoly in this market.

Chile

Chilean agriculture is recurrently hit by frosts –due to the dominating *Andes*-, droughts in the North –besides the Atacama desert- and heavy rains throughout most the territory. In 2000, the Ministry of Agriculture established the agricultural insurance company (COMSA), which is operated by private insurance companies. COMSA grants subsidy depending on farmer production scale. Crop insurance in this country embraces climate and market risks. The subsidy consists of financing 50% of net premiums on average, plus a fix fee (ca. US$ 36) per insurance contract. The subsidy grants small-scale producers with 80% of the premium price; 50% for medium farmers; and less than 50% for large scale farmers. The subsidy covers up to US$1,320 per farmer/season, and embrace most crops types.

Since 2001, net weighted surface coverage of the subsidy exceeds 50% of cropland, noteworthy high compared to Mexico (10%) and Argentina (7.7%). Besides risk management, resources allocation matter: per-farmer subsidy in Chile is around four-fold higher than in Mexico.

Argentina

Only 2 of 26 millions of hectares of cropland are covered by insurance in Argentina. Mainly due to budgetary constraints, the government is reluctant to subsidize. It exacerbated after the 2002 economic crisis. 70% of existing insurance contracts cover exclusively hail, 29% are multi-peril, and 1% covers livestock. Despite the fast growth of the crop insurance market during the present decade (annual 12%), insurance coverage is still expensive for producers: premiums cost fluctuates between 3 and 6% of production costs. During this period, increasing pressure from social and economic actors demand the government to implement crop insurance subsidy in light of the increasing risk associated to the adoption of enhanced technologies along with the climatic variability. The exports boom of agricultural goods (mainly soy bean) and livestock to China over the past five years has generated unexpected revenues to the country, which is being the main argument to give agricultural some subsidies in return (Saldaña 2006).

Specifically in the AIACC project, the questions asked were: To what degree is adaptation to climate change at 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? In this project vulnerability was conceived as a function of sensitivity on a system generated by the characteristics of a system in relation to different climatic events; and, adaptive capacity, or the ability of a system to cope with, recover from and adjust to changing climatic conditions and extreme events (Wehbe et al, 2005). The unit of analysis for the vulnerability assessment was the farm operation or household and the study compared two farmer production strategies in both countries: export-oriented coffee producers to large-scale irrigated farmers. The fieldwork centered its efforts to assess what “choice set” of adaptation options were available to farmers and how those choices were affected by their current capacities, in a context of social, political and economic change (AIACC; Eakin et al,2005) .

Following Downing and Pathwardhan (2005), the AIACC project and the study case in Tlaxcala considered that vulnerability is determined by climatic threat, the type or group in the agricultural sector that is affected and the adaptive capacity of that group.

To assess vulnerability, the adaptive capacity component was considered a key factor in the AIACC project, and was studied using three attributes: flexibility, stability and resource access (Eakin et al, 2005). At household level, flexibility was 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”. Stability of households could be affected by “high risk and volatility in prices, climatic conditions, or market opportunities” … “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). “

Formally, we expressed vulnerability (V) as a function of Sensitivity (S) and adaptive capacity (AC) as follows (Wehbe et al, 2005):

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

where

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

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

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

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

Box 5. Results for Argentina (Final AIACC report).
(AIACC final report, Wehbe et al, 2005)

The whole Córdoba province is about 16.532.100 hectares, 83% of it devoted to agricultural activities. This province is in the center of the Argentina and ranked fifth in size among all the argentine provinces. 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 South of the Cordoba region comprehends 6 of the 13 different agro ecologic zones (AEZ) of the Province. The main agriculture systems are cash crops and livestock. Focus groups, interviews and a survey (similar to the one applied in Mexico) were implemented to construct indicators related to resources (human, financial, social), management capacity/diversity, previous risk mitigation actions, climate information and impacts, economic strategies, public institutions and decision making. Four localities were selected to implement the survey, namely Laboulaye, Río Cuarto, Marcos Juárez and Oncativo.

Climate Sensitivity and adaptive capacity indicators were obtained for 16 farmers groups and each of the indicators represents one or more variables from the survey data. These indicators aimed to identify producers' sensitivity to different adverse climate events and the main resources available for farmers to respond to stress and uncertainty. The overall vulnerability of each farm group was assessed qualitatively by comparing the aggregate scores for the sensitivity and adaptive capacity indices.

Only two farmers' groups can be distinguished within the *low vulnerability class*, 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. This class is comprised of the groups with the lowest sensitivity indices.

The *high vulnerability class* is represented by five of the sixteen defined groups and represents 43% of surveyed farmers, 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).

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.

The diagram in figure 4 show the synthesis of the vulnerability classes and the weighted indicators described above.

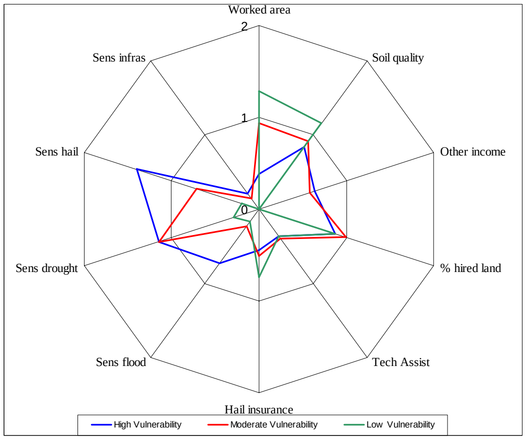


Figure 4. synthesis of the vulnerability classes and the weighted indicators

In order to operationalize this analytical framework, the project drew from the MESMIS framework (Masera and López-Ridaura, 2000) 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. AMOEBA diagrams were used then to highlight the features that most inhibit the development of adaptive capacity, and thus as tools in discussions of policy reform and interventions to improve this capacity, as well as to discuss difference in vulnerability with farmers. Some results from this methodology applied to the Argentinean case are presented in Box 5 above, as well as Box 6 below compares coping and adaptive strategies among communities from the Chiapas Survey.

Box 6. The case of Chiapas, Mexico (II): Off-farm jobs and emigration as coping and adaptive strategies

In order to cope with the increasing uncertainty of agriculture-derived incomes, 43% of interviewees should make use of an alternative source of income. Providing services for other farms represent the main alternative activity (28% of interviewees). The second alternative activity (16%) is construction activities, which usually means working as a building worker in the nearest urban area. The third alternative income (12%) is remittances. This survey found that communities recurrently damaged by natural disasters but without formal financial mechanisms to respond tend to consider out migration more seriously as an adaptive mechanism. In these communities, the presence of *travel agencies* aimed at transporting emigrants to Tijuana (nearly 3,5000 km away from these areas) was stronger, which is the pass to cross the Mexican border to the USA, as evidenced in Cacahoatan. At national level, out migration in Mexico has increased over the past two decades.

The Population Census of 1990 reports that 0.24% of Mexican population was residing abroad, whereas in the 2000 Census this figure rose to 0.41% (INEGI 2007). Currently, Mexico is the first country of origin of migrants to the USA, where nowadays 1 of each 3 migrants was born in Mexico -nearly 12 million so far. In year 2000, the share of population living abroad in the surveyed region was clearly higher than the national mean and with clear signs of rising if the climate continues changing adversely while no disaster prevention strategy succeeds.

In general, 41% of interviewees stated current plans to emigrate. Most these emigration-prone interviewees are being the most recurrently affected by climatic events. They tend as well to belong to families whose members have used emigration as a coping strategy after loss of assets and/or productivity due to extreme climatic events. It suggests that natural disasters is increasingly becoming a crucial trigger to emigrate, as well as that farmers' emigration strategies are clearly supported by an existing familiar networking abroad.

B. Future Vulnerability and Adaptation Strategies.

Climate change scenarios are "a coherent, internally consistent and plausible description of a possible future state of the world" (IPCC, 1994). The use of these scenarios for impact assessments has to deal with the multiple sources of uncertainty imbedded in these climatic scenarios, and the decision making process has to include the evaluation of those uncertainties to develop the collection of possible measures and strategies to reduce vulnerability and enhance adaptive capacity.

A Climate change scenario is not a forecast, since each scenario must be seen as an alternative of how can the climate will behave in the future. Projections of the current conditions can be useful, but climate change scenarios need additional information, such as the future emissions of greenhouse gases. Several emission scenarios are then use to reflect the range of uncertainties of future climatic conditions.

The use of the climate change scenarios for impact and vulnerability studies reported in the Third Assessment Report (TAR) of the Working Group II of the IPCC (IPCC, WGII, 2001) are usually not "in phase" with those reported by Working Group I (IPCC; WGII, 2001). That is why the impact studies used a doubling of CO2 scenarios, while the latest scenarios that could be used were related to dynamic responses of the climatic system to increments in time of CO2 concentrations (called transients).
Regardless of that fact, climate change scenarios were generated for Mexico and Argentina study cases. Climate change scenarios were constructed using mainly the Magicc / Scengen model; version 4.1 (Wigley, 2003; Hulme et al., 2000). The outputs of 3 General Circulation Models (GCMs: EH4TR98, GFDLTR90, HAD3TR00) were used, considering two emission scenarios: A2 and B2 (IPCC, WGIII, 2000; Nakicenovic,. et al., 2000), and for the years 2020 and 2050. Simple interpolation methods have been applied to obtain the possible changes for specific locations. The results obtained were compared also with those shown in the IPCC Data Distribution Center (http://ipcc-ddc.cru.uea.ac.uk/) and, for the Mexican cases studies, the Canadian Institute for Climate Studies (http://www.cics.uvic.ca/scenarios/data/select.cgi).

The assessments of current vulnerability and adaptation are a good proxy method to project future vulnerability and adaptation options (Brooks and Adger, 2005). Uncertainties not only in the scenarios of the future climate, but also in the socioeconomic scenarios make difficult to design plausible strategies if they are not supported with the near-term adaptation measures that are being applied by many social groups that are already highly vulnerable to current climate change and variability processes (IPCC, 2007). This approach can be seen as a "win-win" strategy, that can be constructed gradually, monitoring the possible "climate surprises" that societies might not be prepared or have no previous knowledge to apply.

To assess possible future impacts on climate change conditions, several methods and models have been applied in previous research (Gay et al, 2006b). The results of that research can be seen as the sensitivity analysis for the biophysical systems in the agricultural sector. However, expert judgment and stakeholders' perceptions of the future are two possible ways to assess which of the future scenarios are the most risky conditions and can fundament the design of possible adaptation strategies.

Box 7. Climate Change scenarios and an integrated model. (AIACC final report. Conde et al, 2005)

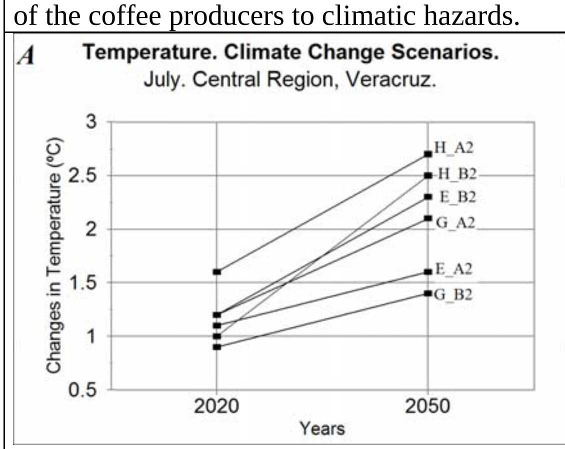
Using the month of July to illustrate climate changes for summer in Veracruz, Figures 6A and 6B show the possible changes in temperature and precipitation for the central region of Veracruz. Considering all the GCMs outputs, the projected changes range from 0.9ºC in 2020 to 2.7 ºC in 2050. The projected changes in precipitation range from a decrease of 29% to an increase of 42%, depending on the year and model used. Similar outputs were obtained for Argentina.

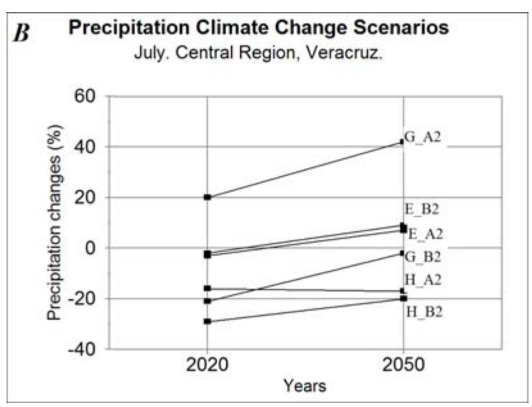
These ranges open the question of what combinations of temperature and precipitation could represent a climatic threat in the future. Also, the key stakeholders in the region decided which combinations of temperature and precipitation have represented threats in the past for their specific region and their specific activity.

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, 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.

The projected changes from the ECHAM4 (A2 and B2) and GFDL (B2) models are within the biophysical coping range (figure 2b). The projected changes for the Hadley model, in the emission scenario A2 were within the coping range space, implying possible important decreases in production, considering the historic impacts and the current climatic threat spaces.

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 7 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 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.





Figures 6A and 6B. Climate change scenarios constructed for the Central Region of Veracruz and for the month of July. 6A show the possible changes for the time horizons 2020 and 2050, figure 6B show the corresponding to precipitation.

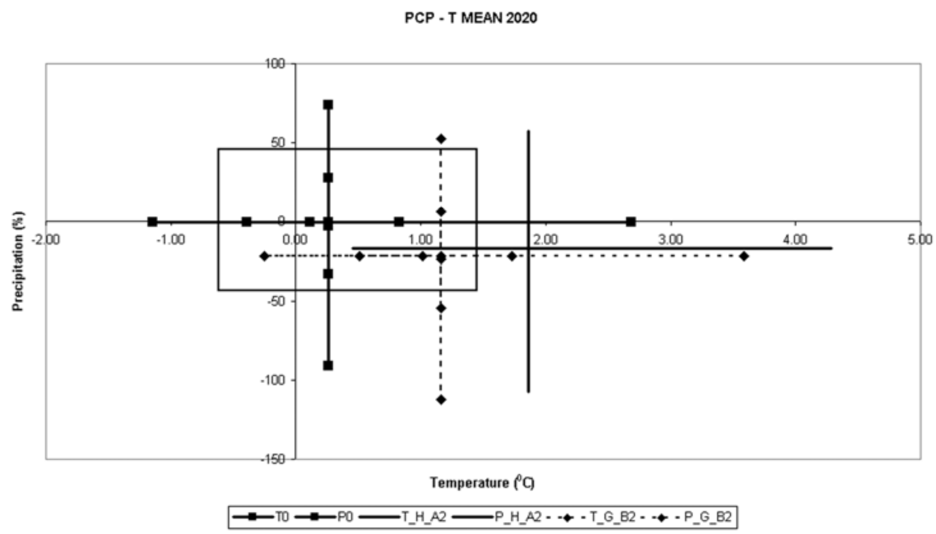


Figure 7. Current mean and variability conditions and climate change scenarios for 2020. The crosses show a mean value and variability for current and for each future scenario of temperature and precipitation. T0 and P0 are current temperature and precipitation conditions and the black box represents the coping range (Figure 12). 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.

Stakeholders' involvement in the design and implementation of these strategies for the uncertain future is crucial. In the case study in Tlaxcala, Mexico, key stakeholders' involvement in the region helped us to decide which of the adaptive measures could be viable under the current conditions and under future climatic conditions. The construction of greenhouses, the use of compost, and dripping irrigation, were some of the techniques selected with the participation of the stakeholders. The enthusiastic responses to these measures allow us to consider that those can prevail in the future, under climate change conditions. However, the adaptation to climate change was mainly perceived as the generation of the capacities to cope with climatic adverse events, more than the technical instruments (greenhouses, dipping irrigation, compost) applied in the project.

The viability of the adaptation measures was assessed with farmers and decision makers using a SWOT (strengths, weakness, opportunities and threats) method. It was clear that the main weakness of the project was the need of continue technical assistance, which could be lost and the end of the project if the students, governmental technicians and researchers in the state abandon the project. The main barriers to develop the project were detected: risk aversion perception among farmers, lack of secure markets for the greenhouse products, and, as a result of that, lack of maintenance of the greenhouses and irrigation system. The last workshops of the project were centered to address those barriers and to design a series of possible measures to overcome them, in the context of an uncertain future.

Box 8. Adaptation Options and Barriers. Case Study: Tlaxcala, Mexico.

The case study that was carried out in three municipalities of the Mexican state of Tlaxcala, was supported by a continuous stakeholder communication, facilitated by the participation of several researchers in different studies since 1997 (Orozco, 2000, Ferrer, 1999, Conde, 1998, Magaña, 1998). These conditions favored the flux of information of stakeholders' needs, perceptions and agreements with the research team, so that the stakeholder driven requirement was achieved. All the members of the project team (researchers, students and producers) have participated together in several workshops and focal groups.

During the first workshop of the project (10/6/2004), it was agreed that the most vulnerable group in the agricultural sector was the rainfed maize producers. Also, drought, frost, hail and strong winds were considered the most important climatic threats in the state. Soil degradation was the most important environmental factor that could reduce the coping capacity of maize producers. Socioeconomic conditions, such as the lack of economical support (particularly the disappearance of subsidies) and of technical support, have highly reduced the access to resources that usually farmers applied to cope with climatic adverse events. Finally, young farmers are migrating to other regions, or changing their occupational expectations. These economic and social circumstances imply a high risk for the food security conditions of all maize farmers in Mexico (Ziervogel et al, 2005).

Climatic threat spaces were used (Conde, 2003a, Conde et al, 2005) as a tool to visualize those years when temperature and precipitation anomalies (with respect to the average values from the period 1961 – 1990). To address the possible impacts of climatic variability and change, crop simulation models, such as the Ceres - Maize model (Jones, 1986, Ferrer, 1999) were applied, particularly to determined maize sensitivity to diverse climatic conditions. Also, social scientists analyzed the current agricultural policies and programs that might be implemented in the state and that could support future projects in this field.

Climate change scenarios were constructed using the outputs of three General Circulation Models (GCMs), using two socioeconomic SRES scenarios (A2 and B2, Nakicenovic, et al. 2000) and for the years 2020 and 2050. These scenarios were introduced in the Ceres – Maize model, so projections of future yields can be obtained. Also, those scenarios were discussed with policy makers in terms of the climatic threat spaces, to assess which of them could represent the worst future climatic risk.

Finally, after one year of applying participatory techniques (Conde and Lonsdale, 2005), the project team (researchers, students and farmers) decided that three practical methods will be applied: the use of compost to organic cultivation of tomatoes and chile, construction of greenhouses, and dripping irrigation, to optimize the use of water. For that purposes, new members of the research team were incorporated (i.e. architects, chemists); particularly, it was considered that students and teachers from the local school of Environmental Studies could guarantee the future the sustainability of the project.

The possible advantages of the selected strategies were: producers' aging will not affect the labor required, women can be integrated to these options, soil fertility can be enhanced with the use of compost and optimization of water consumption can be achieved. Also, these measures increase crop diversity and food variety for the producers and their families and reduce the current climatic risks.

Finally, these options were considered viable adaptation measures for future climatic changes. The adaptation to climate change includes – besides the stated techniques – the generation of the capacities to cope with climatic adverse events, that is, to enhance the adaptive capacities to climate change among the key stakeholders.

The study of the barriers for adaptation measures is possible one of the main issues in current vulnerability and adaptation research. The public policies and instruments established to reduce disaster risks need to be evaluated and monitor, since they are the basic structure for future planned adaptation strategies. Several studies have developed in Mexico to address these issues (Gay et al, 2004, Saldaña, 2006a, Magaña, 1999). Some of the current major barriers that might jeopardize those efforts are the absence or irregularity of human, technical and financial resources at regional or local level (see Box 8 below); lack of efficiency and transparency of the operation of the programs and policy applied; insufficient confidence and participation of the farmers supported by them, and the absence of inter-institutional coordination.

Box 8. Productive re-orientation, a structural adaptation measure

Agriculture in the surveyed region of Chiapas is practically mono-crop. The main agricultural products of the interviewees are white maize (46%) and coffee (41%). It increases their vulnerability given the decreasing prices of white maize and coffee experienced over the last 20 years. The neo-classical approach of economic theory considers mono-crops as positive in that of exploiting local comparative advantages, producing scale economies, as well as due to the benefits derived from high specialization in the sense of the *work division* of Adam Smith. Nevertheless, these advantages counteracted when the respective commodity markets turns highly volatile or price drops dramatically, as in this case.

Low rural incomes in this region are considered a result of a complex economic-climatic process, whose solution should embrace not only social programs, rural-urban emigration, and post-disaster aid, but also issues of inequity, productive reorientation and implementation of disaster prevention instruments. Productive reorientation seems to be a feasible economic response to adapt to negative terms of trade of- and within the agricultural sector. The low dynamism of the industrial sector of the past two decades in Mexico has impeded the urban economy of absorbing most the additional workforce released from the left-behind agricultural sector. For that reason, the productive re-orientation should still be projected within the agricultural sector itself. Otherwise, the current increasing trend of slums proliferation in large cities as well as illegal emigration to abroad will become harder to manage. It implies finding means of both diversifying crops to reduce the probability of getting affected given sudden prices drops in the mono-crop, as well as moving to more rentable crops, that is, whose market prices are relatively higher, with a more stable demand and suitable to regional environmental and climatic conditions. In the Veracruz study, Gay et al (2004) analyze the high vulnerability to extreme climatic conditions in a coffee producing region, which is being increasingly affecting the region, and warns about the low viability of growing coffee there once internalized some negative effects of policy changes and market instability for this sector.

From the Chiapas study, 58% of interviewed farmers stated to have plans to diversify to higher profitability crops given current trends of decreasing prices of traditional agricultural products. Over 87% farmers crop maize and coffee, whose prices have been decreasing over the past ten years. In counterpart, cropping fruits and vegetables represents higher profitability to farmers in this region given favorable climatic conditions and relative prices. Based on a World Bank report, fruits and vegetables are considered to have higher comparative and competitive advantages to the Mexican agricultural sector, especially to export to North-America in the framework of the NAFTA (Lederman et al 2003). Even despite higher freight and insurance costs in the South to export to the USA and Canada, the relative greater water availability in the South may make the said crops highly rentable –of course, once constructed the due water management infrastructure. Under such circumstances, there is widespread demand –from interviewees and stakeholders- to promote more actively the current governmental productive re-orientation process, as well as to operate in a more participatory manner in order to achieve realistic and sustainable results.

In the stakeholders' views, there is also a widespread feeling concerning the absence of an effective and long-term sustainable strategy to strengthen the coping and adaptive capacity of subsistence farmers in this region to external shocks, which is an obstacle for accumulating assets. The prevailing conditions of marginalization and low educative levels in this region may explain the passive attitude of the self affected population to come up with initiatives to reduce vulnerability. It demands a more active promotion from the public. The insufficient government investments in infrastructure, limited credit granting, insufficient subsidies to crop insurance, and lack of investments in more rentable crops, greatly reduces the communities' coping capacity when hazards strike, which in turn is soaring emigration and social instability levels in the region.

Planned adaptation strategies must involve the governmental institutions. Several initiatives in Latin America have been supported (Magaña et al, 2002), some of them are being designed to cope with current climate risks.

A number of studies conducted at the National Autonomous University of Mexico (UNAM) led to establish the nature of risk to climate extremes as a function of hazard or threat and vulnerability in some regions of the country. That is, these studies have centered their efforts in analyzing the use of climate information as an adaptation strategy in the agricultural sector of Mexico (box 9).

Based on such approach, the first steps to make climate information an element of planning in the decision making process were related to the understanding of climate variability and seasonal predictability. Regional climatic phenomena, such as the Mid Summer Drought (*canicula*), the onset of the rainy season, the probability of frosts and other meteorological phenomena have to be examined in order to prepare tailor made climatic products to farmers. The modulating effect of ENSO in the climate of central southern Mexico has become a well known factor that may result in good or bad years in terms of agricultural productivity (Magaña et al 1999). The occurrence of one of the strongest El Niño events in 1997 led several stakeholders to pay more attention to climate diagnosis and prognosis.

Box 9. Useful Climatic information and adaptation options. (Neri 2004)
The case of maize production in the Central Valleys of Oaxaca represents an example where a decision making scheme provides a good opportunity to reduce vulnerability. The relationship between precipitation and maize production may be observed when summer rains in year *i* are compared with the difference in maize yield from year *i-1* and year *i*. The observed decrease in yields reflects the high vulnerability of the rainfed agricultural sector of Oaxaca. This sector is vulnerable mainly due to a continuous loss of fertility in soils, the poor levels of mechanization and the insufficient financial subsidies to change old and inadequate practices.
El Niño is a major threat to agriculture in Oaxaca and other parts of Mexico. Consequently, since end of the past century, agriculturists in the region request information on the ENSO condition to extensionists, and information on El Niño has become of major importance within the regional Climate Prediction Fora.
A decision making scheme was designed (Neri 2004) to assist maize producers in their planning processes considering seasonal climate prediction for ENSO. Under a probabilistic approach for the evaluation of risk, a decision making scheme was designed. The scheme is constructed following four steps:

1. Regional climate diagnosis
2. Construction of futures scenarios in the sector based on seasonal climate predictions
3. Obtain the seasonal climate prediction to evaluate risk for a particular season
4. Make a decision

The scheme is constructed following a decision making tree, where probabilities are constructed based on historical data of climate and yields. For instance, it is necessary to estimate the conditional probability of a low yield during El Niño conditions, or the probability of high yields under La Niña conditions, for instance

$$P(LY \mid \text{El Niño}) = P(LY \cap \text{El Niño}) / P(\text{El Niño}) \quad ; \text{ with LY = Low Yield}$$

Maize yield data for the Central Valleys of Oaxaca for the 1980-2001 period has been used to estimate relative values (based on standard deviation) of Low, Medium and High maize yields in the region (table 4)

Table 4. Maize Yields

Maize Yields (Ton/Ha)	
Low	Lower than 0.78
Medium	Between 0.78 and 1.12
High	Higher than 1.12

Using data on ENSO, a Risk Matrix was constructed to determine the probabilities of High, Medium or Low yields based on a particular phase of ENSO.

Table 5. Risk Matrix

Maize Yield / Event	**Low**	**Medium**	**High**
El Niño	37.5%	62.5%	0.0%
Normal	10.5%	68.4%	21.1%
La Niña	33.3%	50.0%	16.7%

Consequently, if a farmer in the Central Valleys of Oaxaca decides to grow maize in summer during an El Niño year, the probabilities of low yields are higher than during La Niña summer. The next step is related to the use of a seasonal climate forecast and to a determination of the reliability of such seasonal forecasts. According to NOAA, El Niño seasonal predictions are more reliable (84%) than La Niña (49%).
Let's assume three potential preventive actions for the farmer under a certain seasonal climate

prediction and considering the risk matrix for maize production. The three hypothetical actions and costs considered for the present example are:

1.- Irrigation with at a high cost during dry periods, but with high probabilities of obtaining high yields (increase of yields = 100%); 2.- Use of fertilizers to resist dry periods at a medium cost but with less probabilities of obtaining high yields (increase = 50%); 3.- Change of crop, with no cost but with lower probabilities of obtaining high yields (increase of yields (25%).

Under such hypothetical scenario results with probabilities of high, medium and low yields are as follows, including the options of no-action under the seasonal forecasts, this is "business as usual".

Table 6. Forecasts and adaptation options.

Forecast	Event	Response action	Expected result	Risk	Adaptation option 1	Adaptation option 2	Adaptation option3
84% confidence	El Niño	No action	Low yield	37.5%			
			Medium	62.5%			
			High	0.0%			
		Adapts to El Niño	Low yield		0.0%	0.0%	0.0%
			Medium		0.0%	31.5%	52.5%
			High		84%	52.5%	31.5%
49% confidence	La Niña	No action	Low yield	33.3%			
			Medium	50.0%			
			High	16.7%			
		Adapts to La Niña	Low yield		0.0%	0.0%	0.0%
			Medium		0.0%	8.2%	32.7%
			High		49.0%	40.8%	16.3%

As expected, adaptation options based on climate predictions always result in higher probabilities of obtaining high maize yields during El Niño years than the No-Action. However, considering the relatively low reliability for the La Niña seasonal forecasts, the no-action appears to pay better than the adaptation options, specially when it is considered that adaptation has a cost either financial or in terms of the crop obtained.

Final Considerations

Recent case studies in Mexico and Argentina regarding vulnerability and adaptation to climate change and variability show that "no one fits all" in regard to possible methods and models applied. However, it is clear that stakeholders' engagement in the project processes is fundamental to create indicators and perform the required assessments. Future projections of vulnerability and adaptive capacity may greatly benefit from research on hydro-meteorological disasters that occurred in the past, if combined with regional/national economic policy assessments.

Along the surveyed regions, the adaptation to climate change of subsistence farmers is being constrained by current trends in institutional change and agricultural policy and just transitory facilitated by the markets. It demands a more active role of the government to fulfill that gap. Public policy has still to face the challenge of integrating better climate change and variability research into practices and policies. In the case studies of Tlaxcala, Veracruz and Chiapas (Mexico), and in the study sites of Argentina, key stakeholders' came up with concrete adaptive measures, e.g. greenhouses, irrigation, credit, among others. However, technical instruments like these cannot last for long if coping capacity does not embrace a continuous learning process to program adaptation options based on climate and markets predictions.

Currently, the risk management and disaster prevention measures in Latin American countries should overcome institutional and technological barriers for their optimal operation. Future research must center efforts in analyzing barriers and opportunities these measures represent, particularly if, as most likely, new technologies and policies might be needed in sight of the forthcoming global change conditions.

As a common factor among these study cases, current agricultural weakness and insufficient capacity building imply dramatic results if extreme climate events continue to increase in frequency and/or severity. Although we can greatly advance our understanding of climatic extremes in this region through measurement methodologies like the ones here exposed, it might become insufficient if not integrated with solid socioeconomic information for forecasting damages and preventing disaster risk. Although the cases of study here analyzed concerning impacts of climate change on emigration, impoverishment and food security does not embrace the whole Latin-American region, but it provides useful highlights for a number of countries sharing environmental and human conditions. With the implementation of these methodologies, we can approach damaging effects from climate change on human settlements and economic activities. Further directions might consist of managing resources more efficiently to redirect and enhance productive structure, improve institutions functioning and readapt permanently our methodologies to predict climate affectation at lower scale and with a lesser share of uncertainty.

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