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1. Introduction

Agriculture is a risky business. The sensitivity of crops to climatic variability is, in part, what has placed agriculture in the center of climate change impact analysis for several decades. Although such analyses have repeatedly demonstrated how different crops may respond to climatic stimuli, they have been less successful in illustrating the sensitivity of the farm production unit to climate (Smit et al., 1996; Chiotti et al., 1997; Kandlikar and Risbey, 2000). Within regions with similar exposure to climate hazards, the sensitivity of particular farm units to climate impacts will vary considerably, as will the capacity of agricultural producers to adapt, in relation to a wide variety of socioeconomic, institutional, and psychological variables (Easterling, 1996; Brklachich et al., 1997; Eakin, 2002). These variables are not always easily observed or measured at the household level, posing considerable challenges to assessing vulnerability of specific farm populations.

In response to this challenge, this paper focuses specifically on the determination and analysis of the variety of factors that differentiate farm enterprises and farm

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households in terms of both their sensitivity to climate events and their capacity to adjust to changing climatic and market circumstances. For this analysis, two case studies are presented in two different Latin American socioeconomic and climatic contexts: the community of Laboulaye, in Córdoba Province, Argentina and the county (*municipio*) of González, in the state of Tamaulipas, Mexico. Although the cases are quite distinct, the production systems in each case share similar exposure to political and economic uncertainty originating from intensified processes of economic liberalization and market integration in each country. In very aggregate terms, the focus of production is also similar: grains and livestock in different combinations for commercial markets. The comparison of the cases, however, also reveals important differences in the distribution of livelihood resources, the relationship between farmers and the public sector, and thus the flexibility of agriculture in face of both economic and environmental challenges.

1.1 Agricultural vulnerability

In this study the social vulnerability of farm households is considered to be a function of their exposure to climate shocks and extreme events, the sensitivity of the farm to such events in terms of both direct crop impacts and indirect livelihood impacts, and the capacity of households to adapt and adjust to protect themselves from future harm. In the analysis presented below, we explore in depth two of these three attributes of vulnerability: sensitivity and adaptive capacity. Although exposure to climate hazards is, in part, a product of the social construction of risk through, for example, the historical political and economic factors that have affected the geographic distribution of landholdings, physical infrastructure, and populations (see Liverman, 1990), we consider that at the household level, these differences in exposure are captured in differential sensitivities to climate impacts.

The sensitivity to climatic hazards in agriculture is often measured in terms of the degree of decline in yields, losses in agricultural profits or farm value, increased costs of production or losses in production quality (Easterling, 1996; Reilly and Schilmmelpfenning, 1999). Thus, sensitivity is also a product of the organization of a farm system, the technology and information used by the system, and its exposure to other socio-economic and biological factors as mentioned above (Anderson and Dillon, 1992; Chiotti et al., 1997; Smithers and Smit, 1997). If one uses farmers' own assessments of climatic impacts on their production (as we have in this study), then sensitivity becomes a function of risk perception and risk tolerance—variables that are rarely captured in impact studies at sector scales (Risbey et al., 1999; Dessai et al., 2003).

In general terms, adaptive capacity can be viewed as a function of a system's flexibility, stability, and access to key resources—attributes that are overlapping and interacting. Farmers' capacities to respond to stress and uncertainty depend on ownership or access to a wide variety of resources such as landholding size and soil quality, machinery and equipment, credit and insurance, education and age, technical assistance and information, social networking, and public support programs (Blaikie et al., 1994; Scoones, 1998; Ellis, 2000). Both the degree of diversification within the agricultural production system and the economic diversification of the farm household have also been posited as important factors in determining the sustainability of farm households over time, particularly peasant farm systems (Ellis, 2000). As described in the following section, the expectation that diversification will enhance adaptive capacity runs counter to current policy trends, which favor specialization.

1.2 Political-economic context of vulnerability

The rapid rate of agricultural change that has occurred in Latin America over the last several decades has profoundly altered farmers' relations with markets, their use of technology, and their management of resources (de Janvry and Sadoulet, 1993; Loker, 1996; Bebbington, 2000; Berdegué et al., 2001). Neoliberalism, characterized by a suite of policies (privatization, decentralization, liberalization, and deregulation) designed to open up economies to foreign investment and international trade, has been the driving force behind the sweeping reforms and has become the dominant paradigm of economic development in the region.

In both Mexico and Argentina, agricultural policy reforms have been implemented in concert with substantial changes in macroeconomic policy. Over the course of the 1980s and 1990s, in both countries, protectionist policies, price supports and input subsidies for agricultural products have largely been withdrawn, farm service agencies have been privatized and agricultural markets have been deregulated (Appendini, 2001; Obschatko, 1993; Ghezan et al. 2001). Smaller-scale farmers, principally the *ejidatarios* or communal farmers of Mexico and the small family farmers of Argentina, have been particularly sensitive to these changes.

In Argentina, since the beginning of the 1990s, the loss of agricultural income purchasing power has resulted in the concentration of land in larger production units, whereas those smaller farm units that have remained in production have been forced to restructure and have faced an increasing burden of debt (Wehbe, 1997; Peretti, 1999; Latuada, 2000). The economic crisis of 2002 was followed by an increase in the exchange rate and higher prices of soybeans in international markets, both of which gave cash crop producers a new economic opportunity for increasing real income and for canceling debts. The soybean boom, however, is considered to be augmenting soil stress and degradation, particularly under extreme climatic conditions (Cisneros et al., 2004). Beef production—the other important activity in the Argentinean Pampas—has become less profitable in comparison with export crops such as soybeans, the same as with poultry or pork that were used to complement income before liberalizing trade within the Mercosur countries. In general, the new technologies have allowed for increasing yields and an expansion in the agriculture frontier through the replacement of livestock production with soybeans, and the reduction in natural and cultivated pasture areas. Many agricultural analysts in Argentina increasingly fear that this change is resulting in the exchange of more sustainable agricultural practices for practices that are highly dependent on external inputs (Pengue, 2001; Solbrig and Viglizzo, 1999; Solbrig, 1996).

In Mexico, the *ejidatarios* have been offered title to their land through a federal process initiated in 1992 in the hope that this would encourage the more efficient and entrepreneurial farmers to expand their production, while enabling others to leave agriculture (Ibarra Mendívil, 1996; Cornelius and Myhre, 1998). However, there is yet no evidence that this titling has resulted in an increase in land sales, and *ejidatarios* are increasingly dependent on migration and remittances for survival. Access to and use of technology and farm services (credit and insurance) also has polarized the sector, dividing those who have "commercial potential" from those who are considered "unviable" (Myhre, 1998). Although a relatively small number of agribusinesses have enjoyed rapid growth in productivity and exports over the 1990s, rural incomes have generally stagnated or declined in real terms (Kelly, 2001; Hernández Laos and Velásquez Roa, 2003).

2. Methods

Our analysis of social vulnerability in this study was undertaken at various scales of analysis and through a variety of methods, both quantitative (through a household survey) and qualitative (through the use of primary and secondary literature, interviews, and workshops with farmers). Given the importance of historical socioeconomic processes in structuring vulnerability, we undertook an analysis of trends in agricultural and economic policy both at the national scale and (to the extent possible, given data limitations) for the two regions of study, in order to evaluate some of the nonclimatic stress factors that were hypothesized to have affected agricultural sensitivity and capacities in each case. This socioeconomic evaluation was accomplished primarily through use of secondary literature and interviews with key informants (politicians, agricultural specialists, farmers, and other actors in each region). Round-table discussions with farmers also contributed to this analysis.

In addition, a farm survey was implemented in each region in order to collect detailed data on the particular variables that were hypothesized to affect agricultural vulnerability at the household level. A cluster sample of 234 randomly selected households was surveyed in county of González (Mexico), incorporating both communal farmers and private landholders. This sample was designed to be representative of the estimated number and diversity of production units in the county (with a confidence level between 90% and 95%). Of this sample, vulnerability was assessed for 181 cases that had no missing values for the variables of interest. In Laboulaye (Argentina), the sample was constituted by 47 cases incorporating different production systems (livestock, livestock and cash crops, cash cropping only), which were part of a larger representative sample of 240 farm units (a representative sample with a confidence level of 95%), covering three other localities.

Given that there are no single variables that adequately capture differential sensitivities to climate risk, as well as differential capacities to address risk, the household survey was comprehensive. Through both open-ended and closed questions, the survey collected information on household human resources and income sources, production and losses to climate hazards and pests, crop and livestock management practices, commercialization practices, input and machinery use, farmers' decision-making and risk perceptions, farmers' risk mitigation practices, and farmers' access to and use of resources considered important for adaptation (technology, technical assistance, credit and insurance, etc). Although the general content of the surveys was the same, the specific format of the questions posed to farmers differed somewhat between the Mexican and Argentinean cases in order to capture the measures of human capital, physical and financial resources, access to technical support and technology, and sensitivity to climate risk that were most relevant for each case and country context.

In each case, a selection of the survey variables was grouped according to the particular attributes of adaptive capacity or sensitivity they were intended to represent. In Argentina, adaptive capacity was measured by four attributes: material resources, human resources, management capacity, and adaptations. Sensitivity was calculated by main climatic events affecting each main crop; frequency of adverse events; percentage of area usually affected; and type of damage. Crop loss was taken into account as the difference between planted and harvested area within each group and for each of the main crops for the surveyed year. Impacts on livestock production and on infrastructure were also considered. In Mexico, adaptive capacity was measured in five attributes: human resources, material resources, financial resources, information access and use, and economic and agricultural diversity. Sensitivity was defined by variables measuring direct climate impacts on crops and by variables that were hypothesized to indicate greater sensitivity of the farm livelihood to climate shocks.

Using a slightly different method in each of the two case studies[1], aggregate scores (or "importance weights"[3, and 5–7]) for each attribute were then calculated and the attribute scores were combined 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 (qualitatively in the Argentinean case, quantitatively in the Mexican case) to create an overall measure of vulnerability. In the Mexican case study, each household was categorized according to its values for sensitivity and adaptive capacity in one of three vulnerability categories (low, moderate and high). In Argentina, the production units were first grouped into different production systems and then for each system group, indices of sensitivity and adaptive capacity were obtained, assigning each group to a particular vulnerability level (low, moderate, and high) in relation to both their sensitivity and adaptive capacity. The particular variables that appeared to most contribute to the vulnerability of farmers in each case were identified through "amoeba", or radar diagrams. The results, described below, illustrate the characteristics of vulnerability in each case and the particular resources that currently differentiate the sensitivity and capacities of farmers.

3. Case Study 1: Laboulaye, Argentina

Laboulaye City and its surrounding area belong to Presidente Roque Saenz Peña Department in the southeast of Cordoba Province. It is a region in which agriculture has been a primary activity since the "Desert Conquest" of the late 19th century, when white settlers were encouraged to expand the agricultural frontier into what was then indigenous territory. Today, agriculture and services to farmers continue to drive the local economy, although the circumstances of production have become increasingly difficult for the area's family farms. These producers have traditionally pursued a variety of farm strategies, although many have tended to focus on running mixed-crop livestock or small-scale livestock (for beef or milk) businesses (Table 1).

Reflecting the same trends that have been noted at the national scale, these family farmers have been negatively affected by the declining prices for livestock and rising living costs. Official statistics show an expansion of cash-cropping area (by 50%) and a decline in livestock area (13%) and in livestock numbers (by 37%) in the region since the late 1980s (INDEC, 2004; INTA, 2002). Soybeans, favored by the increasing exchange rate and favorable price vector in the aftermath of the 2002 crisis, have rapidly expanded in the region under an intensive monoculture system, or in combination with wheat. Although this trend was already apparent before the 2002 crisis, the recent rapid land use changes have now raised concerns about possible environmental impacts. Practices of crop rotation (together with cattle–agriculture rotation) have been abandoned, more marginal lands have been incorporated into production, and as a result, erosion has increased and problems with pests and diseases have been on the rise (Moscatelli and Pazos, 2002; Pengue, 2001).

Increasingly, these changes in production practices—the lack of crop rotation, monocropping ,and the absence of complementary practices to no-tillage systems—are being associated with the increased impacts from flood events (Cisneros et al., 2004 – unpublished data). The agroecologic zone to which this area belongs to is characterized as a semi-arid to subhumid region (INTA, 1987). Annual rainfall averages (1961–1990) is 841.8 mm, concentrated in spring–summer–fall, predominating in summer and fall (67%). As in much of the Pampas, the region is relatively flat with slight undulations. Although the area is exposed to a variety of climatic hazards, in recent decades, floods have raised the most concern among farmers (Figure 1). Excessive rainfall can cause the rivers (Río Cuarto and Río Quinto) and streams that drain the rainwater runoff to overflow. Additional factors, such as soil saturation, the 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 (Seiler et al., 2002). The floods have incurred a high social cost locally, causing losses in harvests, livestock mobilization, the spread of diseases, and property damage. Livestock and mixed (crop-livestock)-small producers are typically the farmers most concerned with floods, as their smaller landholdings increases the probability that greater portions of their properties will be affected by these events, and these producers tend to have less financial solvency to cope with losses. Type of soils and topography in the flood-prone depressions typically mean that the floodwater remains for some time until the water has evaporated. Flood management thus requires soil- and crop-managing techniques and high investment in infrastructure and sanitation plans (SAGyP/CFA, 1995).

3.1 The farm systems

The forty-seven farm units that were surveyed in Laboulaye were then classified according to land use, resulting in four groups: cash-cropping farms (6 cases); large-scale mixed cash crop-livestock units (8 cases, representing those cases with more than 890 ha); small-scale mixed cash crop-livestock ranches (20 cases, representing those cases with less than 890 ha), and livestock-specializing farms (13 cases).

After the analytical and methodological framework presented in section 2, a number of indicators were constructed based on information from the survey: first, indicators related to resources for adaptation—including measures of management capacity, as well as adaptation measures already taken by the farm units to cope with adverse climatic events or other environmental and economic impacts—were used to make a primary distinction among producers groups in terms of current adaptive capacity to climate variability. Second, indicators of climate sensitivity were obtained with information provided by farmers on their own perceptions of the impacts of different climatic events on crops, livestock, and infrastructure. Finally, both indices were compared in terms of differential degrees of vulnerability among agriculture producers in Laboulaye area.

3.1.1 Adaptive capacity

The selection of variables to use as indicators for adaptive capacity was based on previous knowledge about different production systems in the region and according to hypotheses about what types of resources might enhance the farmers' flexibility to adjust to or cope with climatic variability (Table 2). Each of these variables and variable groupings were weighted through a process of consultation with farmers, to establish their relative importance for adapting to climate risk.[2] An adaptive capacity index was then created from these weighted variables, through a process that involved a summation of the averages values of the weighted indicators for each farm group, normalized by the sample averages.

As indicated in Table 4, this process revealed that the type of farmers who are most numerous in Laboulaye—the mixed small and livestock farmers—appear to have less adaptive capacity than the mixed large farm systems. According to the survey data, the mixed small and livestock producers tended to have the smallest landholdings and reported problems with soil quality (Table 2). In the case of livestock farmers, their choice of production strategy may be a result of the limitations of the soils they have available to them, which prohibit intensive crop production. Although both of these groups reported less total income than the other two groups, they tended to be more diversified economically. Cattle constitute a capital at the same time income generation is typically far less sensitive to climate impacts than crop income. They also tend to rely on technical assistance (however, more related to veterinary services) more than the other farm groups.

Adaptive capacity was similar for the cash-crop producers, although they reported farming in a range of scales (120 ha to 1200 ha), and the interviewed farm managers had higher average incomes and high education levels. However, unlike the mixed-small and livestock farmers, these farmers tended not to own their own machinery nor use technical assistance and did not rely on family labor for production. The highest level of adaptive capacity was associated with the mixed large farm systems, which through large land areas (900 to 3600 ha), were able to enjoy relatively high incomes (since they are devoting increasing proportions of their land to soybeans) and reported high-quality soils. These farmers also reported high education levels, high crop diversity (although low economic diversity), and high use of machinery and other inputs.

3.1.2 Sensitivity

Although sensitivity to climate in agriculture is often interpreted as a function of crop physiology, soils, and management, farmers' perception of their risk can also contribute to their sensitivity. Interviews in the region revealed that, in general, farmers perceived climate change as change in the frequency or impact of extreme events such as flooding, as well as a risk that was intrinsic to their daily activities; thus to a great extent, most of their decisions are taken in terms of market signals. Despite the frequency of flooding and drought in the region, the farmers often confronted their losses with a sense of humor, as well as resignation. Farmers also perceived their sensitivity to climate to be in large part a function of the size of their business; smaller-scale producers tended to overestimate the resilience of larger-scale farmers in face of climatic or other shocks, overlooking the needs of larger-scale operations for government support and associative arrangements. Frustration at the lack of planning and water resource management, poor infrastructure development, and the volatility of the market were also expressed as elements that enhanced their sensitivity to climate impacts.[3] The farmers were well aware of the implications of recent changes in public policy and land use in the region for their sensitivity to climate, citing among other things, the expansion of agriculture and the decline of cattle, the migration of rural households to cities, the disappearance of small farmers, increases in land rental and unemployment, and the irreversibility of many of these trends.

As with the adaptive capacity index, a sensitivity matrix was developed to differentiate farmers' sensitivity not only by the four farm types of Laboulaye, but also by the type of climate event and the nature of its impact on crops, livestock, and infrastructure. Information to construct the matrix was taken from the survey and thus is based on farmers' perceptions of the impacts of climate on their enterprises and livelihoods.[4]

By summing the sensitivity scores of each type of climate event for those farm groups reporting climate impacts on crops (livestock and infrastructure impacts were considered separately), a weighted aggregate score was calculated for each group and climate event (Table 3). This analysis revealed that for cash-crop producers, climate is of not much concern. Flooding and drought were the most worrisome climatic events for the mixed large farm group, whereas flooding appeared to be more important for the mixed small group. Surprisingly, neither mixed-large nor small groups reported impacts on livestock, despite the fact that these groups were both grain and livestock producers, which may be explained by the relatively higher participation of grain production relative to livestock in the total income of these farm units. These scores were then combined with the indicator of impact calculated for the livestock group and the impacts on infrastructure reported for by farmers in all of the groups. The resulting value was the final Sensitivity Index (Table 4). The values suggest that the mixed-small and mixed-large farmers are the most sensitive of the farm groups.

3.2. 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 and Figure 2) and by comparing the farm groups according to the variables considered most important in determining capacity together with overall sensitivity.

For this study, Laboulaye groups' positioning in terms of vulnerability is relative to this particular geographic area, but sensitivity and adaptive capacity indices were calculated in relation to averages within the wider area that corresponds to the whole South of Cordoba Province, where a diversity of production systems, soil conditions, and climatic events are present, as shown in Figure 2. It can be seen in the figure that the mixed-large group of farmers in Laboulaye area were less vulnerable than cash crop and livestock groups, and these three groups were less vulnerable than the mixed-small group. In general, the four groups are relatively more vulnerable than the majority of the other groups of farmers evaluated in the wider project area (represented by the black dots). This is explained partly because the geomorphology of the Laboulaye area makes it prone to floods, in addition to the droughts and hail that occur in the rest of the south center of Cordoba.

The analysis illustrated that although the exposure to climate variability was similar across the Laboulaye area, the sensitivity and adaptive capacity of each group differed according to the nature of their production activities, their soil conditions, and use, as well as their material assets, landholding size, and income (Figure 3). The livestock and cash-crop groups were attributed with moderate levels of vulnerability, reflecting similar overall scores for sensitivity and adaptive capacities, however, with quite different factors contributing to those indices. Livestock production is an activity that is relatively less affected by climate, but presently it is less profitable and tends to take place in marginal cropping areas more susceptible to floods. Cash-crop farmers (generally, soybean farmers) are far more sensitive to the direct impacts of climate events but tend to rent land for this activity with higher-quality soils that are less prone to flooding and with better probabilities for high-income generation (90% of worked area devoted to soybeans). Although cash-crop farmers are not economically diversified, livestock producers are highly dependent on other sources of income (58% of cases have other income similar or greater than the one from agriculture) to fulfill household living requirements.

The highest differences in vulnerability can be seen between mixed-small and mixed-large producers in Laboulaye area (high and low vulnerability, respectively). Although both of these groups showed a high sensitivity to a variety of climate events, the very high adaptive capacity of the mixed-large group outweighed this sensitivity and differentiated the two groups. The landholdings of the mixed-large group is on average five times that of the mixed-small group, reflecting the number of farmers who have expanded production through land rental, as well as land purchases, over the past years. Mixed-small farmers, on the other hand, have been selling off their property. Although their land use is divided between livestock and cash crop production, small landholdings only devote 37% of the worked area to cash crops, whereas the mixed-large farmers, on average, devote more than 60% of their land area to cash crops. This translates into income for mixed-large producers 12 times greater than that of mixed-small farmers (net of direct production and land-renting costs). According to the weights given to income and landholding size in calculating adaptive capacity, the mixed-large farmers scored very high, and accordingly, illustrated lower overall vulnerability. Farmers' participation in organizations is not a distinguishing factor between the groups, a result that was highly expected given the general perception among all farmers that farmers' organizations are not particularly helpful for the less favored rural sectors. The same can be said for technical assistance, whether public or private, given the tendency of larger-scale farmers to rely on their own resources. In summary, we found that the social vulnerability of agricultural producers appeared to be highly related to access to physical and material resources that allow producers greater flexibility in a changing economic and institutional environment.

4. Case Study 2: González, Mexico

The *municipio* of González is located in the southern extension of the northeastern state of Tamaulipas, Mexico. Unlike much of the state of Tamaulipas, which tends to have a relatively arid climate, González is characterized by subhumid conditions with an average temperature of 24 ºC and an accumulated annual rainfall of 850 mm. Historical precipitation records illustrate a decadal pattern rather than any defining trends (Conde, 2005). Some analysts have also observed a correlation between winter precipitation, the Pacific-North American Oscillation and El Niño-Southern Oscillation events (Cavazos, 1997; Magaña and Quintanar, 1997; Cavazos 1999). In addition to periods of drought and flooding, the southern part of the state is particularly susceptible to the impact of hurricanes that occasionally climb the Gulf of Mexico, as occurred in 1955, 1966, 1988, 1995, and 2000. Frost is relatively infrequent, although hailstorms cause occasional crop losses. Other than climate variability, pests have been a consistent problem in the state. Currently, locusts are causing significant damage in annual grain crops.

Tamaulipas is a border state and is heavily influenced by the politics and economy of its northern United States' neighbor, Texas. Tamaulipas is both an importer and exporter of labor, attracting many migrants from Mexico's southern states both to work in Tamaulipas' assembly plants, factories, and fields, as well as with the hope of eventually crossing the Rio Grande to test their fate in the United States. Rural-to-urban and international migration contributes to a scenario of negative population growth in González over the next 30 years. 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 area 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 one-third has not completed primary school.

As in other *municipios* in Mexico, the cultivated area in González is divided between private farmers (*pequeños propietarios),* representing 30% of landholders and farming 70% of agricultural land, and smaller-scale communal farmers (*ejidatarios*) who represent 70% of landholders but 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). Sorghum is known as a crop that is particularly resilient to water stress, and partly for this reason, it was the crop of choice for rain-fed farmers exposed to repeated drought in the 1990s.

In contrast to Argentina where farmers have dramatically expanded the area planted in soybean in response to market signals, the survey data and interviews in the region suggested that significant changes in crop choices of farmers in Tamaulipas (such as a shift from cotton to sorghum) are made generally more in response to government programs and interventions than to price signals, although sorghum and maize tend to be farmed interchangeably according to relative prices. 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.

4.1. The farm systems

4.1.1. Adaptive capacity

As described in the previous section, the agricultural population of González consists of both communal and private farmers (*ejidatarios* and *pequeños propietarios*). Of the reduced sample of 181 farm households used to analyze vulnerability in González, 34 cases were private farmers and 147 were communal farmers. As Table 5 shows, these two groups were distinguished not only in terms of landholding size, but also in terms of education, age, and access to key resources such as credit and insurance.

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. The *pequeños propietarios* reported a higher average number of crops planted but tended to devote more of their total landholding to crop activities (vs. livestock). A higher percentage 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.

Of particular interest were the indicators of diversity at the farm level. In the literature on smallholder systems, crop diversity is often associated with risk management (Wilken, 1987; Netting, 1993; Ellis, 2000). Yet the value of crop diversity compared to crop specialization to a particular household also may depend on the availability and accessibility of alternative means of risk management. For example, with the privatization of Mexico's rural finance system, the primary criteria for credit provision is market viability, such that credit is primarily channeled to large-scale agribusinesses and small- and medium-scale units considered to have good potential for profit in the production of commercial crops (Myhre, 1998). Preferential access to commercial credit for commercially oriented producers, as well as growth in the market for crop insurance could potentially compensate for the function crop diversification plays in smallholder systems. The importance of financial resources and wealth in current agricultural policy in Mexico together with the emphasis on crop specialization resulted in a relatively high importance weighting of these variables in the creation of the adaptive capacity index.

4.1.2 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 6). In part, the similarity of the data on past losses to hazards and 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. Although the northern part of the *municipio* is somewhat more prone to rainfall deficits, the difference is not large, and in general, drought, high temperatures, and the occasional impact of hurricanes (bringing excessive rainfall and flooding) were the primary climatic concerns across the sampled households. 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.

Despite the apparent drought-tolerant nature of sorghum, all farmers reported equally variable yields for sorghum as of maize (declines in yields for all crops averaging around 73%), and climate impacts on sorghum were reported by farmers as being only slightly less spatially extensive (in terms of a percentage of planted area) for sorghum in the 2002–2003 season as for maize (averaging between 40% and 43% in summer for sorghum, vs. 47% to 48% for maize). Farmers reported that the crop with most variable yields in summer was soy and in winter, safflower.

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. Although the farmers generally did not specify the precise period in which they observed changes, the survey data and interviews indicated that climate change was perceived by some as the accumulated outcome of recent extreme events, such as drought or hurricane impacts (e.g., "in the last two years, we have had summer temperatures well over 40˚C" or "since 1997, there is more humidity in September than in July and June; sometimes the crop fails because of too much rain in that month"), as well as a perceived shift in climate conditions over the last two decades (e.g., "it is much drier now"; "about 20 years ago it used to drizzle throughout the winter; now, we hardly have winter anymore, only wind"; "the drought now is *typical*, since about 15 years ago" or "before it used to begin to rain in May; now it's June and the *canicula* also has moved").

The *ejidatarios* also reported less frequent problems with pests and crop diseases, respectively, compared to the *pequeños propietarios*. It is common in Mexico for farmers to associate pest and disease problems in agriculture with climatic variability and to acknowledge that these problems can increase the economic impact of climate impacts (Eakin, 2003). Farmers' concerns with pest and disease problems have also been shown to be an important obstacle to new technology adoption and change (CIMMYT, 1991).

The importance of nonfarm income in a household's income portfolio, or, conversely, the dependence of the household on agricultural income, is also a measure of household sensitivity to climate impacts (Adger, 1999). As measured by the proportion of income derived from a general source (Ellis, 2000), a greater proportion of communal farmers derived more than 66% of their monetary income from at least two sources (e.g., crop/nonfarm; crop/livestock or livestock/nonfarm) than did the *pequeños propietarios* (Figure 4). Communal farmers in general also relied relatively heavily on nonfarm income sources (either as the primary income source or in combination with other activities), while crop income was the primary income source for 47% of private farmers.

4.2 Vulnerability

Each of the variables associated with adaptive capacity and sensitivity was transformed into a 0 to 1 scale and weighted through the Analytical Hierarchy Process.[5] 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 (see Yates, 1981; Sanderson 1986). 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.

To analyze the overall vulnerability of the households, the values for the sensitivity and adaptive capacity indicators were combined through fuzzy logic[6], 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, as expected, associated with the low vulnerability category. However, these farmers were also proportionally more represented in the high-vulnerability class (Figure 5), 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 radar, or "amoeba," diagrams, one can see that for both *pequeños propietarios* and *ejidatarios*, access to financial resources (credit and insurance) and technical assistance, together with crop income dependence and problems with crop pests is what primarily distinguishes the households in the high- and low-vulnerability classes (Figure 6). Although the pairwise comparisons resulted in a relatively high importance weight for financial resources in the adaptive capacity index, this weight is mediated by the frequency of credit and insurance access and use across the sample and the equal weights given to the attributes of sensitivity and adaptive capacity in the calculation of the vulnerability index. Nevertheless, financial resources appear to play an important role in distinguishing the low-vulnerability households from the high-vulnerability households in both private and communal farm groups.

It is interesting to note that in both of the tenure groups, income diversity and crop diversity are both associated with low- and high-vulnerability classes. This may reflect the fact that income diversity—particularly, diversification into temporary low-skilled positions—is a coping strategy for income-insecure households, and thus it could equally be an indicator of poverty and marginalization as an indicator of flexibility in face of risk, depending on the type of nonfarm activity and the other endowments of the household. Although crop diversity (in this case, the number of crops planted by the household in 2002/2003) theoretically provides households with alternatives should a climatic hazard affect one particular crop, greater diversity can also mean increasing one's exposure to a broader variety of climatic hazards and thus increasing the probability that a household will experience crop loss. The greater sensitivity of diversified households was also seen with the mixed-small and mixed-large farm systems of the Laboulaye case study.

5. Discussion and Conclusions

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, these pressures are being articulated through the reform of the 1917 Constitution, permitting the "privatization" of ejidal land, and thus its sale and legal rental, as well as in the exclusion of farm units considered to lack commercial potential from access to productive services (credit, insurance, and technology). The continued important presence of government incentive programs for planting specific crops—first sorghum, now pasture—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 the 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—31% of farmers abandoned agriculture in Argentina from 1988 to 2002 (INDEC, 2004). There is some evidence that the spread of soybean and other cash crops onto land that was previously not used for agriculture is also leading to increased rates of erosion, and in some areas increased susceptibility to floods and droughts, raising the overall costs of climate impacts in the region (Cisneros et al., 2004).

In Mexico, diversification both in terms of agriculture (crop and livestock), as well as in terms of income sources (farm and nonfarm), has been a strong traditional feature of *ejidatario* livelihood strategies. Interviews with agricultural experts in the region suggest that the growing role of nonfarm income in smallholder strategies may be a reflection of increasing economic stress and the decline in the viability of smallholder agriculture. Economic diversification had also become a feature of family farms in the

Pampas in the 1990s; however, Argentina's economic crisis of the past three years has limited the viability of that strategy.

In González, we found that resource scarcity, particularly small landholdings, lack of credit and problems in commercialization tended to restrict the number of crops planted by *ejidatarios*. However, these same constraints were encouraging far greater income diversification—both into livestock, as well as nonfarm activities. In contrast, a greater proportion of private farmers tended to specialize in crop production and tended to plant a larger number of crops. Yet neither the degree of diversification of crops or incomes alone was associated with high or low vulnerability. Instead, the analysis illustrates that households with a high dependence on crop income could be either classified in the low-vulnerability class, if they had access to appropriate financial and technical resources, or, alternatively in the high-vulnerability class if they did not. Moderately vulnerable households tended to be those who, in the absence of alternative sources of formal financial support and risk management, were using a strategy of income diversification to reduce their sensitivity to climate and economic stress. This suggests that in current political environment, diversification remains a viable—and perhaps necessary—risk reduction strategy for farmers operating on the economic margin, whereas among commercial producers, the determining factor in their vulnerability is their access to financial and material resources that can buffer a large-scale producer against climatic risk.

Our study has essentially provided a "snapshot" of vulnerability in a particular tumultuous period in the histories of both countries. Although our selection of indicators was done to reflect the vulnerability of farm units to very dynamic social and climatic processes, we cannot argue that our assessment captures the dynamic nature of vulnerability in either location. We can, however, consider our assessment in the context of plausible scenarios for each region. One such scenario would be the continuation of current policy trends, with the likely result—particularly in Laboulaye—of further land concentration, the continued expansion of monocropping, and the continued economic marginalization of the small family farm. The particular resources identified in our case studies as important in adaptive capacity (credit, insurance, landholding size, and farm profit) would continue to play an important role in determining future vulnerability, by facilitating adaptations, reducing sensitivity or improving coping capacities.

Under this scenario, the farmers who would most likely exit the agriculture sector would likely be those who have been unable to engage fully and profitably in commercial markets, although these same farmers may have reduced their exposure to climatic risk through income diversification. 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. For several decades, researchers have cautioned that very capital intensive models of agricultural development in some cases may actually make production systems less resilient by creating an unsustainable dependency on exogenous inputs and increasing the sensitivity of production to ecological and economic disturbances such as salinity, water scarcity, and pests (Conway, 1987; Buttel and Gertler, 1982; Marsden, 1997).

In one sense, the González case offers a good example of this process. According to the state's agricultural ministry, the problem of erosion and soil degradation from sorghum monocropping are beginning to be evident in northern Tamaulipas, illustrating the environmental consequence of what was imagined in the 1960s to be a perfect adaptation to both water scarcity and market opportunity. A similar future could await Laboulaye, with disturbing implications for the regions' susceptibility to floods and droughts.

Another scenario is possible, although less probable. In Argentina, greater concern over the environmental impacts of expansive agriculture might encourage the development of new regulations to conserve fragile lands and enable more diversified land use once again. A drop in soy prices and increased support for Argentina's livestock industry (perhaps in response to renewed consumer interest in locally produced organic beef) would help revive the opportunities for small-scale family farms. 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; see Tobin (2004) and Tucson Weekly (1996)], such a policy might provide those farmers practicing mixed grain/livestock farming with the resources they need to adjust to new opportunities. One of the benefits of globalization is that it can also facilitate the growth 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. Tamaulipas already is home for a large number of Mennonite farmers, who have practiced low-input, high-yielding agriculture for decades. Public support for the formation of farm associations and producer groups would be a key element in such a scenario.

Regardless of the future scenario, it is clear that vulnerability in both regions will continue to be a product of the incidence and biophysical impact of climate events, the structure and resources of the affected farm units, and the institutional and policy environment in which those farmers are operating. The complex and multivariate nature of vulnerability challenges any simple interpretation of current sensitivities and makes evaluating future risk problematic. We hope the methodologies that we used in this study provide useful insights into how the evolving strategies of farm households are changing the landscape of vulnerability at the local level. Our analysis not only identifies processes presently occurring, which may well have important implications for future risk, but also identifies some areas of possible intervention, both at macro and micro levels, that could enhance farmers' coping capacities to climate risks today and in the future. In this analysis, we have raised important questions about the sustainability of current agricultural development pathways, as well as the implications of these trajectories for future climate risk. The particular variables that make a farm system adaptive are not absolute or invariable but rather products of the ambitions and visions of progress held by broader society and articulated through policy. Who will be adapting and by what means is ultimately a normative question inseparable from the ideology and outcomes of present development processes.

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Endnotes

[1] These differences reflect the slightly different nature of the data collected in each case study, as well as the need to match the methodologies to the structure and typology of production in each case study.

[2]The weights obtained through consultation with farmers were as follows: *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: Uses Public Technical Assistance (0.38); Uses Private Technical Assistance (0.36); Participation in Organizations (0.34); Education (0.34); Experience (0.49); *c)* Management Capacity Group (0.634); Variables: Adaptations (0.634); and 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); Climatic Risk Insurance (0.50). The following procedure was used to obtain these weights. First, a value for each of the groups and variables was obtained in relation to the order of importance given to the variable group and variable by the farmers. Second, these values were indexed using the maximum value given to a group and, then by the maximum value given to a variable.

[3]"*...There is no water policy in Córdoba Province, each farmer does with water what he wants: takes it, manages it, sells it, dumps it on his neighbor or to town. There is lack of governmental control over clandestine works ... here under desperation—and this must be understood—when a farmer is about to lose all his life's efforts, he dumps the water on his neighbor….*" Words of N. Garimano, Mayor of Laboulaye City, 2003.

[4] For Sensitivity Matrix construction, information gathered from the survey for each agriculture producer and in relation to main climatic events affecting each main crop,

frequency of adverse events (freq), percentage of area affected (affa), and type of damage (typd) were systematized. Each response has been given a value from 0 to 3, representing no impact (0); low impact (1); medium impact (2); and, high impact (3). The first result derived: R1= (freq * affa * typd). Crop lost was also taken on account, though in this case, as an average of the differences between planted and harvested area within each group and for main crops (%loss). For each crop, these values were weighted by proportion of agricultural producers concerned with each particular event within their group (n/N) and by the area dedicated to that particular crop related to the total worked area by each producer [%added), and the final result came from: R2= (R1 * (n/N) * (%added) * (%loss)].

[5] The Analytical Hierarchy Process was used to assign weights for each variable and each attribute. First, the natural scales of each variable are transformed through value functions into a scale of 0–1. The variables are then grouped by attribute. Then a series of pairwise comparisons are undertaken of the variables defining each attribute, 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 index value for each concept is calculated as the weighted linear combination of its defining attributes:

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[6] Fuzzy logic is a formal mathematical theory for addressing uncertainty in decision making. It involves determining the degree to which any particular value—a household's value for "adaptive capacity," for example—belongs to a fuzzy set corresponding to linguistic variables such as "high vulnerability" or "low vulnerability," with explicit recognition that set membership is often an ambiguous concept. 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 et al, 2002).

References

ASERCA (Apoyos y Servicios a la Comercialización Agropecuaria). 1997. El sorgo mexicano: entre la autosuficiencia y la dependencia externa. *Claridades Agropecuarias*. 46:3–13.

Adger, N. 1999. Social vulnerability to climate change and extremes in coastal Vietnam. *World Development* 27:249–269.

Adger, W. N., N. Brooks, G. Bentham, M. Agnew, and S. Eriksen. 2004. New indicators of vulnerability and adaptive capacity. *Technical Report 7*. Tyndall Center for Climate Change Research, University of East Anglia, Norwich. http://www.tyndall.ac.uk/publications/pub_list_2004.shtml. Last accessed May 7, 2006.

Anderson, J. and J. Dillon. 1992. *Risk analysis in dryland farming systems*. Rome: Food and Agrcicultural Organisation.

Barkin, D. and B. R. DeWalt. 1988. Sorghum and the Mexican food crisis. *Latin Am. Res. Rev.* 23:30–59.

Bebbington, A. 2000. Reencountering development: Livelihood transitions and place transformations in the Andes. *Ann. Assoc. Am. Geogr.* 90:495–520.

Berdegué, J., T. Reardon, and G. Escobar. 2001. Rural non-farm employment and incomes in Chile. *World Development* 29:411–425.

Blaikie, P., T. Cannon, I. Davis, and B. Wisner. 1994. *At risk: natural hazards, people's vulnerability and disasters*. London: Routledge.

Bojórquez-Tapia, L. A., L. Juárez, and G. Cruz-Bello. 2002. Integrating fuzzy logic, optimization, and GIS for ecological impact assessments. *Environ. Mgmt.* 30:418–433.

Brklachich, M., D. McNabb, C. Bryant, and J. Dumanski. 1997. Adaptability of agriculture systems to global climate change: a Renfrew County, Ontario, Canada Pilot Study. In *Agricultural restructuring and sustainability: A geographical perspective*, edited by B. Ilbery, Q. Chiotti, and T. Rickard. New York: CAB International, pp. 185–200.

Buttel, F.H. and M.E. Gertler. 1982. Agricultural structure, agricultural policy and environmental quality. *Agric. Environ.* 7:101–119.

Cavazos, T. 1997. Downscaling large-scale circulation to local winter rainfall in north-eastern Mexico. *Intl. J. Climatol.* 17:1069–1082.

Cavazos, T. 1999. Large-scale circulation anomalies conducive to extreme precipitation events and derivation of daily rainfall in northeastern Mexico and southeastern Texas. *J. Climate* 12:1506–1522.

Chiotti, Q., T. Johnston, B. Smit, and B. Ebel. 1997. Agricultural response to climate change: A preliminary investigation of farm-level adaptation in southern Alberta. In: *Agricultural Restructuring and Sustainability*, edited by B. Ilbery, Q. Chiotti, and T. Richard. New York: CAB International, pp. 201–218.

CIMMYT. 1991. El enfoque de sistemas agrícolas y la participación de los agricultuores en el desarrollo de una tecnología apropiada. In *Desarrollo agrícola en el tercer mundo*, edited by C. K. Eicher and J. M. Staatz. Mexico City, Mexico: Fondo de Cultura Económica, pp. 443–463.

Conde, C. and H. Eakin. 2003. Adaptation to climatic variability and change in Tlaxcala, Mexico. In: *Climate change, adaptive capacity and development,* edited by S. Huq. Postdam, Germany: Institute for Climate Impact Research, pp. 241–259.

Conway, G. 1987. Properties of agroecosystems. *Agric*. *Syst*. 24:95–117.

Cornelius, W. and D. Myhre, Eds. 1998. *The transformation of rural Mexico: Reforming the Ejido sector*. San Diego, CA: Center for U.S.–Mexico Studies.

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* 21:659–674.

Dessai, S., W. N. Adger, M. Hulme, J. Köhler, J. Turnpenny, and R. Warren. 2003. *Defining and experiencing dangerous climate change*, Tyndall Center for Climate Change Research, Norwich, UK: University of East Anglia.

Eakin, H. 2002. *Rural Households' Vulnerability and Adaptation to Climatic Variability and Institutional Change*. PhD thesis. Department of Geography and Regional Development. University of Arizona, Tucson.

Eakin, H. 2003. The social vulnerability of irrigated vegetable farming households in central Puebla. *J. Environ. Develop.* 12: 414–429.

Easterling, W. 1996. Adapting North American agriculture to climate change in review. *Agric. Forest Meteorol.* 80:1–53.

Ellis, F. 2000. *Rural livelihoods and diversity in developing countries*. Oxford, UK: Oxford University Press.

Ghezan, G., M. Mateos, and J. Elverdin. 2001. Impacto de las políticas de ajuste estructural en el sector agropecuario y agroindustrial: el caso de Argentina. *Serie Desarrollo Productivo* No. 90, Red de Desarrollo Agropecuario. CEPAL, Comisión Económica para América Latina y el Caribe (United Nations), Santiago de Chile.

Hernández Laos, E. and J. Velásquez Roa. 2003. *Globalización, desigualdad y pobreza: Lecciones de la experiencia mexicana.* Mexico City, Mexico: Universidad Autónoma Metropolitana.

Ibarra Mendívil, J. L. 1996. Recent changes in the Mexican constitution and their impact on agrarian reform. In *Reforming Mexico's Agrarian Reform*, edited by L. Randall. Armonk, NY: M.E. Sharpe, pp. 49–60.

Instituto Nacional de Estadísticas y Censos. 2004. Preliminary data National Agriculture Census 2002. Accessed through www.indec.mecon.ar/

INEGI, Instituto Nacional de Estadística, Geografía y Información. 2000. XII Censo General de Población y Vivienda, 2000. INEGI, Aguascalientes.

Instituto Nacional de Tecnología Agropecuaria. 1987. *Análisis de la evolución, situación actual y problemática del sector agropecuario del centro regional Córdoba*. Buenos Aires, Argentina: INTA Centro Regional Córdoba.

Instituto Nacional de Tecnología Agropecuaria.. 2002. *Plan de Tecnología Regional (2001-2004) Centro Regional Córdoba*. Buenos Aires, Argentina: Ediciones INTA.

Kandlikar, M. and J. Risbey. 2000. Agricultural impacts of climate change: If adaptation is the answer, what is the question? *Clim. Change* 45:529–539.

Kelly, T. 2001. Neoliberal reforms and rural poverty. *Latin Am. Perspect.* 28:84–103.

Latuada, M. 2000. El crecimiento económico y el desarrollo sustentable en los pequeños productores agropecuarios Argentinos de Fines de Siglo XX. *Conferencia Electrónica sobre Políticas Públicas*, *Institucionalidad y Desarrollo Rural en América Latina*, www.rlc.fao.org/foro/institucionalidad (Accessed May 7, 2006).

Liverman, D. 1990. Drought impacts in Mexico: Climate, agriculture, technology and land tenure in Sonora and Puebla. *Ann. Assoc. Am. Geogr.* 80:49–72.

Loker, W. M. 1996. 'Campesinos' and the crisis of modernization in Latin America. *J. Pol. Ecol*. 3:69–88.

Magaña-Rueda, V. O. and A. I. Quintanar. 1997. On the use of a general circulation model to study regional climate. In: *Numerical simulations in the environmental and earth sciences. Proceedings from the Second Annual UNAM-CRAY Supercomputing Conference*. edited by F. García García, G. Cisneros, A. Fernández-Equiarte, and R. Álvarez. Cambridge, UK: Cambridge University Press.

Marsden, T. 1997. Reshaping environments: Agriculture and water interactions and the creation of vulnerability. *Trans. Inst. Brit. Geogr.* 22:321–337.

Myhre, D. 1998. The achilles' heel of the reforms: The rural finance system. In: *The transformation of rural Mexico: Reforming the Ejido sector*. edited by W. Cornelius and D. Myhre. San Diego, CA: The Center for U.S.–Mexico Studies.

Moscatelli, G., and M. S. Pazos. 2002. *Soils of Argentina—Nature and use.* www.elsitioagricola.com/articulos/moscatelli/soils%20of%20argentina%20-%20nature%20and%20use.asp (Accessed May 7, 2006).

Netting, R. 1993. *Smallholders, householders: Farm families and the ecology of intensive, sustainable agriculture.* Stanford, CA: Stanford University Press.

Obschatko, E. 1993. *Efectos de la desregulación sobre la competitividad de la producción argentina*. Buenos Aires, Argentina: Grupo Editor Latinoamericano.

Pengue, W. 2001. *The impact of soybean expansion in Argentina*. www.grain.org/seedling/?id=116 (Accessed May 7, 2006).

Peretti, M. 1999. Competitividad de la empresa agropecuaria Argentina en la década de los '90. *Revista Argentina de Economía Agraria*. 11:27–42.

Reilly, J. M. and D. Schilmmelpfenning. 1999. Agricultural impact assessment, vulnerability and the scope for adaptation. *Climatic Change* 43:745–788.

Risbey, J., M. Kandlikar, and H. Dowlatabadi. 1999. Scale, context and decision making in agricultural adaptation to climate variability and change. *Mitigation and Adaptation Strategies for Global Change* 4:137–165.

Secretaría de Agricultura, Ganadería, Pesca y Alimentación (SAGyP)/CFA. 1995. *El Deterioro de las Tierras en la República Argentina*. Buenos Aires, Argentina: SAGyP Ed.

Sanderson, S. 1986. *The transformation of Mexican agriculture: International structure and the politics of rural change.* Princeton, NJ: Princeton University Press.

Scoones, I. 1998. Sustainable rural livelihoods: A framework for analysis. *IDS Working Paper*. Institute for Development Studies, Sussex, United Kingdom.

Seiler, R., M. Hayes, and L. Bressan. 2002. Using the standarized precipitation index for flood risk monitoring. *Intl. J. Climatol.*. 22:1365–1376.

Smit, B., D. McNabb, and J. Smither. 1996. Agricultural adaptation to climatic variation. *Clim. Change* 33:7–29.

Smithers, J., and B. Smit. 1997. Agricultural system response to environmental stress. In: *Agricultural restructuring and sustainability: A geographical perspective*, edited by B. Ilbery, Q. Chiotti, and T. Richard. New York: CAB International.

Solbrig, O. 1996. Towards a sustainable Pampa agriculture: Past performance and prospective analysis*.* *The David S. Rockefeller Center for Latin American Studies Working Paper No.96/97-6* (DRCLAS). Harvard University, Cambridge.

Solbrig, O., and E. Viglizzo. 1999. Sustainable farming in the Argentine Pampas: History, society, economy, and ecology. *The David Rockefeller Center for Latin American Studies Working Paper No.99/00-1* (DRCLAS). Harvard University, Cambridge, MA.

Tobin, M. 2004. Exotic grass vs. palo verde *The Arizona Daily Star.* August 8. http://www.azstarnet.com/dailystar/printDS/33361.php (Last accessed May 8, 2006).

Tucson Weekly. 1996. The grass that ate Sonora (cover story). *The Tucson Weekly*. April 18–24. http://www.tucsonweekly.com/tw/04-18-96/cover.htm (Last accessed May 8, 2006).

Wehbe, M.B. 1997. *Regional Consequences of the Agro-food System: Rural Changes in the South of Córdoba (Argentina).* Ph.D. thesis, Institute of Social Studies, The Hague, The Netherlands.

Wilken, G. 1987. *Good farmers: Traditional agricultural resource management in Mexico and Central America.* Berkley, CA: University of California Press.

Yates, P. L. 1981. *Mexico's agricultural dilemma.* Tucson, AZ: The University of Arizona Press.

Table 1. *Main Production Systems (Laboulaye Area)*

System	Farms		Worked area		Average hectares
	Number	%*	Hectares	%*	
Bovine livestock	641	25.4	284,962	20.4	444.6
Mixed crop-livestock	509	20.2	425,165	30.4	835.3
Small landholdings	222	8.8	21,260	1.5	95.8
Dairy-livestock	186	7.4	79,140	5.7	425.5
Cash crop	169	6.7	63,538	4.5	376.0
Dairy-Mixed	94	3.7	85,834	6.1	913.1
Bovine livestock-Ovine	83	3.3	78,126	5.6	941.3
Total	1,904	75.4	1,038,025	74.3	545.2

Source: INTA, 2002. *These percentages are related to total number of farms (2,525) and total worked area (around 1,397,000 hectares).

Table 2. *Selected Measures of Adaptive Capacity by Farm Group*

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
	(Min/Max)	(120/1,200)	(900/3,600)	(172/ 800)	(50/1,270)
	Machinery index[a]	1.3	2.3	1.3	0.6
	Gross margin (Agr. $) (Income)[a]	207,000	807,000	66,000	0
	Good soil quality (% of cases)	66.66	62.50	35.00	30.77
Management capacity	Rented land (as % of worked area)[b]	89.5	46.4	33.8	40.9
Financial resources	Other sources of income(% of cases)[c]	17	12	25	54
	Hail insurance (% of cases)	33	70	40	7
Information	Number of sources of technical assistance[a]	1	2.25	1.5	1.93
	Consults any type of climate information (% of cases)	83 %	50 %	100 %	84 %
Diversity	Number of crops[a]	1.83	3.0	2.05	0.15
	% of hectares dedicated to cash crops[a]	98.7	61.7	36.7	0

Survey data, 2003.
[a] Average data
[b] Average data, weighted by landholding size
[c] Other sources of income refers only to the same or greater amount of money from other activities but agriculture.

Table 3. *Farmers' Sensitivity by Group and Climate Event (Impacts on Crops)*

	Cash crop	Mixed-small	Mixed-large	All
Flood	0.8	3.52	2.07	6.39
Drought	0.3	0.58	2.57	3.45
Hail	0.15	0.25	0.28	0.68
All	1.27	4.36	4.92	

Source: Survey data, 2003.

Table 4. *Vulnerability of Different Production Systems Within Laboulaye Area*

Farmer group	**Vulnerability**	**Sensitivity**	**Adaptive capacity**
Mixed-small	*High*	5.21	6.82
Livestock	*Moderate*	1.89	6.27
Cash crop	*Moderate*	1.27	6.09
Mixed-large	*Low*	5.67	11.95

Source: Survey data, 2003.

Table 5. *Selected Adaptive Capacity Indicator Variables for Private and Communal Farmers*

Capacity attribute	**Variable**	**Private**	**Communal**
Human capital	Age of farmer (yrs)	46	52
	Education (yrs)	4.6	3.2
	Adults with primary school education	1.5	2.15
Material resources	Landholding size (ha)	332	23
	Animal units	30	10
	Tractor ownership	91%	31%
	Irrigation	15%	37%
Financial resources	Credit	44%	15%
	Insurance	21%	7%
Information	Technical assistance	29%	29%
	Consults climate information	53%	70%
Diversity	Number of crops	2.2	1.5
	Land use in agriculture	90%	69%

Source: Survey data, 2003.

Table 6. *Selected Measures of Sensitivity to Climate Hazards*

Sensitivity attributes	**Private**	**Communal**
Average number of past climate events remembered	2.0	1.6
Average number of pests and diseases that frequently affect crops and livestock	2.4	1.7
Average % area affected by hazards, summer 2002	35%	45%
Average % decline in yields between good and bad years (summer crop)	72%	74%
% of farmers who think climate is changing	71%	92%
% of farmers reporting loss in income 1998–2003	32.4%	35.4%
Dependency of household on crop income	60%	37%

Source: Household survey, 2003.

Figures

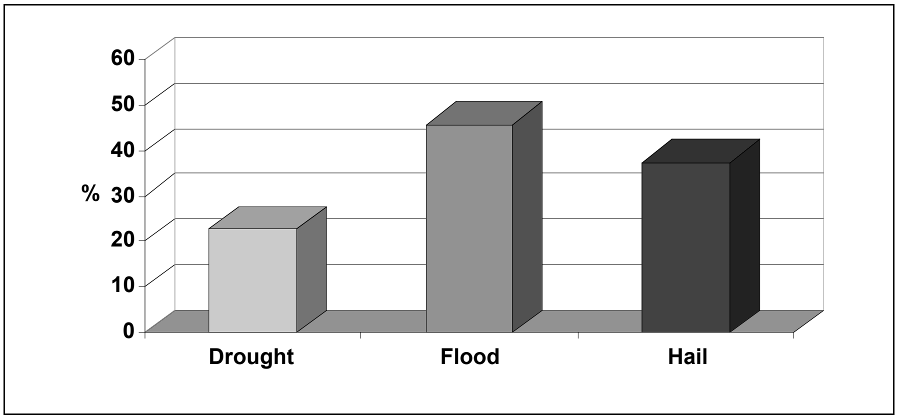


Figure 1. Most worrisome climate events in Laboulaye area. Percentage of agriculture producers concerned with different climate impacts and events. **Source:** Survey data, 2003.

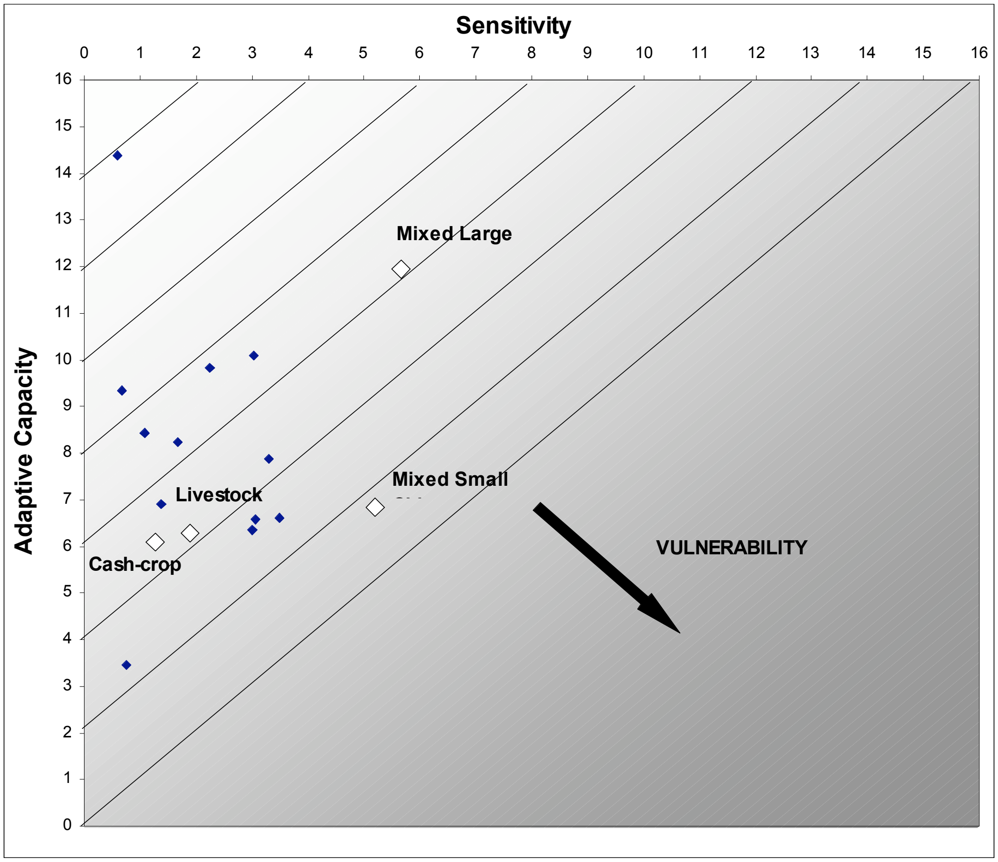


Figure 2. Laboulaye studied groups positioning in terms of vulnerability levels. Because estimating indifference curves is out of scope of this study, a constant unit Marginal Substitution Rate was supposed. However, what the figure shows is consistent with the qualitative analysis that has been done.

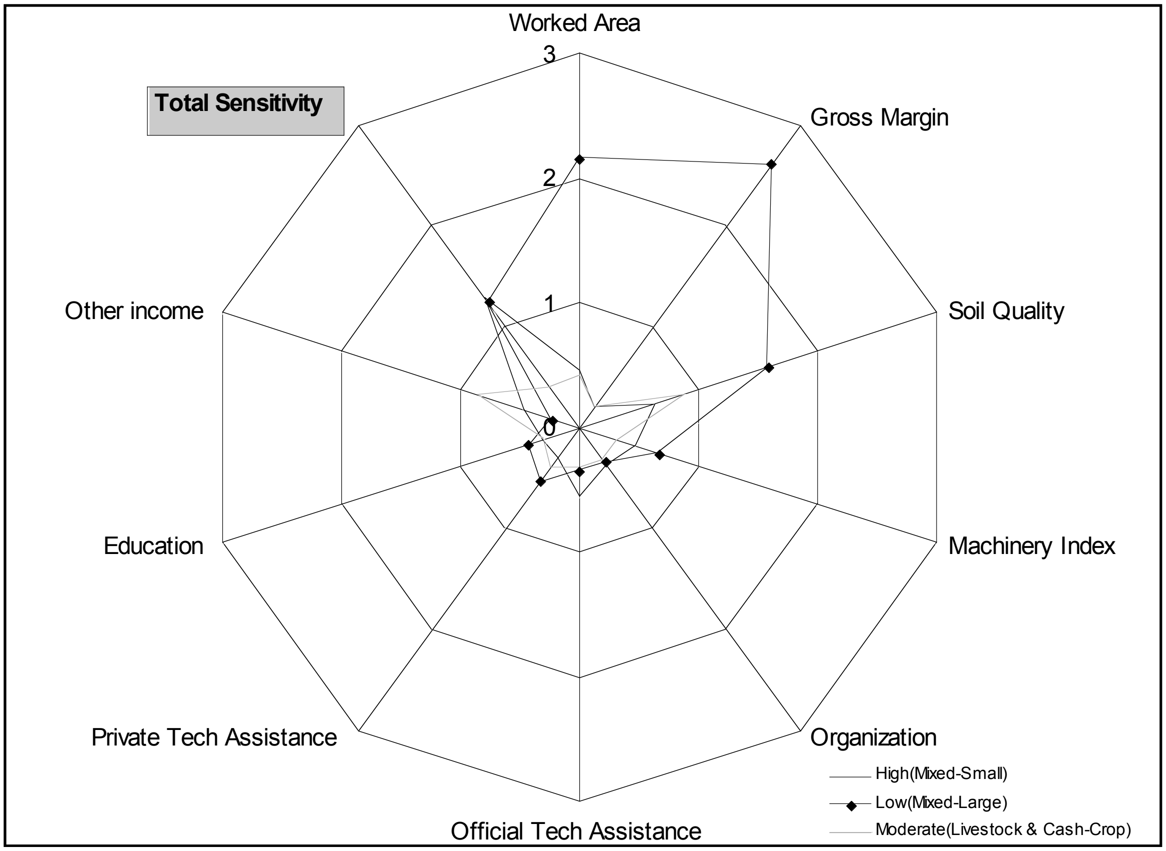


Figure 3. Vulnerability classes, Laboulaye, Argentina. Each of the variables displayed represent average values, which were indexed as to facilitate comparative analysis among the four identified groups. Relationships between total sensitivity and the rest of the displayed variables in the amoeba were used to determine differences in vulnerability levels.

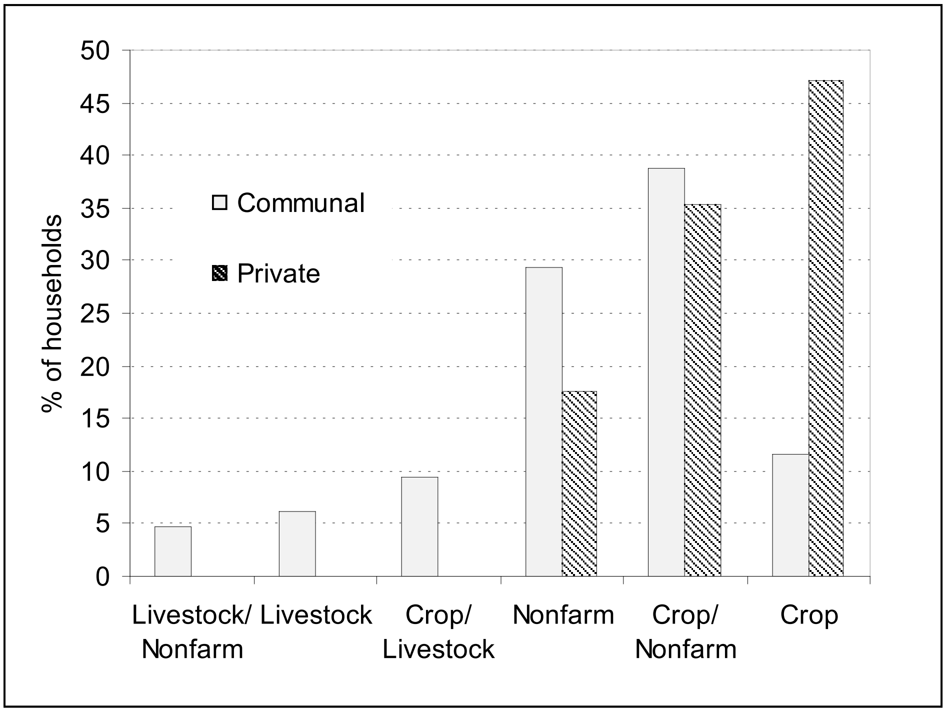


Figure 4. Farm systems in Gonzalez. The farm systems were defined in terms of the source(s) of income that farmers estimated represented 66% or more of their total household income.

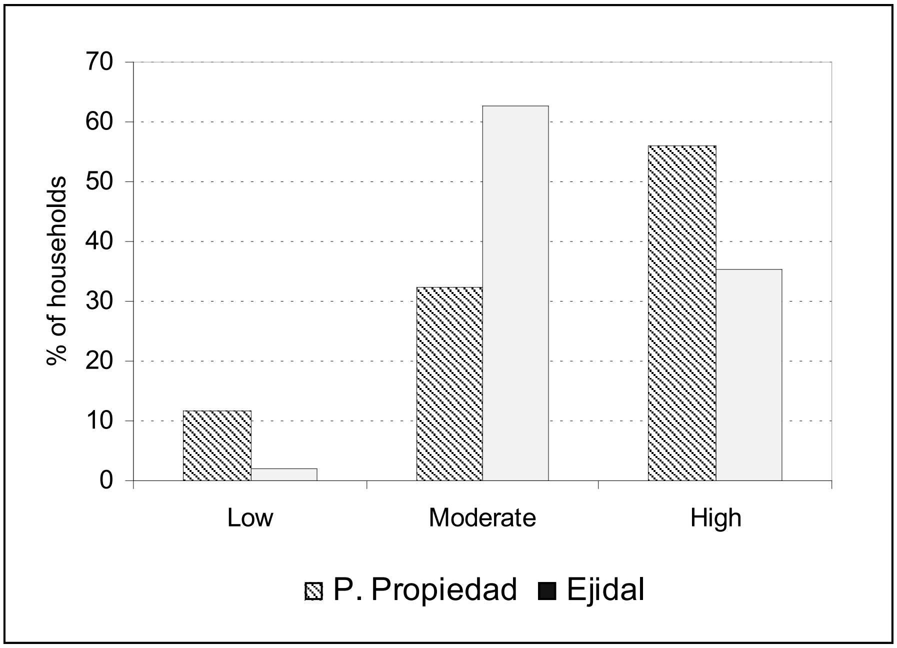
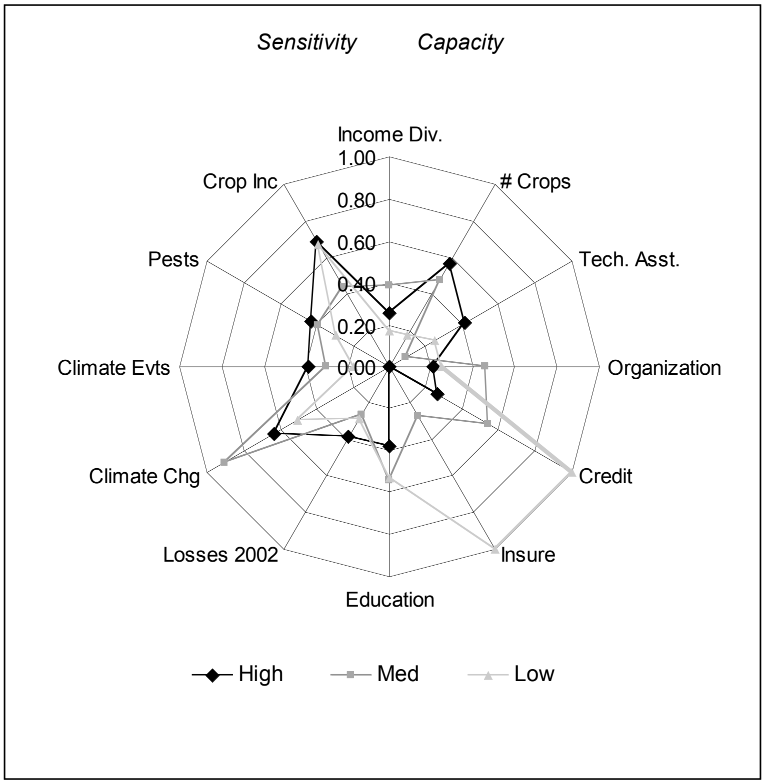


Figure 5. Vulnerability classes in Gonzalez by tenure group.



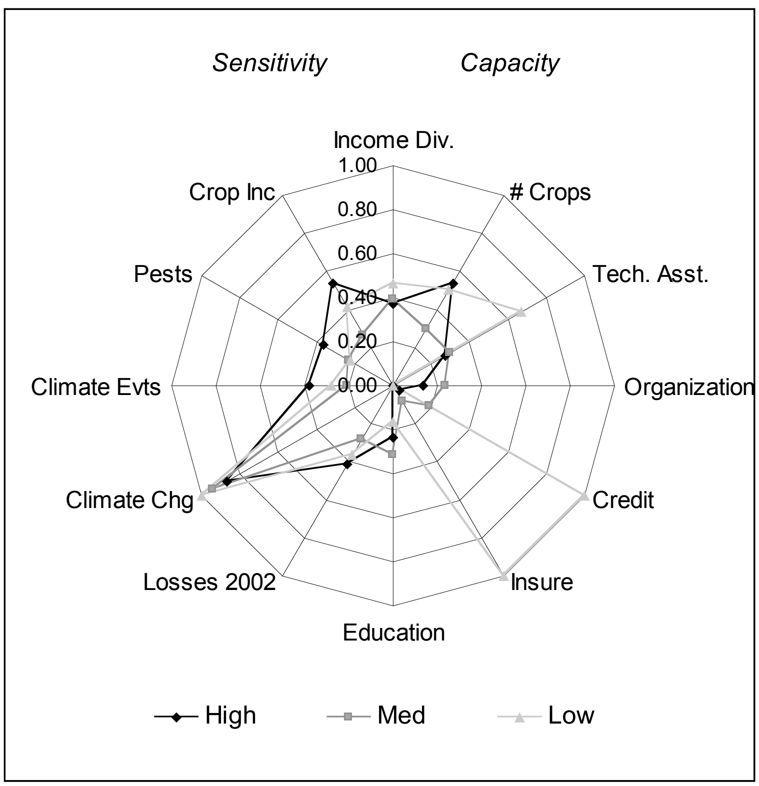


Figure 6. Vulnerability Classes, Pequeña Propiedad (*top*).

Vulnerability classes, Ejidal (*bottom*).