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A comparative assessment of climate vulnerability: agriculture and ranching on both sides of the US–Mexico border

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Abstract

Social science research on climate vulnerability tends to be limited to case studies in either industrial countries or in less-developed nations. The empirical study presented here takes a comparative approach across this divide by examining rural livelihoods on both sides of the United States–Mexico border. Looking beyond single agricultural systems, crossing borders and listening to rural producers in this semi-arid environment offers a more complete picture of how differences in access to resources, state involvement, class and ethnicity result in drastically different vulnerabilities within a similar biophysical context. We distinguish between coping and buffering in examining adaptation strategies and place an emphasis on the historical context of vulnerability as a dynamic social process with socioeconomic and environmental consequences.

1. Introduction

Semi-arid conditions, highly variable precipitation and frequent droughts characterize much of the state of Sonora, Mexico and its northern US neighbor, the state of Arizona. These two regions have the fastest growing populations in their respective countries, and ranching and agricultural livelihoods have been key to their economic development and cultural identity. Also, water resources in both states are scarce and a major cause for concern. Whereas there is general agreement that consecutive years of below normal rainfall may be particularly harmful to those livelihoods tied to the land, vulnerability to drought and climate variability in this semi-arid environment is experienced and perceived in dramatically different ways. In Arizona, most ranchers and farmers perceive a multi-year drought as a problem that causes economic losses but not catastrophes; in Sonora, the same event may mean loss of livelihoods and severe suffering for a significant percentage of the rural population. Thus, local populations operating under similar climatic regimes may perceive climate and define drought in different terms, depending on the level of vulnerability of particular sectors, social classes, ethnic groups, or livelihoods.

In this paper we examine social vulnerability to climate variability from a local perspective and within a historical context. At this level of analysis, climatic events such as droughts or floods are assessed in terms of the characteristics of specific social and environmental systems. We compare and contrast two ranching and farming regions: the *Municipio* (similar to a US county) of Alamos, located in southeastern Sonora, and the Sulphur Springs Valley (SSV), located in southeastern Arizona[1] (see Fig. 1). A comparative approach to understanding vulnerability in regions of similar climatic characteristics is useful in revealing the differential effects of climate on society and in underscoring how social, political, economic, and historical factors shape vulnerability. This is particularly relevant because many studies emphasize biophysical characteristics as determinants of vulnerability—semi-arid and coastal areas, for example, are often categorized as most vulnerable (Watson et al., 1998). Instead, we underscore the role of class and ethnicity as variables that impact vulnerability in a semi-arid region. As natural scientists monitor the impacts of global climatic change (e.g., Watson et al., 1998; McCarthy et al., 2001), an assessment of past and current vulnerabilities will provide important insights into the magnitude of future

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[1] For a detailed account of the Alamos case study see Vásquez-León and Liverman (in press) and for the SSV case study see Vásquez-León et al. (2002).

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Fig. 1. Map of the Sulphur Springs Valley and the Municipio of Alamos.

consequences of climate change particularly as semi-arid regions around the world become increasingly populated and urbanized (Stern and Easterling, 1999).

Like others, we argue that vulnerability is not predominantly a climate-based condition, but rather derives its significance from the interaction of climate and society (Hewitt, 1983; Kates, 1985; Varley, 1994; Kasperson et al., 1995). From this perspective, vulnerability is ultimately determined by a set of socio-economic and political variables (Bohle et al., 1994; Liverman, 1999) and refers to the "degree to which a system is susceptible to, or unable to cope with, adverse effects of climate [variability] and change" (McCarthy et al., 2001, p. 6). Following Adger (2003), the vulnerability of a particular community or livelihood system[2] is a function of three main factors. First, the degree to which a system is *exposed* to climate variability—this captures the degree or intensity of an event; second, of its *sensitivity* to the harmful socio-economic impacts of climate variability; and third of its *adaptive capacity* to deal with, adjust, and recover from the impacts of severe climatic events. The more acute the socioeconomic impacts of an event (e.g. crop losses resulting from drought in a rain-fed agricultural system), the greater the degree of vulnerability; conversely, those livelihoods that have a broader range of short-term responses and a greater long-range recovery capability are less vulnerable to the same climatic events.

Following the "access model" developed by Blaikie et al. (1994) we "show how social systems create the conditions in which hazards have a differential impact on various societies and different groups within society" (p. 46). This model focuses on understanding the range of resources that allow an individual, household, class, or community to secure a livelihood. Access to those resources is "always based on social and economic relations, usually including the social relations of production, gender, ethnicity, status, and age" (Blaikie et al., 1994, p. 48). Similarly, the "architecture of entitlements" model provided by Adger and Kelly (1999), emphasizes how groups bring into play a basket of resources, rights, and entitlements to obtain financial or material assistance during critical times. Smithers and Smit (1997) examine specific agricultural adaptations to climate variability emphasizing the role of farmer decision-making in reducing vulnerability to extreme events and the role of public policy mechanisms in improving the flexibility and capacity of such decision-making.

In this paper we expand the vulnerability literature by taking a comparative approach to examine regional and sectoral differences in vulnerability among farmers and ranchers in two geographically adjacent, but vastly different political, economic and social contexts. Previous research on vulnerability has tended to center either on the "developed world" (Hammer et al., 2000; Ilbery et al., 1997) or on the "developing world" (Campbell, 1999; Kates, 2000; Nelson and Finan, 2000). Norberg-Bohm et al. (2001) propose a country-wide comparison of data needs for the mitigation of environmental hazards, but we are aware of no cross-country comparisons of neighboring communities with vastly different vulnerabilities but similar environments. In addition to examining the differences in vulnerability across the border, we also look at similarities in vulnerability tied to social class and ethnicity. By specifically considering these two variables as components that shape vulnerability across countries, we take into account Kates's (2000) warning to examine poor people rather than just poor countries when assessing vulnerability.

We focus special attention on Hispanics as a rural ethnic minority in the US and *ejidatarios* (communal land users) as a class of rural poor in Mexico. These two groups are more exposed to the negative impacts of climate variability not only because they have less access to critical private resources, but also because their respective marginalized positions within a wider society restrict their access to public resources. We compare their situation to that of the more technologically

[2] Finan et al. (2002) define livelihoods as "complexes of asset endowments and socioeconomic strategies meant to promote or protect household well-being" (p. 300).

advanced agricultural systems found in both regions. These refer to the majority of Anglo-American farmers in the SSV and to large commercial ranchers in Alamos and the SSV. What separates these different groups is that the latter have a broader and more diversified set of entitlements that better allows them to adapt to climate variability (see Finan et al., 2002).

We also look at the vulnerabilities of different rural producers across time—taking into consideration the impacts of economic, demographic, and technological change—and we ask how different individuals and groups adapt to aridity and drought through a historical process of investment in technology, social networks, and institutional assistance. For some of these rural producers, vulnerability has declined through time, as they have developed strategies that have allowed them to subsist and thrive. For others, previously viable adaptation strategies are no longer useful and many have been forced to abandon what were previously considered sustainable livelihoods.

This paper further seeks to expand current understanding of vulnerability by contextualizing findings within what Smit et al. (2000) have called the "anatomy" of adaptation, which looks at adaptation as a dynamic process and specifies (1) who or what adapts; (2) to what do they adapt; and (3) how does adaptation occur. The Intergovernmental Panel Climate Change defines adaptation as an "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities" (McCarthy et al., 2001, p. 72). Different terms have been used to characterize these adaptations, including resilience, mitigation, coping, and buffering. Here, we use the concepts of *buffering* and *coping* to compare the adaptations of different groups that, despite a similar biophysical context, face very different vulnerability profiles.

We build on the work of Davies who distinguishes "coping" from "adaptive" strategies. Whereas coping strategies are "short-term, temporary responses" to "immediate" exigencies, adaptive strategies are "more permanent changes that people make in the 'mix of ways' they protect their livelihoods" (Davies, 1996, pp. 4, 5). We add to this distinction by using the concept of buffering. Buffering refers to the dynamic interaction of technology adjustment and social restructuring that links public policy, social institutions, and private decision-making in such a way that rural residents perceive that climate risk has been reduced to the point where they may no longer see themselves as vulnerable to climate variability (Finan et al., 2002). This perception of "being buffered" is linked to social class with greater access to social capital, political power, entitlements and other resources, where some of the individual risks associated with climate variability are shifted to a higher order of institutional support.

As such, buffering can be related to the adaptation process of Anglo-American farmers in the SSV and to a small group of highly specialized ranchers in Mexico. As recent research on US and Canadian agriculture indicates, the process of buffering is progressive, cumulative, and proactive. It combines farmer decision-making aimed at reducing vulnerability with public policy mechanisms that seek to improve the adaptive capacity of the agricultural system as a whole (Bryant et al., 1997; Granjon, 1999; Warrick, 1983; Smithers and Smit, 1997). The critical distinction is that buffering fundamentally changes how actors perceive nature and their productive activities relative to nature, leading perhaps to a false sense that the forces of nature have been conquered and that climate has become secondary to other concerns such as output prices and the costs of inputs (Finan et al., 2002).

Buffering does not easily explain the adaptive processes of small producers in Alamos or of Hispanic farmers in the SSV. Whereas these actors are constantly adjusting and developing risk management strategies to deal with climatic uncertainty, most have not been able to reduce their vulnerability dramatically enough to diminish sensitivity to climate. For this level of vulnerability, the concept of *coping* is used. Coping strategies are adjustments made by individuals and households with limited technological inputs and fragile public support (see Kinsey et al., 1998; Corbett, 1988; Kates, 2000). Coping does not lead to an increased sense of security or the perception that a community is better prepared to deal with future climatic events. Instead, climate remains one of the most critical and least predictable variables that affect their livelihoods.

Buffering, however, is not assumed to be a permanent solution or viewed as a "successful adaptation." Instead, it focuses on purposive human agency and assesses the dynamic relationships that allow rural producers to reduce their perceived "sensitivity" to climate. In reference to Kates (2000), Finan et al. (2002) question whether adaptations "can be tautologically defined as successful" (p. 301), since the long-term environmental viability of certain societal-scale adaptations to climate (e.g., irrigation in semi-arid environments) is not yet known (see also Brooks and Emel, 1995). Bryant et al. (2000) point out that the confidence that individual Canadian farmers place in their adaptive "tool-kit" to buffer them from climate change is belied by widespread crop losses and increased public relief and compensation (pp. 193–194). Whereas subsidies and crop insurance, for example, play an important role in reducing the sensitivity of producers to adverse conditions, they may also reduce the tendency to change crops in response to seasonality (cf. Warrick, 1983; Vásquez-León et al., 2002). In the long-term, an assessment of the value of adaptive responses is largely dependent on the underlying direction of climate change (Kane and Yohe, 2000).

We begin this comparative analysis by describing the two study sites in terms of their biophysical and socioeconomic characteristics. We then proceed to examine the respective vulnerabilities of farming and ranching livelihoods. This includes a tracing of the history of buffering and coping mechanisms employed to reduce vulnerabilities and a comparison of the local perceptions of the importance of climate variability in people's lives. We end with a discussion on buffering and coping and on the relevance of these concepts in climate change policy.

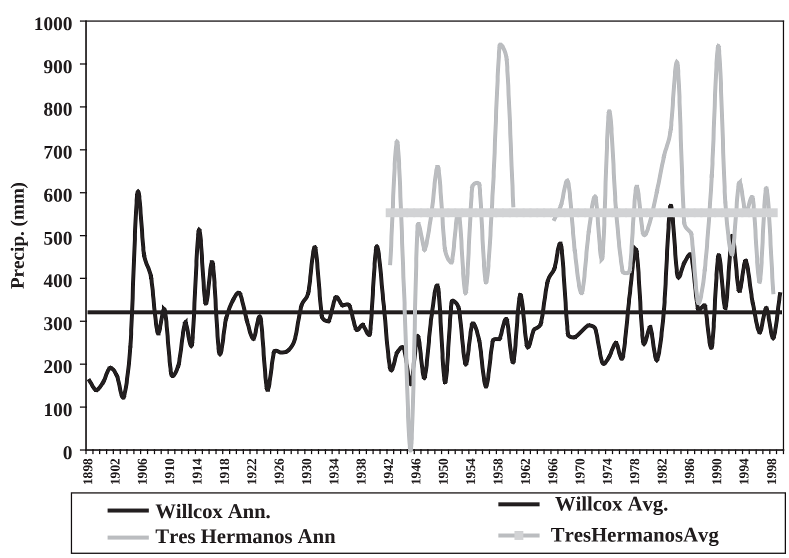
Our study is based mostly on qualitative data collected through a variety of ethnographic techniques such as participant observation, in-depth interviews with key informants, and focus group interviews. Research conducted in the Municipio of Alamos was carried out in 1997 and a total of 70 individuals were interviewed. Research in the SSV was conducted during 2001 and 2002 and 77 individuals were interviewed. In both cases, fieldwork was conducted by teams of researchers with complementary expertise and interests, who were able to tune into and explore relevant multiple contexts. Such team ethnography provided a critical opportunity for internal triangulation of different perspectives on the nature of vulnerability (see Erickson and Stull, 1997). Although the time lag between the two studies does not change the validity of our comparison, the response to more recent droughts, in 1999 and 2000, can only be assessed for the SSV.

2. Comparing the biophysical and socioeconomic conditions of vulnerability

2.1. The biophysical context

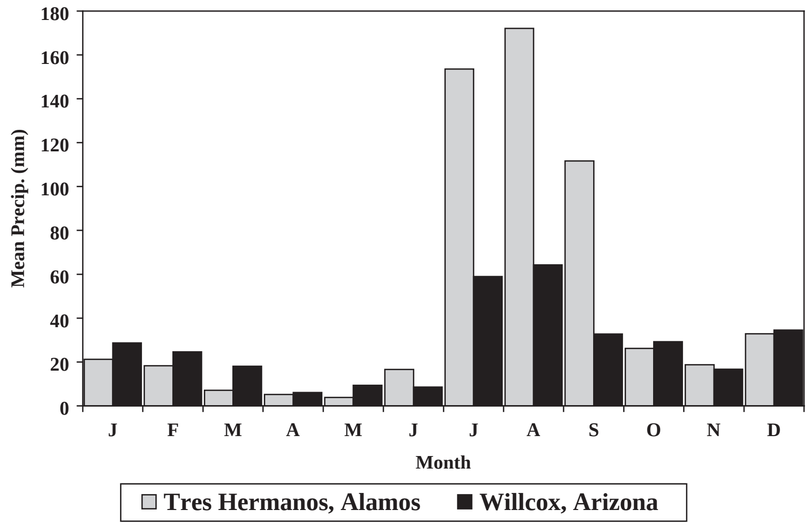
The Municipio of Alamos and the SSV lie at the eastern margins of the Sonoran desert, a distance of approximately 500 km from one another. Alamos is a region of about 6947.47 km^2 characterized by a mostly rugged terrain. Roughly two-thirds of the territory is mountainous, ranging in altitude from 800 to 2500 m. The rest consists of rolling hills averaging 500 m in elevation, scattered narrow alluvial floodplains, and wide valleys. These valleys, located towards the west, contain the largest expanses of cultivated lands and the highest concentration of human settlements in the Municipio. The SSV, located in Cochise County, is one of four valleys in southeastern Arizona. It has an approximate surface area of 4047 km^2 and is bounded by mountains on all sides and by the international border with Mexico to the south. Elevations range from 3265 to less than 1000 m. All agriculture takes place in the valley and cattle ranches are located along the foothills. Elevation changes in both regions have permitted the development of highly diversified rural livelihoods.

The climate of the two regions is influenced by the North American Monsoon (NAM) during the summer months and is characterized by low annual precipitation, high year-to-year variability (see Fig. 2) and a bimodal distribution of annual rainfall (see Fig. 3). Moist air coming from the Gulf of California and the Gulf of Mexico generates heavy rains (more than half of



Source: Data obtained from the Western Regional Climate Center (http://www.wrcc.dri.edu) and IMTA 1999 (http://biblioteca.imta.mx/consulta.htm)

Fig. 2. Alamos and Willcox annual precipitation, 1898–2000.



Source: Data obtained from the Western Regional Climate Center (http://www.wrcc.dri.edu) and IMTA 1999 (http://biblioteca.imta.mx/consulta.htm)

Fig. 3. Monthly distribution of precipitation, 1969–1998.

the annual precipitation) from July to September, sometimes causing floods that damage property and fields. These rains are very localized. Fall is generally dry, although occasional tropical storms reach the regions, bringing heavy rains and causing damage during the harvest season. Winter rains are generated by frontal systems originating in the eastern Pacific Ocean and occur from December to February. These are followed by 4 months of dryness from March to late June or early July (ISPE, 1999).

Although the amount of annual precipitation is higher in Alamos than in the SSV, both regions are considered to be semi-arid and are located in the Northern Hemisphere subtropical high-pressure belt. In Alamos precipitation ranges from an annual mean of 700 mm in the highlands to 432.5 mm in the valleys, allowing for the development of rain-fed agriculture. In the SSV, average annual precipitation ranges from 228.6 to 889 mm at the highest mountains (Bahre, 1991). In the valley itself, annual rainfall averages 304.8 mm, an insufficient amount for rain-fed farming. Extreme summer temperatures are also characteristic of both regions, exceeding 40°C at lower elevations in Alamos and reaching 35°C at lower elevations in the SSV (Municipio de Alamos, 1989; ISPE, 1999).

Although water is scarce in both regions, local hydrology differs significantly. In Alamos there are two permanent sources of surface water: the Mayo and the Cuchujaqui Rivers. Even though both transverse the Municipio, their waters have been diverted for agricultural use in irrigation districts outside of the Municipio. Less than 1 percent of the land is irrigated. In contrast, the SSV has no permanent sources of surface water. This, coupled with low precipitation, has led to urban and rural livelihoods that completely depend on groundwater from two large aquifers which have permitted the development of irrigated agriculture.

Drought events, especially multi-year droughts, represent the most significant climate-related hazard for rural livelihoods. In the case of Alamos, consecutive years of below-normal precipitation can be devastating for farmers, leading to crop losses, bankruptcy and, in extreme cases, the selling-off of land. In the SSV where water withdrawal, mostly for irrigated agriculture, vastly exceeds estimated recharge, prolonged drought can have major long-term impacts on the viability of irrigated farming[3] (Arizona Department of Water Resources, 1994). For ranchers in Arizona and Sonora, as anthropologist Thomas Sheridan (2001) points out, "climate is the strongest, most intractable, natural constraint" (p. 142).

2.2. The socioeconomic context

From a socioeconomic perspective, economic reliance on ranching and agriculture makes the two regions highly vulnerable to climate variability. In Alamos, 42 percent of the economically active population depends on ranching and farming (INEGI, 2000), more that 80 percent of producers are involved in small-scale farming, and the average landholding is of 16.5 ha. In terms of ranching, Alamos is the fourth largest producer of cattle in the state of Sonora with an estimated total of 69,000 head (SAGAR, 1997). The SSV is the most important producer of corn, chiles (hot peppers), nut and non-citrus fruit orchards in Arizona (Clark and Dunn, 1997). It is also one of the top cattle producing regions in the state with herd estimates ranging from 10,303 to 38,283

[3] In Arizona, irrigated farming accounts for 86 percent of the state's annual water consumption (Merideth, 2001).

Table 1
Comparison of socioeconomic groups in Alamos and the SSV

Variables	Commercial private ranchers (Alamos[a])	*Ejidatarios and small landowners (Alamos[a])*	Anglo-American farmers (SSV)	*Hispanic farmers (SSV)*
Number of ranchers	30% (610)	*70% (1428)*	99% (246)	*1% (3)*
Cattle ownership	60% (41,223)	*40% (27,656)*	69,950[b]	
Type of cattle	European varieties	*"Criollo" varieties*	European varieties	*European varieties*
Grazing	Cultivated pastures (buffelgrass)	*Natural vegetation (communal lands)*	Natural vegetation (rented land)	*Natural vegetation (rented land)*
Calendar	Year-round, highly specialized	*Highly diversified, seasonal*	Year-round, specialized	*Highly diversified, seasonal*
Number of farmers	20% (596)	*80% (2386)*	92% (183)	*8% (15)*
Ownership of arable land	63% (29,568 ha)	*37% (26,253 ha)*	99% (Appr. 25,831 ha)[c]	*<1% (Appr. 1000 ha)*[c]
Land use	Cultivated pastures	*Subsistence and market crops*	Commercial	*Mixed*
Economic importance	High	*Combined with ranching and off-farm activities*	High	*Combined with off-farm activities*

[a] INEGI (1996).
[b] Based on Cochise County (NASS, 1997) with no means of disaggregating data by ethnicity.
[c] Based on Clark and Dunn (1997, p. 16) and field note estimates.

(Census of Agriculture Zip Code Tabulation, 1992). In relative terms, the SSV has a large number of agricultural operations (824), making Cochise County the third highest ranking among the state's 15 counties. Farms tend to be family owned and operated, with an average landholding of 611 ha—a relatively small size when compared to the state average of 1752 ha (USDA, 1997).

In both areas, farmers and ranchers face increasing competition for scarce water resources from urban areas and industry (Morehouse et al., 2000). This is largely due to the rapid rate of population growth and urbanization in the region as a whole. In Sonora, these transformations are associated with employment opportunities in the *maquiladora* industry, whereas in Arizona, they are related to the Sunbelt demographic shifts and a large influx of immigrants from Mexico (ISPE, 1999; Finan et al., 2002). Despite accelerated urbanization in both states, the SSV and the Municipio of Alamos have remained essentially rural. The 25,152 residents of Alamos are dispersed in about 300 communities, most of which have less than 1000 residents. The city of Alamos contains 25 percent of the population (INEGI, 2000). The population of the SSV adds up to approximately 34,282 residents, with close to 40 percent found in the border city of Douglas and 10 percent in the city of Willcox. The rest of the valley is composed of small rural communities (US Census Bureau, 2000b) where farming and ranching constitute the most prevalent livelihoods (US Census Bureau, 2000a).

Within both regions there are considerable differences in the way rural residents experience and deal with climatic variability. This is related to differential welfare levels and access to adaptive resources found among different groups of stakeholders (see Table 1). In both regions class and ethnicity are important variables that help explain differences in a producer's ability to respond to extreme climatic events. In the Municipio of Alamos the distribution of resources between large-scale commercial ranchers, who are private sector landowners, and peasant smallholders, including *ejidatarios* (communal landowners), is highly skewed. Although 30 percent of the Municipio's livestock producers are in the private sector, they own 60 percent of the cattle. Of these, only 1 percent own at least 500 head of cattle. Ejidatarios account for 70 percent of the Municipio's livestock producers, yet they own 40 percent of the cattle. The distribution of arable land, including cultivated pastures, is also skewed. Whereas 20 percent of private sector producers own 63 percent of the land, ejidatarios, who account for 80 percent of all producers, control 37 percent of the land (INEGI, 1996).

In the SSV, inequalities between Anglo and Hispanic farmers also have led to differences in vulnerability. Even though residents of Hispanic origin account for 55 percent of the population of Cochise County, only 16 percent of all agricultural producers are Hispanic landowners. Land size among Hispanic farmers ranges between 100 and 400 ha, considerably less than the average for Cochise County (611 ha) (US Census Bureau, 2000b). Relative to Anglo-American farmers, Hispanic farmers are low-technology, resource-scarce producers, with historically lower access to land, climate information, and government aid.

3. Adaptation to climate variability in the Municipio of Alamos

3.1. Historical background

Stock raising and large haciendas were first introduced in the Municipio of Alamos in 1693. Prior to this time, the region was populated by small and scattered settlements of diverse Indian groups, which lived as hunters and gatherers. Because of their relative isolation, little is known about these early inhabitants (Spicer, 1962). The discovery of rich silver deposits[4] attracted Spanish settlers who introduced cattle to the region. Seed stock for the early ranches were driven from Chihuahua and purchased from the Jesuits (West, 1993). These were skinny, muscular, rangy animals of North African and Andalusian origin that adapted well to the arid lands of northern Mexico (Voss, 1982). Mineworkers, mostly Native Americans, created new communities and rain-fed farming became widespread. The City of Alamos became the center of an urban elite of wealthy miners and merchants, which became dependent on a substantial local supply of basic foodstuffs from a wide, arable basin (Voss, 1982).

After the Mexican Revolution of 1910, when most mining operations closed down, rain-fed farming and ranching became the mainstay of the Municipio. During the land reform years (1934–1940) farmers were organized in *ejidos* (communal lands). But land distributed in the Municipio, as in much of eastern Sonora, came without water (Sanderson, 1981). Because of the high mountains that characterize the eastern side of the state of Sonora, it was argued that all agricultural development efforts should concentrate on bringing irrigation to the neighboring flat coastal valleys of western Sonora. To do this, the headwaters of Sonoran rivers, which originate in the sierras, were diverted through the construction of massive dams (West, 1993). This precluded the possibility of developing irrigated farming, a key adaptation in a semi-arid environment.

Up to the 1960s, stock raising was dominated by private land owners who practiced an open range system, allowing beasts to subsist on wild grasses and browse plants such as mesquite (Peña and Chávez, 1985). Subsistence producers became dependent on a system of debt peonage which guaranteed large private cattle owners access to labor and grazing land for commercial stock raising (West, 1993). Big ranchers combined livestock with agriculture as an adaptive mechanism to deal with drought, and during years of severe drought cattle were transferred from private ranges into ejido lands, in an arrangement called *aparceria*, where ejidatarios would care for the cattle in exchange for a percentage of the offspring. This arrangement gave ranchers flexibility to offset the spatial and interannual variability of rainfall.

In Alamos, livestock production for the international market did not begin until the 1970s. In response to an increase in global market demand for high-quality livestock, the Mexican government began the wholesale distribution of subsidies, credit, and technical advice. Wealthy ranchers eyeing the US market started substituting and crossing *criollo* cattle with European varieties like those found in northern Sonora and Arizona. These breeds were less mobile, required more water and needed more nutritious forage. Thus, a massive conversion to cultivated pastures began. Buffelgrass (*Penniserum ciliare*), an African variety well suited to semi-arid conditions, was introduced. Between 1970 and 1990 cultivated pastures in the Municipio increased by over 400 percent and the number of cattle increased by 150 percent (from 63,164 to 96,500 head) (INEGI, 1994).

3.2. Climate risk and contemporary livelihood systems in Alamos

The rapid development that occurred during the 1970s and 1980s led to a widening of the gap between large commercial livestock producers and smallholders, including ejidatarios. To this day, the economic disparity between these different groups largely influences their ability to respond to extreme climatic events.[5] Large specialized commercial ranchers benefited most from the transformations started in the 1970s. Membership in the two ranching associations facilitated access to credit, government subsidies, technological assistance required for the clearing of land and establishment of buffelgrass pastures. They also had better access to emergency relief aid in years of drought. Today, compared to ejidatarios and peasant smallholders, specialized ranchers have a vastly superior infrastructure, including pastures and cattle pens. Most large ranches are located in the flat lands of the Municipio and have at least 200 ha planted with buffelgrass (the largest has around 3000 ha). According to local ranchers, the shift to buffelgrass increased pasture productivity from one head per every 10 ha of natural grazing lands to four heads per hectare of buffelgrass. The higher quality of private ranges provides better forage, leading to lower mortality, higher birth rates and weights. Some private ranchers conserve and improve their rangeland and practice sophisticated techniques of livestock breeding.

Even though buffelgrass became the most important buffering mechanism to deal with drought, multi-year droughts continue to pose risks. This became obvious during the 1995–1996 drought, suffered in the Municipio as well as the rest of Sonora and Northern Mexico (see Chávez, 1999; Liverman, 1999). After 4 years of below-normal precipitation, the winter of 1996 remained dry. By the end of June of 1996, after 10 months of no rain, there was a great deal of anxiety. Those who had

[4] In 1776 nearly two-thirds of the silver produced in Sonora and northern Sinaloa came from the Alamos district (West, 1993).

[5] Eakin (2000) makes a similar argument with reference to small-scale maize producers in Tlaxcala, Mexico.

converted most of their land into buffelgrass suffered the greatest economic losses, although none went bankrupt. Buffelgrass adapts well to semi-arid conditions, but without some rain it dries up quickly and affords little, if any, nutrient benefits. Ranchers initially responded by purchasing feed, which had increased in price by more than 100 percent, and by hauling water. Those who had the economic means to buy forage were able to make it until the end of the drought. Despite some government relief aid, which offered a reduction in the price of forage, and access to credit, only few had the economic means to buy feed for an extended period of time, and ended up selling a large percentage of their cattle at reduced prices.

Ranchers who had left part of their land in native grass suffered less. Although less productive than buffelgrass, native grasses can produce with very little rain (García Zamacona, 1990). The realization that those who diversify their pasture tend to be less vulnerable to extreme drought events led to important transformations. Scientists, who in the beginning of the 1970s advised ranchers to convert as much land as possible into artificial pastures, now advise that only 15 percent of total area be cultivated with buffelgrass, leaving the rest in natural vegetation. Today the trend among large producers is to work in collaboration with scientists to improve soil quality and management of already established artificial pastures—an activity that requires substantial capital investment. Many large ranchers have also gone back to cultivating sorghum as forage, while others are diversifying into poultry and pig farms.[6]

The majority of producers in the Municipio, however, face a different set of risks from those of large-scale commercial ranchers. Ejidatarios and small landowners are characterized by farming systems that combine cattle ranching, rain-fed farming, and off-farm activities. Among these producers, most grazing is done in natural grazing lands and meat is mostly produced for the domestic market. Corn, beans, and squash are grown for household consumption, and cash cropping of sesame, peanuts and sorghum is usually done only to the extent that it allows them to meet basic household needs.

Since rain-fed crops depend on the amount and timing of precipitation, rainfall patterns have restricted cultivation to only one crop per year. Planting begins in June and harvesting is done by November. Whether it rains too much or too little, there is always the risk of losing the harvest. Since the 1950s small producers have adapted by using varieties of corn that mature quickly and require little water, and by following a cyclical pattern of outmigration during the dry season. Most seek wage employment, harvesting commercial crops in the coastal irrigation districts of western Sonora or at the US–Mexico border. During years of severe drought the cycle of migration intensifies and fields are left unplanted as many leave the region. This happened during the 1996 drought when many smallholders perceived that their capacity to cope with another dry year had eroded. The few who remained either had enough cattle or access to forest resources to sustain themselves.

Dependence on natural grazing lands for cattle grazing is also risky. Too much rain rots some grasses, and every year during the dry season cattle lose weight as the green forage disappears. The stubble from local agriculture is used for cattle feed during this critical time. During particularly dry years, small producers sell part of their herd to purchase sorghum or hay. Overgrazing has become an acute problem[7] that is aggravated during severe droughts when, as happened during the 1996 drought, poor pastures are cleared to accommodate cattle from specialized ranchers.

Changes in seasonal precipitation are such important aspects of the daily lives of small producers that particularly severe droughts mark the passage of time. Being able to accurately predict rain is a respected skill and there are well-known specialists as well as a variety of folk methods.[8] Right before summer rains begin, local rain forecasters are consulted on a daily basis. In general, there is a strong perception that accelerated deforestation has led to a change in rainfall patterns. As explained by Don Fulgencio, a skillful rain forecaster and farmer, "too much clearing of land might bring less rain. Water is attracted by vegetation, that is why in the valleys it rains less than in the sierra, and that is why to sweep the mountains is bad, the rains negate themselves."

Lack of credit remains one of the greatest limitations on ejidos in terms of allowing them to respond better to drought. Unlike large private ranchers, and despite a substantial initial infusion of credit in the 1970s, ejidatarios have had neither the capital nor a timely source of credit required for maintaining buffelgrass pastures. Even those ejidos known as livestock ejidos have little or no buffelgrass pastures and very few cattle. During the1980s, government incentives for this sector became highly irregular and clearly began to dwindle when Banrural, the public sector bank, left the area. The credit situation worsened with land privatization in 1992

[6] An additional risk of buffelgrass specialization is the "salivazo" or mosca pinta (*Aeneolamia albofaciata*) invasion, which thrives in years of high precipitation (Johnson and Navarro, 1992).

[7] The grazing coefficient recommended for the municipio is 18–36 ha/animal unit (a.u.). The approximate real coefficient is of 7.1 ha/a.u. (SAGAR, 1997).

[8] A trusted forecasting method is based on careful observation of the first 12 days of the year, which represent the 12 months of the year. The 7th day stands for July, the time of the *cabañuelas*, or first summer rains.

and the devaluation of the peso in 1994. While the process of obtaining legal land titles for ejidatarios dragged on for years, private banks refused credit to farmers that had no land to put as collateral. In addition, with the implementation of free-market policies related to NAFTA, meat imports increased and cattle prices in Mexico went down.

With the exception of a few agricultural subsidies specialized government subsidy programs are geared towards large-scale commercial operations. Today lack of credit, coupled with drought and land degradation, have resulted in abandonment of land and permanent outmigration of ejidatarios to the point where some settlements are losing most of their young adults.[9]

Finally, ambiguity as to who will have access to land in the future has also contributed to the problems of overgrazing, lack of management of grazing areas, and low investment in infrastructure. Obtaining legal title to land is perceived as the only way to alleviate the credit situation. This may, however, increase vulnerability to climate variability since many would prefer to continue using the land collectively. As one ejidatario explained, "here it rains, and three kilometers a bit further it doesn't rain. If we don't have access to land in different areas, we are doomed." From the point of view of those who want to leave the community, however, being able to sell the land is the most viable option.

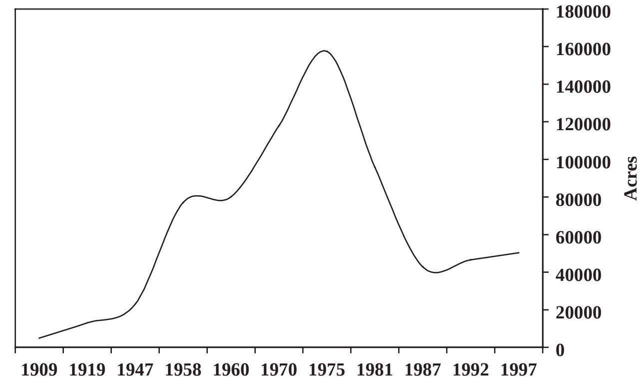
4. Buffering against and coping with climate variability in the SSV

In contrast to the Municipio of Alamos, ranching and farming in the SSV did not begin until the late 1880s. Even though at the onset the two economic activities were complementary, their historical development diverged in the beginning of the 20th Century. Today it is uncommon for households to engage in both activities on a commercial scale.

4.1. Ranching in the SSV

Cattle were first introduced in southern Arizona by Spanish missionaries in 1699 (Sheridan, 1996). After the subjugation of the Chiracahua Apache in the early 1870s and with the construction of the railroad in southern Arizona, the activity began to flourish among Anglo-American settlers (Bahre and Shelton, 1996). After a failed attempt at developing rain-fed farming from 1905 to 1907, years of higher than average precipitation (see Fig. 4), settlers began consolidating homestead claims to establish grazing lands for cattle (Schultz, 1980). By 1890, there were around 50,000 head of cattle in the SSV

[9] See Meze-Hausken (2000) for a discussion of migration and climate change in dryland areas.



Source: Vásquez-León *et al.* 2002

Fig. 4. Cochise County irrigated acreage, 1953–1995.

(Bahre, 1991, p. 112), accounting for nearly 25 percent of all the cattle found in the Territory of Arizona (Wagoner, 1952, pp. 53–54).

Since its beginning, ranching has been particularly impacted by drought. Droughts between 1891 and 1893 across southeastern Arizona were so acute that an estimated 60 percent of the animals died of starvation and thirst (Wagoner, 1952). Climate alone did not cause this catastrophe—the ranges of southern Arizona had been overstocked for years (Bahre, 1991). During these droughts most of the small ranching families in the SSV were forced out of the region, leaving a few large corporate ranches (Bailey, 1994).

The industry, however, has undergone a process of adaptation to aridity and rainfall variability that has significantly reduced vulnerability. Technological improvements since the 1930s centered around increasing the availability of water on rangeland through the use of pumps and polypropylene pipe, both of which allowed the extraction and dispersion of water over large expanses of land. Cost-sharing programs for range improvements have been in place since 1936 (Wagoner, 1952). These have aided ranchers in deepening wells, installing pipe, and obtaining diesel pumps. Today, state and federal disaster relief programs reimburse ranchers for supplementary feed and forgive taxes on earned income from the sale of cattle when the county is declared a drought disaster area.

A complex system of public and private land management also offers ranchers flexibility that mitigates the effects of drought. While 41 percent of the land in the county is private or "deeded" land, the other 59 percent is administered by state and federal agencies, which lease parcels of land to ranchers. Leases can be bought at a fraction of what it would cost to purchase private lands. Most ranchers in the SSV use a combination of deeded and leased land (Conley et al., 1999). This system of land tenure gives ranchers added flexibility to counteract the spatial and interannual variability of rainfall.

Recent droughts illustrate the decreased impact and concern over droughts and illustrate how cattlemen and institutions interact. Cochise County was declared a drought disaster area in the summers of 1999 and 2000. Yet, SSV ranchers and extension personnel expressed little concern about the dry conditions. Due to an extremely dry winter in 1999, federal drought disaster relief authorized the Internal Revenue Service to forgive capital-gains taxes for cattle sold-off due to drought. Similar winter conditions in 2000 prompted another drought declaration, allowing affected families to obtain low interest loans from the United States Department of Agriculture (USDA). When asked in July of 2000 if the local area was in a state of severe drought, one agent told us "drought disaster relief is a political thing. When enough ranchers and farmers complain, the governor declares a drought disaster."

But despite their improved ability to deal with climate variability, today ranchers are facing a number of political and economic pressures. Along with decreased prices of cattle,[10] environmentalist groups have increasingly denounced grazing on public lands (Sheridan, 2001). Land subdivision and conversion to "ranchettes"[11] is also becoming an increasingly important trend (Finan and West, 2000). However, as in the case of Alamos' specialized ranchers, ranching families in southeastern Arizona are forming partnerships with scientists and conservation groups whereby they manage rangelands to preserve both biodiversity and a ranching heritage in Southern Arizona.

4.2. Farming and irrigation in the SSV

Large-scale commercial agriculture did not become possible in the Valley until the establishment of the Sulphur Springs Valley Electrical Cooperative (SSVEC) in the 1940s. Inexpensive energy to power electric pumps for irrigation, plus increased demand for agricultural commodities during World War II, led to a farming boom, inducing farmers from less productive regions to relocate in the SSV. By 1955, the SSV had 299 commercial farmers producing mainly cotton and corn, but also sorghum and vegetables (Sheridan, 1996; Schultz, 1980). As shown in Fig. 4, agricultural acreage expanded rapidly until 1976, when a combination of crises struck the SSV.

[10] Average national prices paid for feeder cattle declined from $80/cwt in 1994 to $59/cwt in 1996 although these same prices fluctuated between $86/cwt and $104/cwt in 2000–2001 (Sheridan, 2001, p. 146).

[11] The high proportion of private ownership in Cochise County has allowed outsiders to purchase and subdivide 640-acre sections that are then sold and turned into hobby ranches called "ranchettes" where a few cattle are raised. This is a cause for concern because it is argued that the number of cattle generally exceeds the carrying capacity of the range.

The first crisis involved the local aquifers. Annual water withdrawal began to exceed recharge in the late 1960s and static water depths began to drop. Droughts between 1973 and 1980 (see Fig. 2) exacerbated the problem to the point that, in 1980, part of the region was declared as an irrigation non-expansion area and no new irrigation wells were allowed. At the same time, the energy crisis of 1976 led to an exorbitant increase in the price of natural gas. In combination, these climatic and economic events drove a large number of farming families out of the region and, as shown in Fig. 4, irrigated acreage in Cochise County declined by 65 percent (Clark and Dunn, 1997).

The crisis, however, prompted a number of critical adaptations. Changes in irrigation technology, crop diversification, and market orientation allowed those able to continue farming in the valley to become better prepared to deal with future extreme climatic and economic conditions. The most important adaptation strategy to low and erratic precipitation is the adoption of water-efficient irrigation technologies. At the beginning of the 1990s most farmers had replaced old flood furrow irrigation systems by center pivots, sprinklers, and drip irrigation. The new technologies use less water per hectare and decrease evaporation rates, increasing field irrigation efficiency from 60 percent with flood furrow to 80 percent with sprinklers and up to 90 percent with drip irrigation (Ayer and Hoyt, 2001).

After the crisis, diversification became an important adaptation. Some abandoned fields were changed to fruit, pecan, and pistachio orchards. Other parcels were converted to food-grade corn, chile, lettuce, and a wide variety of other vegetables. Those who continue to grow traditional row crops such as corn, sorghum, cotton, and alfalfa generally do it in combination with other crops. Also, unable to compete with more traditional markets due to the high costs of water, farmers are increasingly targeting niche markets such as those for organic fruits and vegetables and U-pick farms. Since 1992, three vegetable greenhouses have been constructed in the area. These raise crops in a controlled environment where temperature and humidity are constantly adjusted to meet plant requirements and production is intensive and year-round.

Public policy has played an important role in facilitating these changes. Since the 1940s, farmers have benefited substantially from a variety of federal crop subsidy programs. During the late 1980s and the 1990s, the USDA provided incentives to farmers for the adoption of water-efficient irrigation technologies through cost-sharing programs. It also assisted farmers by providing low-interest loans for water conservation projects. Today, federal crop subsidy programs are being replaced by crop disaster programs. In addition, crop insurance, often required by banks and federal agencies, has been a key factor in allowing farmers to recuperate from an extreme event. Farmers often say that they would rather get a drought than too much rain because without precipitation growers can better control the development of their crops. Vegetable growers, for example, benefit from droughts in that the likelihood of plant diseases and pests declines.

Not all farmers, however, have been equally capable of adopting new technologies or diversifying their production. Among those are the majority of Hispanic farmers. With one exception, the seven Hispanic farmers that we contacted in the Valley were operating under significant economic pressures and two Hispanic ranching families who had resided in the valley since the 1960s had stopped ranching the year prior to our study. Although some Hispanic farmers blame lack of success on "not taking care of business" or "not working hard enough," Hispanic farmers do share certain characteristics that make them more vulnerable to climatic extremes.

Compared to other farmers in the region, Hispanic farmers tend to cultivate smaller plots of land. With one exception, these farmers reported owning between 40 and 160 ha of land, while the average for Cochise County is around 600 ha. Cultivating small plots of land means that any crop loss represents a larger portion of their overall profits. Also, given the localized nature of rainfall in the valley, cultivating a large amount of land minimizes the impact of climate-related damage. Hispanic farmers also have less access to financial capital, which limits their possibilities of adopting drip irrigation. All but one of the Hispanic farmers interviewed continue to use flood irrigation techniques, which means that their water costs per hectare are roughly double.

Issues of language and literacy also influence access to institutional adaptations; Hispanic farmers indicated that language and literacy represent a possible obstacle in avoiding, coping with, and recovering from climate events—specifically in terms of receiving credit and obtaining disaster relief funds from the government. All of the Hispanic farmers interviewed spoke Spanish as their first language and had varying levels of fluency in English. In fact, one of the farm owners with limited English proficiency explained that he had applied for a government loan in 1999, but his application was rejected because he could not fill out the form correctly. A related issue, which deserves further research, is that of computer literacy. As indicated by our interviews with Anglo farmers, computer literacy is an important tool for accessing climate and weather information. However, only one Hispanic farmer reported using computer forecasts.

Hispanic farmers have disproportionately suffered the consequences of extreme climatic events. In October 2000, a stationary Pacific cold front combined with a tropical storm delivered up to 330 mm of rain to some parts of the SSV over the month. Vegetable farmers who had not yet picked their crops were particularly hard hit. But whereas the majority of vegetable farmers in the SSV were able to recuperate their losses and continue their activities, four out of the seven Hispanic farmers that the project had been following were forced out of business. These were all small chile farmers who were already operating at the margin and who had no insurance. These cases, however preliminary, indicate that there are links between ethnicity and access to resources and information that put some farmers at a notable disadvantage. This observation is concurrent with a pending law suit filed on behalf of 20,000 Hispanic farmers against USDA for systematically denying loans to Hispanic farmers over the past 20 years (Husain, 2000).

5. Buffering and coping across the border

In this paper we have attempted to show the differences in vulnerability to climate variability found among a variety of socioeconomic groups whose livelihoods are directly tied to a semi-arid and highly variable natural environment. The vulnerability experienced by ranchers and farmers on both sides of the US–Mexico border differs drastically and is conditioned by a multiplicity of factors that have to do with individual decision-making, public policy, access to land, economic assets, technology, and position within the power structure. We examined vulnerability comparatively and by placing an emphasis on process and social change. This emphasis shows that, in measuring vulnerability, weighing only economic impacts can be misleading. Whereas a particular climatic event may lead to far greater losses in purely monetary terms for those who have been able to buffer against climate variability, for the most vulnerable, that same event may lead to a loss of livelihood.

As shown in Table 2, we have identified a continuum of vulnerability concerns and perceptions of the impact of climate variability. At one end are most of the farmers in the SSV. Through technology and social organization, they have been able to buffer against climate variability to the point where they feel highly confident in their ability to deal with climatic extremes. Among these farmers, drought is hardly mentioned. For some (e.g. corn growers) concern with water availability or drought is limited to times when diesel prices increase and pumping costs go up, for others a drought can be profitable. This ability to withstand drought and even ignore it is the result of a buffering process that began in the 1940s and has involved decades of technological innovations and public policy adaptations specifically aimed at improving the adaptive capacity of the agricultural system as a whole. The crisis of the 1970s, which was partly climatic and partly economic, led to

Table 2
Vulnerability characteristics of different sectors

Vulnerability factors	Alamos ejidos	SSV Hispanic farmers	Alamos ranchers	SSV ranchers	SSV farmers
Perceived water availability	Scarce	Scarce	Scarce	Scarce	Abundant
Perceived climate impact	Extremely high	Extremely high	High	Medium	Medium to low
Risks related to drought	Extremely high	Medium	Medium	Medium	Low
Vulnerability concerns	Drought and policy	Access to system-wide adaptations	Market prices and drought	Market prices and policy	Markets and aquifer depletion

important technological and institutional changes that significantly reduced the perception of vulnerability among these farmers. Consistent with this case, Chiotti et al. (1997) have observed that in Canadian agriculture "Although not conclusive, the relative absence of climate as an important challenge in both the recent past and immediate future suggests that farmers are not particularly concerned with climate, perhaps illustrating a high degree of confidence in their ability to adapt, or reflecting a preoccupation with other societal influences such as trade or government policy" (p. 211).

Next in this continuum of vulnerability concerns and perceptions are specialized ranchers in Arizona and Sonora. While both have used technology, public policy, and social organization to counter the impacts of climate variability on their livelihoods, drought can still cause economic losses in any given year. At the same time, droughts have offered an opportunity to innovate and change management practices in such a way that ranchers today feel more prepared to deal with similar future climatic events. These ranchers, however, have not acted in isolation. Individual decisions are backed by complex institutional, political, and economic systems already in place. Mexican and US governments offer drought relief and technical assistance, private banks and lending institutions offer credit, and the ranchers themselves have access to the physical and economic assets that allow them to withstand crises, recover, and respond proactively. Despite the severity of the droughts, in the end, none of these ranchers have lost their livelihood. This was not the case 100 years ago, when ranching livelihoods were seriously compromised by climatic extremes.

The same droughts, however, underscore the vulnerability of the most marginal producers, who are at the other end of the continuum. Here is where ethnicity and class become important variables through which vulnerability can be examined as they underscore some of the factors that result in inequalities in resource allocation and risks associated to the impacts of and adaptations to climate variability. For small-scale producers, the majority of the rural population in Alamos, the droughts of the 1990s were devastating. Many ended up not planting altogether, lost their cattle, and had to rely on increasingly tentative economic strategies. For the most marginal, seasonal migration turned into permanent outmigration. Whereas the drought itself was severe, it was not completely unexpected. In fact, farmers in this semi-arid environment have always dealt with seasonality and extreme events. The critical issue for this socioeconomic group was that the drought coincided with a moment of high institutional and socioeconomic vulnerability. Decades of development efforts focused on export-oriented large-scale irrigated agriculture in the coastal valleys and specialized cattle ranching led to the rapid deterioration of land resources on ejido lands. In addition, privatization and structural adjustment reforms have led to a highly uncertain situation in terms of landownership. The coping strategies that many of these farming communities used in the past, and that probably allowed for reasonably effective responses to climate variability, are no longer functional.

In the SSV, Hispanic farmers have also been severely impacted by climatic events. The fall 2000 heavy rains wiped out the most marginal. Again, seasonality coincided with particularly vulnerable time for chile and vegetable growers: the harvest season. A number of Hispanic farmers who were already at the edge lost their farms and with it their source of livelihood. For a variety of reasons, including the lack of access to system-wide adaptations such as crop insurance, water efficiency irrigation technologies, and other forms of government support, in the end, these farmers were unable to fully benefit from the process of buffering experienced by their Anglo counterparts.

As exemplified by the regions under study, the degree to which a system changes as a result of particular extreme events can be positive or negative and can have short- as well as long-term consequences. To emphasize this point, we have made a distinction between coping and buffering as adaptation strategies. Coping, on the one hand, as evidenced by the behavior of peasant smallholders in Alamos and Hispanic farmers in the SSV, involves incremental, low-input, and short-term investments that help farmers "get by" during droughts. While for farmers in Alamos a variety of coping strategies developed through time allowed them to successfully adapt to the vagaries of climate and persist in the region for over 300 years, in the past 20 years their ability to cope has been progressively eroding. The sustainability of their livelihood has been seriously challenged by what they perceive as more frequent and intense droughts and the withdrawal of the state. This study clearly shows that those with the least access to resources are the most socially vulnerable to extreme climate events, both in the US and Mexico. The vulnerability of these disadvantaged producers is as much related to exposure as to factors affecting coping and adapting, with widespread lack of institutional support as a key factor affecting vulnerability.

On the other hand, the buffering strategies of mechanized groundwater-dependent agriculture and state-subsidized ranching are relatively recent activities in this semi-arid environment. Buffered livelihoods have proven viable on the order of decades and appear sustainable for at least the near-future. However, under long-term scenarios of climatic, economic, and political change they may be unviable. If climate change leads to an increase in the incidence of drought in the US Southwest and in northwestern Mexico, where water is a scarce resource, current buffering strategies may become "maladaptations" in the future (see Smit et al., 1999). The concept of buffering is useful in raising several questions related to long-term sustainability of agricultural adaptations that significantly diminish sensitivity to climate and encourage perceptions that climate is not a primary challenge. Are external institutional interventions, for example, exacerbating vulnerabilities in the long term by perpetuating farmer reliance on external agencies such as the federal government and insurance companies instead of by promoting adaptation to the natural environment? These are issues that need to be addressed and researched further.

Thus, the notion of the buffering has a direct relevance in climate change policy (see Smithers and Smit, 1997), as it is useful in recognizing technologies, institutional arrangements and innovations that jointly reduce sensitivity to climate. Also, as Davies (1996) argues, policy interventions should not merely monitor local adaptation mechanisms; they should measure the intensity and types of adaptive strategies being used so as to identify where groups of people fall in the continuum of the adaptation process. Buffering represents the extreme end of this continuum whereby livelihoods are perceived as both resilient and insensitive to climate and climatic events. Coping represents the other pole of the adaptation spectrum—groups locked in a position of only being able to get by. In either case, the effectiveness of past and current adaptations to climate variability must be evaluated in terms of their economic feasibility and environmental sustainability (Tol, 1996) in order to ask the question of "what measures should be undertaken to facilitate adequate adaptation to climate change?" (Smit et al., 1999, p. 210).

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