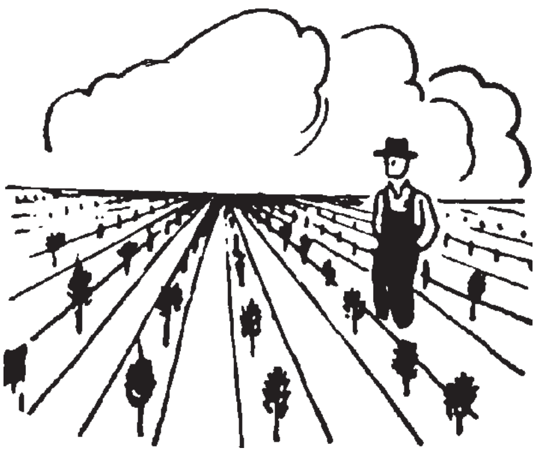
Vulnerability to Climate Variability in the Farming Sector

A Case Study of Groundwater-Dependent Agriculture in Southeastern Arizona



Marcela Vásquez-León, Colin Thor West, Barbara Wolf, Jane Moody, and Timothy J. Finan

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This report is dedicated to the memory of Page Bakarich, a former high school teacher and local historian of Willcox, AZ. Nearly everyone we interviewed fondly mentioned him and we are glad that we had the opportunity to speak extensively with him before he passed away.

Table of Contents

List of Case Studies

List of Tables

List of Figures

Executive Summary

This report is part of the Climate Assessment for the Southwest project, funded by the National Oceanic and Atmospheric Administration (NOAA) and carried out by a multidisciplinary group of researchers at Institute for the Study of Planet Earth, the University of Arizona. The work presented here focuses on the assessment of vulnerability and adaptation to climate variability among rural populations in the southwestern United States. It is the result of 18 months of field research in the Sulphur Springs Valley (SSV), Arizona among groundwater-dependent farmers and farm workers. The study, conducted by a team of researchers from the Bureau of Applied Research in Anthropology, had three main goals: (1) to assess the vulnerability of groundwater-dependent agriculture to climate variability, (2) to identify historical and current processes of adaptation to the vagaries of climate in the region—these refer to both system wide adaptations and individual farmer's adaptations, and, (3) to assess the use of and needs for seasonal climate forecast information in agricultural decision making. The study identified a variety of farming livelihoods and examined the vulnerabilities faced by each type. These included corn, hay, chiles, and vegetable farmers, fruit and nut orchard growers, and greenhouse operators. The study also examined the relationship between ethnicity and vulnerability by taking a closer look at Hispanic farmers and migrant farm workers. Each sector faces different vulnerabilities and has developed different adaptations through time.

The report is targeted at institutional stakeholders (i.e., agricultural extension personnel), physical scientists (particularly climatologists), and policymakers (at the level of NOAA and other federal agencies). Specific recommendations are made to these groups in order to improve the delivery of seasonal forecasts, set research priorities, and inform public policy.

Vulnerability and Adaptation

Definitions of the concept of social vulnerability to climate variability abound in the literature. Blaikie et al.'s definition is useful. In their words, vulnerability refers to "the characteristics of a person or group in terms of the capacity to anticipate, cope with, resist, and recover from the impact of a natural hazard" (1994:9). For the purposes of our case study in the SSV, the most evident natural hazards are interannual variability in temperature and precipitation, and total dependence on groundwater for irrigation. We identified several aspects of climate that impinge on farmers' livelihoods, the most prominent of which are droughts, excessive fall rains, hail, and frosts.

Adaptation is the flip side of vulnerability. As Finan et al. state, "If climate vulnerability is an undesirable state of risk faced by an individual or group, adaptation can be seen as the sets of system changes, or behavioral responses, that seek to diminish this vulnerability" (2002:300). Throughout our research we examined how farmers have historically recovered from the impacts of these events. Excessive rain (fall of 2000) and frosts (spring of 2001) occurred in the SSV over the course of our fieldwork. These unfortunate circumstances provided our team with the opportunity to observe farmers in the process of recovery from these events. We documented not only how adaptation has occurred over time but we also witnessed this process taking place.

Seasonal Climate Forecasts

One of the key issues pursued in our fieldwork was the potential for stakeholders in the SSV to use seasonal climate forecasts in order to reduce their vulnerability to climate variability. These forecasts are three-month predictions of temperature and precipitation that are made at lead times of one to several months. We found that farmers are interested in looking at seasonal forecasts, but that they need to have them tailored to their particular needs. These needs and desires regarding forecasts are discussed for each of the sectors mentioned above.

Our key findings are summarized as follows:

1. Access to water is the principal limiting factor for agriculture in the region. Its availability is largely determined by depth from which water has to be pumped and the costs of pumping it. Climatic conditions and events (i.e., temperature, cloud cover, solar radiation, and wind) influence the water needs of plants and determine to a large extent

the availability of water, evapotranspiration rates, and soil moisture levels. Technological adaptations across sectors have focused on increasing the efficiency of water extraction and use.

2. High water costs place SSV farmers at an economic disadvantage *vis-à-vis* farmers in other parts of the United States and the world. To reduce their vulnerability, farmers in the SSV look for climate forecasting information in competing regions.

3. Farmers' concerns about climate are influenced by their perceptions of their own adaptive capacity. In most cases, they perceive that the vulnerability of agriculture has declined because of available technology and larger societal-scale adaptations such as crop insurance.

4. Farmers expect and have adapted to a great deal of climatic variability from one year or season to the next, and concern about changes in annual average conditions is relatively low.

5. Unexpected and short-term extreme climatic events are a common concern to all stakeholders. Frost, heavy rain, strong winds, hail, and floods can be more damaging than a season-long drought. There is great interest in better forecasts of an unusual event and forecasting information that ties climate to specific events.

6. Farmers expressed the need for climate information more finely tuned to the local area, including historical data.

7. There is interest in the long-term changes in climate that would affect the water table. Because farmers perceive that winter precipitation is the main source of aquifer recharge, they want winter precipitation forecasts that extend into the future (two to five years).

8. Farmers would like a list of available climate information web sites that is easily accessible.

9. Farmers rely on both vertical (institutional), and horizontal (social capital) networks to reduce their vulnerability. These formal and informal networks provide access to climate information and to financial and other assets that allow farmers to respond and adapt.

10. Of all stakeholders identified, Hispanic farmers and migrant farm workers are the most vulnerable to climate variability. They tend to have less access to climate forecasting information and to institutional adaptations, such as credit and crop insurance programs.

Summary of Stakeholder Forecast Wishes

Table 1 summarizes seasonal forecast needs for each sector. The columns state when such forecasts are needed, the characteristics farmers would like predicted, and the lead-time they would need in order to take advantage of such predictions. A complete list of forecast needs appears in Appendix B.

Recommendations

The points below summarize our recommendations to institutional stakeholders, policymakers, and the scientific forecasting community.

1. Agricultural Cooperative Extension could become a key conduit through which to channel climate information to ranchers, farmers, and farm workers in the SSV. This would entail the training of extension personnel and other agriculture agents in seasonal climate forecast interpretation.

2. For federal policymakers, it is important to understand that different agricultural sectors have varying vulnerabilities and potentials to adapt to climate variability. Policies should encourage adaptation to a semiarid environment by, for example, increasing the ability of all farmers to obtain credit in order to purchase water conservation devices.

3. For social scientists involved in climate research, there is a need to assess the role of social networks in the transmission of climate information among migrant farm workers. Because this group of stakeholders has been identified as the most vulnerable, it is important to understand the mechanisms through which they obtain climate information. Access to improved climate forecasts in different regions of the Southwest would clearly allow migrant farm workers to better plan the timing and trajectory of their seasonal migrations.

4. For climate researchers, results from this study

Table 1. Summary of Seasonal Forecast Needs by Sector.

Type	Season	Forecast Need	Lead time
Corn farmers	Summer Summer Fall	1. Predictions of the timing of the onset of summer monsoon could help them reduce irrigation to take advantage of rain. 2. Prediction of droughts and flooding in the Midwest could allow farmers to store grain or harvest early. 3. Predictions concerning excessive fall precipitation could help them harvest corn early.	1 month 3 months 1 month
Chile farmers	Fall	1. Predictions of fall flooding would allow them to harvest early or reserve green chiles for later harvest as red chiles.	Several weeks prior
Alfalfa hay farmers	Summer	1. Predictions of when and where it will rain in late summer could help farmers to time cuttings.	1 week prior
Fruit tree operators	Summer Spring/early summer	1. Temperature predictions could assist in pheromone application in June. 2. Temperature predictions for spring and early summer could allow operators to predict when fruit will be mature and permit them to advertise fruit availability more accurately.	1 month 90 days prior to harvest
Nut tree operators	Nov.-Dec. Summer and fall	1. Predictions of fall flooding would allow operators to arrange machinery for early harvesting. 2. Predictions of droughts or floods in Georgia and Texas would allow them to refrigerate nuts to await higher prices.	1-3 months 3 months
Vegetable farmers	July-Dec. Winter Sept.-Oct.	1. Predictions of flooding would allow some farmers not to plant in anticipation of failed harvest. 2. Winter predictions of flooding in California can help farmers decide whether or not to plant spring lettuce. 3. Predictions of frosts and freezes allow farmers to spray crop with Frost guard or turn on sprinklers to reduce frost damage to mature produce.	6 months 1 month 3 days to one week
Farm Workers	Sept.-Oct.	1. Predictions of fall storms would allow farm workers to change the harvesting schedule or find alternative off farm employment in anticipation of failed harvest. 2. Prediction of early frosts in the fall that reduce harvesting opportunities would also allow farm workers to change harvest schedule or find alternative employment in case of failed harvest.	3 weeks to 2 months

show that seasonal forecasts have to take into account that different sectors require different types of forecasts. Furthermore, stakeholders are particularly vulnerable to meteorological events such as frosts and floods. Thus, it is strongly recommended that researchers focus on how to use forecasting knowledge to predict the probabilities of short-term extreme events. This is a significant challenge to the current state of climate forecasting, but the predictability of these events lie at core of farmers' decision making.

5. Finally, farmers want the agricultural forecasting service provided by NOAA through the National Weather Service office in Phoenix reinstated. Farmers are willing to work closer with forecasters to obtain more accurate predictions specific to their area of interest and to particular hazards.

1. Vulnerability in the Sulphur Springs Valley

1.1 Introduction

In the semiarid environment of the southwestern United States, where annual precipitation is low, temperatures are high, and water is a scarce resource, agriculture is one of the economic sectors most vulnerable to climate variability and change. The reasons for this are manifold. Because rain-fed farming is limited by low annual rainfall and extreme temporal and spatial variability, agriculture relies heavily on irrigation. Agriculture also is the largest consumer of water in the Southwest. In 1995, agriculture accounted for 86 percent of the water utilized in Arizona and 81 percent in New Mexico (Solley et al. 1998). In addition, agriculture tends to be concentrated in relatively constrained areas, which means that localized climatic events can affect much of the production of both states (Meredith 2001).

The availability of water for irrigation is strongly influenced, but not exclusively, by climate. Competition for water from multiple economic sectors (e.g., urban and industrial) and increasing pressure from a growing population also contribute to the vulnerability of ranchers and farmers in the region. The Southwest is the fastest growing region in the United States and this expansion is occurring primarily in regional cities and in smaller urban settlements that attract both newcomers from outside the Sunbelt and a large influx of immigrants from Mexico (Sprigg and Hinkley 2000). As demographers predict that the rate of growth in the region will remain high (Table 1.1), municipal and industrial demands are likely to incur significant transfers of water away from agriculture (Meredith 2001; Morehouse et al. 2000). Even though most people in the Southwest reside in major urban areas (Table 1.2), numerous rural communities in the region do continue to depend almost entirely on agriculture. Not only are these communities particularly vulnerable to significant or prolonged climatic events such as floods or multiyear droughts, but their vulnerability is likely to increase as the Southwest transforms itself into a more urban-based economy.

The mission of the Climate Assessment for the Southwest (CLIMAS) Project is to enhance the understanding climate-society interactions. As part of this mission, this report presents the second vulnerability assessment case study in a series of such studies that will examine the ways in which communities of the Southwest comprised of different hydrological regimes and livelihood systems are vulnerable to climate variability. It builds upon an initial pilot study carried out in 1998 (Benequista and James 1999) and upon the first community assessment case study done in the Middle San Pedro River Valley (Finan and West 2000). The vulnerability assessment presented here also is part of the larger CLIMAS commitment to improve decision makers' ability to respond to climatic events through access to better information about climate and its impacts. The CLIMAS Project, funded by the U.S. National Oceanic and Atmospheric Administration's

Table 1.1. Population and Growth of States in the Southwest United States, 1990 to 2000.

Area	Census Population		Change, 1990 to 2000		Growth Rate Rank
	April 1, 2000	April 1, 1990	Numeric	Percent	
Nevada	1,998,257	1,201,833	796,424	66.3	1
Arizona	5,130,632	3,665,228	1,465,404	40.0	2
Colorado	4,301,261	3,294,394	1,006,867	30.6	3
Utah	2,233,169	1,722,850	510,319	29.6	4
Texas	20,851,820	16,986,510	3,865,310	22.8	8
New Mexico	1,819,046	1,515,069	303,977	20.1	12
California	33,871,648	29,760,021	4,111,627	13.8	18

Source: U.S. Census Bureau (2001).

Table 1.2. Comparison of Rural and Urban Populations for Select States of the Southwest United States, 1990.

State	Total Population	Total Urban Pop.	Total Rural Pop.	Percent Urban
Arizona	3,665,228	3,206,973	458,255	87.50
California	29,760,021	27,571,321	2,188,700	92.60
Colorado	3,294,394	2,715,517	578,877	82.40
Nevada	1,201,833	1,061,444	140,389	88.30
New Mexico	1,515,069	1,105,651	409,418	73.00
Texas	16,986,510	13,634,517	3,351,993	80.30
Utah	1,722,850	1,499,081	223,769	87.00

Source: U.S. Census Bureau (1995).

Office of Global Programs, was inaugurated in 1998. As a stakeholder-driven project, the CLIMAS research agenda is determined by the needs and issues identified by representatives of sensitive sectors and by those communities whose livelihoods and decisions depend on precise and timely climate information.

Of particular interest in terms of assessing social vulnerability in the Southwest are rural communities that depend on irrigated agriculture. The Sulphur Springs Valley (SSV), the target region in this study, relies entirely on groundwater as the only source of irrigation. In this case, the SSV represents the situation of many communities in the region. According to U.S. Geological Survey data, groundwater aquifers supply 42 percent of the water in Arizona for rural, urban, and industrial needs, and 49 percent in New Mexico (compared to a United States average of 19 percent; Solley et al. 1998). Trends in water use in Arizona indicate that groundwater overdraft continues to be a major concern, as more groundwater is pumped than is replenished by precipitation or other recharge; however, the percentage of total water used by agriculture has declined over time.

In this project we seek to (a) document the nature of vulnerability to climate variability of an agricultural valley that completely depends on groundwater for irrigation; (b) identify and analyze the private and public strategies of farmers and agricultural migrant workers to reduce social vulnerability to climate; and (c) identify specific stakeholder uses of and needs for climate information. This chapter defines key terms used in the report, provides a brief description of the methodology used in our research, and presents the major characteristics of the community under study.

1.2 Vulnerability Defined

Our working definition of vulnerability, discussed in more detail elsewhere (Finan et al. 2002), has two central components. The first is the susceptibility of a community to the negative socioeconomic impacts of climate variability—the more severe the impacts of an event, the greater the degree of vulnerability of a particular human population. A vulnerability assessment identifies who in society is susceptible, degrees of susceptibility among different socioeconomic groups, and the causes of that susceptibility (Ribot et al. 1996). The second component of vulnerability is the degree to which a community is capable of coping with, resisting, and recovering from the impacts of severe climatic events. The less vulnerable community or livelihood has a broader range of short-term responses to climate events and a greater long-range capability of quick recovery and adaptation.

We introduce and apply in this report the concept of *buffering* to describe the process by which communities adapt to climate events. As shall be seen, buffering involves the dynamic interaction of technology adjustment and social restructuring that links public policy, social institutions, and private decision making in such a way that it insulates a community of stakeholders from the impacts of climate variability. Moreover, buffering is a cumulative process and differs from the short-term coping adjustments made by individuals and households. In contrast to buffering, coping strategies do not lead to an increased sense of security—that is, a perception that the impacts of climate variability have been minimized or that a community is better prepared to deal with future climatic events (Corbett 1988; Kinsey et al. 1998). Thus, effective buffering is the historical process by which communities reduce the impacts of climate variability in their lives.

Vulnerability is not predominantly a climate-based condition, but rather derives its significance from the interaction of climate and society. Consistent with existing literature (Hewitt 1983; Kasperson et al. 1995), our definition of vulnerability emphasizes the social characteristics and configurations used to face the challenges of the physical environment (Bohle et al. 1994; Varley 1994). In this approach, vulnerability varies both spatially and temporally. It is possible to compare vulnerabilities locally and regionally, by livelihood system and socioeconomic group (Downing 1993) or across time—taking into consideration the impacts of economic, demographic, and technological change (Liverman 1999). In this vulnerability assessment, we also analyze vulnerability in terms of ethnicity by focusing special attention on Mexican-American and Mexican farmers and agricultural migrant workers. As discussed in chapter 7, ethnicity itself, especially in a society where the dominant culture provides most climate information, helps to explain how and why some groups in society are more exposed than others to the negative impacts of climate variability (Blaikie et al. 1994; Cannon 1994).

Finally, this vulnerability assessment seeks to establish a direct relevance to public policy making. In this respect, we look at changing perceptions of climate vulnerability and how they are formed within a community discourse. As shown by Kempton et al. (1995), understanding perceptions facilitates communication between stakeholders and experts in the science and policy of climate variability (Kates et al. 1985). In addition, given the salience of the debate in political, scientific, and media circles surrounding global warming, greenhouse gases, ozone holes, and global climate change, policymakers at the international, regional, federal, state, and local levels have increasingly been asked to make important decisions regarding the adaptation to a changing environment. This report aims to describe the complex relationship between public and private strategies for mitigating climate impacts and to discover the particular role for enhanced climate information within this context.

1.3 Assessing Vulnerability within Agriculture

Previous research on the impacts of climate variability upon technologically advanced agricultural systems offers a point of departure for this assessment. As reviewed by Bryant et al. (2000), earlier studies mostly focused on the crop yield impacts of climate change (Warrick 1983), and the use of climate-modeling techniques to estimate likely consequences of different climate change scenarios (McCarthy et al. 2001). This research, in contrast to the approach presented here, tends not to focus on farmers as decision makers under varying economic, social, and political conditions. More recent studies have shifted focus into a more precise examination of the actual adaptations of agriculture to climatic variability (Bryant et al. 1997). These studies emphasize the role of farmer decision making aimed at reducing vulnerability to extreme events, and public policy mechanisms aimed at altering or improving the adaptive capacity of the agricultural system (Smithers and Smit 1997).

Such research provides three insights of significance to this assessment. First, farmers' concerns about climate are directly related to perceptions of their own adaptive capacity. In general, they assert that agriculture has become less vulnerable because of improved technology and larger societal-scale buffers such as crop insurance (Chiotti et al. 1997). Second, farmers are primarily attentive to the frequency and timing of extreme events (e.g., frosts) and seasonal and interannual climate variability, rather than to longer-term changes in annual average conditions. Finally, the long-term sustainability of currently successful buffering mechanisms must be reviewed (Kelly and Adger 2000).

1.4 Ethnographic Methods in a Sectoral Assessment

This study utilized a rapid ethnographic approach for conducting a community-level assessment of climate-related vulnerability. This methodology was developed during our first vulnerability assessment in the Middle San Pedro River Valley, and a more detailed description of the methodology can be found in that final report (Finan and West 2000; Finan et al. 2002). Here we provide a brief outline how this methodology was applied in the SSV.

The overall strategy used to collect data was based on a rapid ethnographic methodology, which places an emphasis on targeted research around a well-defined topic. A research team carried out all phases of the project. This type of team ethnography effectively provides detailed information about livelihood systems and their vulnerability profiles, stakeholder perceptions, and their buffering mechanisms, both private and public. In addition, this approach seeks to understand local networks and to build rapport with a variety of stakeholders. It also requires the use of field researchers with complementary expertise and interests, who can explore the multiple contexts in which stakeholders make decisions (Erickson and Stull 1998).

The research process unfolded in sequential phases. The first phase involved a review of relevant literature and secondary sources to obtain contextual information on the community. This included the systematic compilation of existing climate, hydrological, demographic, and economic data, as well as historical accounts of the region. The second phase employed a "rapid ethnographic assessment" technique to gather the primary data set. It was initiated in the summer of 2000 through a series of concentrated site visits by the research team to conduct open-ended interviews with officials and representatives of the community. This process identified potential informants representing key economic and public service sectors. Snowball sampling techniques were used to identify other stakeholders, that is, initial informants in turn recommended other persons with knowledge relevant to the project.

During the fall of 2000 and spring and summer of 2001, in-depth interviews were conducted with representative stakeholders. These followed a semi-structured format and covered topics that included stakeholder occupational histories, household economic profile, schedules of annual farming activities with an emphasis on climate decision making, perceptions of climate change and extreme events, and current uses of climate information (see Appendix A). These interviews lasted an average of 1.5 hours each. Focus group discussions also were conducted with members of various associations. In this process, we identified key informants to whom we returned to clarify specific issues, verify data sets, and fill in information gaps. These key informants were chosen to represent different livelihood strategies and principal crop choices found in the SSV, each of which is differently impacted by climate. We also gathered oral histories from stakeholders whose families have resided in the study site for several generations and who have specialized knowledge of key agricultural sectors. Through oral histories we identified the nature of differing vulnerabilities in more detail and were better able to document the historical process of climate buffering.

After each site visit, researchers converted field notes to electronic format, and coded and stored them in a common database. Each researcher in the team had access to the information gathered by other team members, and discussions of the field data were routinely held among team members. A total of 77 people were interviewed and a total of 90 interviews were conducted. Table 1.3 classifies these interviews by category.

Table 1.3. Number of People Interviewed and Number of Interviews per Sector.

Sector	Persons Interviewed	Number of Interviews
Corn farmers	4	7
Fruit orchard growers	5	7
Chile farmers	5	7
Hay farmers	2	2
Vegetable growers	5	5
Nut growers	5	5
Greenhouses	3	3
Cotton growers	3	4
Diversified farmers	8	9
Ranchers	2	3
Rancher/ farmers	2	2
Public officials	2	2
Agricultural labor	11	11
Government Ag personnel	7	10
Financial	6	6
Miscellaneous	7	7
TOTAL	**77**	**90**

There are several advantages to using the ethnographic approach for conducting the community-level assessment of climate-related vulnerability. First, as pointed out by Finan and West (2000), ethnographic research investigates the interrelationships that constitute the components of vulnerability. In this way stakeholders are seen not only as individual decision makers, but also as members of a larger community that itself provides sets of buffering mechanisms. By taking this holistic perspective, ethnographic research allows us to identify all relevant private, public, and social resources available to individual decision makers. Second, ethnographic research facilitates the building of strong ties with stakeholders and communities. It seeks to establish a sense of trust, the fundamental element of a long-term relationship between scientist and stakeholder. This process of establishing a community/CLIMAS partnership greatly benefited from the participation of project representatives from the climate and hydrology components of CLIMAS in interviews with key informants.

1.5 The Sulphur Springs Valley: A Brief Introduction to the Region

The SSV is situated in the high desert of southeastern Arizona (see Figure 2.1). It is mostly located within Cochise County, except for its northern tip, which is part of Graham County. Cochise County is characterized by a succession of isolated mountain ranges separated by broad valleys forming a semiarid basin. The SSV is one of four valleys. In this valley, runoff from mountains contributes to underground aquifers that lie beneath flat farmland on the valley floor and ranches in the foothills (Bahre 1991). Climatically, the region is characterized by low annual precipitation, high year-to-year variability, and a bimodal distribution of annual rainfall. As shall be detailed in chapter 2, extreme events—such as periods of drought sometimes broken by episodes of extreme flooding—are not uncommon. Hydrologically, the SSV has no permanent source of surface water; thus urban and rural livelihoods completely depend on groundwater from two basin aquifers. For decades groundwater withdrawal, mostly for irrigated agriculture, has significantly exceeded estimated recharge in both basins.

Although little is known of the early inhabitants of the region, archaeological evidence indicates that humans have lived in the SSV for at least 12,000 years. The modern history of the valley, however, does not begin until the late 1870s. Major Anglo-American settlement focused initially on the development of ranching and farming. Rain-fed agriculture in the SSV was carried out for a brief period at the beginning of the century when higher than average precipitation attracted a large number of settlers. Few understood the climate of the Southwest, and the lack of rains eventually forced most of the new settlers out of the valley (Schultz 1980). Those able to adjust acquired an important comprehension of the limitations imposed by this semiarid environment. As explained in chapter 3, adaptation to aridity is a common theme throughout the history of agricultural settlement in the SSV and is as relevant today as it was 100 years ago.

While ranching has been a key economic activity in the valley since the late 1800s, agriculture did not become important until World War II when the demand for agricultural products soared, electricity became cheap, and efficient, low-cost groundwater pumping became available. Commercial irrigated agriculture expanded rapidly from the 1940s to the 1960s, leading to the conversion of thousands of acres of desert scrub and grassland into "some of the most productive cropland in the American Southwest" (Bahre 1991:164). By the mid-1970s, however, irrigated agriculture in the valley had declined precipitously. Thousands of acres of land were abandoned, with grave consequences for the physical environment and the economy of the region.

As will become evident throughout this report, since the 1980s agriculture in the valley has undergone profound transformations. Those families able to withstand the crisis of the 1970s ushered in a number of successful adaptations that have resulted in a general perception that the threat of climate variability has been significantly reduced throughout the valley. On the other hand, agriculture in the valley has declined in the 1990s. While technology has certainly reduced short-term vulnerability to drought, it also has increased vulnerability to multiyear droughts, which lower the water table and substantially increase the costs of irrigation.

1.5.1 The Socioeconomic Context

Today, the SSV has a population of about 34,282 residents, comprising approximately 29 percent of the population of Cochise County. The county's rate of growth has been relatively low. While population in the state increased by 40 percent over this decade, Cochise County showed an increase of 20 percent and the SSV of 15 percent (Table 1.4). In the last 10 years the county's rate of growth has been sluggish, ranking 12th among 15 counties in the State of Arizona for the period from 1990 to 2000. In absolute terms, however, the increase in population has been significant.

The composition of the population in the SSV also differs from that of the state in that about 55 percent of the valley residents are of Hispanic origin, compared to 25 percent statewide. The city of Douglas, with 84 percent of its residents of Hispanic origin, has the largest proportion in the state (U.S. Census Bureau 2000b). In addition, a large number of agricultural

Table 1.4. Population Growth in Selected Geographic Areas, 1990 to 2000.

Geographic Area	Population 2000	Population 1990	Percent Change
Arizona	5,130,632	3,665,228	40
Cochise	117,755	97,624	20.6
SSV	34,282	29,761	15

Source: U.S. Census Bureau (2001).

workers cross the border and arrive from other parts of the Southwest during the agricultural season, roughly from August to December.

The main population concentration within the SSV is found in Douglas, a city of 14,312 residents on the Mexican border approximately 118 miles southeast of Tucson (see Figure 2.1). The city of Willcox, at the northern end of the valley, follows with a population of 3,733 residents (U.S. Census Bureau 2000b). The rest of the valley is a composite of small rural communities dependent on ranching and agriculture. At the southern limit of the valley is the Douglas Division with a population of 4,825, excluding the city of Douglas. To the north is the Elfrida Division, including the communities of McNeal and Elfrida, with a total population of 5,229; and the Willcox Division with a population of 6,183, including the communities of Cochise, Pearce, Sunsites, Kansas Settlement, and the Bonita and Stewart Districts but excluding the city of Willcox (U.S. Census Bureau 2000a). Willcox, located 80 miles east of Tucson on Interstate-10 and the Southern Pacific railroad line, serves as the major trade and service center for agriculture in Cochise County (Clark and Dunn 1997).

Excluding Douglas, where retail trade is the main source of employment (U.S. Census Bureau 2000a), farming and ranching today constitute the most prevalent livelihoods in the SSV. Table 1.5 indicates how Cochise County compares to the State of Arizona in some agricultural characteristics. The SSV contains 86 percent (57,500 acres) of the irrigated acreage within Cochise County (Clark and Dunn 1997). The SSV leads the state in corn and chile production. Although Cochise County ranks fourth among Arizona counties in terms of the number of cattle, it hosts 18 percent of the state's range—as opposed to feedlot—cattle which makes it the number one producer of range cattle (McReynolds 1997).

According to the U.S. Census, there are 572 persons (1.3 percent of total) age 16 years and over whose primary occupation is in the farming, fishing, or forestry sector (U.S. Census Bureau 2001). There also are an estimated 1,800 people employed in productive agriculture through out the year and an additional 800 seasonal laborers (Clark and Dunn 1997).

1.5.2 Climate and Agriculture in the Context of Vulnerability

The climate of southeastern Arizona presents farmers with both opportunities and risks. The risks consist of a wide range of uncertainties that constrain production (e.g., frost or hail) and affect other aspects of livelihoods and safety (e.g., droughts and floods). The opportunities are found in the pattern of moderate year-round temperatures and the availability of different microclimates within the valley, which has allowed for wide diversity in crop choice.

Despite the high productivity of their agriculture, farmers and ranchers in Cochise County are more vulnerable to climate variability than other producers in the Southwest. In relative terms, the county has a large number of agricultural operations (824), ranking third highest among the state's 15 counties. As shown in Table 1.6, the county has 379 irrigated farms or 11 percent of the state total. Farms are characterized by wide crop diversity, and tend to be small and medium in size. Whereas the average number of irrigated acres per farm in the State of Arizona is 3,869, in Cochise County the average number of harvested irrigated acres per farm was only 167 in 1997 (U.S. Department of Agriculture 1997). The distribution of irrigated land by farm size is shown in Figure 1.1, which indicates that 40 per-

Table 1.5. Percentage and/or Rank of Cochise County Agriculture Compared to Arizona, 1997.

Characteristic	Amount	Percentage of Arizona Total	Rank among Arizona Counties (N=15)
Groundwater Irrigated Acreage	–	23 **	–
Irrigated Land – Acreage	63,252 acres *	6.2 *	–
Corn for Grain – Acreage	15,293 acres *	38.1 *	1 *
Land Used for Vegetables – Acres	6,931 acres *	5.3 *	4 *
Land in Orchards – Acres	6,032 acres *	8.9 *	4 *
Cattle and Calves – number	69,950 head *	–	4 *

Source: *USDA (1997); ** Solley et al. (1998) and Clark and Dunn (1997).
— Means that no comparison could be made with existing data.

Table 1.6. Comparison of Arizona Agriculture, 1997.

Area	Farms*	Avg. Size of Farms* (acres)	No. of Irrigated Farms*	Irrigated Land* (acres)
Arizona	6,135	4,379	3,426	1,013,902
Average per County (N=15)	409	4,379	228	67,593
Cochise County	824	1,529	379	63,252
Cochise County % of AZ	13.4%	34.9%	11.1%	6.2%

Source: Data obtained through U.S. Department of Agriculture (1997).
* The Census of Agriculture 1997 includes ranching operations in this category.

cent of the farms have up to 100 acres of irrigated land, while 14 percent have 2,000 acres or more. Size is an important variable in terms of vulnerability concerns. Smaller farms have less ability to spread risks over larger expanses of land and to benefit from certain technologies that offer economies of scale.

Cochise County also has the highest percentage of land under private ownership in Arizona (41 percent) (see Figure 2.1; Clark and Dunn 1997). Most farms in the SSV are family-owned and operated. Land ownership has two implications with regard to vulnerability. First, risks are faced by individual households rather than large corporations, as is the case in other agricultural areas of the Southwest (Sheridan 1995). Second, due to relatively less government intervention on private land, there is a greater likelihood that farmland will be sold for real estate development.

Finally, complete reliance on groundwater to irrigate crops can be extremely costly. The cost of pumping has been a key factor shaping agriculture in the SSV. During periods of water table declines and increased energy costs, larger farmers have tended to absorb those that are too small to be able to cover the rising costs of irrigation. Those farmers who continue to survive today are large enough to adopt a variety of technologies that enhance water efficiency or better control temperature extremes. Also successful are the growers that have been able to find niche markets for specialty crops and value-added products, and those that have diversified crop production as well as their operations, such as with agro-tourism in the form of “U-pick” farms.

We have defined different agricultural subsectors in the SSV according to type of crops produced as shown in Table 1.7. Even though most farms are diversified and produce multiple crops, the National Agricultural Statistics Service (U.S. Department of Agriculture 1997) estimates the distribution of farms by their principal activity, as shown in Table 1.7. In general, the pattern includes tree crops (fruit and nuts), field crops, such as corn, cotton, and alfalfa, and higher value field crops such as vegetables, lettuce, and chiles.

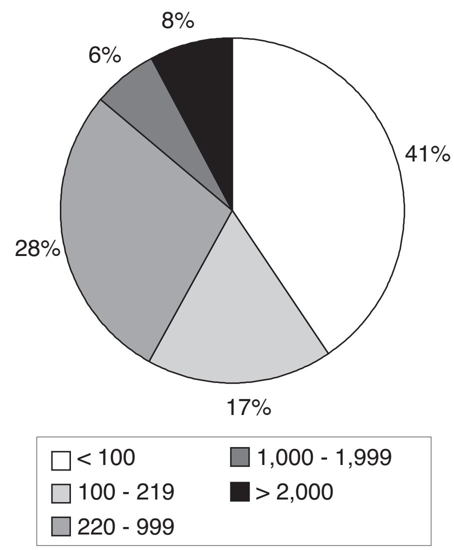


Figure 1.1. Percentage of Cochise County Farms in Each Acreage Category, 1997. Source: Data compiled from U.S. Department of Agriculture (1997).

This diversity provides ample data with which to investigate the relationship between climatic variability and the process of societal adjustment in the agricultural context. Each crop type requires a different amount of water and a different irrigation schedule. Each also is susceptible to particular climate and weather-related events. Frosts and warm winters are a problem for orchard growers, while low summer precipitation is a major concern of corn farmers. Vegetable growers prefer aridity to rain so that they can control pests, molds, and disease, and greenhouses are almost oblivious to climate, as long as there is enough solar radiation. Labor requirements also vary a great deal depending on the crop, on available technology, and on the timing of very specific climate-related events. This range of variation gives us the opportunity to explore the impacts of climate and the vulnerabilities experienced by different types of farmers as well as agricultural workers.

In this report we first examine the biophysical context of vulnerability by exploring the ways in which climate, hydrology, and topography have impacted the development of agriculture in the SSV. In chapter 3, we focus on how human populations in the valley have dealt with climate variability from a historical perspective, and we explore how perceptions of vulnerability have changed through time. We emphasize the role of technology and individual decision making in the process of adaptation. Chapter 4 takes a more detailed look at adaptations from a system-wide perspective. We present a description of the various programs available to farmers that have fueled the perception that vulnerability to climatic extremes has been substantially reduced.

Chapters 5, 6, and 7 examine, through a series of selected case studies, the most important farming systems found in the region. More specifically, in chapters 5 and 6, we analyze the impact of climatic variability upon corn farms, fruit orchards, chile farms, hay farms, nut orchards, vegetable producers, U-pick farm operations, and greenhouses. In these chapters, the specific vulnerabilities of each livelihood system are assessed by comparing the level of exposure to the buffering mechanisms that have been adopted. We further examine stakeholders' perceptions of vulnerability, the specific climatic factors that affect them, and their adaptive strategies, as well as their use and need for climate forecasting information. Chapter 7 concentrates on Hispanic farmers as a separate group of low technology, small-scale farmers, and on agricultural migrant workers, the most vulnerable stakeholders found in the region.

Table 1.7. Estimated Number of Farms in SSV for Each Crop, 1997.

Type	Number
Corn*	51
Chile	28
Apple*	46
Hay	88
Pecan*	91
Pistachio*	38
Vegetable (includes chile)	65
Lettuce and romaine	15

Source: Data obtained from U.S. Department of Agriculture (1997).
*Estimates includes the Graham County portion of the SSV.

2. The Physical Sources of Vulnerability

The climate and hydrology of the Southwest have been fundamental factors shaping ecological and socioeconomic processes, and in configuring the different livelihood strategies that have developed and that exist today in the SSV. The climatic conditions and events that carry potentially negative effects for crop production are numerous. In addition to the threat posed by high summer temperatures, the region faces occasional floods, droughts, wind, hail, heavy rains, and frost dangers. Because the specific needs of each crop are different, farmers' responses to threats posed by climatic conditions and events are varied and their adaptations have changed through history.

An understanding of societal vulnerability to climate variability requires an awareness of the basic biophysical conditions that humans have to face and respond to as well as the impact of humans on the environment. In this chapter we examine the biophysical context under which farmers operate and make decisions. We also outline the most obvious impacts of weather, climate, and hydrology on the development of agriculture.

2.1 Topography and Climate in the Sulphur Springs Valley

The SSV, located in Southeastern Arizona, trends southeast to northwest and has an approximate area of 1 million acres. The valley is bounded by mountains; the Pinaleño (Graham) to the northeast, the Dos Cabezas, Chiricahua, Swisshelm, Pedregosa, and Perilla Mountains to the east, and the Mule, Dragoon, and Winchester Mountains to the west. The international border with Mexico limits its southern extent. Elevation ranges from 10,713 feet above sea level at the highest peaks, to less than 3,900 feet above sea level at the International Border near Douglas, AZ. Within the valley elevation averages 4,000 feet, making the region cooler than in the lower desert of Southeastern Arizona (see Figure 2.1).

The exceptionally diverse vegetation found in the region is attributed to changes in elevation. Semi-desert grassland, Chihuahuan Desert scrub, and Plains grassland characterize the valley floor, and most of the native vegetation contains species from the Chihuahuan and Sonoran desert ecosystems. The mountains surrounding the valley give rise to vertical ecosystem changes. Desert species of the valley floor yield to agave, yucca, and manzanita. At elevations of 4,000 to 6,000 feet mesquite and oak-pinyon-juniper woodlands dominate. The remaining area is a ponderosa pine and mixed-conifer forest that ascends to almost 10,000 feet (Bahre 1991).

Climate patterns in the SSV vary throughout the region depending on the elevation and the proximity to nearby mountains. Average annual precipitation increases eastward with higher elevations. It ranges from 9 to 25 inches, but may go above 35 inches at the highest elevations (Bahre 1991). Cattle ranches tend to be located in the foothills, where precipitation is higher. In the valley itself, where all farming takes place, annual rainfall averages 12.63 inches, an insufficient amount for the development of rain-fed farming. As in much of the Southwest, low annual precipitation and the related presence of a persistent subtropical high-pressure ridge (Sheppard et al. 1999) produce moderate year-round temperatures (see Figure 2.2).

Looking at average annual precipitation, however, can be deceptive. The Southwest is situated between the mid-latitude and subtropical atmospheric circulation regimes. Shifts in these regimes can lead to significant seasonal, annual, and multiyear changes (Sheppard et al. 1999). The ability to adapt to this variability has been a central factor in the development of farming. Crops require different amounts of humidity during different stages within their growth cycle. Thus, for farmers, average yearly amount of rain is not as significant as its timing and spatial distribution throughout the year.

As shown in Figure 2.2, precipitation varies a great deal from season to season. The region is influenced by the North American Monsoon, which brings moist air from the Gulf of California and the Gulf of Mexico and generates heavy rains in the summer months of July, August, and September. These convection storms sometimes cause flooding that damages property and fields (Sprigg and Hinkley 2000). These rains can be torrential; as much as 50 percent of annual precipitation may fall during this period (see Figure 2.2). This also is a time when evapotranspiration rates are highest. There is, however, a great deal of spatial variability

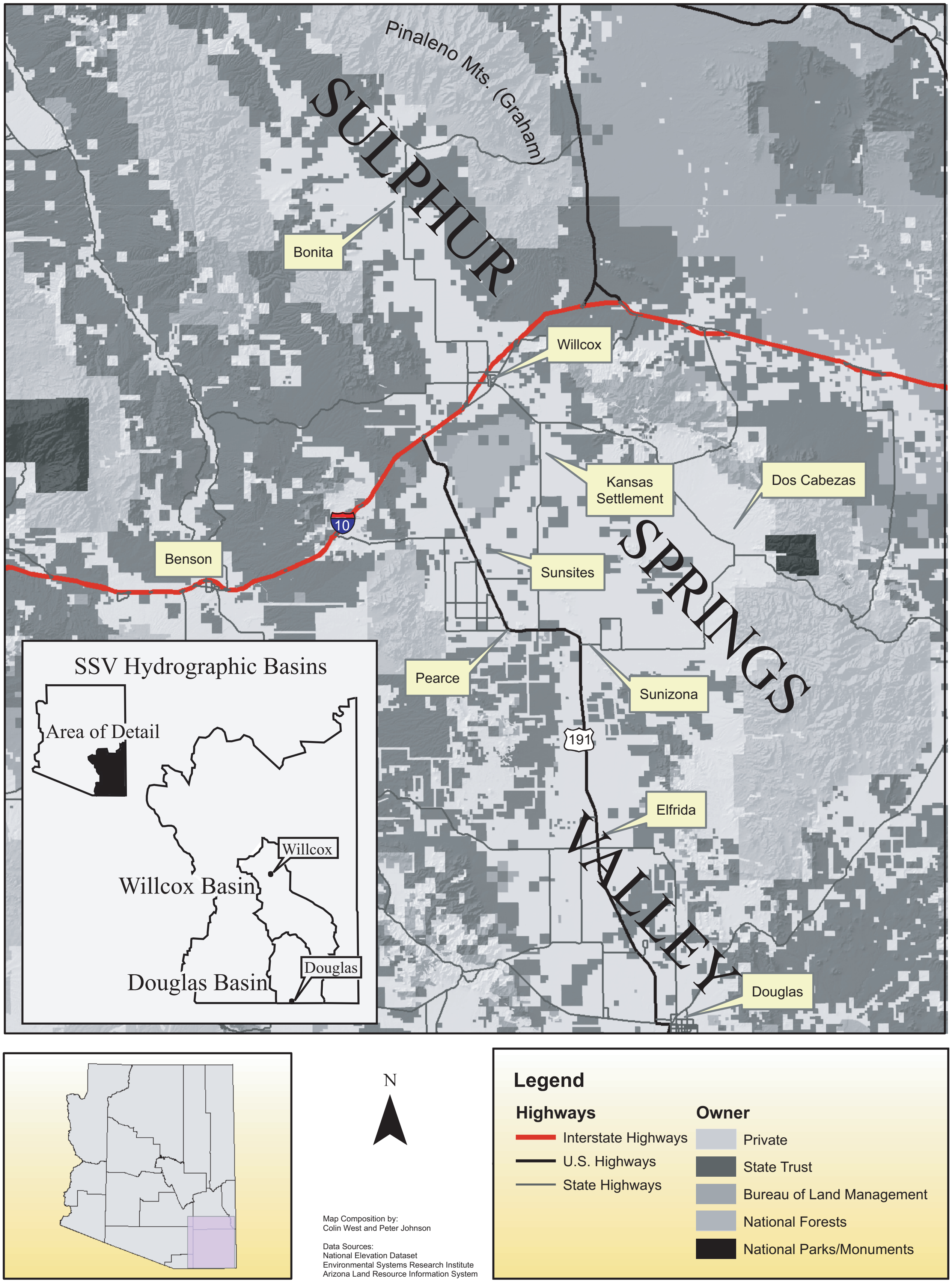


Figure 2.1. Map of SSV Including Land Ownership and Hydrological Basins.
Map prepared by the Center for Applied Spatial Analysis (CASA) at the University of Arizona.

in precipitation, related to the basin and range topography of the region. The large isolated mountain ranges and broad valley bottoms result in certain places receiving a great deal of rain, and others receiving very little due to the rain shadow effects of the mountains (McReynolds 1997).

Summer rains are followed by fall aridity, although occasional tropical storms may reach the region during the harvest season, bringing long, heavy rains and causing crop damage. This has particularly detrimental effects on farm workers who receive most of their yearly salary during the fall harvest season. Vegetable farmers may also suffer significant losses.

Scattered light winter rains are generated by frontal systems originating in the eastern Pacific Ocean and occur during the months of December, January, and February. Both the El Niño-Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO) influence climatic variability during the winter. El Niño, for example, usually results in wet winters while La Niña tends to have the opposite effect (see Sheppard et al. 1999). Winter is followed by four months of dryness from March to late June or early July. The characteristic seasonal variation in precipitation can be seen in Figure 2.2, which shows mean monthly precipitation for the Willcox area.

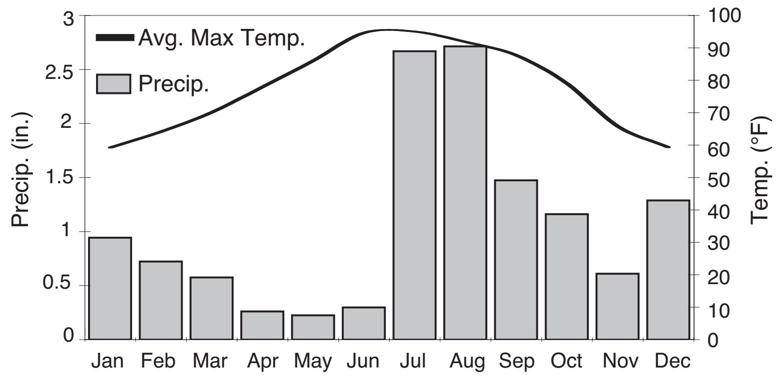


Figure 2.2. Average Monthly Precipitation and Temperature for Willcox, AZ, 1961 to 1990. Source: Data obtained through WRCC (2002).

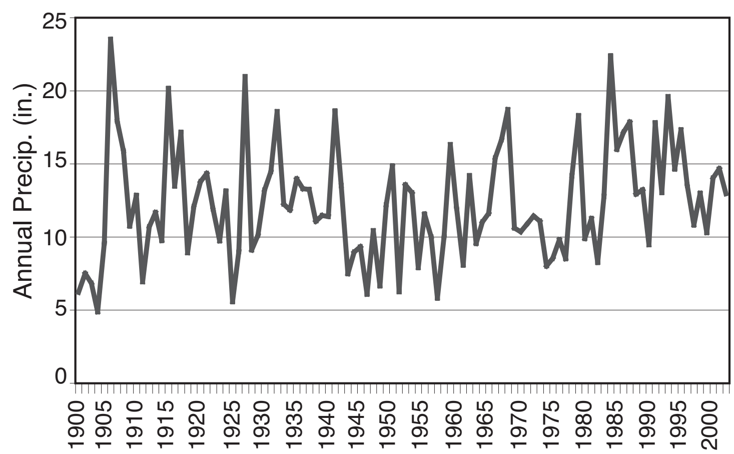


Figure 2.3. Annual Precipitation for Willcox, AZ, 1900 to 2001.* Source: Data obtained through WRCC (2002).
* Missing data from some years obtained from nearby stations at Cochise Stronghold (1926); Cochise 4 S.E. (1911, 1922, 1923); Douglas Smelter (1939); and Pearce-Sunsites (1958).

Precipitation also varies considerably from year to year. Figure 2.3 shows clear evidence of this. For example, from 1982 to 1983 annual precipitation rose from 12.79 inches, a year of higher than average precipitation, to 22.39 inches, an increase of 75 percent. At the lower extreme, annual rainfall between 1943 and 1947 averaged 8.29 inches, or 36 percent below average conditions. Annual variability in precipitation, much more than changes in average conditions, is a considerable factor influencing decisions and the agrarian economy of the SSV.

Temperatures also vary according to elevation. Extreme temperatures range from 1°F to 109°F (Western Regional Climate Center 2002). The high elevation of the valley, relative to other parts of southern Arizona, and the low latitude (32°N) lead to moderate summer and winter temperatures. In July, high temperatures often reach 96°F contributing to high evaporation rates, estimated at 67 inches per year. In January average temperatures drop to about 50°F. This relatively moderate temperature regime has allowed farmers to invest in a variety of vegetable and fruit crops. Low winter temperatures, for example, provide the required dormancy period for nut and fruit trees. Relatively cool temperatures in the spring and summer allow for the agricultural year to be extended into the fall. This permits farmers to obtain better market price for such crops as chile and lettuce. In addition, high solar radiation has attracted a number of Dutch and Canadian greenhouse owners to the region (discussed in chapter 6).

Within the valley there are different agro-climatic subregions due to orographic effects (see Figure 2.1).

Table 2.1. Cultivable Land in the SSV, including Bonita, 1997.

Growing Area	Current Acreage Under Production (acres)	Potential Cultivable Land (acres)
Bonita	10,500	12,000 - 15,000
Stewart District	6,000	20,300 - 48,000
Cochise-Pearce	4,500	3,500 - 5,000
Kansas Settlement	19,000	25,800 - 65,000
Elfrida/Douglas	17,500	30,000 - 38,000
Total	57,500	91,600 - 171,000

Source: Clark and Dunn (1997).

Bonita, located north of Willcox, is higher, cooler and receives more rainfall than the rest of the valley. Frost is a significant problem for orchard growers in this area. The area around Willcox, from the Stewart District south to Kansas Settlement, is lower and warmer than Bonita but remains vulnerable to frost damage in the late spring and early fall. The Cochise/Pearce/Sunsites area (along U.S. 191), locally known as the "banana belt" because temperatures tend to be higher year-round, offers a slightly longer growing season (Clark and Dunn 1997). This area has become a new haven for pistachio orchards due to the lower risk of frost. Because farmers stagger the planting of crops, having access to land in the banana belt allows them to plant earlier than in the rest of the SSV. The southern part of the valley, spanning from Elfrida to Douglas, is warmer and has a longer growing season than the rest of the valley. Most chiles are grown in this sub-region (Clark and Dunn 1997). Current acreage under cultivation as well as potentially cultivable land in each of the growing areas are indicated in Table 2.1.

2.2 Hydrology in the Sulphur Springs Valley

The SSV overlays the Willcox and Douglas hydrological basins. These basins are part of a structural trough that extends from the central portion of Aravaipa Canyon to the northeastern section of the State of Sonora, Mexico. Because agricultural production in the SSV is completely dependent on groundwater sources, the characteristics of the local groundwater aquifers must be examined. It is believed that the large aquifers in the basins were originally formed thousands of years ago by percolating water. The aquifers consist of deep alluvial fill material, predominately layers of sand and gravel interbedded with clay and silt, which becomes shallower toward the mountain fronts (Clark and Dunn 1997). As there are no permanent sources of surface water in the valley, groundwater from these aquifers supplies all local urban and rural water needs (Arizona Department of Water Resources 1994b). Like much of the Southwest, residents of the valley rely on extensive infrastructure and technology to deliver the water to agricultural, industrial, and municipal users.

The Willcox basin occupies the northern three-fifths of the valley and covers approximately 1,911 square miles. This area of the valley is hydrologically and topographically separate from the southern part of the SSV. The basin is closed; all drainage is internal and flows to the Willcox Playa in the south-central part of the basin (see Figure 2.1). The Willcox basin is the largest source of groundwater with an estimated 45.3 million acre-feet of groundwater stored to 1,200 feet (Arizona Department of Water Resources 1989).

Within the Willcox basin well depths vary. In the Bonita aquifers, well depths range from 200 to 400 feet. Relative to the rest of the SSV, the water in these aquifers is considered to be abundant and of excellent quality. Farmers pumping from the Bonita aquifers have set national records for irrigated corn yields (Clark and Dunn 1997). In the Stewart District, where all of the water pumped comes from alluvial fill materials, irrigation water is obtained from relatively shallow aquifers ranging in depth between 100 to 150 feet. By contrast, Kansas Settlement irrigation water comes from deep aquifers. According to Clark and Dunn (1997), wells 400 to 750 feet deep must be drilled to reach water in this area. The average well depth is 450 feet. In the Cochise/Sunsites area aquifers are shallower, with depth to static water varying from 30 to 250 feet.

The Douglas basin occupies the southern two-fifths of the valley and contains approximately 750 square miles. It is drained by the Whitewater Draw, which originates in the Chiricahua Mountains and flows south into the Yaqui River of Mexico. The Whitewater Draw is ephemeral and only flows in response to local rainfall. The Douglas basin has an estimated 32 million acre-feet of groundwater stored at 1,200 feet (Arizona Department of Water Resources 1994a).

Groundwater recharge in these basins is largely a function of rainfall and temperature. Abundant summer rainfall, however, does not contribute to aquifer recharge. On the one hand, high summer temperatures at lower elevations in July increase evaporation and transpiration rates. On the other hand, clay and silt layers that characterize the greater part of the upper basins' fill impede downward percolation of water, making recharge from rainfall and irrigation water on the valley floor negligible (Arizona Department of Water Resources 1994a).

The principal source of groundwater recharge for the basins is winter precipitation, including snowmelt from the surrounding mountain ranges, which is transported to the valley by streams and washes (Mann et al. 1978). Although winter precipitation amounts are lower than the summer averages, winter precipitation is a much more significant contributor to groundwater recharge. Because temperatures are cooler in the winter, the evaporation and transpiration rates are much lower, allowing a higher percentage of the precipitation to reach the aquifers (Sprigg and Hinkley 2000). Consecutive years of drought, especially during the winter, can lead to a decline in the water table and have major long-term impacts on irrigated agriculture. Local farmers are very aware of the importance of winter precipitation for aquifer recharge. Noting the seven inches of rain that fell in November 2000 and the visible snow on the nearby mountains, one local farmer commented, "We're tickled to death with all this winter moisture."

For the Willcox basin, estimates of the annual natural recharge vary. The Arizona Department of Water Resources (ADWR), for example, estimates it to be 15,000 acre-feet per year (1994a). Clark and Dunn (1997) report a much higher recharge of 75,000 acre-feet per year. Recharge estimates for the Douglas basin range from 20,000 to 22,000 acre-feet per year. As explained in the following chapter, however, even though the future of the industry is contingent upon the continual recharge of these aquifers, in both basins withdrawal has largely exceeded recharge since the development of large-scale irrigated agriculture in the 1940s.

The topography and hydrology of the SSV also shape land use. Agricultural fields are found on the valley floor due to the fact that the water table is higher in these areas. The depth to water increases substantially as one moves from the Playa toward the mountains. Thus, livestock grazing is pursued in the mountains and on the mountain slopes because water availability is sufficient for cattle but not for crops. Within the past 10 years, however, a growing number of "ranchettes" or hobby ranches have been established on 40-acre parcels on which 5–20 cattle may graze. Because the stocking rate is normally around 10 head per section (640 acres), local ranchers and extension personnel express concern over the fact that these small herds are permanently confined to locations that are far too small and considered unsuitable as rangeland. The Playa itself is used for neither ranching nor farming because of its propensity to flood and the fact that its soil is heavily alkaline. It does, however, foster large numbers of migrating birds.

2.3 Climate, Water, and the Economics of Irrigated Farming in the Desert

As mentioned in the introduction, trends in water use in Arizona indicate that while agriculture is by far the largest water user, the percentage of total water used has declined over time. While in 1960 agriculture consumed 93 percent of the water in the state, water consumption declined to an estimated 78 percent in 1990 (Table 2.2).

As shown in Figure 2.4, historical average annual diversion of surface water supplies and groundwater pumped indicates that groundwater is the most important source of water. Historic trends also indicate a decline in the average amount of water pumped. This, according to the ADWR, is due to a reduction in agricultural water use in the state.

Table 2.2. Agricultural Water Use in Arizona.

Year	1000 Acre- feet	% of Total State Water Use
1960	6,334	93
1970	6,050	91
1980	6,355	86
1990	4,802	78
2001	4,410 (est.)	73

Source: Ayer and Hoyt (1993a).

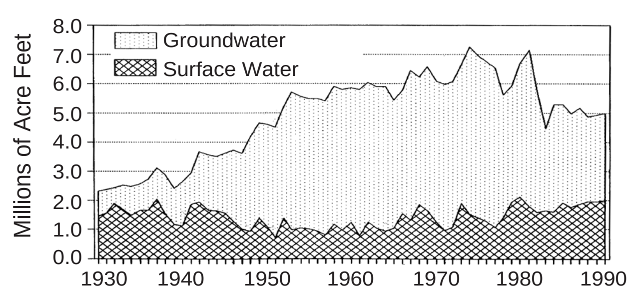


Figure 2.4. Surface and Groundwater Annual Extraction: Arizona, 1930 to 1990. Source: Arizona Department of Water Resources (1994b).

Groundwater overdraft, however, continues to be a major concern throughout the region as more groundwater is being pumped than is being replenished by precipitation or other recharge. The cost of water is one of the most important factors that affect water use in groundwater-dependent agriculture. Pumped water from underground sources tends to be more expensive than surface water delivered from reservoirs and rivers. (Ayer and Hoyt 1993a) estimate that the cost to pump and deliver groundwater to the field in Arizona ranges from $25 to $100 per acre-foot. In contrast, they estimate surface water costs to be from $3 to $20 per acre-foot.

Within Arizona, Cochise County and the SSV in particular, have been most affected by increases in water costs in combination with decline in the water table. Crop acreage declined by almost 70 percent from 1975 to 1985 as a result of high pumping costs (see Figure 3.1). During the same period, crop acreage declined by only 5 percent in Yuma County, where agriculture depends on low-cost surface water (Ayer and Hoyt 1993b). Of significance in terms of vulnerability to multiyear droughts is that Cochise County incurs on average the highest irrigation costs in the state. According to Wade's estimates of average water costs for groundwater pumping in 1991, farmers in Cochise County were paying an average of $66.44 per acre-foot, followed by Maricopa with $53.90 per acre-foot. The average for the state was $33.77 per acre-foot (Wade 1991).

Table 2.3. Seasonal Consumptive Water Use* for Various Crops in Cochise County.

Crop	Total inches per year
Alfalfa	41.6
Apple	35.6
Barley	17.1
Chile	35.0
Corn	23.0
Cotton	24.2
Lettuce, fall	10.5
Lettuce, spring	8.0
Onion	26.5
Pecan	47.9
Pinto beans (May)	20.8
Pinto beans (July)	16.8
Pistachio	31.3
Potato	21.5
Small grains	14.6
Wheat	15.5

Source: Clark and Dunn (1997).

*Clark and Dunn define consumptive use as "the unit amount of water used on a given area in transpiration, building plant tissues, and evaporation from adjacent soil" (1997:21).

Another critical factor in determining water use within agriculture is the field efficiency of an irrigation system. As defined by Ayer and Hoyt (1993a:2), field efficiency refers to "the amount of water actually delivered to a crop's root zone divided by the total amount of water applied to a field." Field irrigation efficiency depends on a variety of different factors such as the type of irrigation system used. For example while the typical field irrigation efficiency of a drip system is 90 percent, the irrigation efficiency for gravity furrow is only 60 percent. As discussed in more detail in subsequent chapters, farmers in the SSV have adapted to water scarcity by increasing field irrigation efficiency mainly through the adoption of drip and center-pivot irrigation technologies.

Water use also is determined by crop type. As indicated in Table 2.3, different crops require different amounts of water. Pecan and alfalfa, for example, require the most water per acre whereas lettuce is a very water efficient crop. Even though irrigated acreage has decreased in the SSV, one of the managers of the SSV Electrical Cooperative notes that water usage is going up. On the one hand, the major crops being grown—corn, chiles, fruit and nut orchards—are very water intensive. On the other hand, with increasing diversity of crops (discussed below), intensive water usage is not as seasonally marked because irrigation takes place all year long, to suit the needs of different crops. According to this manager, "They probably didn't pump that much less in the olden days, but got less water on the field " because much water from ditch irrigation was lost to evaporation.

Given that water is a scarce but high-demand resource in the Southwest, in the next three chapters we address the issue of overdraft as a problem that can threaten the viability of agriculture. We also ask whether the agricultural system has historically responded to changes in environmental conditions (e.g., decline in the water table, droughts and high temperatures) by adopting water efficient irrigation technologies and changing crops to reduce reliance on groundwater, or whether adaptation strategies are more related to the costs of energy. The answer to this is probably somewhere in between, as the following transcript of a taped interview with an orchard owner in the SSV indicates:

> Do I need to be concerned about the water table? These are the long-term environmental things that are important to me, now, if I am saying as a farmer, I am sure the hydrologists can build models of water usage in the SSV. I am sure they can talk about recharge, I know the university has mapped this basin and they know what the storage capability of this basin is. I am sure they can do some really simple models: This is what the storage looks like, this is the consumption, this is the predicted recharge of what we are looking at, and this is what is going to happen to you guys.
>
> The question is, drought lowers the water table, is there going to continue to be these dry winters? We need to know. And if it is bad, then we need to talk to the state, we need to do something about it. I am not the kind of person that buries his head in the sand and then one day is going to wake up and go, oh no! I can make some intelligent decision. We already have made some decisions about water usage on our own, we need to conserve as economics are right now, and as winter rains have been so low, we need to look at the future.

As every farmer knows, pumping costs are a function of water levels and of energy prices, so as water levels decline and the price of energy increases, the cost of groundwater irrigation goes up and with it the vulnerability of irrigated agriculture to extended periods of drought. Access to water presents the greatest challenge to the local farming industry. Those that require more water may be more vulnerable as explained by a farmer in the north end of the valley:

> If water becomes a problem in this area, the corn farmers are going to be the first to go because corn prices are very low. We need to understand if our life is going to change drastically…we are all tied to the same system, we all need to be cautious. And don't take me wrong, I am not an alarmist, but knowing things allow us to manage our business better. So, yes, we want to know about El Niño and La Niña and how they affect winter precipitation and aquifer recharge.

3. A History of Climate Variability

In this chapter we focus on the process of adaptation to the physical environment by highlighting the interaction between climate, economy, water, and technology from a historical perspective. We show how rural inhabitants and communities in the SSV have been affected by climate variability, how they have responded, and how their responses impact vulnerability to climatic events in the long term. Adaptation to climate variability in the SSV is an iterative process that has led to the development of important buffering strategies. These have drastically changed the perception that farmers have today of their own vulnerability and of the importance of climate in decision making. This process of adaptation and today's buffering strategies have also had an impact on the physical environment. Thus, we ask, however preliminarily, how viable and sustainable are these strategies given the fragility of the physical environment?

3.1 The Prehistoric Period

Although little is known of the early inhabitants of southeastern Arizona, archaeological evidence indicates that humans have lived in the SSV for at least 12,000 years. By 9,300 BC southeastern Arizona was inhabited by Paleoindian Clovis big game hunters who depended on large mammals, such as mammoth and bison, for survival (Haynes 1991). In fact, the Double Adobe site, southwest of the valley, yielded one of the few records of human fashioned artifacts in association with mammoth tusks (Woosley et al. 1987). Paleoindians were followed by hunters and gatherers of the Archaic (Sulphur Spring stage) Cochise culture group. These people lived in nomadic groups and hunted small game. Evidence of farming peoples who also manufactured ceramic pottery date from 1450 to 800 BC.

It is estimated that approximately 30,000 Indians lived in southeastern Arizona at the time of Spanish contact between 1536 and 1770 (Bahre 1995). Since then Spain, then Mexico after 1821, and the United States after 1854, have successively "possessed" the region. Actual control, however, remained in Native American hands. The Chiricahua Apache were the last native peoples to permanently occupy and control the area until their relocation to Alabama and Florida in 1886 (Sheridan 1995). This band of the Apache led by Mangas Coloradas, Cochise, Juh, and Geronimo were consummate raiders who intimidated other Native American, Spanish, Mexican, and early Anglo-American occupants.

The archaeological record reveals strong relationships between climatic changes and prehistoric human settlement patterns. During the late Pleistocene, conditions were cooler and wetter than today with less temperature variation between seasons (Cordell 1997). Under these conditions, the Willcox Playa was a permanent shallow lake referred to as Lake Cochise in the geologic and archaeological literature. This lacustrine environment probably provided a rich supply of plant, animal and aquatic food sources for early humans but scant material from the late Pleistocene exists in the archaeological record. Warmer temperatures and greater aridity mark the shift from the Pleistocene to the Holocene at which time Lake Cochise dried up. These changing climatic conditions contributed to the extinction of large fauna such as mammoth and bison although human predation may have played a role as well. This shift also marks the transition from Paleoindian to Archaic peoples.

Numerous Archaic sites are documented within the SSV and they are found mostly adjacent to the remains of Lake Cochise or the Willcox Playa where groundwater would have been close to the surface. Hearth and tool assemblages indicate that these areas were probably base camps whereas smaller sites with more specific artifacts indicate specialized use areas. Altogether, Archaic hunter-gatherers ranged over the entire SSV and took advantage of its relatively lush environment and ample water (Woosley 1987).

Such generous conditions did not exist for the later farming and ceramic manufacturing peoples. Who exactly these people were remains controversial, but archaeologists now classify them as members of the Salado culture (Reid and Whittlesey 1997). By the time of their establishment as early as AD 500, Lake Cochise was completely dry and the bimodal distribution of low rainfall prevailed as it does today. Habitation sites are found exclusively at the mouths of canyons, adjacent to springs, along washes, and beside ephemeral streams (Woosley et al. 1987). Thus, as climate conditions became more arid, water became scarcer and settlements became more localized. Ceramic evidence suggests that agriculturalists abandoned the SSV around 1450 (Woosley et al. 1987), which corresponds to a period of intense flooding and drought in southern Arizona (Reid and Whittlesey 1997). Thus, climatic change was a strong determinant of prehistoric occupation in the SSV.

Based on Francisco de Coronado's documents, southeastern Arizona was unpopulated at the time of his expedition in 1540 (Spicer 1962), but Sheridan (1995) points out that native inhabitants may have deliberately avoided the conquistadors. Nonetheless, the area was certainly sparsely populated and Apache groups probably did not enter southeastern Arizona until at least 1680 (Bahre 1991). The Apache themselves are Athapaskan speakers related to the Navajo and were historically recognized as different "bands" such as the Western, Mescalero, San Carlos, Mimbreño, and Chiricahua Apache. Spanish-Apache contact occurred at a time when both groups were in the process of occupying new territory, leading to great hostility and conflict. Depredations by what came to be known as the Chiricahua Band of the Apache prevented permanent Spanish and Mexican settlement in the SSV.

Hunting, gathering, and particularly raiding were the main lifeways of the Chiricahua Apache and it appears that they never practiced any form of agriculture in the SSV. This selection against farming was probably not due to climatic, environmental, or even cultural conditions but rather to the relative ease with which raiding could be accomplished using Mexican and Native American villages as targets and the rugged mountains surrounding the SSV as bases. In fact, Geronimo and his Chiricahua band became some of the most industrious farmers during their brief stays on both the San Carlos and Fort Apache Reservations (Spicer 1997; Sheridan 1995).

Overall, it appears that settled agriculture in the SSV lasted from approximately AD 500 to 1450 and then ceased. Native American subsistence strategies ranged from largely hunting by Paleoindians to primarily plant-gathering and processing by Archaic peoples (Waters 1998) to settled agriculture by the Salado and finally raiding by the Chiracahua Apache. Some of these transitions in lifeways were accompanied by climatic change. The bio-geographic landscape of the SSV made it an ideal location for a variety of land uses. After the arrival of Anglo-American settlers, the primary land uses became ranching and farming.

3.2 Anglo-American Settlement and the Development of Ranching

Major Anglo-American settlement did not begin until the late 1870s, after the subjugation of the Apache and the discovery of important mining districts on the periphery of the valley. Early settlers described the SSV as "the only all grass valley in the territory [of Arizona]" which contained "an abundance of wide open space with grass in every direction" that sometimes reached heights up to a man's knees (Bailey 1994:21). These early descriptions reached prospective investors in the Midwest and East Coast and enticed them to begin establishing ranches as early as 1872.

Following the completion of two transcontinental railroad lines across Arizona in 1881, the cattle ranching industry boomed as American and British investment money flooded the Western cattle industry. In the late 1880s large numbers of sheep and cattle were brought from different parts of the United States where, for ecological and economic reasons, cattle ranching had become an unprofitable business (Sheridan 2001). The SSV became a dominant cattle-raising area and the town of Willcox grew from a village to a town of 500 people by 1884 (Schultz 1980). From 1885 to 1889 at least 41 families were grazing cattle in the SSV, although four corporate ranches dominated: the Chiricahua, Erie, Kansas, and Tombstone Land and Cattle Companies (Bailey 1994). In 1890, at least 50,000 head of cattle roamed the ranges of the valley (Bahre 1991).

Accelerated land use change prompted by the rapid development of the cattle industry led to ecological disaster. Overstocking and overgrazing became considerable problems, which were exacerbated by extended droughts that hit Arizona from 1891 to 1893, from 1898 to 1904 (Bahre and Shelton 1996), and from 1910 to 1911. The droughts were extreme events that had profound effects on local livelihoods as well as on the physical environment. Page Bakarich, a local historian, recounts short-term strategies to deal with drought and lack of feed. People would burn off the thorns from cacti and chop up yucca for forage. In the 1920s people would burn mescal (a type of agave) in pits and leave it for a couple of days covered up with earth. "They'd roll those heads into the pits and roll them out. Those cattle would smell it and come to eat those cooked heads" (personal communication 2000).

During severe droughts, many ranching families' only method of coping was to let starvation and thirst kill off their animals on the range. Mortality rates of this kind ranged between 50 and 75 percent in southern Arizona and the estimated mortality rate for Cochise County was 25 percent (Wagoner 1952). A local rancher from one of the earliest families to settle remembers family accounts of the time. "Small ranchers watched their cattle die. They picked up bones around here from the dead cattle…it is said that there were bones all over the place from the females that died." Bigger ranchers who had the financial means shipped their herds by train to other states in the Midwest, Nevada, Texas, and California. Others moved their animals to New Mexico or Sonora, Mexico.

The droughts also prompted changes in production and breeding that proved long lasting. Ranchers began raising mostly feeder calves rather than mature bulls, steers, and cows because the latter put too much strain on scarce resources. Operators also switched from mixed-breed longhorns to purebred Hereford cattle that were better adapted to dry conditions (Schultz 1980). A few stockmen also commenced raising sorghum and alfalfa to supplement the forage.

Local SSV residents often joke that it is "always a drought" in southern Arizona. The long-term response to these semiarid conditions by ranchers was to acquire large tracts of land with reliable water sources from wells or ephemeral springs. The first artesian well in the Arizona Territory was developed in the SSV in 1883 and steam powered pumps followed soon after in 1888 (Schultz 1980). The fact that artesian wells could be drilled and water could be found close to the surface induced families to install windmills, which appeared as early as 1885 (Bailey 1994). Families banded together to consolidate homestead claims or purchase the ranches of others. An extensive range could compensate for scattered rainfall. Even though families held title to parcels of land, it was still an open range and cattle roamed throughout the valley. Rodeos were held every year in the spring to round up cattle that bore specific brands (Bailey 1994).

Ownership of land permitted ranchers to install pumps or windmills and gave them the legitimacy to prevent the cattle of others from grazing on these improved pastures. Thus, the long-term adaptation to aridity was ranching on a "permanent" basis on set parcels of land with improved water sources rather than on the "open range" (Wagoner 1952). The advent of inexpensive fencing and influx of farmers in 1909 further sped the process of permanent ranching and the free range was effectively closed in the SSV by 1911 (Schultz 1980).

The passage of the Taylor Grazing Act in 1934 effectively terminated the free-range era throughout the West. Under it, all unappropriated federal lands were turned over to the General Land Office—now known as the Bureau of Land Management—and fencing became mandated. These agencies, along with the pre-existing U.S. Forest Service and Arizona State Land Department, established lease agreements with cattlemen and imposed limits on the number of livestock that could be grazed on a particular lease for a given amount of time (Sheridan 2001). The process of permanent grazing was thus instated by institutional relationships with the federal and state governments. Ranchers currently use a combination of leased and deeded land.

Today, Cochise County has approximately 77,000 head of cattle (McReynolds 1997). Estimates of SSV's herds in the 1980s range from 10,303 to 38,283 (U.S. Department of Agriculture 1997b). Ranching consists almost entirely of cow-calf operations (Conley et al. 1999) and local stockmen raise primarily Herefords. Individual adaptation strategies to the vagaries of climate continue to be of extreme importance. In times of drought, the primary response is to cull herds, an action that is sometimes required on public grazing leases (Eakin and Conley 2002). Another option during drought is to supplement range forage with alfalfa hay, although this option is expensive. Ranching families that own land on the valley floor have an advantage because they are able to raise their own alfalfa. Such is the case with one family who are amicably referred to by other residents as the "cowboy farmers" because they combine farming with ranching. They proudly informed us that unlike other ranchers, they never cull their cattle because they can always provide adequate supplemental feed. As this cowboy farmer stated, "With our hay farm, we have insulated ourselves very well against drought."

Since the advent of Anglo-American ranchers in the 1870s, grazing has seriously altered the landscape of the SSV. The combination of overgrazing, particularly during the early years of cattle ranching, and extended droughts resulted in degradation of the range and ruined the luxuriant grasses in most of southeastern Arizona (Bahre 1991). The native perennial grasses have been replaced by exotic annuals, grasslands have been over-run by woodier species such as mesquite, and streams that were once perennial, such as Whitewater Draw, are now intermittent. In his book, *A Legacy of Change* (1991), Conrad J. Bahre paints these changes in a negative light. However, most ranchers regard the presence of the exotic Lehmann's lovegrass (*Eragrostis lehmanniana*) and annual California poppy (*Eschscholzia californica*) as signs of the rangeland's health and vitality rather than its decline. Moreover, one former rancher emphatically stated that the pernicious mesquite proliferate on land that has *not* been grazed and insisted that cattle grazing actually benefits the range. Local descriptions of environmental degradation and the role of ranching in this process differ greatly from the authoritative ones presented by Bahre.

The loss of grass cover made the soil more susceptible to torrential rains and led to large-scale erosion and arroyo-cutting. In the early 20th century, Dr. David Griffiths, an extension agent charged with restoring the region's rangelands, reported that southern Arizona range destruction was nearly "complete" and in his opinion represented the worst degradation in the western United States (Griffiths 1901). Within his report Griffiths noted, however, that the SSV was not as severely impacted as other parts of southeastern Arizona, at least up to 1901. This was partially due to the fact that many of the ranches in the SSV had conscientious operators such as Colonel Henry Clay Hooker, the Riggs brothers, and the Chiricahua Cattle Company, who were early opponents of overstocking.

Images of this negative environmental legacy live on today. Sheridan (2001) states that ranching is "one of the most mythologized, demonized, but least understood industries in the western United States or northern Mexico." Ranchers today are acutely aware of the potential damage overgrazing can cause. They also go to great lengths to avoid causing harm. The "cowboy farmers" we interviewed in the SSV have invested in miles of polypipe to spread their water throughout their grazing leases in the Graham (Pinaleño) Mountains. By watering every inch of pasture, they can prevent cattle from overgrazing around water sources. Their use of supplemental feed during droughts also minimizes the impact of grazing on plant cover. This "zero impact" cattle management means, "when [cattle] leave a pasturage, you can't tell they were there."

An interview with a long-term resident and rancher of the SSV demonstrated another form of ecological conscientiousness. The management philosophy of this older rancher uses the "rule of 60 percent." If rainfall is 60 percent of the mean, then one can assume that grass production will also be around 60 percent. Thus, you stock your range at 60 percent of its normal capacity. In times of drought, this rancher culls his herd accordingly although he also occasionally purchases supplemental feed depending on its price. Thus, these two ranchers exemplify the role of range management in mitigating the environmental impact of cattle ranching. The combination of government intervention, improved breeds, technology, and better management by ranchers has ameliorated range conditions in the SSV since the 1891–1904 droughts. The environmental sustainability of ranching appears viable for years to come although economic conditions continue to threaten it as a livelihood.

3.3 Early Attempts at Rain-fed Farming

Unlike ranching, agriculture developed much later in the valley. The main constraint was water availability. An early attempt at rain-fed agriculture in the SSV was carried out during the 1890s by failed miners (Schultz 1980). Abundant rains from 1905 to 1907 attracted a large influx of farmers from the Midwest to homestead in the SSV. As shown in Figure 2.2, average yearly rainfall in Willcox during this period was 19.3 inches or over 50 percent greater than the 1900 to 2001 average of 12.63 inches. Communities such as the Stewart District, Kansas Settlement, and Elfrida were established virtually overnight (Schultz 1980). Congress approved the Desert Land Act in 1909 that allowed settlers in the arid West to obtain 640-acre homesteads. Within several months, a thousand families moved from Texas, Oklahoma, and Kansas to Kansas Settlement (Bailey 1994).

Ranchers had already grown frustrated by the booms and busts of raising cattle and many sold their pastures to the incoming farmers (Bailey 1994). Few of these newcomers understood the climate of the Southwest and realized that the high precipitation totals between 1905 and 1907 were an anomaly. When the rains returned to the annual average of 12 inches after 1910, most farmers were forced to abandon their fields. Those families better able to adjust remained. They used earthen catchments and shallow wells to irrigate beans and alfalfa (Schultz 1980). These early farmers acquired an important understanding of the limitations imposed by this semiarid environment. Most of the families who stayed, however, took up ranching as a more viable livelihood in the arid climate and began consolidating homestead claims to establish grazing lands for cattle.

But if rain-fed farming failed, the floor of the SSV, with its largely flat lands that gently dip toward the Playa in the Willcox Basin and towards Douglas in the Douglas Basin, was an ideal location for irrigated agriculture. The fundamental constraint was the availability of appropriate technologies that could bring adequate amounts of water to the surface and disperse it over cropland.

Some settlers built check dams and ditches to divert rainfall into fields of beans and alfalfa on the mountain slopes. But, as one farmer recalls, "There was not enough water in the creeks for anything, so farmers began to create long drainage canals from different wells that could drain water down to hay and orchard fields. Everyone knew that dry-land beans was the best you could do." Artesian wells could provide copious amounts of water but only in specific locations. One inventive farmer constructed an experimental solar motor that delivered 1500 gallons per minute in 1906. However, a severe hailstorm destroyed its 4800 mirrors several years later (Schultz 1980). Annual rainfall never returned to the record 23.52 inches set in 1905 and the farming of corn, beans, lettuce, watermelon, and other crops remained small-scale due to the limited capacity of windmills or small gasoline pumps.

3.4 The Development of Large-scale Irrigated Agriculture, 1940s–1970s

Large-scale agriculture did not become possible until World War II when demand for agricultural products soared, electricity became inexpensive, and large-scale pumping became available. From the 1940s to the 1960s groundwater irrigation practices underwent a significant expansion, leading to a farming boom. The critical factor in this transformation was the advent of the SSV Electrical Cooperative and its electricity generating station near McNeal in 1940. The prospect of irrigated agriculture brought a new flow of settlers to the valley. Farmers from the Midwest, especially from Kansas and Texas, continued to settle in the region during the 1950s, 1960s, and 1970s. By 1955 there were 299 farming families in the SSV, raising mostly cotton and corn (Schultz 1980). Agricultural acreage expanded rapidly, from 60,000 acres in 1963 to a peak of 170,000 acres in 1976 (see Figures 3.1 and 3.2). Accelerated expansion led to the conversion of thousands of acres of desert scrub and grassland into "some of the most productive cropland in the American Southwest" (Bahre 1991:164).

Initially, the agricultural boom in the SSV and the rest of Arizona was driven by wartime demand for cotton. The entire southern half of the state is well suited to the production of this crop because of high summer temperatures. Monsoons in July through September provide adequate humidity at the right stage of cotton's cycle to further promote the development of bolls. Aridity at other points in the season eliminates standing water, which decreases water-borne diseases and permits the bolls to be uniform in color and texture. The SSV was actively promoted by the cotton industry, which extended credit, machinery, and expertise to entice farmers to migrate to the SSV from Texas, Oklahoma, and Kansas.

Cotton farming from the 1950s through the early 1970s was quite profitable. As a commodity, the price of cotton was consistently higher than its cost of production for growers in Arizona. However, the combined energy crisis and the agricultural embargo of the early 1980s were particularly hard on cotton growers. Farmers complain that whereas the price of cotton has remained essentially the same since 1950, the cost of raising it has doubled. In addition, cotton growing and harvesting require specialized machinery, which makes it less amenable to center-pivot irrigation, one of the key water-saving adaptation technologies in the valley. Cotton production has plummeted in the SSV since the 1970s and particularly in the 1990s (see Figure 3.3). Ten years ago, there were five cotton gins in Cochise County and now there is only one, located in Kansas Settlement.

The large water requirements of cotton and feed grains including corn, sorghum, wheat, and barley of which the SSV was a major producer, led to severe overdraft in both basins. In the Douglas Basin, for example, pumpage up to the 1940s was estimated at less than 5,000 acre-feet per year (Coates and Cushman 1955). At this time, water moved from recharge areas in the mountains towards the center of the basin and then south towards Mexico. From 1950 to 1989 the U.S. Geological Survey estimates that pumpage for irrigation averaged 77,000 acre-feet per year, leading to a change in the direction of flow. Several cones of depression were created, the largest one located north of Elfrida. Here, groundwater currently moves north from the Elfrida area towards the cone's center (Mann and English 1980).

In the Willcox basin it is estimated that during the peak of agricultural production (1967–1975) groundwater pumpage averaged 300,000 acre-feet per year (Mann et al. 1978). Overdraft in the Willcox basin also led to a change in the flow of water. Prior to the 1940s water flowed from the perimeter of the SSV toward the Willcox Playa and perhaps south toward the Douglas basin. In 1975, the general direction of groundwater changed toward pumping centers in the main agricultural areas along the valley floor. There are two large cones of depression found in the basin. One is located approximately three miles northeast of Three Sister Buttes in the southern part of the basin and the other one is located about six miles northwest of the town of Willcox (Mann et al. 1978). Some farmers in the Kansas Settlement area remember this period and stated that it forced them to "chase" water with their wells. Thus, they had to deepen and relocate irrigation wells to adjust to the changed flow. One individual remembered seeing a hydrological map at this time that showed how the flow resembled an underground river. All of the best wells lay on that "river." Operators incurred additional costs for well deepening and relocating due to these cones of depression.

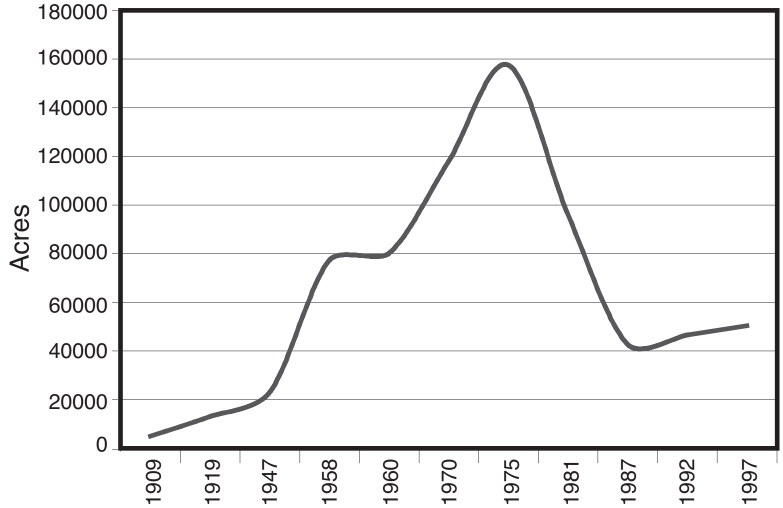


Figure 3.1. Irrigated Acreage Change in Cochise County, 1909 to 1997. Source: Data obtained through U.S. Department of Agriculture (2001a); Valley National Bank of Arizona (1982), (1976), (1971), (1961), (1959), (1948); and U.S. Bureau of the Census (1924).

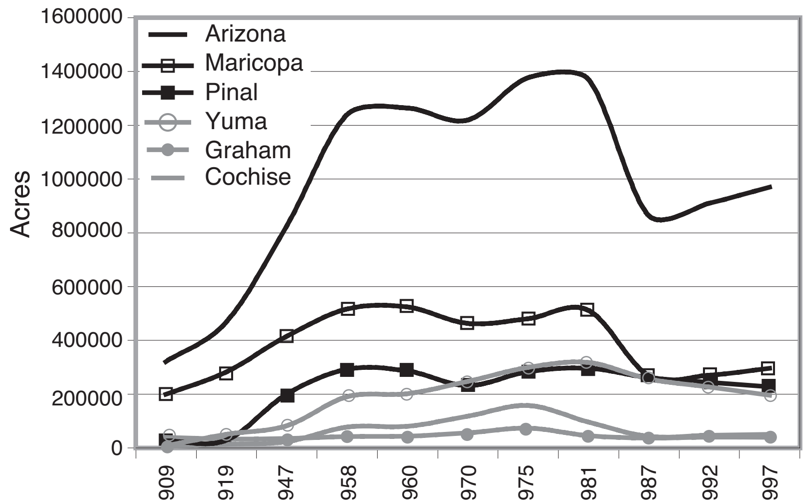


Figure 3.2. Irrigated Acreage Change in Arizona and Select Counties, 1909 to 1997. Source: Data obtained through U.S. Department of Agriculture (2001a); Valley National Bank (1982), (1976), (1971), (1961), (1959), (1948); and U.S. Bureau of the Census (1924).

By the mid-1970s agriculture in the valley had declined precipitously. In the course of a few years, irrigated acreage in Cochise County declined by more than 66 percent, the largest decline of any county in Arizona (see Figures 3.1 and 3.2). This sudden drop was the culmination of a series of interacting events. The problem of overdraft and land subsidence was aggravated by severe droughts in the 1950s. In 1950, 1953, and 1956 precipitation in the valley was well below the annual average of 12.63 inches calculated for the past 100 years—at 6.25 inches, 7.91 inches, and 5.82 inches respectively. From 1968 to 1976 farmers in the valley experienced nine consecutive years of below average precipitation. Mean annual precipitation for those years was 9.92 inches, or 2.71 inches per year below the average. Water table levels in the county dropped an average of two feet per year between 1975 and 1980 (see Figure 3.3; Clark and Dunn 1997). As the water table declined, farmers were forced to pump from greater depths, drastically increasing costs of production. This situation had become increasingly problematic. A cotton farmer in Kansas Settlement told us that in the early 1970s the cost of pumping was one-third of what it was at the end of the decade; "If you couldn't make money then something was wrong with you."

Drought and drops in aquifer levels combined with the energy crisis of 1976 when prices for gas and electricity soared led to a sharp increase in irrigation costs. One

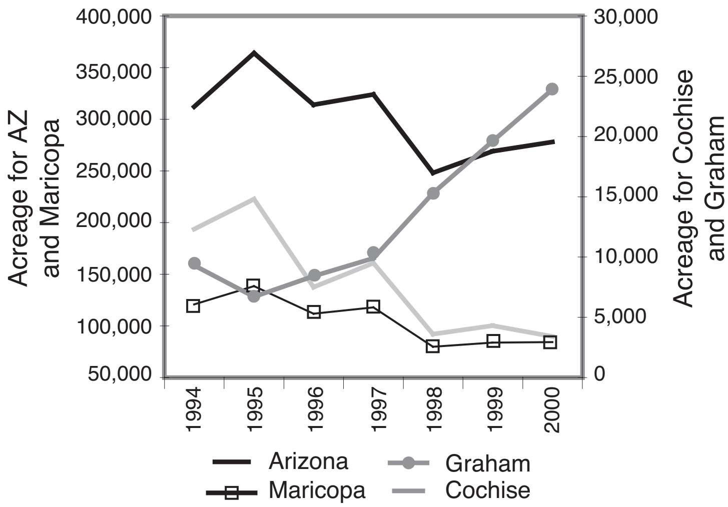


Figure 3.3. Changes in Irrigated Upland Cotton Production for Arizona and Selected Counties, 1994 to 2000. Source: Data obtained through U.S. Department of Agriculture (2001a).

long-time farmer near Elfrida reported that in a six-month period the cost of pumping increased from $300 per acre to $3,000 per acre. This was accompanied by a drop in prices for most agricultural commodities. In 1980, President Carter issued a grain embargo against the Soviet Union, which caused commodity prices to fall drastically while the United States' balance of payments went from "black to red." By the early 1980s, as the costs of pumping groundwater became exorbitant, more than 38 percent of farmland was taken out of production county-wide and locals estimated that 80 percent of the farms around Kansas Settlement sold-out. The majority of farm owners left the region in search of new occupations or better farming conditions. The abandonment of thousands of acres, as Bahre (1991) points out, has had serious consequences for the physical environment. Vacant agricultural land has allowed exotic species such as Russian thistle, more commonly called tumbleweed, to proliferate and also permitted mesquite trees to become reestablished. These species out-compete indigenous grasses and shrubs, which in turn diminishes the grazing potential of the land.

The crisis also led to important changes in the use of water. Recognizing the rapidly declining groundwater levels, the Critical Groundwater Area in the Douglas basin, delineated in 1965, became the Douglas Irrigated Non-Expansion Area (INA—also called the Whitewater Draw INA) with the passage of the 1980 Groundwater Code. According to the ADWR the "Groundwater Code promotes water conservation and long-range planning of [Arizona's] water resources" by specifying restrictions on agricultural expansion (Arizona Department of Water Resources 1994a:12).

INA status means that only those acres within the designated area that had been irrigated any time during the five years previous to 1980 can continue to be irrigated (see Arizona Revised Statutes [A.R.S.] 45 §437.A). Farmers may substitute non-irrigated acreage if they are contiguous to irrigated parcels and they retire the same number of already irrigated acres. They can only do this under particular circumstances by applying to the Director of ADWR (A.R.S. 45 §437.03). In the Douglas INA, land may be substituted if floods damaged the original acres or if the original acres pose an impediment to the implementation of more water efficient irrigation practices (A.R.S. 45 §437.02). The latter provision was crucial to farming in the Douglas INA because it allowed farmers to place new acreage under center-pivot irrigation by retiring adjacent acres that were not center-pivot acceptable due to roads and buildings. Farmers can use as much water as necessary but they must keep a log and send water pumping reports to the ADWR. They may also deepen wells but need permits to do so (A.R.S. 45 §437). Essentially, INA status designates that no new acreage may be put under irrigation and a limit is placed on the amount of irrigated acreage but not necessarily on the amount of water used. The amount of water used and its effect on groundwater levels is, however, monitored through annual reports filed by operators.

Some farmers, discontent with the regulation, explained that water rights are key to farming in this area—around Elfrida and McNeal—and that some parcels of land cannot be farmed because the owner and the land lost their water rights. According to one of the agricultural extension agents, "The Whitewater Draw INA was probably not brought on by the local farmers but imposed by the state." He emphasized that farmers are very independent and do not want more government regulations, such as the INA districts. This opinion, however, is not shared by everyone. Some local residents argue that the INA designation has been beneficial because it decreased pressure on the aquifer.

Today, the wide adoption of water-efficient irrigation technologies has allowed farmers to regain a greater sense of the stability that had been lost in the 1970s. The agriculture industry in the SSV, however, remains extremely vulnerable to changes in precipitation patterns and subsequent changes in the groundwater aquifers. Even with the general decline in agriculture during

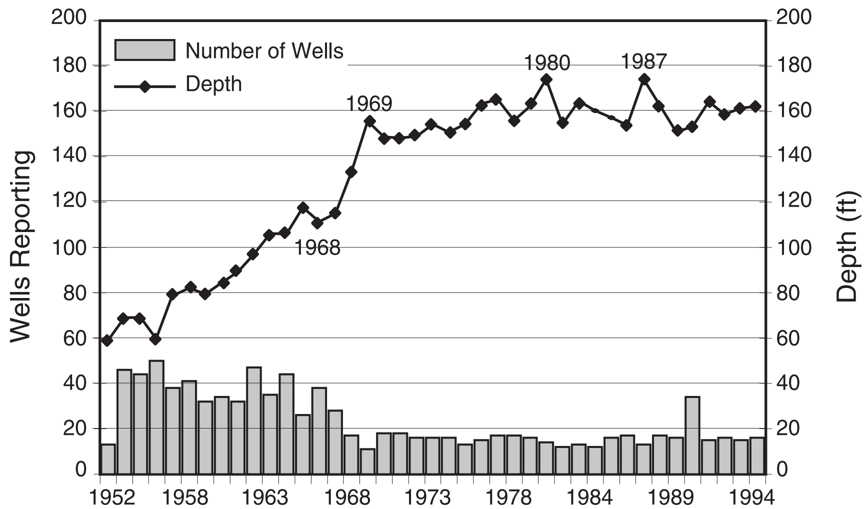


Figure 3.4. Average Winter (DJF) Static Water Levels of Irrigation Wells in the Sulphur Springs Valley, 1952 to 1994. Source: Data obtained through U.S. Geological Survey (2001).

Table 3.1. Average Annual Groundwater Withdrawals (acre-feet).

Groundwater Basin	1971-1975	1976-1980	1981-1985	1986-1990
Willcox	308,000	214,000	117,000	86,000
Douglas	110,000	90,000	61,000	38,000

Source: Arizona Department of Water Resources (1994a).

the 1980s and a steady decline in water extraction in the last 20 years (see Figure 3.4 and Table 3.1), ground water pumpage continues to exceed estimated recharge. And, even though little is known about the impacts of overdraft in the region, or about how much water is available and how long it can last at the present rate of exploitation, local concern for future water availability is ambivalent. Local farmers point to technological advances in irrigation techniques aimed at reducing water use as a critical component of the future of the agriculture industry in the SSV, and local government organizations estimate potential cultivable land at twice the current acreage under production (Clark and Dunn 1997).

3.5 Contemporary Agriculture: New Technology, New Crops, and New Markets

Within the last decade agriculture in the SSV and the agricultural system as a whole have undergone substantial changes. We believe that the overwhelming factor prompting these changes is economic. The profitability of current agriculture is a major concern. As one farmer commented, “Today’s farmers have to be pretty sharp business people.” Profit, however, has to do with keeping costs of production low. Climate, more specifically changes in seasonal precipitation and temperature, is indeed a key factor influencing the costs of irrigated agriculture. Those farmers able to withstand the crisis of the 1970s and 1980s have led the valley into a number of successful adaptations, including the adoption of water efficient irrigation technologies, crop diversification, and a change in market orientation.

3.5.1 Changes in Technology

Technological innovation has been a key source of adaptation not only to climatic variability, but also to declining market prices and increasing costs of inputs. Technology translates into efficiency and an increasing sense that nature is being conquered and success in farming is no longer as at-risk from climatic variability and extreme events.

The most important innovation that resulted from the crisis of the 1980s was the adoption of water-efficient irrigation technologies. Sprinkler and drip irrigation systems started to become important in the SSV by the mid-1980s. Before the crisis, farmers relied on flood-furrow or row irrigation. Most of these farming operations became uneconomical with increased water costs. While flood-furrow is relatively inexpensive, it wastes large quantities of water. The basic gravity furrow system distributes water at the high end of a slightly sloped field. Gravity transports the water to the lower end of the field. According to Rogers et al. (1997) up to 50 percent of the water is lost to deep percolation, runoff, and evaporation with furrow irrigation systems. In addition, the labor requirements of furrow irrigation are much higher that the requirements of newer technologies. One local corn farmer, for example, used 400-foot aluminum gated pipe in 200-foot rows in his 1,800-acre farm. He had 10 or 12 wells and had to move pipe every day. He switched to center-pivot irrigation in 1990 and, in his words, “Center-pivot basically took the labor out.”

Center-pivot irrigation is the technology that, according to local farmers, “saved the SSV.” Although this technology was first introduced in the SSV in 1972, it took almost two decades for it to become widely used. By the mid-1980s only 30 percent of farms had adopted the technology. By the end of the 1990s there were more than 300 center-pivots in the county. The pivot went through several transformations. Early pivots had high-pressure pumps that drove the wheels and irrigated the crop, with high-pressure nozzles located high on the support structure. These were replaced by pivots that were electrically rotated (Clark and Dunn 1997). Later, pivots were modified to have "drop" nozzles that allow for the release of water close to the ground, reducing evaporation and decreasing the pressure needed in order to save pumping power. Like other forms of sprinkler irrigation, center-pivots have increased field irrigation efficiency from 60 percent (gravity furrow) to over 80 percent (Ayer and Hoyt 1993a).

Center-pivots have other advantages. They allow for the application of fertilizer, and, as one farmer told us, they also "have these paddles which do diking, or inter-ribs between rows, making dikes, or sort of a little basin, so there is no runoff." In combination with other technologies, center-pivots also allow for the optimization of rainfall and irrigation water. As one farmer explained, "Tractors are custom manufactured so that you make furrows that are even closer together." They went from 38 to 40 inch rows, to 30-inch rows, and with pivots the rows are now 20 inches apart. "Now plants are so densely packed that evaporation is reduced as well as the need for herbicides. So you can plant less acreage but increase yield." This same farmer remembered a torrential rain in which they got three inches of rain in one day: "Thanks to the center-pivot I did not lose one drop."

Initial investment in center-pivot technology is expensive, however. One of the first farmers to adopt the technology estimated that it cost him $20,000 in 1976 to change from furrow irrigation. It took this farmer, considered the best corn producer in Arizona, three years to pay back the investment on his 1,500-acre farm. Today the cost of purchasing and installing one center-pivot ranges between $50,000 and $100,000. There are other limitations involved. For example, land has to be "center-pivot acceptable" which means, as one farmer stated, that "you have enough land and it has to be unobstructed for a pivot to rotate." In addition, not all crops are amenable to center-pivot irrigation. Most cotton farmers, for instance, continue to use flood-furrow irrigation, and only in the last three or four years have they started to switch to center-pivots. This has to do with the convenience of furrows during harvest time. As one cotton farmer explained, cotton has furrows that are relatively tall. The cotton picker that harvests and bales cotton gets damaged if it runs across furrows as it would have to with circular center-pivot plots. With flood irrigation, on the other hand, the machine can easily harvest along the furrows. One of the innovations in cotton irrigation has been the process of diking and checkerboarding the ground to prevent run-off.

Today, better-off farmers predict that those who still use furrow irrigation "aren't going to make it." They estimate that 6 pivots are the minimum economic unit for a farm in the SSV, that 10 pivots are the ideal, and 22 is the maximum. As discussed in chapter 7, this observation was confirmed during the time of our research when a number of farmers who were already at the margin and using the old irrigation technology were unable to withstand the damage caused by one extreme climatic event and went bankrupt.

Drip irrigation also has been an important water-efficient technology adopted by farmers in the SSV, mostly orchard and vegetable growers. This system basically conducts water through small tubes directly to the area near the root of the plant. The field irrigation efficiency of the drip system is considered to be 90 percent (Ayer and Hoyt 1993a). According to local farmers, it may save 50 percent in water costs compared with flood irrigation. The cost of installing drip irrigation, however, is more than double that of center-pivot; thus the adoption of drip systems has been much lower. Clark and Dunn (1997) estimate that by the mid-1980s about 10 percent of the farmers were irrigating by drip. It costs between $600 and $1000 per year for an 80-acre U-pick vegetable farm to water using drip lines. A few residents speculate that eventually center-pivots will give way to subsurface drip irrigation (SDI) on corn or cotton farms because this technique is so efficient despite its high installation investment. O'Brien et al. demonstrated that the financial benefits of SDI are greater for 32-acre corn fields than for 160-acre corn fields in western Kansas (O'Brien et al. 1997). However, given the willingness of local farmers to take risks, invest in technology, and strive for water conservation, SDI systems may become more prevalent especially if irrigation costs increase.

A third important innovation in the valley has been the adoption of frost-control technology. Freezing temperatures in the spring and fall can wipe out buds and damage mature fruit, so mitigating frost danger has been a crucial adaptation strategy for orchards, particularly for fruit and pistachio growers. To raise temperatures during frost events, farmers have tried a variety of techniques. As apple and pistachio orchards became established in the SSV in the mid-1970s, their managers had two recourses in times of spring and autumn frost warnings: call in helicopters or fire up smudge pots. Helicopters would fly in from Tucson and hover over orchards in order to create convection currents over the trees. While a few better-off farmers purchased helicopters, most rented them for two or three hours when there was a high chance of frost. Smudge pots were initially used to raise temperatures near the trees. The pots were filled with diesel and placed around the perimeter of an orchard. At the threat of frost, the diesel was ignited and the smudge pots heated the parcel. Both methods were inefficient and smudge pots were particularly labor-intensive, requiring a crew of seven or eight workers to light the pots in a 50-acre orchard.

Currently, orchard owners rely on wind machines, propane burners, and sprinklers to combat frost. Most orchards have an entire network of these devices linked to one another by computer. Thermometers in the orchard set off alarms and the network can be triggered from a central computer in an office. This evolution of frost mitigation technologies has made orchards more self-reliant and less dependent on outside help from helicopter agencies or temporary laborers to light the smudge pots. Investment in these technologies, however, is expensive and not all operators are able to afford them. One farmer stated than in 1994 he paid $16,000 for a wind machine and had 15 of them in his 600-acre orchard. Orchards that do not have wind machines are at an extreme disadvantage. One family who no longer raises fruit told us that not having wind machines "was killing" them and they had a good crop "only every six or seven years." A few farmers also are using propane heaters that, as discussed in more detail in chapter 5, are very costly to run.

Finally, sprinkler irrigation systems also are effective in maintaining temperatures and increasing humidity. This became evident after a recent frost that devastated many in the valley (see chapter 5). The event was so extreme that wind machines and propane burners were ineffective. The few growers who used low-tech impact sprinklers for irrigation, however, turned them on and did not incur any losses. It is likely that the use of sprinklers to control temperatures will become more widespread, and may have a slight impact for increasing water demand and water pumping expenditures. What this event shows, however, is that in the face of extreme events, management and technology are crucial variables in coping with climate variability.

3.5.2 Crop and Market Diversification

Southeastern Arizona distinguishes itself from other agriculture areas in the state by its agricultural diversity (see Figure 3.5; Clark and Dunn 1997). The SSV epitomizes this diversity because one finds the entire range of production—from ranching to corn farming and wine vineyards—within its boundaries. Ranching and farming have always complemented each other in the area whereas peach orchards, bean fields, and vegetable plots have existed side-by-side since at least the 1930s. Today, however, such differing agricultural operations are more widespread and involve larger economies of scale. As an example, the first fruit orchard, near Pearce-Sunsites, consisted of 40 acres of peach trees. Now, orchards are found throughout the SSV and operations range in size from 35 to 400 acres.

The diversity one sees today is largely a result of the agricultural shakeout of the 1970s (see Figure 3.6). As farmers left the SSV, newcomers purchased their farmland and converted it from traditional row crops to orchards or vegetables. During this same period the University of Arizona Cooperative Extension program began promoting the area as an ideal location for raising fruit and nut trees, mainly because of its cool winters. In a few cases, farmers who could no longer make it in cotton or sorghum switched to tree crops that could fetch higher prices with less water. In a similar vein, the U-pick vegetable farms were started by local

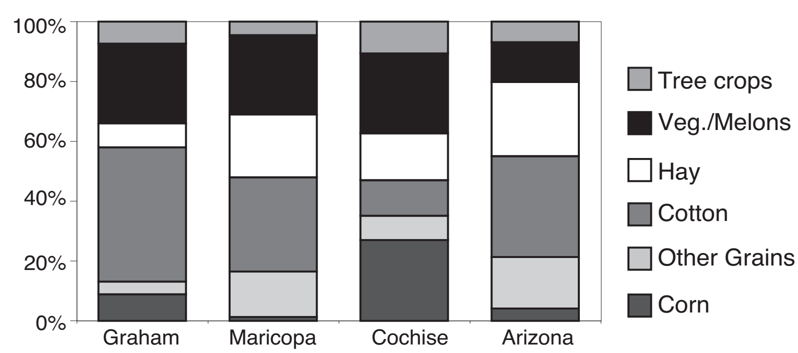


Figure 3.5. Ratio of Specific Crop Acreage to Total Irrigated Acreage for Arizona and Select Counties, 1997. Source: Data compiled from U.S. Department of Agriculture (1997).

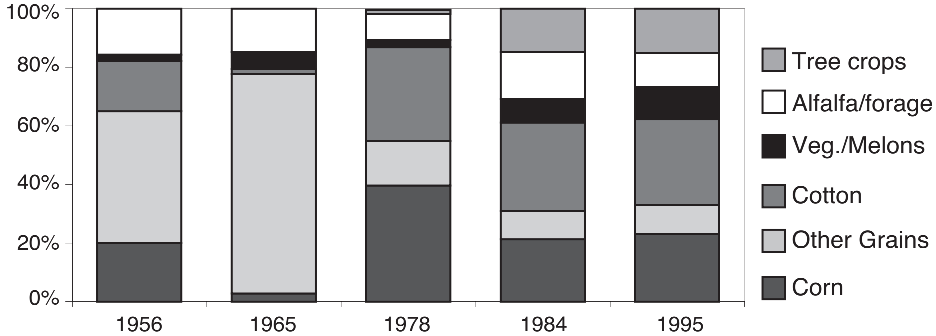


Figure 3.6. Ratio of Specific Crops to Total Agricultural Production for Cochise County, 1956 to 1995. Source: Data compiled from Clark and Dunn (1997).

farmers who saw the opportunity to maintain the farming lifestyle but with less land, less water, and less reliance on commodity markets. Nonetheless, diversification entailed risks. Nearly all orchard and vegetable farmers had to take out large loans to start production. In the case of fruit and nut growers, these farmers had to be willing to wait five to seven years before realizing any financial rewards because it takes this long for trees to bear their first fruit.

In the last 10 years, the SSV has seen a shift toward niche markets and value-added agricultural production. One farmer, for example, raises an Asian Kabocha squash that he sells to wholesalers in Japan. Another example is the development of greenhouses that produce tomatoes and cucumbers year-round. These capital-intensive operations can supply distributors in the winter when there are few other sources of such produce. Even within row crops, a few corn growers are raising high-quality white corn for tortilla chips. They sell directly to manufacturers in Tucson or Phoenix, thus avoiding the stagnant prices of the commodity market. U-pick fruit and vegetable farms cater to the tastes of regional and local consumers by producing a number of value-added products such as home-baked apple, peach, and pecan pies, fruit juices, and also by selling locally produced ostrich burgers during the annual harvest festival.

Agricultural diversification is made possible by the ideal growing conditions of the SSV. Moderate temperatures, large quantities of sunshine, adequate water, good soil, and a variety of microclimates foster this trend. Several farmers state that they intend to give up raising cotton and corn in order to switch to nuts, chiles, or grapes. This is due largely to concerns over groundwater and the cost of irrigation *vis-à-vis* rain-fed farming in other parts of the country. One farmer summarized this sentiment and asked, "Why grow here what others can grow for free somewhere else?"

As discussed throughout this chapter, the current livelihood strategies found in the SSV are the result of decades of adaptation to the natural environment. Figure 3.7 highlights the interaction between climate, economy, water, and technology. It summarizes the history of change and of sometimes failed and sometimes successful adaptation to the vagaries of climate. That history involves private decisions on the part of land users, as well as a multitude of socioeconomic processes and organizations that enhance the risks and opportunities posed by climate and the environment. In the following chapter we look more closely at the wider institutional context of government support programs in which vulnerability to climate variability must be assessed.

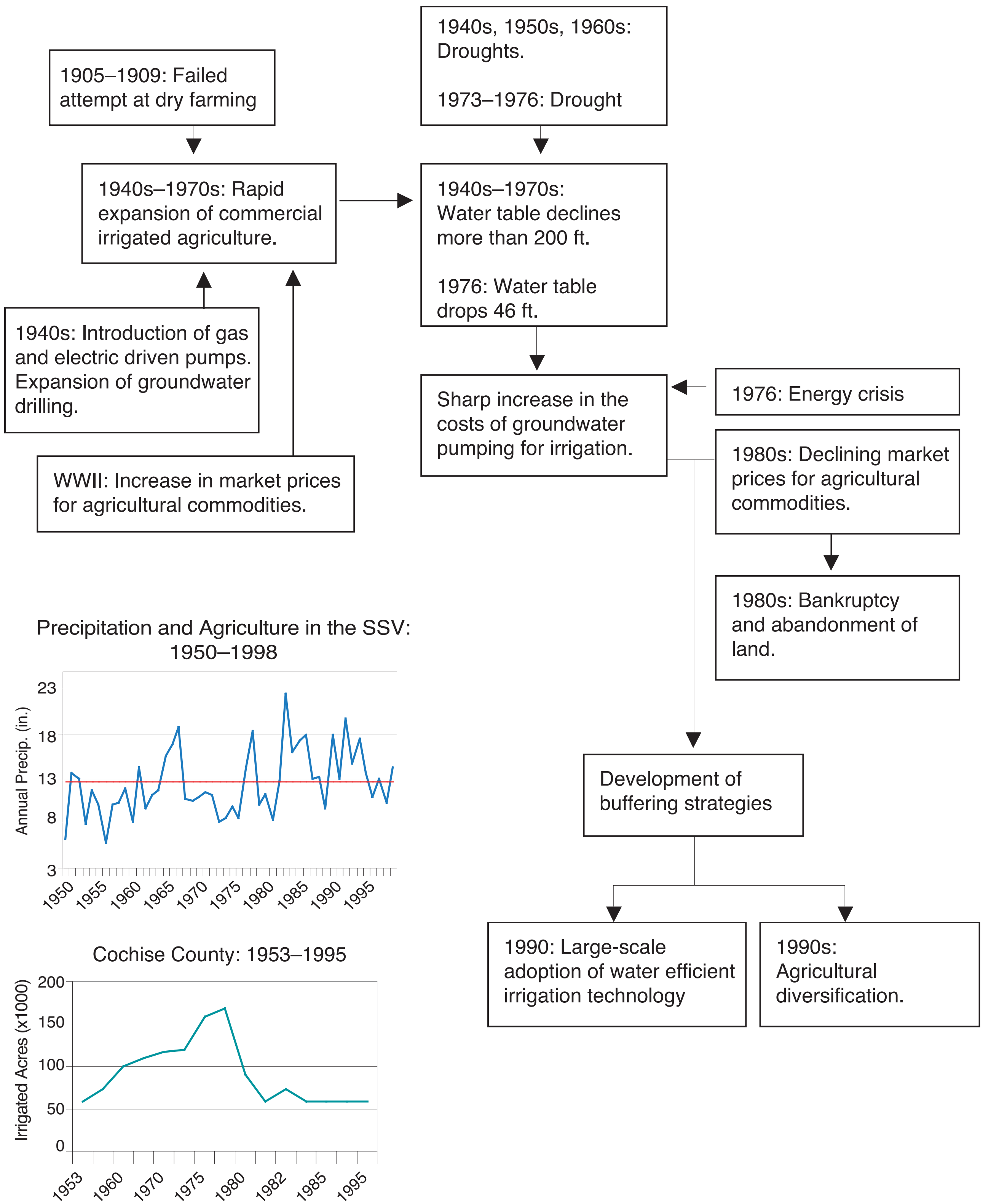


Figure 3.7. History of Agricultural Adaptation in the SSV: Climate, Economy, Water, and Technology.

4. The Wider Institutional Context

The adaptive capacity of farmers is not limited to technological change, responses to market signals, or individual managerial decisions at the farm level. Research on the vulnerability of farmers to climate variability and on their adaptive capacity must consider system-level institutional adaptations. Today, a complex of federal crop subsidies, federal and private crop insurance programs, federal disaster relief programs, extension services and loans, as well as private credit providers, help farmers to recover from extreme climatic events that damage or destroy crops.

In this chapter we focus on the role of public and private sector institutions in financing agricultural stabilization and compensation programs that buffer farmers against the negative consequences of variation in climatic conditions. We are interested in finding out how institutions alter the level of sensitivity of the farming sector to climatic variability, and how they contribute to changes in perceptions of vulnerability.

The decision to purchase crop insurance, or to participate in the various government support programs offered to farmers can be seen as a farmer-level adaptation. However, the fact that government subsidized insurance and the programs discussed throughout this chapter are available is a manifestation of institutional adaptations to climatic and other constraints that affect the viability of agriculture. While there is no question that these programs and options have significantly reduced farmers' vulnerability to climate variability and extremes in the short- and medium-term, the viability of these adaptations and their long-term impact on the natural environment has been questioned by a number of studies on agricultural adaptation in industrialized countries (Bryant et al. 2000; Lewandrowski and Brazee 1993).

The general argument is that while in the process of protecting farmers from the effects of climate variability, government programs can disrupt "natural selection" that would eliminate ecologically or economically unsustainable agricultural enterprises, or discourage innovative adaptations to changing natural conditions. The question that we raise here is: Are government assistance programs to agriculture buffering farmers from the effects of climate variability and extremes to the point where it discourages adaptations at the farm level? In order to begin to answer that question, we provide a review of the different programs available to farmers and of their use by farmers in the SSV.

4.1 Government Programs

Historically, the role of government programs in the development of agriculture is a reflection of the cultural and social importance of farming in the United States. As early as 1820 an Agriculture Committee was established in the U.S. House of Representatives, followed by one in the Senate in 1825 (U.S. Department of Agriculture n.d.). The U.S. Department of Agriculture (USDA) was set up in 1862. Its mission has shifted through time. Beginning in the 1930s, policy focused on price and income supports by managing supplies through acreage limits and commodity storage programs (U.S. Department of Agriculture 2001). In 1935, the Farm Resettlement Administration was established during the Roosevelt administration to fight rural poverty in response to the Dust Bowl, and in 1938 federal crop insurance was introduced. According to the local agency's credit specialist that we interviewed, the government's philosophy at the time was that "when an economic crisis happens, farm producers are the worst hurt, there is simply nothing that a farmer could quit doing, so the government had to step in." This became more evident after World War II. Whereas during the war prices for certain agricultural commodities such as cotton and corn skyrocketed, after the war prices collapsed, leading to a production surplus. The government responded by making loans to farmers through the establishment of the Farmers Home Administration (FHA) in 1946. At the regional level, the decades of the 1950s and 1960s stand out as the time when farmers in southeastern Arizona received the most loans.

Starting in the 1980s, according to the Economic Research Service of the USDA, agricultural policy "moved toward greater market orientation and reduced government involvement." In 1996 the Federal Agriculture Improvement and Reform Act, also known as the Freedom to Farm Act or the Farm Act, marked another change in agricultural policy. It emphasized "increased reliance on market forces and improved risk management education." It included a seven-year program planned to run through 2002 which intended to phase out subsidies (some of which had been in effect since the 1930s) (U.S. Department of Agriculture 2001b). The Farm Act created the Farm Service Agency (FSA) by combining the services of the FHA, the Agricultural Stabilization and Conservation Service, and the Federal Crop Insurance Corporation. The latter became the separate Risk Management Agency (RMA) within the USDA. It administers federal crop insurance and is a public-private enterprise.

Today the FSA states its mission as "[s]tabilizing farm income, helping farmers conserve land and water resources, providing credit to new or disadvantaged farmers and ranchers, and helping farm operations recover from the effects of disaster…" (Farm Service Agency 2002). Even though government has moved away from subsidies, a complex of supports and emergency aid to farmers continues, suggesting that government programs will continue to play a significant role in sustaining American agriculture.[1]

At the local level, the USDA works through local FSA offices to administer federal agricultural programs, with input from local farmers. Arizona has two FSA districts and nine county offices (Arizona Farm Service Agency 2000). The FSA and the Natural Resources Conservation Service (NRCS) have a menu of programs that protect and encourage farming. These agencies have offices at the regional level. The Cochise County FSA Office, and the Willcox-San Simon and Whitewater Draw Natural Resource Conservation Districts (NRCD), the offices located in our study area, are charged with promoting and implementing federal programs directly with the producers.

4.1.1 The Farm Service Agency

In the 2000 crop year, FSA programs in Arizona included a suite of loans, the Agricultural Marketing and Transition Act program, Marketing Loss Assistance payments, Loan Deficiency payments, price support programs for commodities such as cotton, wheat, corn, and dairy products, the Environmental Quality Incentives Program, Crop Disaster Program, and the American Indian Livestock Feed Program (Arizona Farm Service Agency 2000). These types of loan programs help farmers recover when weather and climate are bad enough to damage crops, but not bad enough for disaster declaration programs to kick in (discussed below). A brief discussion of a few of these loan programs is illustrative of how they work.

Agricultural Marketing and Transition Act
According to the Executive Director of the Cochise County FSA office, the most active FSA program operating in the county is the Agricultural Marketing and Transition Act (AMTA), a product of the 1996 Farm Bill. The program applies only to major commodity crops (cotton, wheat, barley, oats, corn and grain sorghum). To qualify, farmers had to sign up in 1996 for this program, which runs for seven years, ending in 2002. In contrast to earlier subsidy programs, in which farmers had to plant what they had always planted on the same acres (or restrict their acreage of it) in order to receive payments, AMTA allows farmers to make their own planting decisions based on market and environmental conditions. To benefit from AMTA, their land has to have a history of growing the crop, but they do not necessarily have to plant it every year. Benefits take the form of payments that progressively diminish each year—as farmers presumably transition to relying completely on market conditions.

Cochise County received a total of $2,261,235 in AMTA payments for crop year 2000, 6 percent of AMTA payments in the state overall. More than half of that figure was for upland cotton (Arizona Farm Service Agency 2000), but because very little cotton is grown in the SSV, most of these payments went elsewhere in the county. The next greatest payment in Cochise County was for corn, accounting for 69 percent of all AMTA corn payments made in the state in 1999. Interestingly, because the crop history is attached to the land and not the farmer, landowners such as retirees who do not farm can also receive payments from the program if their land has a crop history.

Marketing Loss Assistance
Marketing Loss Assistance (MLA) payments are issued when poor market conditions cause losses to producers of commodity crops—corn, wheat, cotton, sorghum, soybeans, barley, oats, cotton, rice, and minor oilseeds. Such conditions might be caused by high production in competing regions, which create lower prices for local producers. Market prices are naturally affected by climate conditions in production areas. The Secretary of Agriculture authorized MLA payments in crop years 2000 and 1999. Cochise County received $2,460,941 in MLA payments in crop year 2000 (Arizona Farm Service Agency 2000); payments in 1999 were equal to AMTA payment amounts shown above.

Loans and price supports

Price supports programs are designed to stimulate domestic production of specific commodities such as corn, wheat, and cotton. The FSA administers price support programs on behalf of the Commodity Credit Corporation, a part of the USDA.[2] One such aspect of price support is the non-recourse commodity loan, where the harvested commodity is used as collateral, usually on a 10-month modest loan. During the loan period, the farmer reads market conditions. If world average price is below the loan rate (the price per unit of product received from the loan), the farmer may repay the loan, take back the collateral for a rate lower than originally set, and sell the commodity in the open market. The loan is designed to provide the producer with the finances to continue operating until market conditions are more favorable. In the SSV, corn, feed grains, wheat, and cotton growers have benefited from these programs (Arizona Farm Service Agency 2000).

The Loan Deficiency Payment (LDP) is an alternative to a Price Support loan. A farmer can bypass the process of placing his/her product under loan (with its lien), and simply apply for a direct payment of the difference between the going national loan rate (the price per unit of product the farmer can receive on loan) and the adjusted world price. The margin of difference (the LDP) becomes available when deteriorating world prices drop below the loan rate. When market conditions are so poor that LDP rates trigger, SSV growers of eligible commodities generally apply for the LDP (Arizona Farm Service Agency Official, personal communication 2000).

Effectively, marketing loan benefits buffer commodity farmers from low prices by allowing them the flexibility to market their crops when prices are best, and by the government absorbing the difference between the market price and a lower sale price. A Cochise County FSA credit specialist stated that 90 percent of farmers in the SSV participate in the Loan Deficiency Program. Insofar as climate affects production in the SSV and in competing regions, and thus market prices, such loan programs indirectly buffer producers of commodity crops from climate impacts.

Other loan programs

In addition to the loans described above, farmers may be eligible for Emergency Loans (discussed below), Farm Ownership Loans, Farm Operating Loans, Youth Project, Loans and Indian Land Acquisition Loans. Direct loans and loan guarantee programs are designed to help farmers stay in business. Loans can be used for operating expenses such as equipment purchase or repair, livestock, feed, fuel, fertilizer, insurance, or family subsistence expenses. They can also be used for "minor building improvements, costs associated with land and water development, and…to refinance debts under certain conditions." FSA's Guaranteed Loan Program guarantees loans of up to $717,000 made by conventional agricultural lenders for up to 90 percent of any loss (the maximum amount is adjusted annually) (Arizona Farm Service Agency 1999; Farm Service Agency 2000). Commercial lenders, not the farmers, apply directly to the FSA for the loan guarantee; thus any farmer with a commercial loan has a guaranteed loan. In the SSV, most loans are either Farm Operating Loans or New Farm (Farm Ownership) Loans (FSA Farm Loan Officer, personal communication 2000).

The FSA also has a funding pool reserved for Loans for Socially Disadvantaged Persons[3] that applies to women and minorities to help them purchase and operate farms. Although both of these types of farmers operate in the SSV, no one has applied to the local FSA for this type of assistance since at least 1996, when records become available (FSA Farm Loan Officer, personal communication 2000).

FSA's direct farm loan programs are intended for producers who are temporarily unable to obtain commercial credit or a loan guarantee. Under those conditions, the FSA makes a direct loan of up to $200,000 per farm at a rate significantly below the current commercial interest rate.[4] However, if they qualify for credit at a regular lender at *any* rate of interest, they cannot obtain the FSA loan at more reasonable rates, and thus may not be able to afford any loan at all. An FSA credit specialist noted that the FSA is a "lender of last resort" and is "reasonable, but not that easy." Statewide figures indicate that from 1996 to 2000 the number of guaranteed borrowers has grown from 34 to 54, while the number of direct borrowers has fallen since 1996 from 601 to 353; unfortunately, comparative data is not available for Cochise County.

As an example of the necessity for farm loans, one local private lender, the Farm Credit Services (FCS), a cooperative in Safford, holds about half of the loans in the SSV. Their customers are mainly large (2000+ acres) commodity farmers who are in the top 60 percent in terms of production. FCS lends to only a few chile or lettuce farmers due to the risky nature of those crops. According to a bank representative, about 20 percent of farmers need loans in any given year, and about 30 percent each year are "out of business," including in the SSV. This bank representative also estimated that without government payments the previous year, about one-third of farmers would have gone under due to a combination of factors. These included low market prices, increases in energy costs, and extreme climatic events. The latter, as discussed in subsequent chapters, had a particularly negative impact on farmers who were already operating at the margin. An officer of the local community bank noted that smaller farmers, those with less than 600 acres, have more difficulty obtaining credit from larger lenders like FCS, so they must rely more heavily on the FSA.

Environmental Quality Incentives Program
The Environmental Quality Incentives Program (EQIP) is a cost-share program managed by the NRCS. EQIP, funded by the Commodity Credit Corporation, provides technical, educational, and financial assistance to farmers and ranchers who express concern over soil, water, and related natural resource issues. The objective of the program is to help in the installation of structural (livestock or irrigation pipelines), vegetative (pastures), and management (irrigation water management) practices to improve the environment. Five- to 10-year contracts are made with eligible producers and the USDA will pay up to 75 percent of the cost of eligible practices. The program is carried out primarily in priority areas that may be watersheds, regions, or multi-state areas, and for significant statewide natural resource concerns that are outside of geographic priority areas. At least half the funding is allocated to addressing environmental issues associated with livestock production. In 2000, Cochise County received $129,452 in EQIP payments (Arizona Farm Service Agency 2000). We expect that concern about climate change and variability and/or declining water tables, might make this type of loan more important in the future.

4.1.2 Disaster Assistance

Disaster assistance programs are triggered when losses occur specifically due to weather and climate, including disease or pest damage caused by climate conditions. The President or the Secretary of Agriculture must declare a disaster in order for funds to be released. Within the last five years, there has been a shift of emphasis by the USDA away from agricultural subsidies and towards disaster assistance. As one local NRCD official told us, "Basically, disaster relief programs are replacing subsidies…The financial support to help farmers and ranchers stay in business is still there, but now the emphasis is on climate-related disaster." An Arizona FSA official echoed this opinion, commenting that recent policy reflects that the government would rather strengthen the safety net during "bad times" than provide ongoing subsidies.

Disaster relief programs may take the form of either loans or direct payments. The programs most appropriate for farmers in Cochise County are the Non-Insured Crop Disaster Assistance Program (NAP), and the Crop Disaster Program (CDP).

Non-Insured Crop Disaster Assistance Program
NAP[5] applies to crops for which crop insurance is not available, when production losses result from a natural disaster. The program is designed to provide a benefit similar to Federal Crop Insurance Corporation's (FCIC) catastrophic coverage (discussed in Section 4.2). Unlike insurance programs, there are no premiums other than the $100 per crop processing fee. State and county FSA committees monitor weather and crop conditions and are charged with ensuring that applications which are approved for payment cover losses resulting from legitimate abnormal weather conditions. Producers must meet application and reporting requirements of the program each year prior to a disaster occurring. Eligible crops include specialty crops such as ornamental nursery, Christmas trees, turf for sod, and industrial crops. NAP payments cannot exceed $100,000 to any single person, and that person generally cannot also receive compensation for the same loss under any other USDA program (Farm Service Agency 2001). A producer can, however, receive NAP benefits along with CDP and private hail insurance payments.

Crop Disaster Program
In 2000, the CDP was funded by the federal government to assist farmers who suffered crop losses in that year that could be "directly attributed to adverse weather and related conditions."[6] CDP covered all crops, whether insured, uninsured (crop insurance was available but not purchased), or non-insurable. Farmers with losses of 35 percent of historic yields or greater were eligible. Those with crop insurance were to be compensated at 65 percent of crop insurance market price elections. Losses to uninsured crops would garner 60 percent of crop insurance market price elections. Farmers with losses to non-insurable crops were eligible for compensation at 65 percent of the five-year

Table 4.1. U.S. Farm Subsidy Payments, 1996 through 2000.

	Cochise County	Arizona	New Mexico	Iowa	United States
Farming Subsidies (incl. Conservation programs)	27,821,902	364,697,418	290,890,670	6,690,215,984	67,293,254,175
Disaster Payments	2,826,547	33,836,248	39,143,443	60,550,908	4,236,742,384
Total	$30,648,449	$398,533,666	$330,034,113	$6,750,766,892	$71,529,996,559
Total recipients	551	7,021	12,740	160,208	2,411,027
Payment per recipient	$55,623	$56,763	$25,905	$42,138	$29,668

Source: Environmental Working Group (2002).

Table 4.2. A Comparison of U.S. Farm Subsidy Payments with a Sample of Hispanic Farmers in Cochise County, 1996 through 2000.

	Hispanic Farmers*	Cochise County	Arizona
Farming Subsidies (incl. Conservation programs)	27,821,902	364,697,418	290,890,670
Disaster Payments	$12,549	$2,826,547	$33,836,248
Total	$139,842	$30,648,449	$398,533,666
Total Recipients	11	551	7,021
Avg. payment per recipient	$12,713	$55,623	$56,763

Source: Environmental Working Group (2002).
*The category of Hispanic farmers was created based on last name and does not include all Hispanic farmers in Cochise County.

average price. Benefits were limited to $80,000 per person, and those with a gross annual income of $2.5 million or more in tax year 1999 were not eligible. Producers who requested CDP benefits in 2000 for losses to an uninsured crop were required to purchase crop insurance on that crop for 2001 and 2002 (Farm Service Agency 2001). They could, however, receive CDP benefits in addition to NAP, Multi-Peril Crop Insurance (federally subsidized crop insurance discussed below), and Emergency Loan payments. About 25 people in the SSV applied for disaster payments in crop year 2000, most of them as a result of a hailstorm that affected chile peppers and pecans.

Cochise County received $542,515 in CDP payments in 2000. “CDP and NAP are ideally suited for Cochise County,” a state FSA official said. Regarding the weather, FSA has a saying, “If it *can* happen, it *will* happen in Cochise County!” This appears to be borne out by the fact that Cochise is the most consistently participating county in these disaster programs. One of the criticisms to this type of program is that the expectation of assistance in the case of low production or low prices due to natural disasters “may encourage producers to keep riskier land in production” (U.S. Department of Agriculture 2000). Table 4.1 shows federal payments to farmers in Cochise County compared to those received countywide, statewide, in selected states, and the United States as a whole. Although the table shows an average per-capita payment, in fact payments are not evenly distributed. For example, whereas the average annual payment per recipient in Cochise County is over $55,000, among the few Hispanic farmers who actually participate in the program, the average payment is only $12,712 (see Table 4.2 and discussion of Hispanic farmers in chapter 7). Payments to individuals in Cochise County range from as little as $22 to more than $810,000 over the 5-year period.

As Table 4.1 indicates, the average payments per recipient from various subsidies and disaster programs in Cochise County is almost twice as much as the national figure and higher than in a major farm state such as Iowa. Looking just at disaster payments, these figures suggest that farmers in Cochise County rely substantially on government programs to buffer them from climate-related loss.

Emergency loans
The FSA makes emergency loans available to family farmers to help cover production and physical losses in counties declared disaster areas by the President or Secretary of Agriculture. These loans are extended at an even lower rate of interest than FSA's standard below-market rate. Two key criteria for eligibility are a loss of at least 30 percent in any essential farm or ranch enterprise; and the inability to obtain commercial credit. Emergency loans can be used to replace damaged property or equipment; pay production costs in the disaster year; pay for essential living expenses; reorganize the farming operation; or refinance debt. Such flexibility carries with it the responsibility to keep acceptable farm records; operate according to a farm plan developed in collaboration with the FSA; and in some cases, to participate in a financial management training program or obtain crop insurance (Farm Service Agency 2001).

In the SSV, Emergency Loan payments were authorized to farmers and ranchers who experienced losses due to heavy rains in October 2000, regardless of crop. About 25 SSV producers applied for these loans (FSA Farm Loan officer, personal communication 2000). Ranchers, who rely less on groundwater and irrigation, are more likely than farmers to apply during drought years, when range conditions deteriorate.

Overall, during the 1999–2000 fiscal year producers in Cochise County received a total of $11,337,586 through a variety of agricultural programs implemented by the Cochise County FSA Office (Cochise County Farm Service Agency 2001), as specified in Table B.1 in Appendix B. The Willcox-San Simon NRCD implemented a variety of programs at the local level during the year 2000. Conservation plans were developed on 60,413 acres, and irrigation systems were installed including 36,060 feet of pipeline, five sprinkler systems, and three drip systems (Natural Resources Conservation District n.d.).

4.2 Crop Insurance

Federal crop insurance was first authorized by Congress to help agriculture recover from the Great Depression and the Dust Bowl of the 1930s through the FCIC. Since then, the program has undergone changes designed to encourage farmer participation. For example, the Federal Crop Insurance Act of 1980 introduced a subsidy for the purchase of crop insurance (Risk Management Agency 1999) and expanded to include more crops. According to a local crop insurance agent, the objective was to reduce the burden of payouts from disaster programs. In 1988, disaster assistance was authorized to help farmers impacted by a major drought.

In 1994, the Federal Crop Insurance Reform Act made crop insurance mandatory if farmers were to be eligible for price support payments, certain loans, or other benefits. Mandatory crop insurance led to the creation of the minimum-level catastrophic coverage, with the premium fully subsidized; farmers had only to pay a small administrative fee. Subsidies increased for higher levels of coverage. In 1996, legislation repealed the mandatory participation requirement, but farmers who did not purchase crop insurance were required to waive their eligibility for other kinds of disaster benefits. This requirement remains in effect. The Agricultural Risk Protection Act of 2000 further increased government subsidies for crop insurance (including crop revenue insurance) and restructured other aspects of the programs as will be discussed below.

4.2.1 How Crop Insurance Works

Crop insurance is considered a public-private partnership. It is sold through private insurance companies but reinsured (subsidized) by the government through the FCIC. The FCIC is administered by the RMA within the USDA (Risk Management Agency 2001c). The purpose of the FCIC "is to promote the national welfare by improving the economic stability of agriculture through a sound system of crop insurance" (Risk Management Agency 2001a). The FCIC approves and subsidizes commercial insurers who sell acceptable commodity insurance plans that also must be FCIC approved. The RMA provides policies for more than 100 crops (not counting individual crop varieties insured in every U.S. county); crops eligible for insurance vary by county (Risk Management Agency 2001b).

Farmers select from a menu of different kinds of insurance policies and coverage levels, for which the government pays a portion of the premium. Insurance companies assign farmers to different risk pools, and can place the highest risk customers in the government's risk pool (crop insurance agent, personal communication 2001). In this way the insurance companies protect their own interests by allowing the government to absorb the payouts to their highest risk customers. The government thus funds much of both the cost of insurance policies for individual producers, and, through reinsurance, the cost of paying those producers' claims.

Crop insurance mitigates the risk of income loss from low yields or low prices that result from circumstances beyond a farmer's control, such as climate or weather events. Depending on the crop, crop insurance may also pay benefits when adverse weather prevents or delays planting or causes loss of quality. Similarly, subsidized revenue protection policies protect farmers from income loss when yields or prices fall below expected levels. Crop insurance and revenue insurance are part of a suite of risk management strategies that the government and private insurers promote to farmers. Other risk management strategies include private hail insurance and financial strategies such as forward contracting, hedging, and futures and options (Crop Insurance Today 2001).

Today crop insurance programs are becoming an increasingly important external factor that lowers the negative economic impacts of climate variability at the farm level.[7] As suggested by Smithers and Smit in their study of Canadian agriculture, crop insurance "may… be viewed as a response to climatic stress in its own right" (1997:178). At least CAT-level crop insurance is required in order for farmers to receive benefits from other federal agricultural assistance programs. Further, a number of those we interviewed in the SSV pointed out that farmers who do not carry crop insurance cannot get loans from either the government or private lenders.

In order to understand the different choices of crop insurance that farmers have today, and to relate that to the process of buffering against climate variability, it is important to consider the different categories of crop insurance available. These are broadly divided into yield-based insurance coverage and revenue insurance plans.

4.2.2 Yield-based Insurance Coverage

Multiple-Peril Crop Insurance

Standard Multiple-Peril Crop Insurance (MPCI) is considered the workhorse of risk management plans (Crop Insurance Today 2001). It provides comprehensive protection against weather-related losses such as drought, excessive moisture, hail, wind, frost, insects, and disease (Risk Management Agency 2001c). At the time of purchase, farmers select the amount of average yield to protect (50 percent to 75 percent, or 85 percent in some areas), and also elect to insure from 60 percent to 100 percent of the RMA-established expected market price for their crops. The yield guarantee is a function of a formula based on a producer's actual production history for a period of 4 to 10 consecutive years preceding the insured year.

If the harvest is less than the yield insured, the farmer is paid an indemnity based on the difference. According to the RMA (2001c), indemnities are calculated by multiplying this difference by the insured percentage of the established price chosen when crop insurance was bought. The government subsidizes from 38 percent to 67 percent of the premium, depending on the level of coverage selected (the higher the coverage, the lower the percent subsidized). Farmers must be using "good farming practices," and mechanisms to combat fraud and abuse of the system were made more stringent in the Agricultural Risk Protection Act of 2000.

Minimum Catastrophic Risk Protection (CAT) is the lowest level of coverage and the most basic MPCI policy. CAT coverage is 100 percent subsidized (although farmers must pay an administrative fee, currently $100), but the policy only pays off when losses exceed 50 percent of the yield guarantee, and at only 55 percent of the expected market price for the crop in question (Crop Insurance Today 2001). To encourage farmers to purchase more adequate insurance, ARPA substantially increased the percent of premiums subsidized at all levels.[8]

Crop-hail insurance

Crop-hail insurance is a private insurance company product, and is not government subsidized. It is designed to protect the portion of a crop damaged by hail when losses are not severe enough to drop the whole farm's average yield, do not meet the insurance deductible, or do not lower yield sufficiently to activate a revenue insurance policy. It is valuable when damage does not meet the pay-off criteria of government subsidized MPCI policies. Private hail insurance is priced per acre, depending on location and particular crop. Insurance companies determine rates based on hail losses in each 6-mile-square township, and are regulated by state departments of insurance. Hail insurance can protect up to the actual cash value of the destroyed portion of the crop. At 65/100 levels of MPCI (65 percent of yield, 100 percent of price) and higher, the farmer can delete the hail coverage portion of the MPCI policy, and use the savings to help make private hail insurance more affordable (Crop Insurance Today 2001).

Within Arizona, the risk of hail damage is greater in the southeastern region than elsewhere, and within southeastern Arizona the SSV is one of the highest risk areas. This means that in the SSV the price of hail insurance is commensurately higher than in other, lower-risk regions of the state such as Yuma. Chile farmers in the SSV are likely to pay $30 to $50 an acre for hail insurance; by contrast, minimum CAT coverage (50 percent yield protection) for cotton or corn may be only about $3/acre in less vulnerable areas (crop insurance agent, personal communication 2001). One crop insurance salesman estimated that perhaps 90 percent of farmers in the SSV have hail insurance. SSV farmers realize that hail is spatially variable (one field may be damaged and another a few miles down the road spared) and unpredictable. An apple orchard owner in the SSV observed that there is not much that can be done even if a farmer knows a week or month ahead of time that a hailstorm is coming. A successful corn and chile farmer who also sells crop insurance concurred that the only thing one can do to protect from hail damage is "buy more hail insurance." Because hail insurance is relatively costly in the SSV, especially for vulnerable vegetable crops, some farmers take their chances and do not purchase it. One farmer purchases it for his high-value chile crop, but buys less or none for his corn.

4.2.3 Revenue Insurance Plans

Revenue protection policies protect against revenue losses from low yields, poor quality, or low prices. Revenue insurance can be used as a risk management tool in conjunction with MPCI policies. They can improve farmers' access to credit by making collateral more secure, reducing lender risk and perhaps garnering lower interest rates (Crop Insurance Today 2001). The Agricultural Risk Protection Act of 2000 increased subsidies for revenue insurance as well as for crop insurance (Cain 2001). There are several types of revenue insurance plans that are available on different crops in different states, but of these only Crop Revenue Coverage (CRC) on corn, cotton, and wheat appears to be available in Arizona at this time (Fireman's Fund Insurance Company 2002).

CRC guarantees a stated amount of revenue, covering losses from low prices, low yield, or a combination. Policy premiums are subsidized by the federal government and base yield expectations on actual production history. CRC, however, protects the *price* a farmer receives for his crop, paying the difference between a Minimum Guaranteed Income per acre (an expected price derived using the appropriate futures market and actual production history) and actual yield and price at harvest (Crop Insurance Today 2001).

4.2.4 Use of Climate Information for Crop Insurance Decisions

Crop insurance agents can be advisors and educators on risk management. According to industry literature (Crane 2000), farmers meet with their agents face-to-face at least once a year. Risk management education (RME) was mandated in Section 192 of Federal Agricultural Improvement and Reform Act of 1996. Although RME is a joint effort of various federal entities, it relies heavily on the private sector, such as insurance companies, to educate farmers about risk management tools and strategies of which crop insurance is only one, albeit important, example (Risk Management Agency 2001a). With this relationship crop insurance agents have the potential to become conduits for climate information that can be incorporated to farmers' risk assessment.

To envision how climate information might be used by both those selling and those purchasing crop insurance, it is useful to understand how the process is administered. Crop insurance operates on a yearly cycle that starts when the RMA announces changes to insurance products for the upcoming crop year. The announcement takes place on or before the "contract change date," which is the deadline for notifying policyholders of any changes to their coverage. The contract change date is three to four months before the sales closing date. While sales closing dates vary according to crop and usual planting date in a given region, they are scheduled early enough that neither the insurance purchaser nor the insurer has knowledge of the crop's production outlook for the year.

Further, farmers must insure "all the eligible acreage of a crop planted in a particular county" (but can choose to insure crops on a county-by-county basis). This condition exists to avoid "adverse selection against the insurance provider… [which] generally exists whenever *the insured person has better knowledge of the relative riskiness of a particular situation than the insurance provider does*" (Risk Management Agency 1999; emphasis added). Clearly, reliable advance information about climate or weather conditions could be of great value to both farmers and insurance companies for assessing the risk to crops in a given year and making better-informed decisions.

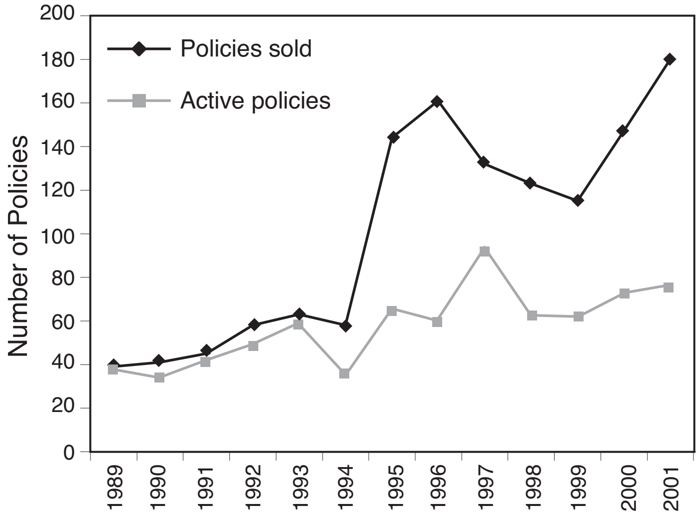


Figure 4.1. Crop Insurance in Cochise County: Policies Sold and Active Policies, 1989 to 2001. Source: Risk Management Agency (2002).

In Figure 4.1, the difference between policies sold and active policies illustrates how significant forecasts could be to both insurance purchase and planting decisions. "Policies sold" reflects the number of farmers who purchased insurance on their crop(s). "Active policies" refers to the number of policyholders who actually planted the insured crop. In nearly all years, fewer farmers planted than bought insurance. The sales closing date in Cochise County for chiles is January 31, and February 28 for corn (Risk Management Agency 2002); planting takes place in April. With early, accurate information about likely weather conditions, farmers would have a solid basis for deciding how much insurance to purchase and which crops to actually plant and insure (for more information on crop insurance in Cochise County, see Table B.2 in Appendix B).

Continuing disaster assistance programs are thought by some to discourage farmers from purchasing even subsidized crop insurance products, because disaster benefits act as free insurance (Ker 1999). According to this perspective, Congress sends mixed messages by both subsidizing crop insurance and funding disaster payments. The 1996 ruling that farmers who elect not to purchase crop insurance must waive their right to disaster benefits begins to address this problem.

4.3 Agricultural Extension

Cooperative Extension began with the Smith-Lever Act in 1914, to connect Land Grant Colleges and Universities with their surrounding communities. Arizona adopted the Act in 1915 and the first Cochise County extension agents were hired in that year (Arizona Cooperative Extension 2001). Extension is funded by federal, state, and county governments to help bring the scientific knowledge developed in academic institutions to people who can use it. The mission of Cooperative Extension is to "make science useful" and to provide services based on the needs of people at the county and community level. Through university-trained extension agents, Cooperative Extension has developed a direct relationship with farmers, ranchers, and other rural residents. Agents work in conjunction with County Extension Boards. These consist of seven county residents, four of whom make their living producing agricultural commodities, and three of whom represent other people and organizations that use county extension services.

Cooperative Extension programs have specific services targeted directly to farmers and ranchers. One of the first programs in Cochise County sought to assist dryland farmers through research in the Extension Service Cochise Dry Farm during the early 1920s. Other more recent programs have sought to address problems of disease and pest control, such as the codling moth for apple growers (see chapter 5). Cooperative Extension programs also address community needs as diverse as parenting, violence prevention, nutrition, and sustainable use of natural resources (Arizona Cooperative Extension 2002).

According to two different extension agents, however, farmers do not fully use available Cooperative Extension services. As one agent told us, "There are times when farmers don't know that the agricultural extension service exists. Farmers won't travel to come to meetings." There also is the perception that farmers do not need as much assistance from agricultural extension as in the past. A credit specialist who had long been with the FSA remarked that many farmers now have agricultural degrees and do not need much agricultural advice. His role within the FSA has changed through time. While in the past he was considered to be an extension agent, "Now you have to be a real expert to advise farmers. And since we are less and less prepared to advise farmers, we just give them loans."

Despite its limitations, Agricultural Cooperative Extension affords an ideal model for the provision of climate information to rural stakeholders. In addition to having direct contact with stakeholders, extension agents have the institutional support needed to sustain efforts at the local level. One extension agent was particularly concerned about how to get the information on climate to the user "out in the country." According to this agent, there is a lot of research done at the University of Arizona that never reaches the extension office. If Cooperative Extension were better utilized and extension agents were trained in forecast interpretation and transmission, it would be the ideal conduit through which to channel climate information to farmers and ranchers in the SSV.

4.4 Adaptations at the Regional Level: Agricultural Forecasts by the National Weather Service

The provision of weather and climate information by the federal government also plays a role in reducing farmer vulnerability. Until 1996, NOAA provided agricultural forecasts on a regular basis through the National Weather Service office in Phoenix. These became an important aspect of decision making among farmers in the SSV. The Weather Service issued detailed information on a daily basis, by county. Such information included rainfall amounts, relative humidity, and any hazardous situation specific to the area. Forecasters worked closely with and relied a great deal upon farmers and ranchers, who would call on a daily basis with detailed information about their specific locations. Thus forecasters obtained reliable information from a wide variety of locations. The Phoenix Weather Service used to do the agricultural forecasts in Arizona, specifically the SSV, Salt River Valley, and Yuma areas where farmers regularly requested specific information. Frost forecasts were specifically tailored to orchard growers who asked for the service. The service was free of charge and farmers spoke favorably of its accuracy and about the man behind the predictions: "He used to give very good predictions within a few degrees."

The National Weather Service was prohibited from issuing agricultural forecasts in 1996. According to meteorologists at the Tucson Bureau of the National Weather Service, this was a political issue external to the Weather Service and was related to public/private partnership issues. Basically the private sector lobbied to obtain the right to sell agricultural forecasting information. As discussed in chapter 5, orchard growers must now purchase forecasting information from a private company. The information, however, is considered unreliable and farmers would like to have the agricultural weather forecasting service provided by NOAA back.

4.5 The Sulphur Springs Valley Electrical Cooperative

The Sulphur Springs Valley Electrical Cooperative (SSVEC) provides electricity to Southeastern Arizona. It covers an area of more than 6,000 square miles, including the SSV and most of Cochise County (Finan and West 2000). They are distributors, rather than producers of electricity, which they purchase from Arizona Electric Power Cooperative (AEPCO), in which SSVEC is a part-owner.

Because the cost of irrigation is a major variable in farming in the SSV, efforts to decrease energy costs that would potentially benefit the agricultural sector and reduce short-term perceptions of vulnerability must be considered as system-wide adaptations. According to the SSVEC supervisor, demand is primarily linked to temperature. Higher summer temperatures increase the demand for electricity, to run both irrigation pumps and air conditioners. As discussed in Finan and West (2000), the net increase in demand affects all users, so when electricity is the energy source for pumping, the cost of power becomes directly linked to climate.

As explained in the previous chapter, the cost of energy in combination with drought has had dramatic impacts on groundwater-dependent agriculture. But just as farmers responded to the energy crisis of the mid-1970s by increasing irrigation efficiency, AEPCO responded by building a coal-fired generating plant in 1978 that has helped to more or less stabilize the cost of electricity since then. With the recent increase in the price of natural gas (2000–2001), the price of electricity became competitive and many farmers have switched to electricity to run their pumps; in the past year the number of farmers using electric pumps has nearly doubled in AEPCO's service area. Switching to lower cost energy sources is not unprecedented. As one NRCD official commented, "In the '80s when electricity was high, everybody switched over to natural gas, now they're switching back. Whatever is cheaper." The costs of switching, however, can be substantial.

To encourage the switch from natural gas to electricity, in the spring of 2001 the SSVEC created a new rate for farmers that is expected to remain competitive even if the price of gas falls again—the rate slides depending on usage; the more consumed, the lower the cost per kwh (kilowatt). The SSVEC's demand monitoring manager favors farmers during times when he has to "shed load," that is, reduce the amount of power SSVEC is getting from AEPCO when demand reaches a peak. He has three strategies to do so: he can slightly reduce voltage to the system, (commonly called a "brownout") causing no noticeable negative effects to consumers or their equipment, he can switch to generators owned by a Bonita greenhouse or, as a last resort, cut power to irrigation pumps. This is naturally an annoyance to farmers but is part of the deal for the reduced rate to irrigators.

Programs such as the special electricity pricing offered by the SSVEC can help protect farmer's profitability, especially during years when temperatures are extremely high and rainfall is low. An economic analysis of the links between climate and peak demands would undoubtedly be revealing. Like government disaster payments, however, the discount energy program may act to minimize farmer's perception of risks from climate variability and discourage further shifts toward lower water usage.

4.6 System-level Adaptations and Their Effect on Farmers' Perceptions of Vulnerability to Climate Variability

In the SSV, government assistance has been an important factor in buffering farmers against climate variability. According to a banker for Farm Credit Services, without government payments last year, about one-third of farmers would have gone under. He added that pretty much everyone in the area is getting commodity subsidies and most farmers have some sort of crop insurance. Another interviewee sarcastically commented that there are a few cases of farmers that work the system more than they work their farms, adding that these farmers are relying on the government to buffer them from the risks of natural events.

Despite the variety of crop insurance programs available, and their promotion, interviews with farmers suggest that many do not take full advantage of such risk management practices. One NRCD agent explained this by saying that SSV farmers are "optimistic about ideal [climatic] conditions occurring." He said they do not generally base management decisions on seasonal forecasts, which they have found to be unreliable in the past. They are more likely to wait through dry periods until it is certain there is "really a drought," and then react to manage crisis. Government disaster programs enable this behavior and, for the most marginal farmers, participation in these programs may make the difference between continuing to farm and going bankrupt. Except for some programs in which benefits are linked to conservation practices, the government provides little incentive for adaptation to the natural environment.

Most farmers in the SSV, however, and certainly the most successful ones, have made conscious efforts to reduce their long-term vulnerability by, in some cases, switching crops to adapt to drought conditions or adopting more water efficient irrigation technologies. This indicates that there are important linkages between farmer investment in crop and technology choice and a wider institutional context of crop insurance, government subsidies, and agricultural extension assistance. These linkages, as discussed in the remaining chapters, put a premium on climate information.

5. Adaptation and Forecast Needs Among Corn, Fruit Orchards, and Chile Farmers

Even though the system-wide adaptations discussed in the previous chapters are important mechanisms that allow farmers to buffer against climate variability, other factors are just as important. Among the principal farm-level adaptation strategies acknowledged by farm owners in the SSV are the managerial skill of individual farm operators, the successful application of technologies in the farm, and the use of improved climate forecasts. Each crop is impacted differently by climate, requires specific climatic conditions throughout its life cycle, and permits a different set of adaptations. Thus, the ability of farmers to capitalize on the positive elements of the regional climate and to minimize the impact of negative events dictates the success or failure of each crop. It also determines the well being of all the individuals involved in the agricultural industry, from the farm owner to the tractor operator to the migrant workers employed during the harvest.

In this and the next two chapters, we focus on how the process of adaptation has developed among selected representative farm systems. These are defined based on the different combination of assets and strategies that make each distinct. In this chapter, we examine in more detail the sophisticated corn farmer, fruit orchard operators, and diversified chile farmers. Information about these different farming systems, plus those presented in the next two chapters, is summarized in Appendix B. The degree of vulnerability and the possibilities of adapting to climate variability vary a great deal among these different stakeholders. Each of the case studies presented is intended to demonstrate the powerful impact of climate and weather at the farm level, the adaptations that different farm systems have undergone, and changes in perceptions of vulnerability. They also are intended to contextualize and document use, perceptions, and need for specific climate forecasting information. The information presented in each case study is based on our observations and interviews, and has been synthesized to create composite profiles. The names of stakeholders have been omitted to protect their privacy.

5.1 The Sophisticated Corn Farmer

In the SSV the area cultivated in corn expanded rapidly from 1960 to 1980 as extensive development of cropland occurred in the Stewart District, Kansas Settlement, Cochise-Pearce, Elfrida, and McNeal. Corn became a primary crop along with cotton, grain sorghum, and alfalfa. Since 1994 acreage planted has more than doubled, going from around 11,000 acres to 26,000 acres in 2000 (see Table C.1 in Appendix C). Today, Cochise County is the most important producer of corn in the State of Arizona (see Figure 5.1). In the year 2000, for example, the state produced 181,100 tons of corn, of which Cochise County produced 141,570 tons, or over 75 percent of the state's total. Cochise County also has the highest corn yield per acre in Arizona. In 2000 average corn yield per acre for the state was estimated at 10,980 pounds, whereas average corn yield for Cochise County was 11,060 pounds per acre. The SSV produces over 80 percent of the county's total yield. Growers in the Bonita area, where yields of 15,000 pounds of corn per acre are common, continuously set national records in yield per acre as well as quality of corn (Clark and Dunn 1997).

Even though production and yields have increased, the number of corn farms in operation has declined. Ac-

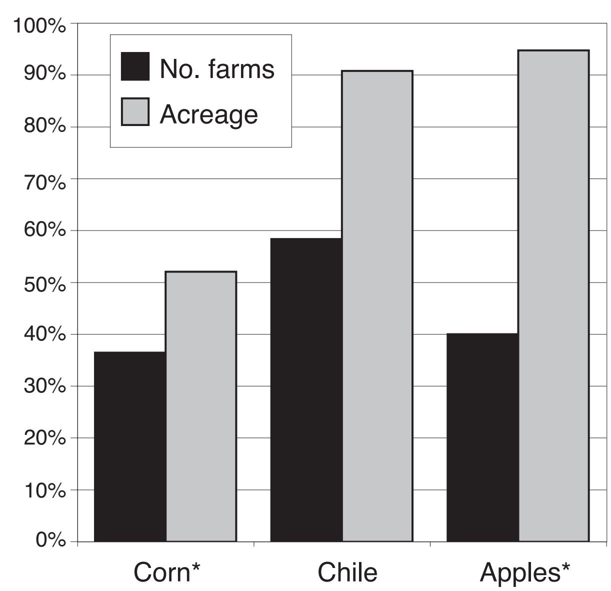


Figure 5.1. Percentage of Arizona Farms and Acreage in Cochise County: Corn, Chile, and Apples, 1997. * Includes parts of Graham County that lie within the SSV. Source: U.S. Department of Agriculture (1997).

cording to the Census of Agriculture (U.S. Department of Agriculture 1997), in 1987 there were 55 corn farms in Cochise County, this number declined to 26 in 1992, and went up to 39 farms in 1997. According to the USDA, in 1997 there were 37 corn farms in Cochise County with sales of $10,000 or more (U.S. Department of Agriculture 1997). This represents about 10 percent of the total number (379) of irrigated farms in the county. The market value of corn sold by these farms in that year was $6,166,000 or 36 percent of the value of corn sold at the state level. Most of the corn is for cow, chicken, and pig feed and is sold in Arizona. Although many corn farmers produce corn in combination with other crops, the important producers in the region are highly specialized.

5.1.1 Agricultural Schedule

Corn requires a lot of water, and in the semiarid environment of the Southwest, decisions regarding water use are critical to the success of farmers that depend on corn. Corn requires almost as much water as cotton (see Table 2.3), and, for the farmer, water represents the largest cost in the budget. Irrigation costs largely depend on the timing of precipitation falling, on summer temperatures, on wind and cloud cover, and on the depth from which water must be pumped. In addition, as already has been emphasized, water costs depend on energy prices and the irrigation technology used by the farmer. Ultimate profitability also is influenced by market prices. These are directly related to supply in other corn producing regions. Negative climatic events in other important corn producing regions of the United States generally translate into higher market prices, benefiting farmers in the SSV.

Because corn farmers are aware of the delicate balance of climate, energy costs, and markets in relation to water use, "deep water" decisions, or getting deep moisture into the fields, are made early in the spring, before the season begins. Land preparation is generally done

Case Study: Corn farmers*

Mr. R is a retired corn farmer. He arrived in the SSV with his parents in the early 1950s. After more than 15 years of farming in California, the family was forced to move when the local aquifer ran out of water. First the water table started dropping too far to easily pump water and then it actually dried up.

Mr. R's parents started looking for land and decided to move to southeastern Arizona. They had heard that land was relatively inexpensive and that growing conditions were good. They drilled several wells and started growing cotton. At that time, Mr. R recalls, "all you needed was 80 to 100 acres, that was enough to raise a family, now it's not enough to buy a truck." When his father died, Mr. R took over the farm and continued raising cotton until the early 1980s. After the energy crisis of the late 1970s, inputs became more expensive. At the same time, yields declined and cotton prices dropped. Mr. R saw many farmers go bankrupt and leave the area in the early 1980s. In order to survive he switched to corn and expanded the farm; large volume production allowed him to remain in business.

Today Mr. R's two sons have taken over the corn farm. They grow high quality yellow and white corn used for food such as tamales and tortilla chips. They dry, bag, and store the corn themselves, and are able to sell all year-round. Within the last couple of years they also have started growing chiles.

One of Mr. R's major preoccupations is the water table level. He emphasized that the area is becoming more arid and that there has been less precipitation over the last 10 years. One of the principal indications of this change is a loss in wildlife. "There used to be more deer," he commented, "but now there is less vegetation and they have gone away. Drought also has killed off creosote and hurt the mesquite…There also used to be a lot of javelina that ate my corn." Mr. R also has observed that there are more woody species, mesquite and thornbushes, where there was once just grass. He attributes this change to a combination of overgrazing, lack of fires, and drought.

*Composite of multiple stakeholder experiences. Names have been omitted to protect privacy.

in November and January when fields are disked and rippers are dug into the soil to loosen it up and obtain a fine consistency. Winter precipitation is important for soil preparation because it maintains soil moisture, allowing nutrients and minerals to seep into the soil. By March, fields are disked again with a tractor to clear them of weeds.

The decision about when to plant is based on a variety of factors such as date, temperature, and precipitation. Today's corn farmers have access to information from satellites and have Global Positioning Systems and computers in their combines. Before planting they map their fields and do moisture testing. This information is fed into a computer program that will analyze for the optimal number of seeds per acre or the changing rate of seeding, as well as the optimal amount of fertilizer that needs to be applied. For example, in areas where the ground is sandy, the recommended spacing between seeds might be six inches. In good soil spacing may be reduced to four inches and less fertilizer may be applied.

Temperature has to be right for corn to germinate, and knowing if and when it is going to rain is important information. "If you know it is going to rain you can prepare to seed and do it right before the rain." Generally, corn planting begins by mid-April. Fields are planted sequentially in order to space harvesting during the fall. A farmer, for example, that has 1,200 acres will plant two or three circles each week and be finished in four weeks.

Although hail is not a major concern of corn farmers, it can cause a great deal of damage if it occurs before the corn pollinates. Corn has a tassel-like head made out of the silky fibers that line the husk. If it hails before pollination, the hail beats the tassel and no pollen falls. Hail has led to large losses among uninsured farmers in the past. Today, purchasing hail insurance is becoming increasingly common among these farmers.

From plating onwards, corn plants are watered heavily and irrigation is continuous until the month of August. Irrigation amount is changed according to need. Set at high speed, a sprinkler takes 24 hours to irrigate a circle of 120 acres; at the slowest setting it takes 96 hours (four days). During May and June irrigation is on 24 hours a day. This is a costly undertaking. In 2000 farmers estimated an average cost of $100 a day to irrigate 120 acres. A farmer with 10 center-pivots or 1,200 acres spent an average of $1,000 a day on irrigation alone. Monsoon rains are awaited therefore with impatience because they allow for a reduction in the application of water.

The monsoons generally arrive after the corn pollinates. Early onset of monsoon rains brings a savings on irrigation costs. During the summer of 1999, for example, precipitation was higher than average and the monsoons arrived earlier than expected. One farmer pointed out that he was able to shut off his pumps three days a week and this saved him approximately $6,000–$7,000.

While droughts do not affect production to any great extent, they can be costly. When precipitation is below average, costs of production may increase by about 20 to 25 percent. As explained by a farmer, "if you don't have deep moisture, decreased rain increases pumping costs by $200 to $250 per sprinkler and we have to be running them pumps real hard at 900 gallons per minute." Wind and cloud cover also are critical factors. For corn farmers a cloudy day with no wind is ideal as pumps can be turned off without fear of losing too much soil moisture. "Wind takes a lot of moisture away, so if it continues cloudy like today, I don't have to worry; if it becomes sunny and windy again then I have to turn the pumps on right away." Hot, windy summers will result in the excessive drying of corn at the fringes of the field, whereas at the center, the corn will remain green.

When the corn is mature, farmers further decrease irrigation at the beginning of the fall to let the corn "dry out" for the harvest. Corn is allowed to dry on the stalk until it reaches an ideal moisture content of between 18 and 20 percent. Harvesting of corn starts between the 1st and 15th of September and continues until November. Because there is always a slight chance of fall precipitation, harvesting is done as quickly as possible once ideal moisture conditions are reached. Combines, which may harvest eight rows at a time, automatically cut the corn and separate the grain from the cob. The cob and other organic materials are left in the field to prevent erosion and enrich the soil. The grain is weighed and transferred to containers, taken to the dryer, and then stored in silos. Some corn farmers have their own combines with headers; those who do not own the equipment hire it from outfits that are passing through and are contracted to harvest the corn.

While rain is desired before and during the monsoon season, rain during the harvest can be costly. If the fields are wet, corn cannot be harvested because the combines will get stuck in the mud. In addition, precipitation is associated with higher humidity, which in turn means that the corn has to be dried with blowers, which is an expensive process. Corn that is not dried properly cannot be stored because it will mold.

Corn can be planted in the same field for about seven or eight years. Seed is ordered in November for the following year to ensure availability. During the winter months equipment is maintained and repaired and the marketing of corn begins. Most farmers grow yellow corn, which is sold mainly as cattle, chicken, and pig feed within Arizona. Those who have silos ship grain through the winter. Some farmers will sell 30 to 50 percent of their crop in the spring on contract right before planting. Other farmers buy and sell in futures markets. In general, prices are based on commodity market dynamics in the Midwest.

To compete with the Midwest, where irrigation and the cost of water is not a major concern, farmers in the SSV have had to double their yields. They estimate that while in the 1970s they produced about 6,000 or 7,000 pounds of corn per acre, today they are producing about 13,000 pounds of corn per acre. This has been achieved mainly through technological innovation such as center-pivot irrigation and new varieties of biotech corn. Some farmers will cultivate 90 percent of the fields with biotech corn leaving a required 10 percent in natural corn to protect biodiversity. But farmers contend that costs of production have gone up sixfold since the 1970s. While in the early 1970s production costs were about $70 per acre, in the 1990s production costs have increased to about $450–$500 per acre. The price of grain, farmers argue, remains the same as it was 30 years ago, while input prices have been steadily increasing for the last 28 years. Thus, to remain in business, as one farmer put it, "you will not find the farmer in overalls milking a cow, that doesn't exist anymore. Now corn farmers are pretty sharp business people. We go to corn conventions every year and we see the younger generation catching on to technological change much quicker."

5.1.2 Perceptions of Vulnerability, Use of Forecasts, and Climate Information Needs

With center-pivot irrigation technology and other innovations, climatic variability or climatic extremes alone are not a key concern of corn farmers. Although they perceive that climate can affect crops, by itself it is not perceived as a threat that can lead to loss of livelihood. The combination, however, of below normal precipitation and increased costs of energy continues to be a considerable problem. This was the experience of all corn farmers during the 2001 monsoon season. As gas prices soared, precipitation was below average. In fact, it was the 14th driest monsoon season on record (Glueck 2001), with higher than average temperatures and evapotranspiration rates. For corn farmers, this combination resulted in a 100 percent increase in the costs of pumping. Whereas in 2000 farmers paid $100 per acre for irrigation, in 2001 pumping costs reached $200 per acre. To deal with the crisis, many farmers have switched to electric pumping. The costs of switching, however, can be substantial. One farmer estimated that it cost him $10,000 per pump to switch to electric motors.

Climate and weather forecasting is clearly an important part of a corn farmer's decision making. Weather reports are watched on a daily basis during the summer. As one farmer emphasized, "We are weather conscious." Many farmers subscribe to the Data Transmission Network (DTN) service and obtain 24-hour up to 90-day forecasts. This service, which costs at least $200 per year, is provided by a private vendor who repackages weather service information, data from NOAA, graphics, and information on futures prices, tailored to specific clients. Clients receive not only weather and climate information at a national level, but also information on commodity markets and agricultural news. Satellite images on the web are a favorite among farmers, although sometimes there are problems. As one farmer explained: "a few years back there was a hurricane coming from Baja and the SSV was not in the picture, so we couldn't see what was going and we were really worried."

"Because nothing in Arizona grows without water" as a farmer pointed out, short-term and seasonal forecasting information of precipitation throughout the agricultural cycle is critical. It allows farmers to make more accurate decisions regarding when to turn irrigation pumps on and off. It also allows them to better time irrigation, use water more efficiently, and reduce costs. If summer precipitation is predicted to be low, for example, farmers may be able to better prepare for expected increases in the costs of pumping water. Also, short-term, two-week forecasts of the beginning and end of the monsoon season are advantageous because part of the overall strategy of corn farmers is to plant and harvest their corn as quickly as possible to take advantage of early rain and beat the rain in the fall.

A two-week warning of approaching storms during the fall can be particularly advantageous because it would allow farmers to harvest earlier on dry ground. As indicated by the following account, farmers are willing to make decisions based on forecasts, even when these may turn out to be inaccurate.

> Three years ago there was hurricane Nora coming from Baja California, in mid-September. Forecasters were saying that it was going to hit the valley and make a lot of damage. So everyone started harvesting early. We worked 18 hours for five days in a row. We were expecting high winds and a lot of rain. When all the harvesting was done the storm went to Yuma. We lost money because when we harvested, the corn had a 23 percent moisture content and we had to spend a lot on fuel to dry it down. Everyone was running to get their corn to the only three dryers found in the valley.

Corn farmers also are very interested in seasonal forecasts for other corn-producing regions in the United States. If a major drought is predicted in the Midwest, for example, where land is not irrigated, farmers expect that prices for corn will go up nationwide. Thus a farmer in the SSV may decide not to sell his corn right away but wait until prices go up. On some occasions farmers have benefited from accurate forecasts; at other times inaccuracy has been costly:

> A drought had been forecasted for the Midwest. The 90-day forecast predicted hot and dry weather, no rain, no subsoil moisture. This would imply rising prices for corn…The drought was predicted from April through May, so I didn't sell my corn thinking that prices would keep on going up as the drought in the Midwest continued. All of a sudden it started raining in the Midwest, it rained May, June, and July and the corn farmers there ended up getting the best crop. Prices went down and I lost $150,000. Maybe I was a fool; maybe I should have sold when it was a halfway decent price.

Long-range forecasts of winter precipitation, although not critical to immediate decision making, are important to farmers as they perceive that water recharge is based on winter precipitation and snow on Mt. Graham, in the Pinaleños Mountains. One retired corn farmer observed with concern that "the past seven years have been really dry, winter rain has been sporadic, and last year [1999] they were nonexistent…Drought lowers the water table and we need to know if this trend is going to continue." But most corn farmers are skeptical about the predictability of precipitation. As another farmer commented:

> Rain and water varies a lot within the valley. There are channels in the valley that get more rain. The closer you are to the mountain the better, you see a curtain of rain descending from the mountain and coming into the valley, and then it suddenly stops and you see the rain pouring over there and you don't get a drop here. But really, it varies from year to year.

5.2 Fruit Orchards

After the energy crisis of the 1970s, as fewer farmers grew furrow-irrigated crops, higher-value horticultural crops became important. Almost 10,000 acres went into fruit orchard production in the SSV. These orchards generally combine apples, peaches, and pears. The valley is the largest producer of apples and peaches in the State of Arizona. Most of its production is concentrated in the northern side of the valley, in the Bonita area, which overlaps both Cochise and Graham County (see Figure 5.1). This area holds more than 80 percent of the state's 3,772 acres in apple orchards. The region produces 1,840,350 pounds of apples per year (U.S. Department of Agriculture 1997). Despite its relatively high production, there has been a large drop in acreage from 5,770 acres in 1992 to 3,772 acres in 1997. State rankings at the national level indicate that while Arizona ranked 10th in apple production 1992, it ranked 19th in 1997. Productivity per acre, however, more than doubled for the year 2000 as yields increased from 44 million pounds in 1997 to 94.5 million in 2000 (see Table C.2 in Appendix C).

5.2.1 Agricultural Schedule

For fruit orchard growers, temperature is the most important climatic factor influencing their decisions through the year and prompting considerable technological innovation. As one farmer stated, "Orchards are particularly susceptible to climate in the SSV because temperatures fluctuate so radically and are so unpredictable." The most critical season of the year is the spring, when frost events are a significant source of

Case Study: Fruit Orchards*

Mr. S's grandfather arrived at the SSV from Oklahoma when he was six years old. The family was looking for better agricultural and ranching lands and homesteaded in the SSV in 1909. Mr. S's grandfather planted the first apple orchards in the valley, and his father, after noticing that blooms never froze, started a peach orchard in the 1930s. The 40-acre peach orchard was situated near a railroad stop, so peaches could be easily shipped and sold. People also would arrive from Phoenix and Tucson to pick peaches. Although it was not a U-pick farm, it was certainly the first attempt at one. Mr. S' grandfather, and later on his father, also grew cotton and raised cattle.

Mr. S took over the ranch and orchard when his father retired. The orchard, which was situated on a slope that allowed cold air to pass through, had never been damaged by a frost until 1955. After that, Mr. S observed that crop losses to frost became more frequent and he had to start investing in frost-control technologies. In 1985, he stopped raising peaches and converted the orchards to cotton fields. A few years later, the cotton fields were converted to irrigated pasture.

A few years before Mr. S quit raising peaches, other families arrived to the north of the valley. The first apple orchard was started in the late 1970s. A University of Arizona report recommended apple growing in the SSV and by the beginning of the 1980s the apple boom started in the Bonita area. The first organic farms in Arizona also began in this region and U-pick farms became more common. Some farms process apples and peaches into cider, jams, and pies to be sold on weekends during the peach and apple festivals held during the harvest every year.

*Composite of multiple stakeholder experiences. Names have been omitted to protect privacy.

anxiety and avoiding the potential damage that frost can cause on blooms is a major undertaking. This most critical period, according to farmers, starts on March 10th and ends on May 10th. By this time, day temperatures already have reached over 5°F and buds have started to develop. The impact of cold temperatures at this time depends on the blossoming sequence. A frost will have a lower impact on trees in their initial bloom as opposed to those in full bloom. The later the blossom, the higher the possibility is of setting fruit. Peaches tend to blossom first, sometime in March, and apples last, starting during the first week of April and continuing until the end of the month.

Because apples and peaches are highly susceptible to frost, which can cause blooms to die and fruit to mature unevenly, temperatures are constantly monitored. One of the farming couples interviewed has eight thermometers dispersed throughout their 35-acre orchard, continually monitoring highs and lows. They have a frost alarm next to their bed that warns them when the outside temperature drops to 34°F. During nights that are perceived to be dangerous, thermometers are checked every hour through the night, in case the alarm fails. If a killing frost comes, they only have a few hours to prevent harm to their trees.

Farmers are keenly aware of the connection between temperature and other meteorological indicators. One of the farmers interviewed, for example, has an elaborate computerized system to monitor weather conditions in the orchard. The system measures temperature through the orchard at eight different locations at five-minute intervals. Dew point and humidity levels also are measured every five minutes in two different locations, and soil moisture levels are measured every five minutes in four locations. As this farmer has observed, when the dew point is in the low teens, the danger of frost increases. If it is dry the temperature drops faster. In contrast, cloud cover decreases the possibility of frost because clouds act like a blanket and temperatures remain higher.

Apple and peach trees can survive temperatures that fall a few degrees below freezing. However, if temperatures fall below 29°F, farmers estimate a 10 percent crop loss. A drop of just two degrees more, to 27°F, means a loss of 90 percent of the crop. Wind machines are commonly used to prevent trees from freezing and are generally activated on the 10th of March. These stir up the air at 60 feet, sucking down hot air and mixing it with cold air, producing up to a 10-degree inversion. Although a 3- to 4- degree inversion is more common, sometimes no inversion is produced. Some orchard owners also have propane line heaters throughout the orchards that are fired up to warm the trees. These, however, are costly to run. Farmers will spend on average $200 per hour on propane, or $2,000 per night for 10 to 12 nights. Sprinkler irrigation systems also are effective in maintaining temperatures and increasing humidity. Farmers who have overhead sprinklers will turn them on the morning of the day in which a frost is predicted.

Once the danger of frost is over and temperatures start going up, irrigation, which is initiated in March, is increased. Peak times for water usage occur when the fruit comes out, roughly from May until August. For organic farmers in the region, April is the time for applying pheromones, which are used to control the codling moth by disrupting its mating.[9] Temperature is a key factor in applying pheromones. Basically, high temperatures change the structure of pheromones and destroy them. Because pheromones are extremely expensive, in the summer farmers carefully monitor daytime high temperatures and look at forecast information.

Before the monsoon starts, fields are thinned, disked, and mowed. The monsoon season has the potential for good and bad. Rain during the summer is highly desirable because it not only decreases irrigation costs but also has higher nitrogen content than groundwater. This is good for the trees. The monsoon also brings hail, which is particularly problematic for farmers who fresh-pack their fruit. As one farmer explains, "We've got some hail that basically…the fruit got so damaged we had to use it for juice, you can't fresh pack hail-damaged fruit, which means put it into boxes and send it to the grocery store. Because we are pushing more towards fresh pack, then we can get more damaged by hail." In some cases, hail can lead to a total loss, "We saw some big hail, not here but in a neighbor's block, that actually cut the skin of the apple and bacteria gets in and it will rot, you can't do anything with that fruit."

Wind can also be problematic. Strong winds will knock apples and peaches from the trees, leading sometimes to an 80 percent production loss. Wind also bangs apples together, blemishing them and rendering them unmarketable. To minimize the impact of wind on trees, they are planted from north to south so that the wind will flow downhill through the orchards. To minimize risk from hail and wind, farmers spread their orchards apart by at least a mile and a half. As explained by one grower:

> Having orchards in different locations is good, but it's kind of the odds and you do as much as you can. You know in Arizona that you are going to have wind and rain and that thunderstorms bring a chance of hail every year. Everybody says it's going to happen. And this has been a pretty light monsoon and we just had one that got strong enough, and it wasn't big hail, it was like little pellet size hail that just happened to put little marks, and a little mark is all it takes. It didn't damage the fruit for as far as juice but it damaged in terms of fresh pack, our markets are pretty finicky.

Finally, to combat excessive summer heat and sunlight, trees are planted close together so that they can provide shade for one another and help the soil retain moisture.

Peach harvesting usually starts by the beginning of August; harvesting of the wide range of apples grown in the SSV follows. Apple harvesting begins in early September and finishes by the end of October or first week of November. Summer temperatures, however, play an important role in the rate at which fruit matures. Hot summers can be hard on trees and costly in irrigation as evapotranspiration increases. Hot summers can also lead to an early harvest. For example, the high summer temperatures of 2000 led to an earlier than usual harvest period. Peaches had to be harvested more than a month in advance of the expected date. Because fruit trees have to be hand harvested, the major problem created by an early harvest is the availability of labor. A 600-acre orchard may require a total of 80 to 90 workers for picking and packing the fruit. As discussed in chapter 7, workers have a general migration schedule that they follow. If an early harvest is not expected, then labor will not be available.

In the case of U-pick farms, dates for the beginning of the peach and apple festivals must be established two or three months in advance in order to print newsletters publicizing the event. According to Clark and Dunn (1997), festivals may attract as many as 100,000 visitors during the summer months, generating over $1 million in sales. Farmers decide on these dates based on the number of days from bloom time to harvest. During the summer of 2000 one of the U-pick farms targeted 20,000 pounds of peaches to be ready for the peach festival on the 5th and 6th of August. The owners expected between 3,000 and 6,000 people to visit the orchard per week during that time. The peaches, however, were ready for harvest on the 18th of July.

Close to 30 percent of the peaches were not harvested on time.

By November the first frosts arrive. Temperatures during the winter months affect dormancy. Trees need a certain number of rest or "chill" hours to bloom strongly and consistently in the spring. Thus a mild winter will result in a scattered bloom. Farmers estimate that ideal temperatures during the winter are below 45°F. Winter rain also is desired to keep the ground moist. The low winter precipitation in the valley during 1999 and 2000 led orchard owners to irrigate considerably more in the winter.

5.2.2 Perceptions of Vulnerability, Use of Forecasts, and Climate Information Needs

Farmers have clear recollections of particular frost events. A number of farmers talked about how, on May 5, 1995, many lost their apple crop when temperatures dropped to 18°F. One farmer talked about losing 85 percent of his crop. The latest and one of the most damaging frosts occurred on April 10, 2001. Most peach and apple crops in the valley were lost. On that night, as described by farmers, temperatures dropped to 19°F. The severity of the frost damage was exacerbated by the fact that trees were in full bloom and the frost killed all of the buds. Due to the extensive damage caused by the frost, one particular farmer, an absentee landowner whose manager participated in our research, decided to sell his 300-acre orchard. The farm manager turned the wind machines on when temperatures were already dropping, and was able to elevate temperature by 6°F, but it was not enough. Efforts also were made to save the trees from the frost by lighting "smudge pots" beneath them to raise the temperature. This strategy, however, failed as the pots were not lit until 4:00 a.m., when the coldest period of the night had already passed. This farm's manager blamed the "unnatural climate that the SSV has for growing apples" on the decision to sell the land.

Because weather information regarding frost is such a critical aspect of fruit orchard production, farmers in the SSV contract with a meteorological service in Seattle that monitors temperature and humidity to predict nightly temperatures. The SSV Apple Growers Association collects money from its 12 members and contracts with the Seattle forecaster to deliver rainfall and frost forecasting information during the spring. The information is based on remote meteorological stations located throughout the valley for the Willcox, Bonita, Winchester, Dragoon, and Bowie areas. This same service also is contracted by the Citrus Growers Association out of Mesa, Arizona. But farmers are generally dissatisfied with the service and consider it to be often "quite inaccurate." They perceive, however, that "there is no other option." During a frost event that occurred in the spring of 2000, for example, the temperature was predicted to drop to 43°F; it actually went down to 27°F. Trusting the forecast, one of the orchard growers that we interviewed went out of town that night. Farmers also complain that there is no system in place to update information quickly. Forecasts are issued at certain times during the day (5:00 a.m., 2:30 p.m., and 10:00 p.m.) but they are not updated in between.

Orchard growers often compare the Seattle service with the agricultural forecasting service that NOAA provided in the past via the National Weather Service office in Phoenix (see chapter 4). Frost forecasts were particularly beneficial. A five-day forecast to predict frost or freezing temperatures during the critical period from March 15 to April 30th was issued only in the spring. If temperatures were still too low, the forecast would be extended to the first or second week in May. The forecast was specifically tailored to orchard growers who asked for the service. At the time most growers used helicopters to control temperatures (this was prior to the introduction of wind machines), so knowing in advance was critical for them in order to have the helicopters over their fields on time.

Short-term forecasting of frost events, with five or six hours' lead-time, can make a significant difference. If farmers expect that temperatures are going to decline sharply during the night, they can begin elevating the orchards' temperature by, for example, starting wind machines and heaters early and thus maximizing their effectiveness.

During the monsoon season farmers look at the Weather Channel every night. They also consult the National Weather Service web site and look at the satellite images. One farmer said, "I watch the satellite for monsoon water moisture, especially coming from Mexico, in order to decipher if we'll get a monsoon. I listen to the weather but I don't believe anything in what the weather stations say, I kind of watch the monsoon water moisture." For organic growers, knowing if there are going to be heavy rains a week in advance is useful in making the decision of when to apply sulfur or calcium because a very strong monsoon rain will wash the nutrients out of the soil.

One farmer summed up the needs of fruit growers in the SSV in the following words:

> You got to get applied. We as [an] orchard organization use science and technology much more than anybody else here; we are interested in applying technology to business. If we can get environmental models of the past and relate them to the future that would be great, if we can get real time weather information, oh boy! Predictive models of weather, anything is better than what we have now and I think the technology is there that can help us. But the National Weather Service kind of dropped that. If we get some kind of agricultural weather, I mean real time thunderstorm prediction and real-time radar and that sort of product…We need environmental support, from NOAA or whatever. We need science that can be applied. Is there a way we could pay the same and get something better? Can we as an association petition for a grant? Can we get an evaluation of our water resources?

Farmers, however, are aware of the difficulties in predicting short-term events in a very specific area. As one farmer put it, "Predicting amount and location of monsoon rains would be ideal, but we know it's almost impossible in so limited an area. But anyway, predicting that would be nice." Farmers also are aware of the difficulty of predicting strong winds and hail. In this case farmers do not make specific decisions based on forecasts. When farmers were asked such questions as, "If you knew you were going to have lots of wind and hail, would you decide in advance that you are going to sell juice rather than package the fruit?" the most typical response, as one farmer succinctly put it, was: "No, that's the roll of the dice, you know one block over here had hail, the rest of the blocks don't. We saw some big hail, not here but in a neighbor's block." All the fruit orchard growers, however, have hail insurance.

Organic growers also would like seasonal temperature forecasts for pheromone application. As one of the most progressive orchard owners noted,

> I am trying to build heat models with my pheromones. This year was hotter than last year, so the model that I applied this year was the one I built last year and I was just buzzing along really well and then I just found out that we run out, they just wore out [the pheromones]. If we knew that we were expecting higher temperatures, by degree, or some kind of predictive model, then I can apply that to the model that I am using and see when I am going to need to apply them [the pheromones]. I am talking a month in advance, if I knew in April or May that you are expecting X percentage, let's say there is going to be a 10 percent increase in temperatures, then I take last year's model and multiply it by 10 percent. I could use that information very good. But don't tell me it's going to be hotter than normal.

5.3 Chile Farmers

The SSV is known for its high-quality green chiles. According to extension agents Clark and Dunn (1997), in the 1990s Cochise County saw a dramatic increase in chile production from 800 acres in 1984 to 4,500 acres in 1995. According to the USDA (1997), 28 out of the 48 chile farms in the State of Arizona are located in Cochise County. Census data also indicates that Cochise County produced 90 percent of the chiles in the state (see Figure 5.1; Table C.3 in Appendix C). Compared to New Mexico, however, Arizona is a small producer. According to the 1997 U.S. census of agriculture, there were 355 chile farms in New Mexico producing a total of 20,528 acres (U.S. Department of Agriculture 1997).

5.3.1 Agricultural Schedule

The amount and timing of precipitation is the most critical climatic factor for chile growers throughout the agricultural cycle. Like most crops in the SSV, chile planting begins in March and continues through May. Fertilizer needs to be applied immediately before planting. If it rains during or just prior to fertilizer application, rain will wash it out. Farmers are particularly attentive to precipitation forecasts. Fertilizer is an expensive input[10] and because it is a byproduct of natural gas, increases in the cost of natural gas have led to increases in the price of fertilizer.

Like corn, the planting of chiles is staggered to avoid having to harvest all fields at the same time. Chiles require "lots of heat units" so planting must wait until soil temperature reaches around 55°F. In terms of marketing, however, it is advantageous to plant as early as possible and either be a price setter or beat others to the market. Frost forecasting also is an issue in deciding when to plant. From the time seeds are planted, it takes chile plants three to five weeks to begin germinating. Late frosts can be very damaging; a frost that arrives in May will kill the crop that was planted in April. The biggest concern and possible source of damage during this particular time is wind, especially during the months of April and May. While wind gusts of 30 mph pose little threat to the emerging small and vulnerable chile plants, wind gusts of 35 mph will pick up sand and "burn" the plants. Wind can also break off the vines when the chiles are small.

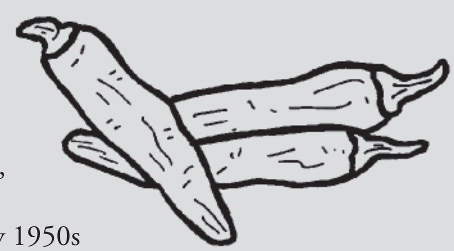
During the growing season farmers depend on irrigation, either center-pivots (for the more affluent farmers), or furrow irrigation. The most advantageous characteristic of center-pivots for chile farmers is that pivots allow the farmer more control and avoid creating standing water. In addition, as one farmer asked in comparing center-pivot irrigation and flood irrigation, "Would you rather have two gallons of water now or a cup all day long? With row irrigation, you flooded and then cut the water for two weeks. With center-pivot irrigation, we control and put in what we want, you never have standing water in your chile field and we have reduced the incidence of disease."

In the spring, pivots are set at a high speed of 18-hour and 12-hour cycles, keeping the soil constantly moist. The arrival of summer monsoons is looked upon with a combination of relief and fear. As one farmer said, "chile loves rain, but if you water a hair too much, you kill it." Once plants get their load of chile pods, they cannot be stressed. Too much water will rot or waterlog the chiles, and will also lead to the spread of disease and weeds. So if farmers know that it is going to rain an inch they immediately stop irrigating.
Chiles are susceptible to a variety of diseases, insects, and weeds, any of which can seriously reduce yields. The incidence of these largely depends on temperature and humidity. Fungicides are applied to control diseases such as Phytophthora blight[11] and leaf spot, as well as to get rid of weed seeds and nematodes, which grow in the roots of the chile plants and prevent nutrient uptake. The application of pesticides also requires careful monitoring of temperature and precipitation.

Hail during the summer can be dangerous. Although most farmers have not had problems with hail in the past 20 years, when a farmer gets hit, the whole crop can be lost. In 1952, for example, one farmer remembered losing 100 percent of his chile crop to hail, and 60 percent the following year. He has not had any losses to hail since. Farmers are very aware that there is nothing they can do about hail. There is no technology and no possible response, except to buy hail insurance every year, which most farmers do.

Chile harvesting is generally done in two parts. A first crop of fresh green chiles, generally covering half of the fields, is harvested beginning around the 25th of August and continuing until the first frost sets in. An

Case Study: Diversified Chile Farmers*



The Cs arrived in the SSV in the early 1950s. Even though both Mr. and Mrs. C came from farming families, in their region of origin there was no land available. The SSV seemed like a good place. There was plenty of land and wells were being dug, a cotton gin had opened, and a chile canning plant was established, producing 40,000 cans of chiles a day. The SSV began producing chiles in 1945 and by the early 1950s Elfrida began calling itself "the chile capital of the world." The Double Adobe area was the biggest farming area at a time when 40 acres was considered big. Like most chile farmers, the Cs were highly diversified, growing chiles, cotton, and some corn. They originally leased 80 acres and in 1975 they had about 1,000 acres. Today they farm chiles and corn, which they rotate with barley.

Their son started farming on his own in the early 1970s. Rather than settling in one place, he leased land and farmed chiles in different areas all the way from Elfrida to Cochise and even in West Texas. Like he said, "my dad planted chiles and it's been good to us." He settled and bought land in the 1980s and began growing spring and fall lettuce in 1985. Today he grows chiles and lettuce each year, and rotates with corn, small grains, barley and wheat. He also has diversified into the production of value-added products such as chile sauce.

*Composite of multiple stakeholder experiences. Names have been omitted to protect privacy.

early freeze in October can be devastating because the chiles have not matured enough and still have high moisture content. An early freeze will therefore turn them to mush. The second harvest takes place after the first or second frost in November. At this time, the chiles have turned red and are dry. Chiles have to be hand picked and migrant workers are hired for the task. As discussed below, heavy rains before or during harvest can severely damage chiles and make it impossible for labor to enter the fields.

Some farmers pre-contract the chile crop prior to planting, to be sold as fresh-market greens and reds. The contractor and distributor agree on the price beforehand. Other farmers sell green chiles to the local cannery at McNeal, where chiles are canned whole and diced. Red chiles are dried, ground, and generally sold as powder. Chile is a risky crop because it can be severely damaged by climatic and weather events and it is expensive to grow. It also is a high dollar crop that can produce large profit margins. In addition, the SSV has to face large competitors: Hatch in New Mexico and the Rio Grande Valley and El Paso in Texas.

Of all producers in the SSV, chile farmers are the most diversified. Chile crops require a three-year rotation period with other crops such as alfalfa, wheat, or barley. The few farmers who only plant chiles must have enough land to change plots.

5.3.2 Perceptions of Vulnerability, Use of Forecasts, and Climate Information Needs

A chile farmer in the SSV argues that climate and weather "can affect every aspect of farming and in numerous different ways." He says that the climate is key to making decisions as a farm owner and that everything else is "just numbers." Chile farmers are as concerned about the seasonal climate as they are about specific weather conditions and particular events. A farmer needs a two-week lead rain forecast right before the season begins, when fertilizer needs to be applied. Fertilizer has to be ordered two weeks in advance. Once it is delivered, it needs to be spread throughout the field within two hours from when it is dumped on the ground. If it rains before it is spread, the fertilizer will be lost. Farmers watch the weather carefully and check with various sources of forecasting information before ordering fertilizer. Their decision of when to order and apply fertilizer is based on a combination of forecasting information and "guess work."

Short-term forecasts for frost prediction also are important to chile farmers, and they often consult with apple producers. The April freeze of 2001 hurt some chile farmers, who lost part of their crop and had to replant. Replanting means that chiles will be harvested later, and will become susceptible to the risk of an early (fall) frost or rains increases.

A 30- to 60-day forecast of seasonal temperature and precipitation may be highly beneficial to the more diversified farmer. This is the case for C family, who grow chiles and corn. If there is a forecast for a wet summer and Mr. C feels confident about the prediction, he may decide to plant corn on his chile fields or, as he stated, "If I knew it was going to rain 20 inches, I wouldn't plant a stalk of chile. If I *knew* that. Because there are so many things out there…" This farmer might also look at a 30-day forecast to see if it is going to be dry, in order to decide when the last day of irrigation should be.

Forecasts of strong winds during the entire season may also impact farmers' decisions. For example, if unusually strong winds are predicted for planting season, a farmer may decide to plant barley in February—barley, like wheat and oats, does not freeze—and then plant rows of chiles in between the barley. The barley acts as a "cover crop" that will protect the chiles. With sufficient warning of strong winds farmers also can "cultivate" the soil, or mix the dirt, pushing the loose sand underneath. Chile farmers also watch wind forecast information on a daily basis, especially when the plants are small and fragile. A short-term wind forecast allows farmers to irrigate the fields to hold down loose sand. This strategy, however, is only temporary, as strong winds will quickly dry the field again.

During the growing season farmers can depend on the pivots for irrigation, but if they know 24 to 48 hours in advance that it is going to rain, they can cut back on irrigation and save on water as well as decrease the possibility of plant disease and pest infestation. Like corn farmers, chile farmers prefer to base their decision on when to irrigate on weekly forecast information. Farmers watch the news every night, although they complain that forecasters do not realize how important the information is for farmers. As one farmer said, "They don't understand that the information is not just used to know if you can wash the car or not."

Farmers prefer to look at satellite maps on their computers, watching for cloud cover. They also consult weather information on the DTN (Data Transmission Network) system, which gives information by radar. If there are going to be heavy rains, farmers will change the speed of their center-pivots and use a smaller sized nozzle, according to how much rain is expected. But if they think it is going to be dry, they will deep-irrigate.

Chile farmers also need to know within-month rainfall patterns in order to plan for fungicide application. To be effective, fungicide needs to be applied during optimal conditions of temperature and humidity, and with some degree of certainty that it will not rain. Longer-term decisions regarding fungicide use also can be made if adequate forecasts are available. As one farmer said, "If I knew that next year was going to be a wet summer I would put Vapan on whatever ground I was going to use. Vapan gets rid of Phytophthora, leaf spot, weed seed, and nematodes. But it's expensive and has to be applied with care."

In the fall, before the harvest, farmers watch jet streams and use precipitation forecasts to decide whether they will need to pick the chiles early. Warning of up to a month in advance of a fall storm would be ideal because the possibility of picking the chiles before the rains is contingent upon having a labor crew available to harvest. One farmer gave the following example of when a forecast can be useful: "Two years ago I had lots of chiles and it was raining and I was really short on labor. The workers were like 'vamanos' but from my computer information I could tell it would pass and I asked them to stay and they didn't want to but I asked again and sure enough it did pass." If there is a lot of rain or if it is very cold, it is difficult to get labor; "We have to twist their arm to get them in. When you are at 4,200 feet it's cold at 5:30 a.m. during the harvest and if it is raining it gets muddy and very difficult to work, there also are lots of snakes in the field."

An unexpected event during the harvest also can be problematic. One farmer had to gather 300 workers to harvest all of his 360 acres of chiles in two days, when a 48-hour forecast was issued predicting heavy rains. If the forecast had provided earlier warning, he would have been able to gather the crew sooner. When an event is not forecasted, the impacts can be devastating. This is what happened in October 2000 when a series of five storms—tropical storm Olivia, a pair of weather systems moving through the Great Basin, and two storms originating from the Gulf of Alaska—hit southeastern Arizona. This has been described as the wettest October on record; it rained for over 14 days (Glueck 2001). Some farmers reported getting 13 inches of rain that month. Those who were waiting to harvest their red chiles lost their crop.[12]

Chile farmers in the SSV could use seasonal forecasts to their advantage by looking at forecasts for other chile producing areas, such as Deming, New Mexico. One farmer emphasized that if he knew with some certainty that March and April in New Mexico were going to be cold and rainy, he would plant even more chiles because he would know that New Mexico was not going to have a good crop. Another farmer stated that "If we know that it is going to rain in Deming, then we are going to have to pick six instead of four semis [full of chiles] and get all of the laborers we can." If farmers in the SSV can get their chiles to market before those in New Mexico, they will be able to set prices.

5.4 Conclusion

The sophisticated farmer, the fruit orchard grower, and the diversified chile farmer are representatives of the three most important adaptation strategies found in the SSV today. While each crop requires a different set of climatic conditions and each is affected differently by climate and weather, in the three cases there is the perception that vulnerability to climate variability has been significantly reduced. This is the result of a combination of the growers' managerial skills, access to technology to counter the effects of specific climatic events, and access to such system-wide adaptations as crop insurance. Nevertheless, despite the tremendous resources available to farmers today, they remain vulnerable and climate information continues to be important to reduce farmer vulnerability. Useful forecasting information that ties climate to specific events is critical to farmers and an important challenge for the scientific community to address.

As the following statement by a chile farmer indicates, farmers combine imperfect forecast information with their own observations to make decision:

> Sometimes forecasts are accurate, sometimes they aren't, so I use my own experience. For example the trend has been that the moisture from Mexico has been splitting off and we didn't get any rain this July [2000]. We pray for southeasterly winds because if it shifts, we'll get rain. When it rains in Baja we'll get rain. If it's raining in San Diego, 80 percent of the time we'll get it by morning.

6. Adaptation and Forecast Needs Among Hay, Nut Orchards, and Vegetable Growers

In this chapter we turn to more peripheral farming operations: hay farms, nut orchards, and different types of vegetable farms. The climate vulnerabilities faced by these producers are similar to those of producers discussed in the previous chapter. In general, drought, excessive rain, extreme temperatures, and hail endanger these crops in similar ways. However, climate imposes very unique constraints on them and requires a different set of adaptations for each. This section elucidates these relationships.

6.1 Hay Farming

In the SSV, alfalfa hay was one of the first crops to be grown by Anglo-American settlers. Records indicate that Colonel Henry Clay Hooker began raising it in 1872 to supplement his cattle forage (Bailey 1994). Although Cochise County is not the largest producer of hay in Arizona, according to locals it does produce the highest-quality hay in the state (see Figure 6.1). The high elevation results in lower summer daytime temperatures than in the counties surrounding Phoenix that lead Arizona in hay production. In addition, the elevation causes wide summer diurnal temperature ranges. The average maximum July temperature in Willcox is 95°F and the average minimum temperature is 63°F (Clark and Dunn 1997). This wide range and overall cooler temperature profile allows alfalfa to grow very slowly and increases its protein content.

The ability to produce high-quality alfalfa hay has led to an increase in the number of families raising hay

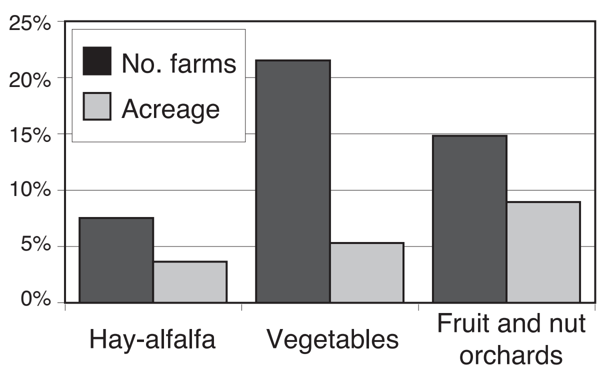


Figure 6.1. Percentage of Arizona Farms and Acreage in Cochise County: Hay, Vegetables, and Orchards, 1997. Source: U.S. Department of Agriculture (1997),

over the last three years. This also may be tied to speculation that dairies will eventually arrive in the SSV. The relatively moist and green hay produced in the region is considered to have more protein and nutrients and commands a higher price. Loads of hay are often sold over the phone and deals are sealed with a phone call or handshake; the buyer does not see the hay until it arrives. More than perhaps any other crop in the area, hay sales are based on reputation and trust and prices are relatively stable. One farmer discussed the relationship that a large feedlot owner had with local hay farmers: “He’ll pay [for the hay] based on your word alone and then he’d send you a check. If you ever cheated him, he’d never buy from you again. You don’t need to write nothing down with him.”

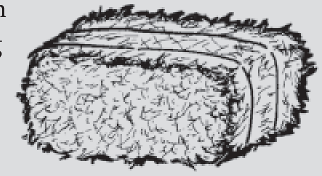
Hay can be easily irrigated with center-pivots. However, harvesting requires specialized equipment to form the hay into windrows, turn it, and bale it. Furthermore, raising hay demands specialized knowledge about *when* to cut, turn, and bale. Thus, it is difficult and rare for farmers to switch from producing a crop such as corn, to hay. The converse also is difficult. The ability of hay farmers to diversify production is more limited than for other types of farm operations.

6.1.1 Agricultural Schedule

Alfalfa fields are normally seeded in April. Irrigation starts immediately and increases gradually as the alfalfa matures. By July, the alfalfa is ready to be cut and irrigation will stop for a couple of days prior to cutting. After the alfalfa is cut, it is left to dry in the sun for four to six days. Next the hay is turned into strips, or windrows, and pairs of windrows are eventually rolled together to form one single row. This facilitates drying and baling because the number of windrows gets cut in half. Finally, the hay is baled and transported to barns to await pick up by trucks.

Fertilizer is added in the summer via center-pivot irrigation. Bales also are tested periodically to ensure the quality of the hay. Hay farmers generally do not have to worry about diseases or pests. Hay, however, *must* be cut every 27 to 30 days in the summer, before it matures. Otherwise it goes to seed and loses value.

Case Study: Hay Farming*



The Hs recently moved to the SSV from New Mexico, where their father had been raising hay for 30 years. The family would never consider switching to anything else. One brother stated, "This is what we do and what we know. It fits our lifestyle."

Alfalfa hay is a perennial crop that can remain in the same field for up to seven years and is cut several times per growing season. These "cuttings" are essentially multiple "harvests." After hay is cut, it is piled up into "windrows" and left to dry. Afterwards, it is baled. Whereas hay requires less labor than other crops because it does not need to be re-planted every year, the multiple harvests entail working round the clock in the late summer. Climate played a central role in the H's decision to relocate and buy land in the SSV. In the location where they farmed previously, the first winter frost occurs two weeks earlier and the first spring frost occurs two weeks later than in the SSV. Thus, frost-free conditions in the SSV add an additional month to the growing season, which allows farmers to make extra cuttings.

Hay is sold to feedlots and dairies in Arizona, New Mexico, and Texas. Companies send trucks to pick up bales for which the price has been previously arranged. This is the main disadvantage of raising hay in the SSV: there are not enough local ranchers to purchase hay and the transportation costs are high for regional dairies and feedlots.

*Composite of multiple stakeholder experiences. Names have been omitted to protect privacy.

In the SSV the last cutting usually takes place in mid-November.

6.1.2 Perceptions of Vulnerability, Use of Forecasts, and Climate Information Needs

As is the case for other types of farms, climate provides both constraints and opportunities for hay farmers. Several operators ironically stated that "drought is good" and that "if you're a hay farmer, you don't want a drop of rain in July through September." Summer drought also forces local ranchers to purchase more hay as supplemental feed, which benefits local growers.

On the one hand, summer rain lowers the value of cut hay and delays baling. Rainfall on hay that has already been cut can leach nutrients out of the product. Rain-soaked cut hay cannot be baled because it will rot. On the other hand, precipitation in the summer can also decrease irrigation costs. However, maximizing production by obtaining the greatest number of cuttings is the primary profit strategy of hay operations. Thus, most hay farmers would prefer higher irrigation costs if it afforded them more cuttings.

Temperatures in the spring and summer are a concern. Lower temperatures mean slower growth and less cutting but higher crop values. Hot, dry summers permit more cuttings. Because the plants have no fruit or grains, hail poses a minimal threat to hay fields. However, excessive rain in the fall can prevent harvesting. The fall rain in 1999 was costly and some farmers lost at least three cuttings. Although this translated into monetary losses, farmers expressed little concern because they already had obtained profits from at least two harvests.

In general, hay farmers "want to know when it's going to rain." Short-term forecasts that predict where it will rain, especially in the summer, would be most beneficial because it would help farmers to decide which fields to cut and bale. Farmers, however, are aware of the impossibility of such predictions. Although hay farmers look at the DTN for weather and climate information, skepticism about long-lead forecasts of seasonal rainfall was often expressed as one hay farmer said: "We heard at the beginning of this year [2000] that it was going to be the wettest year ever and that the monsoon was going to be a month long. But the monsoons were less than normal and not long at all."

Having a large number of dispersed fields is advantageous. Because summer rainfall is characteristically spotty, chances are good that some of the fields will be dry enough to cut, turn, or bale on any given day. At the same time, scale hinders the possibilities of diversifying into other crops. On the one hand, hay requires very specialized equipment. On the other hand, the perennial nature of alfalfa prevents hay farmers from alternating crops.

6.2 Nut Orchards

Pecan and pistachio orchards dot the landscape throughout the SSV. The first orchards began around Elfrida in 1971, largely through contact with a single entrepreneur. The University of Arizona Cooperative Extension also provided assistance with the establishment of the first orchards. In 1997, Cochise County was home to about 52 percent of Arizona's pistachio farms, 78 percent of the state's pistachio acreage, 28 percent of all Arizona pecan farms, and 24 percent of the state's pecan acreage (see Figure 6.2).

As farms began to fail in the late-1970s, entrepreneurs began to purchase former farmland in order to establish nut orchards. Several factors contributed to this. Newcomers found land with the requisite field-scale irrigation infrastructure—i.e., pumps, wells, and ditches. Also, agricultural land in the SSV has always been less expensive than in other parts of the state. This is because urban areas do not encroach and drive up land prices. Likewise, parcels do not lie on expensive irrigation networks such as the Central Arizona Project (CAP) or extensive canal systems. A few local farmers decided to switch production from row crops to tree crops, but such instances were rare. It takes seven to eight years before trees bear nuts that can be harvested and sold. Thus, investors must wait a long period of time before realizing any return on their investment. In most cases, retirees or those with outside income manage pecan and pistachio orchards. Nut orchards are rarely the primary source of household income.

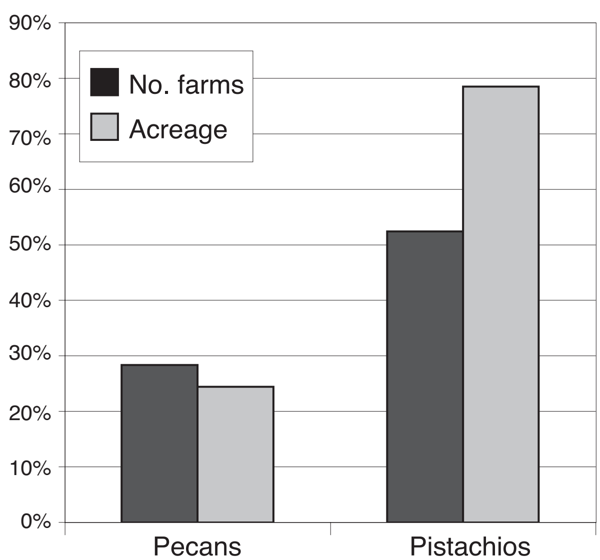


Figure 6.2. Percentage of Arizona Nut Farms and Acreage in Cochise County, 1997. Source: U.S. Department of Agriculture (1997)

Pistachio orchards, in particular, use much less water than row crops and return a greater profit per unit of water than corn. As concern grows about the viability of local aquifers, some long-time farmers in the SSV are now beginning to follow the innovations of newcomers by converting their row crop fields to nut orchards.

6.2.1 Agricultural Schedule

Pistachios and pecans are "alternate bearing" trees. This means that orchards have a two-year cycle. An "on" year will have a large production of nuts, and be followed by an "off" year with low productivity. Orchard operators take advantage of this cycle to schedule management tasks. Every couple of years, rows within an orchard are hedged (branches are trimmed back), to permit more sunlight to enter. This is ideally done in the winter preceding the next "on" year. Compared to fruit orchards, nut orchards require a great deal less management. This fact has enticed retirees and absentee landowners to raise pecans and pistachios on the side because, as one retired couple with a 40-acre orchard stated, "it's something we can handle ourselves."

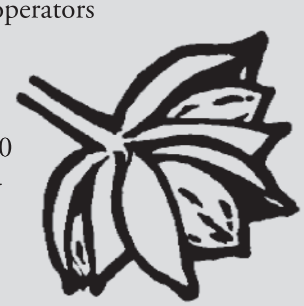
Pistachio and pecan trees begin blooming in March and April. Following this, the trees are watered every 10 days or once every two weeks depending on springtime temperatures. During the summer, irrigation requirements increase because the nuts are filling up. In orchards where drip irrigation is used, trees are watered every four to six days. Orchards with sprinklers must be watered every 10 days and the water is left on longer. Insecticides and herbicides are sprayed in the late spring and early summer.

By September, pistachios are ready to be harvested. Pecans are harvested in November and December. Machines are brought from Casa Grande or California to shake the pecan trees. Afterwards, the pecan nuts are gathered off the ground and shipped to processing centers. Catching frames are used to pick pistachio nuts from the tree so that the nuts never touch the ground. The nuts are then transferred to bins to be taken to the processing plant where they are sorted. Pistachios can be processed in Bowie or Cochise, whereas the nearest processing site for pecans is in Las Cruces, New Mexico. Pistachio farmers generally have a signed contract with a buyer before harvesting, so price is not an issue. Pistachios have different grades of quality that depend on the appearance of the shells. Prices will be much lower if the shells are stained or closed than if the shells are

Case Study: Nut Production in the SSV*

Mr. and Ms. L started their pistachio orchards more than 20 years ago. They were among the first families to start nut production in the SSV. Pistachios are native to the Middle East and the varieties in the SSV are found in Iran. These trees are well suited to the arid conditions. The altitude of the area also is conducive to pistachio production because the low winter temperatures supply the requisite number of chilling hours to produce blooms and hence nuts. For those farmers whose orchards lie on the valley floor, where cold air tends to sink in the spring, frosts pose a greater threat to their trees than to other operators on hillsides or slopes.

Mr. and Ms. L sell their pistachios to distributors in Bowie, which lies approximately 20 miles east of Willcox. Prices fluctuate. One year they may get only $1.00 per pound while in other years the price may be as high as $1.80. Like other pistachio growers in the SSV, they have consistently invested in technologies that increase profitability. When they first started, the orchard was watered using flood-furrow irrigation. Eventually, they switched to drip irrigation and now they use sprinklers.



*Composite of multiple stakeholder experiences. Names have been omitted to protect privacy.

open or the nuts are split. For pecans, there are no grades *per se,* and the price is based on ratio of meat to shell. The price is determined by the wholesale buyer at the time of purchase and is based on the quality of the nuts and the amount of "meat," as well as the appearance of the shells.

6.2.2 Perceptions of Vulnerability, Use of Forecasts, and Climate Information Needs

Like fruit orchards, pistachio trees are particularly vulnerable to spring frosts. Frosts kill off blooms and buds, preventing nuts from forming. The April 2001 freeze (discussed in chapter 5) was devastating. Some pistachio orchards lost their entire crop and earned zero profits that year. The Schmidt's remembered another severe freeze in 1978 that killed younger trees. Like fruit growers, pistachio farmers have adopted numerous technologies to mitigate frost. They use wind machines, smudge pots, and sprinklers.

Pecan trees were also damaged by the 2001 freeze, but farmers lost one-half of their annual crop. Unlike pistachios, pecan trees can have a second bloom if the first one fails. Pecan farmers do not usually invest in frost protection, although one pecan-raising couple successfully used sprinklers—rather than heaters or wind machines—to deal with the 2001 freeze.

Because pecans are not harvested until November, they are vulnerable to fall frosts as well. Frosts in October and November can cause the meat to stick to the shell and induce stems to rot, which causes nuts to fall off trees too early, lowering the market value of pecans. Autumn rain is also a problem for nut growers. It impairs the use of machinery to enter fields for harvesting. In the case of pistachios, fall rains can stain the shells, lowering quality and, therefore, the price received. Summer rain is largely beneficial because it decreases pumping costs, although excessive rain can cause fungal diseases for pistachio roots.

In terms of forecasting, nut growers want improved frost predictions. Some operators share frost information through the Apple Growers Association, but some of the newer growers are not part of these social networks. Pecan growers expressed interest in knowing drought and flood forecasts for Georgia and Texas, which are the two major competitor regions. If they knew in November that these areas would have poor harvests, pecan growers might be willing to keep their nuts in Las Cruces storage facilities in anticipation of better prices.

6.3 Vegetable Producers

The SSV hosts a wide variety of vegetable producers. These vegetable farms range from 800-acre onion farms to 20-acre U-pick produce farms. Vegetable operations differ from representative corn or chile farms in that they are smaller in scale. A vegetable farm may be economically viable with only 40 acres while a chile farm must have at least 1,400 acres in order to sustain crop rotation and meet production demands.

Vegetable farming has a long history in the SSV dating back to 1933 when tomato canneries produced 1,000 cans per day of local tomatoes (Schultz 1980). Economic conditions caused the demise of these farms, and canneries and vegetable farming have gone through cycles of boom and bust ever since. The overall mild temperatures, ample sunlight, transportation networks, and proximity to produce brokers in Nogales, Arizona make the SSV a good location for raising produce. Although the SSV does not represent a large share of Arizona's overall vegetable production, it does have a substantial percentage of the state's vegetable farms and acreage in certain crops as evidenced by data for Cochise County in Table 6.1.

Table 6.1. Percentage of Arizona Vegetable Farms and Acreage in Cochise County, 1997.

Criteria (irrigated)	Number of Farms	% of AZ Farms	Number of Acres	% of AZ Acreage
Land used for vegetables	65	21.5	6,931	0.06
Lettuce and romaine	15	12.8	1,331	0.02
Chile	28	58.3	3,696	90.8
Pumpkin	13	50	398	63.3
Squash	19	51.4	574	76.7
Sweet corn	7	16.3	110	0.04
Watermelon	18	26.4	261	0.04

Source: Data compiled from U.S. Department of Agriculture (1997).

Raising vegetables can be tremendously lucrative. The Asian squash farmer is "happy as a hog on ice" with only about 360 acres of squash and about 20 acres of Afghan pines that he sells as Christmas trees. Several local farmers experiment with fall and spring lettuce. Farming in the valley is often referred to as "gambling" because markets and weather can either present one with ruin or reward one with profits. Corn is regarded as penny slots, chile is roulette, and lettuce is high-stakes poker. The profitability of lettuce largely depends on its price elsewhere—places such as Salinas, California. Thus, if either the spring or fall lettuce crop there fails, SSV farmers can make substantial profits. However, if Salinas succeeds then SSV farmers actually disk their lettuce back into the soil rather than even attempting to harvest. No one grows lettuce exclusively.

Perhaps the most novel form of vegetable production in the SSV is the U-pick vegetable farm. These family-run operations bring approximately 64,000 visitors to the valley annually, mostly from Sierra Vista and Tucson (Leones et al. 1994). Although not tremendously lucrative, U-pick farms permit their owners to enjoy a more relaxed lifestyle than their neighbors whose livelihoods depend on market prices and efficiency of scale. One family explained that they began their U-pick farm to avoid the "rat race" of other farming occupations. With a U-pick vegetable farm, it is possible to make a living on only 80 acres. However, few U-pick farm families relied entirely on their vegetable farm as their main source of income. Most other operators have their retirement, investments, or savings that allow them to raise vegetables on the side.

6.3.1 Agricultural Schedule

Agricultural schedules depend on the type of vegetable produced. For example, spring lettuce is planted in the November-December timeframe and is harvested in May and June. Fall lettuce, on the other hand, is sown in July and August and is picked from September through November. U-pick vegetable farms typically raise their own seedlings, which are started in greenhouses in late January and February. Farmers outplant the seedlings in March and April. U-pick farmers attempt to stagger plantings so that certain vegetables are available throughout the tourist season, which lasts from July through October. The final products to become available are pumpkins, and some U-pick operations depend heavily on their Halloween season "Pumpkin Harvest" to "make those payments." Irrigating, weeding, and applying fertilizers and fungicides occupy the months between planting and harvesting.

The most critical decision for any vegetable grower is when to plant. Whether sowing seeds or planting seedlings, farmers must await sufficiently warm soil temperatures to allow for germination and maturation of their crops. Typically, conditions are favorable by early April. Some farmers rent fields on higher land in the western edge of the SSV because these areas tend to become warm earlier in the season than in other parts of the valley.

Following planting, farmers have to time their irrigation schedules. Vegetables require far less water than

Case Study: Vegetable Growers*

In the 1990s the D family moved to the SSV to grow onions. Their family has been raising onions in the Northwest for three generations. Whereas in the Northwest onions are only raised in winter, in the SSV it is possible to get two crops per year. In addition, the Ds grow chiles, fall lettuce, watermelon, and squash.

Their 800-acre farm does not have enough room for center-pivot rotation. Thus, the Ds continue to rely on flood-furrow irrigation, although they are starting to invest in sub-surface drip irrigation through loans and assistance from the FSA and NRCD. Vegetable farming affords a great deal of flexibility in terms of produce varieties. If a broker is interested in a specific type of chile, for instance, the Ds can easily comply. They constantly watch the market through trade magazines and are always "looking for a niche." This is one of the key strategies in vegetable production: finding a niche market and then providing the product on contract.

The Ds believe that farming in the SSV is very unforgiving. Since they started farming in the area, they have seen their crops severely damaged by hail and by floods, and have not had "a good year yet." They also stated that Arizona is not "agriculture-friendly." Fuel, fertilizer, and seed are taxed in Arizona, whereas farm necessities are exempt from state tax in the area where they came from. They enjoy farming and feel a sense of duty to provide others with food. However, Ms. D told us that they felt particularly challenged here in the SSV and stated that God was "testing them with steel." The Ds exemplify how newcomers to the SSV have to struggle in order to cope with the climatic and economic exigencies of the area. They don't have the accumulated knowledge of long-term residents who have a better idea of which areas get hit by hail or are more prone to flooding.

*Composite of multiple stakeholder experiences. Names have been omitted to protect privacy.

row crops and fields are typically irrigated once a day for a set time. This can be moderated based on rainfall. Fungicides to counter Phytophthora and fertilizers are applied when plants approach maturity and temperatures and humidity are moderate, before the start of the monsoon season. Due to potential contact with tourists, chemicals cannot be applied when vegetable crops are mature and ready to pick.

Advertising when their produce will be available is an enormous expense for U-pick farmers. Promotional materials must be printed months in advance and distributed to tourist bureaus, individuals, and newspapers. Estimating when specific crops will be available is therefore crucial to bringing people out to the fields at the right time. One crop for which this is particularly important is sweet corn, a popular summertime treat that is available for only a limited period of time.

6.3.2 Perceptions of Vulnerability, Use of Forecasts, and Climate Information Needs

Drought was the bane of vegetable farmers in the early 20th century. Farms relied on gated-pipe or flood-furrow irrigation, which wasted tremendous amounts of water. Also, because fields were flooded, the susceptibility to Phytophthora, which can wipe out an entire crop in a few days, was high. Today, most vegetable farmers have converted their fields to either center-pivot or drip irrigation systems. A few families have installed sub-surface drip irrigation with the financial assistance of the NRCD. Drip irrigation reduces the threat of Phytophthora by avoiding standing water. It also allows laborers to work in the field even when the irrigation is on because fields are not flooded.

Frosts in both the spring and fall are hazardous to vegetable farmers. Spring frosts damage seedlings and fall frosts damage mature fruit. To cope with spring frosts, farmers can delay planting. The freeze that occurred in April 2001 concerned many vegetable growers, but most of them were adequately prepared for it. One U-pick farmer reported that he had already planted his seedlings in the ground. Experience and "47 years in Cochise County" warned him to expect another freeze. Thus, he held back on irrigating the seedlings so that they lay dormant during the freeze. He suffered little damage. In the fall, before vegetables are harvested, operators can spray a chemical called "Frostguard" on their plants to prevent damage. This is expensive and must be done well in advance. Most farmers resort to harvesting early or just letting nature take its course in response to fall frost threats.

Wind is another hazard in the spring. It can entrain soil particles and "blast" seedlings with sand. This flattens furrows and can cut plants off at the trunk. One farmer told us that windstorms in 1996 reduced onion yields by 33 percent and cut his chile crop in half. Wind insurance is available. However, the entire crop must be destroyed by wind in order to collect insurance.

By far the greatest climatic perils for vegetable farmers are hailstorms in the summer and heavy rains in the fall. Nothing can be done about hail except to purchase hail insurance, which is only available for certain types of vegetables. Because vegetable crops are not commodities, hail insurance premiums may be prohibitively expensive. Heavy rains in the fall can be devastating, mainly because workers and machinery are unable to enter the fields and harvest the crops. The heavy rains of October 2000 (discussed in chapter 5) compromised the pumpkin harvests and propelled the one family who had been in the business longest to cease operations. To cope with floods, a farmer's only choice is to harvest early or wait for possible federal disaster relief funding. In order to qualify for disaster assistance, however, the entire county must have suffered at least a 50 percent loss in agricultural production due to the event. This occurred during the fall flood of 2000, although most farmers felt that the disaster payment would not nearly offset their losses.

Weather and climate forecasting information to assist vegetable farmers in the face of these hazards is critical. Vegetable farmers in the area reported using the Farmer's Almanac, weather web sites, and even their bones to predict rain and frosts. Long-time residents also spoke frequently of personal experience in predicting temperature and precipitation. Numerous interviewees told us that they "just knew" that the 2001 spring freeze was going to occur. Although we could not discern *how* they predicted this event, such statements exemplify how individual "gut feelings" about weather inform agricultural decision making.

Among vegetable farmers, their priority is for fall flood predictions. These events cripple production and the only real recourse is to harvest early. Thus, having a two-week advance warning of tropical storms or frontal storms could be of great value to these stakeholders. Lettuce growing reveals the potential utility of seasonal climate forecasts. In 1997, brokers from Salinas approached many farmers in the SSV to grow fall lettuce.

Fall lettuce is planted in the fall and harvested in November and December. It was an El Niño year and meteorologists predicted that Salinas was going to be flooded out. Numerous SSV farmers chose to sow lettuce that fall, which is possible because most fields have been harvested at that time and the fields are essentially fallow. Brokers typically offer a farmer the seed and labor for harvesting, and the farmer provides the land, water, and machinery. They negotiate how to split the profits before harvest. Most farmers thought that "it was a sure thing" and took most of the risk. Salinas was flooded out by El Niño rains, but the growers there still realized a harvest because they rented upland fields that are not prone to flooding from other California farmers. There was no shortage in the lettuce market and SSV farmers wound up disking their lettuce rather than harvesting it. No one would tell us how much money they lost in machinery and fuel but one person told us that he "lost his keister." One farmer who has raised lettuce on the side every year reported that the profitability of lettuce ranges from $2,300 an acre in a bad year to $17,600 an acre in the best years.

U-pick vegetable farmers could also potentially take advantage of seasonal temperature and precipitation forecasts for the spring and summer. They invest large sums of money and effort into advertising the availability of their produce. Thus, a long-lead forecast of spring and early summer temperatures may allow them to better predict when sweet corn would be ready to be picked. Such predictions could give them an advantage over other U-pick farms that rely more on word-of-mouth. However, most vegetable farmers expressed skepticism about climate forecasts and one noted, "Mother Nature always gets the last word."

6.4 Controlled Environment Agriculture: Greenhouses in the SSV

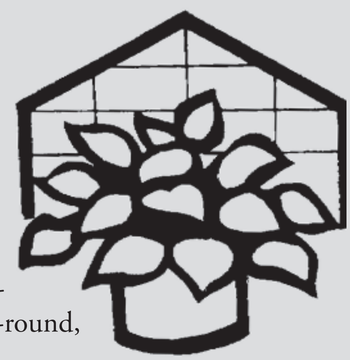
Greenhouses are relatively new to the SSV. Of all agricultural practices found in the region, the level of technology used by greenhouses to control such factors as temperature and humidity makes them the least vulnerable to climate variability. Yield per acre is considerably higher when compared to field production. While field tomatoes in Southeastern Arizona produce an average of 10 to 30 tons per acre and are available from July to September, tomato greenhouses produce an average yield of 160 tons per acre over a nine-month growing season (Clark and Dunn 1997). The quality of the tomatoes is better, although costs are higher and prices to the consumer are higher. Greenhouse tomatoes are four times more expensive than field tomatoes.

6.4.1 Agricultural Schedule

The amount of light available is the most important limiting factor in the production of greenhouse vegetables. The total amount of radiation, measured in joules, determines production throughout the plant's life cycle. Everything else is controlled and it is through technology that climate is a comparatively unimportant concern. Precipitation, for example, is only a factor in that the amount of cloud cover will result in less light. In fact, as one greenhouse owner emphasized, El Niño can cause problems, "There is a big difference in El Niño years. El Niño means more storms and less sunlight."

For the tomato greenhouses, the new season begins around July 20th. As one of the owners said, "We work against nature here. We start growing tomatoes in the summer and have them produce during the winter, all the way through June." July is the time for cleaning and sterilizing the greenhouse, although this is not done every year. If a hot summer is predicted, sterilization, done with a boiler and steam, is done more thoroughly to avoid disease. Plants are grown in a medium of rock wool made from crushed granite. These are steamed and covered with a blanket. Then the seeding is done and the pots are left until the beginning of August. For the first three to four weeks, plants can handle heat very well, but eventually whitewash has to be applied on the glass to filter the sun.

Case Study: Greenhouses in the SSV*



The SSV is an ideal location for greenhouses. The I-10 interstate highway and Nogales provide excellent access to markets and transportation. The region has the right altitude, excellent water, and, most importantly, the right amount of light. Solar radiation is the key climatic factor that allows farmers to produce year-round. As the manager of one greenhouse stated, "We don't care about temperature or precipitation. What we want, we can create. But the amount of light available, that is difficult to control." Labor availability also is an important factor. Greenhouses do not employ migrant labor; instead workers are year-round, full-time employees.

In the SSV, tomatoes and cucumbers are raised in greenhouses. Tomatoes and cucumbers are highly sensitive to humidity and to nighttime temperatures: "Mt. Graham plays a big part in dictating climate; nights cool off better, the cool air runs down the mountain towards Willcox, and that is important for the greenhouse…All crops need a cold night." For small greenhouse operators in the valley—the largest greenhouse has 120 acres under glass and the smallest one has 1.5 acres—climate seems to be more of a concern. As one of the owners stated, "People think that greenhouses are immune to climate. In reality, running a greenhouse requires huge investments in technology to monitor and control climatic conditions." Greenhouses are controlled by computer systems that monitor humidity levels, temperature, and irrigation and fertilizer application schedules.

Greenhouse owners and operators must have a vast experience in the industry. Those who have settled in the SSV have had many years of experience in the industry and have been trained in countries where greenhouses are common. Before moving to the SSV, Mr. and Ms. B were one of a group of growers helping each other. They would get funding for research. There were agricultural experimental stations and the government provided loans. In the SSV, the Bs are alone and it will take them a long time to fine-tune production. Because initial infrastructure for their greenhouse was expensive, optimal yields are required to recover the investment. For them, as for others in the same business, the greatest limitation has been financing, "Banks are not interested; they don't know about greenhouses. For banks, what I do is experimental and high risk, a novelty."

*Composite of multiple stakeholder experiences. Names have been omitted to protect privacy.

Rain can wash whitewash off the glass, so dry conditions are preferred. Large windows on the roof are opened for ventilation. When plants get bigger, transpiration will increase humidity and temperatures cool down.

During the summer, greenhouses are cooled through the use of high-pressure fog, evaporative coolers, or vents located on the glass roofs. Cold weather coming down the mountain at night is very important as cool nights are good for pollination. Monsoon rains that last until September can be problematic. Excessive humidity reduces the chance of cool nights and also may increase the risk of fungal infections. Better fruit is obtained when the monsoons are over. At this time, plants begin to produce one cluster of tomatoes per week. It is a vulnerable time for the plants because hot nights can interfere with fruit growth. Harvesting begins around the first of October and continues until July of the following year. Plants can live up to 13 months and grow up to 40 feet long. By October the whitewash is removed as the amount of light starts to decline.

Because of market conditions, winter tomatoes obtain the best price. In winter there is interplanting. On the 10th of December seeding is done again and three weeks later the small plants are planted under the old ones. From January to March the days are short and production declines. Although sunlight is consistent in the SSV, tomatoes are planted in rows running on a north-south axis, which allows for equal distribution of sunlight. When the sunlight is not evenly distributed, only fruit from one side of the nursery can be sold. During the winter of 2000–2001 there were more clouds and less light than usual. The average amount of light decreased by 10 percent and led to a 10 percent decline in production. Although fewer clouds mean more irrigation, it is estimated that a one percent change in the amount of light equals a one percent change in production.

Winter temperature also is an important factor. Coils filled with water at 100°F are used to heat the greenhouses. Cold winters are good for the plants, but costs of production go up because more gas has to be used for heating, especially when nights are clear. As one greenhouse operator explained, "Day radiation goes in and without clouds you lose heat." Greenhouses are heated throughout the year. Hot water is stored in tanks and pumped through the greenhouses in floor-level pipes. These heated pipes produce a small change in temperature that induces convection. This circulation of air helps prevent diseases.

By February whitewash has to be slowly applied again to prevent incoming radiation from burning leaves. Whitewash prevents the greenhouse from heating up too fast and causing the plants to experience "climate shock." One farmer commented, "The sun in Arizona is so strong, that the night and day transition is 15 minutes, while in Holland, it is two hours. So we use heaters to preheat for a short period of time before the sun comes up." By the second half of March, the January plantings begin to produce.

Market prices are very much influenced by Mexican tomato production. In 1999, for example, there were no frosts in Florida or Mexico, resulting in overproduction. Prices plummeted to a 30-year low level. Although greenhouse growers suffered, field growers "got killed." The mild winter of 2000 also led to high production in Mexico and reduced market prices.

Greenhouses are the most water-efficient operations found in the valley. Drip irrigation lines in the form of little spaghetti-like hoses branch off from a main line and are plugged into the rockwool of each plant. In this way, a lot more product is obtained per gallon of water used. As one greenhouse operator jokingly commented, "If the water table in the region gets too low then all the farmers should leave the fields and start greenhouses. They get more production per unit water."

Greenhouse operators predict that more greenhouses will arrive to the SSV, especially if costs of irrigation continue to increase. However, initial investment is so high and the management expertise required is so specialized that current operators predict that most will fail.

6.4.2 Perceptions of Vulnerability, Use of Forecasts, and Climate Information Needs

Even with their sophisticated technology and relatively low vulnerability to climate variability, this form of controlled-environment agriculture can benefit from seasonal forecasts. For example, with a four-month warning of the severity of El Niño or of a cool winter, the cucumber grower would be able to change his strategies to lower the impact of reduced sunlight and cooler nights by selecting different varieties that are better adapted to predicted temperatures and light. In his words, "With an accurate long-range forecast of temperatures I might decide to grow a different variety of cucumbers that has a different sensitivity to night-time temperatures."

Good forecasting information during the winter is of particular importance as the reductions in sunlight from winter storms, particularly those coming from the west, need to be countered in order to keep the greenhouse running smoothly. Greenhouse owners and managers reported watching the Weather Channel, CNN, and Tucson weather. They have no interest in paying for weather information, and commented that in Holland, climatologists are experimenting with the use of short-term forecasts.

6.5 Conclusion

Farmers in the SSV have decreased the impacts of climatic conditions on their agricultural operations through the use of various buffering strategies. Among the principal strategies identified are technological improvements involving farming equipment, managerial ability and experience, better climate information, and federal aid during times of need.

This analysis of different types of farming illustrates the importance of diversification in diminishing the overall vulnerability of agriculture to climate. Temperature and rainfall conditions of the SSV are conducive to the growth of numerous agricultural products and therefore enable the diversification process. Outsiders contribute to this process by bringing new ideas, technologies, and crops. For long-term residents of the SSV, diversification is partly a response to water scarcity and high water costs. Some row crop farmers, for example, are switching their fields to nut trees or grapes because these crops yield higher financial returns with less water. Vegetable farmers are experimenting with different crop varieties such as Kabocha squash or alternative production schemes, such as U-pick farms in order to make a living off the land. The trend to raise high-valued agricultural products that fit into niche rather than commodity markets is becoming increasingly important.

In terms of using forecasts, farmers willing to "gamble" on lettuce may be most interested in predictions of winter rain in other parts of the country. Pecan growers could also use seasonal rainfall predictions of other regions to inform their decision making. Greenhouse growers are interested in forecasts of winter temperatures and cloud cover to select specific crop varieties or adjust heating energy budgets.

Most agricultural decisions are based on years of experience or "gut feelings" about the weather, and most interviewees expressed skepticism in climate forecasts. However, this skepticism could be overcome by showing farmers the track record of regional climate forecasts and explaining the limitations inherent in predicting seasonal precipitation and temperature. Thus, climate forecasts have the potential to be another one of the myriad factors farmers take into account in making decisions.

7. Hispanic Farmers and Agricultural Migrant Workers

Not everyone within the agricultural sector in the SSV has had the same access to the adaptive resources described in previous chapters. In this chapter we focus on two of the most vulnerable groups of stakeholders in the region: Hispanic farmers and farm workers. We explore the relationship between ethnicity and climate vulnerability, building on preliminary observations that suggest that Hispanic farmers are more vulnerable to climate variability than other farmers in the SSV. We then discuss the case of farm workers, the vast majority of whom have extremely limited access to adaptive resources.

Even though the relationship between ethnicity and climate vulnerability *per se* has not been frequently addressed, it is possible to extrapolate from studies assessing the relationship between ethnicity and natural disasters to inform the current research. As is the case with climate vulnerability, vulnerability to natural disasters is measured by people's ability to avoid, cope with, and recover from negative events. Research on disasters describes the existence of particular at-risk populations who have been marginalized by economic, political, and social inequalities. As pointed out by Bolin and Stanford, "It is well-documented that environmental risks and disaster effects in the United States are distributed unequally by class, race, ethnicity, gender and age" (1999:91). Accordingly, groups with an increased vulnerability to disasters include low-income households, ethnic minorities, elders, and female-headed households (Bolin and Stanford 1999). Other characteristics identified by Bolin and Stanford that also impact an individual's vulnerability to disasters are language/literacy and migration/residency (1999). With the exception of gender, all of the factors are potentially relevant to the case of Hispanic farmers and farm workers in the SSV.

While the number of Hispanic farmers and farm workers involved in the current research is too small to allow for any conclusive findings, the data do reveal some preliminary patterns. Moreover, the tendencies discovered among Hispanic farmers and farm workers in the SSV offer direction for future research on the relationship between ethnicity, class, and climate vulnerability.

7.1 Hispanic Farmers: A Preliminary Assessment

A small percentage of the farms in the SSV are owned and operated by Hispanic farmers. Local residents estimate that 10 percent of the farmers in the valley are Hispanic, while an estimated 55 percent of the SSV residents are of Hispanic origin. In Cochise County there are approximately 61 Hispanic farmers, representing 16 percent of Hispanic farmers in the state and the second highest county concentration, behind Maricopa County with 66 Hispanic farmers (U.S. Department of Agriculture 1997).

The Hispanic farmers involved in our research were typically low-technology, resource-scarce producers, with historically lower access to land, government aid, and other system-wide adaptations. With one exception, the Hispanic farmers that we contacted were in financial trouble. Two families who had resided in the valley since the 1960s moved away after losing their crops during the October 2000 rains. We met another longtime resident farmer who recently stopped farming and was in the process of selling his land. We also learned of two Hispanic farmers who had recently stopped production and shut down their farms. 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 may increase their vulnerability to climatic conditions.

Using Bolin and Stanford's model of vulnerability, we evaluate social class, language/literacy, migration, and age as variables that impact the vulnerability of Hispanic farmers in the SSV. Social class as related to economic power is potentially significant when considered in terms of land ownership. Compared to other farmers in the region, Hispanic farmers own and actively farm smaller amounts of land. With the exception of one, Hispanic farmers in the region reported owning from 100 to 400 acres of land; the average for Cochise County is around 1,500 acres of land. Because less acreage is cultivated, each acre represents a greater percentage of the total crop and therefore any crop loss will have a greater impact on the farmer's overall profits. In a

Case Study: Hispanic Farmers*

Mr. E was born in Mexico. As a young man he cultivated corn and beans, and cared for cattle. He came to the United States with the bracero program (see page 70). As he explains, "They told me that dollars could be easily earned in the U.S., so I just came." In the 1950s he married a Mexican-American woman and settled in the SSV, where they raised their children. For many years Mr. E worked as foreman on different farms in the valley. In 1974, when agricultural land became cheap, the Es were able to get an FHA loan and purchased 80 acres of land on which they planted cotton. Years later they bought more farm land to raise mostly chiles, but they also produce corn, pumpkins, and watermelon. They also began leasing land for cattle and in the early 1990s they owned 200 head. For this family, cattle are viewed as a form of security in case crops fail.

The 1990s have been particularly difficult times for the E family. They rely on flood-furrow irrigation technology and their costs of production have increased dramatically with rising pumping costs, especially during drought years. As Mr. E observes, "The last five years have been very dry and…the water table has gone down." In addition, they lost chile crops to hail during two consecutive years in the mid-1990s. At the time they did not have insurance and did not receive disaster relief money from the government. Instead they were forced to sell most of their cattle. They have struggled to recuperate financially and recent climate events have only slowed their recovery. In 2000, they lost their squash and green chile crops during the heavy October rains. Like other Hispanic farmers, Mr. and Ms. E do not want their children to continue farming, but rather have encouraged them to find employment in Tucson and Phoenix.

*Composite of multiple stakeholder experiences. Names have been omitted to protect privacy.

comparable reference to natural disasters, Bolin and Stanford explain, "Although the middle class and the wealthy generally experience greater absolute disaster losses in dollar terms than do the poor in U.S. disasters, in relative terms, the poor generally lose a larger percentage of their material assets and suffer more lasting negative effects" (1999:92). Given the localized nature of climatic events in the valley (i.e., hail and monsoon rains), the ability to cultivate a large amount of land is an important strategy for minimizing the impact of climate-related damage.

Owning less land also is a limiting factor in terms of a farmer's ability to adopt certain technologies and to gain access to capital. In the SSV, all but one of the Hispanic farmers interviewed continue to use flood irrigation technology. The failure to install center-pivots is attributed to both lack of capital and the lack of the necessary large plots of contiguous flat land. Lack of capital also has prevented the adoption of drip irrigation, an effective method for minimizing water costs and increasing the efficiency of water use for small vegetable producers.

A second factor that may increase the vulnerability of Hispanic farmers involves issues of language and literacy, particularly when language and literacy abilities present obstacles to information and resources in critical times. While the current research did not specifically explore these themes, interviews with Hispanic farmers did indicate that language and literacy represent a possible obstacle for averting, 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. One of the Hispanic farm owners with limited proficiency in English explained that he had applied for a government loan in 1999, but his application was rejected because he had not filled out the form correctly. Another one stated that he did not like to apply for government loans, noting that it is difficult for him to fill out the forms in English. A related issue that warrants further research is the level of computer literacy among Hispanic farmers. Computer literacy is an important tool for accessing climate and weather information; only one Hispanic farmer reported using a computer to obtain forecasts.

A third factor that may impact the vulnerability of Hispanic farmers relates to migration and residency. Whereas all of the Hispanic farmers interviewed were U.S. citizens, several were born in Mexico. This issue may be relevant when assessing climate vulnerability. According to Bolin and Stanford, immigrants often face increased challenges in recovering from disasters. They describe an "abrasive anti-immigrant discourse" in state politics and notes that even legal immigrants are at times ineligible for certain types of government assistance. The impact of immigrant status for farm owners remains to be explored in detail. Although Hispanic farmers often maintain that they have the same credit opportunities as any other farmer, they also believe that government is often suspicious. As one farmer commented, "They [government agencies] don't want you to be asking for money because they are always suspicious that you are laundering money." As discussed in chapter 4, Hispanic farmers receive substantially less money from the government through farm subsidy payments.

The final factor that may impact the vulnerability of Hispanic farmers in the SSV is age. Bolin and Stanford report that elderly households may lack the physical ability to avoid rapid-onset disasters and the mobility to acquire recovery resources (1999). Based solely on observations, the average age of the Hispanic farmers in the region appears higher than the overall average age of farmers regionally. Anecdotal evidence suggests that the Hispanic farmers entered the industry as part of the family trade. However, the majority of the Hispanic farmers interviewed explained they had explicitly directed their own children away from farming and toward other professions, believing farming in the SSV holds a bleak future. As a result, most of the Hispanic farmers are in their 60s or 70s, and most of the Hispanic-owned family farms in the valley may cease to produce beyond the current generation.

The use of informal social networks[13] has been an important coping strategy that Hispanic farmers use regularly to mitigate the impacts of climatic conditions, to improve their capacity to deal with climatic extremes, and to optimize their economic situation. Social networks function to reduce production costs, increase profits, serve as an insurance mechanism, and allow for the transmission of weather and climate forecasting information. Although we believe that social capital is an important resource to all stakeholders, and we have hinted at its importance for Anglo farmers in previous chapters, it is particularly relevant to understanding the situation of those who are most vulnerable. In contrast to Anglo farmers, Hispanic farmers tend to have more significant social ties with farm workers whom they typically contract directly, rather than relying on labor contractors. By utilizing their own social networks to fill their labor needs, they eliminate the expense of labor contractors and reduce their overall production costs. In reference to weather and climate, it is common for farm workers from Mexico or other regions of the United States to call Hispanic growers by phone ahead of time to find out about forecasts or actual conditions in relation to work opportunities.

In addition to the use of social networks to meet labor needs, several of the Hispanic farmers interviewed also capitalize on social ties to obtain loans. Several farmers mentioned that they prefer to rely on informal loans provided by "friends and acquaintances" than to apply for government loans. Social networks also are important in the market context. They report having well-developed market ties with Mexican growers, Mexican brokers, and both Mexican and Mexican-American clients. For example, *elote*, or white corn used to make tamales, is grown exclusively by Hispanic farmers. This corn sells at a much higher price than yellow corn that is produced as livestock feed. Elote must be hand picked and, although it offers higher profits than yellow corn, it involves increased risks because it must be harvested at precisely the right time, when it is not too dry and not too moist. If it becomes too dry it can be sold as livestock feed, but at a much lower price. The clientele is almost exclusively Mexican and the purchases are typically described as exchanges among friends. One Hispanic farmer explained, "I sell some of my elote, chiles, and pumpkins to a friend who sells on 12th Avenue in South Tucson." Social ties become increasingly important during years when elote production is limited by poor climate conditions, including extended periods of high heat and low precipitation. During years of poor production in the SSV, Hispanic farmers rely on personal contacts with friends, growers, and brokers to facilitate the purchase of elote from Mexico, which is then resold to clients in the United States.

Hispanic farmers acknowledge a strong network among the local elote producers themselves. If one grower cannot fill an elote order at a given time, he may ask another farmer to cover the order. Given the delicacy of elote with regard to the time of harvest, such social ties offer an important form of insurance. The social ties function to minimize the risks associated with slow or off-timed production, as well as crop damage from climate conditions, and in this way protect farmers from losing clients due to unfilled orders.

As already mentioned earlier, one Hispanic farmer in the SSV did not fit the general description outlined in this section. This farmer differs from other Hispanic farmers in several ways. Not only does he own over

1,000 acres of land and has nine center-pivots, but he is in his 30s, has a Master's degree and is a third-generation U.S. citizen. This farmer has the advantage of being able to access both worlds. On the one hand, he has the education and English proficiency to be able to capitalize on the system-wide adaptations described in previous chapters that buffer farmers from climatic events. For instance, he obtains forecasting information from satellite maps on his computer, and sometimes uses his neighbor's (an Anglo farmer) DTN system to find out about weather and climate. On the other hand, he also is part of the informal network of Hispanic farmers and farm workers. When asked about his success as a Hispanic farmer, he responded: "Being a Hispanic farmer was more difficult at first, to start up, especially in terms of getting a first loan, which is like pulling teeth. But today my banker makes no difference between me and an Anglo. Racism was a problem 20 years ago. Now banks are just interested in whether or not you will be successful when they decide whether or not to give you a loan." In this farmer's view, one of the major differences between Hispanic and Anglo farmers is that most Hispanic farmers have been involved in farming all of their lives, "We worked when we were kids—hoeing, weeding, driving tractors. I know the stuff from the bottom up." In contrast, he believes that Anglos learn farming from a different point of view that emphasizes economics, profitability, and technology, and, he concludes, "Today, a farmer has to be more of a businessman than a farmer."

This farmer is much more economically stable than the other Hispanic farmers we encountered. The fact that he owns more than 1000 acres of land not only offers increased opportunities for profit, but also allows him to spread risk from climatic events across a larger crop area, thereby reducing the significance of any localized crop damage to his overall profit. Moreover, his access to capital and his high level of "literacy" (including computer literacy) allows him to take advantage of additional buffering strategies—beyond those offered through social networks—such as improved irrigation and forecasting technology. This farmer's case offers support to the argument that class (represented by land ownership), language/literacy, migration, and age may impact climate vulnerability.

7.2 Migratory Farm Labor

In contrast to farm owners, farm workers have not benefited from system-wide adaptations or from technological advances. Farm workers typically lack access to credit and insurance and are seldom eligible for either disaster relief funds or other government aid programs for the agricultural sector. In fact, in most cases technological innovations have produced negative consequences for farm workers by reducing the demand for labor. The apparently successful adaptation to the natural environment by the agricultural system as a whole, has largely neglected farm workers and their vulnerability to climate variability remains extremely high.

Before discussing the impact of climatic conditions on farm workers in the SSV, it is useful to briefly review their general socioeconomic status and the historical context in which current migration patterns developed. The migration of Mexican farm workers to the United States is not a recent phenomenon. Rather, contemporary migratory patterns were firmly established during the early 20th century. Early U.S. immigration policies reflected a pattern of recruitment and repatriation based on domestic labor demands. Workers were recruited and welcomed as laborers during periods of economic expansion or labor shortages, but were never integrated as permanent members of the U.S. society (Garcia y Griego 1980).

Mexicans began migrating to work in the United States in large numbers in the late 19th century. The reign of Porfirio Diaz (1872–1911) in Mexico left nearly 97 percent of peasant families without land (Massey et al. 1987). Many of these landless peasants migrated north into the United States where job opportunities expanded as the agricultural, mining, and railroad industries developed. Demand for labor in the United States fell during the Depression years and as many as one-half million people, including U.S. citizens of Mexican descent, were deported to Mexico.

With the development of irrigated agriculture in the early 1940s and World War II, the need for labor rose once again. Fearing labor shortages, vegetable and cotton growers in California, Texas, and Arizona lobbied for the creation of the bracero program, which provided a solution for labor needs through the issuance of temporary work contracts to Mexican farm workers. The program, which lasted 22 years (from 1942 to 1964), ultimately resulted in the issuance of nearly five million labor contracts to Mexican men. As one observer remarked, "For the growers the program was a dream: a seemingly endless army of cheap, unorganized workers brought to their doorstep by the government" (Calavita 1992).

The bracero program was officially terminated when increased mechanization in the U.S. farming industry raised productivity while reducing the per-unit demand for workers and shortening the harvest season. However, the legacies of the bracero program are numerous and have long outlived the official duration of the program. Among the most obvious are the patterns of agricultural labor migration established through social networks between Mexican farm workers and U.S. growers, as well as among farm workers themselves (Garcia y Griego 1980; Weaver 2001). Furthermore, the program institutionalized the low wage and poor working condition standards that continue to characterize the experiences of Mexican farm workers today.

A second immigration policy with ongoing impacts on workers and the agriculture industry was the Immigration Reform and Control Act (IRCA) of 1986. Its basic strategy was to legalize some of the undocumented workers already in the United States and then to reduce future undocumented immigration by imposing strict sanctions against employers who knowingly hired them. However, an additional program, The Replenishment Agricultural Workers program, ensured the availability of replenishment workers, should the number of workers legalized not be sufficient to meet labor demands (Heppel and Amendola 1992). Like the bracero program, IRCA reinforced labor migration patterns—including undocumented immigration—and strengthened the social networks that provide the foundation for migration, as well as upheld the wage and working condition standards established during the bracero program.

7.2.1 Current Socioeconomic Conditions

During a typical year the U.S employs over 2.5 million farm workers, predominately for 3- to 10-week harvest jobs in the fruit, vegetable, and horticulture industries. The U.S. Department of Labor's National Agricultural Workers Survey presents a useful profile of contemporary U.S. farm workers. The data, gathered through a random sample of farm workers from 1988–1995, indicate that nearly 70 percent of farm workers are foreign-born and of the foreign-born workers, 94 percent were born in Mexico. More than 80 percent of the farm workers are men, and most are married and have children either in Mexico or in the United States. The average yearly income from farm work was reported to be between \$2,500 and \$5,000; among undocumented workers, more than 80 percent live in poverty (Mines et al. 1997). In the past two decades, farm workers' real wages have fallen 20 to 25 percent—and up to as much as 40 percent in a few crops (Rothenberg 1998). Despite the widespread poverty, few farm workers—documented or otherwise—use social service programs (Mines et al. 1997).[14]

Farm workers also suffer from persistent health problems. The combination of low socioeconomic status, a mobile lifestyle, and, in some cases, undocumented immigration status makes it difficult for farm workers and their families to obtain comprehensive healthcare. Use of preventive health care services is rare; most medical services sought by farm workers are limited to emergency situations. Only six percent of farm workers have health insurance. Many of the common health ailments suffered by this population, and particularly by farm worker children, are preventable. Common problems include malnutrition, infectious diseases (both respiratory and diarrheal), dental cavities, pesticide exposure, and accidents due to the nature of farm work itself (Morrison et al. 1995).

Access to adequate housing represents an additional challenge for Mexican farm workers. Few employers provide on-site housing; instead farm workers typically stay in cheap motels, tents, cars, or in open fields. Overcrowding and the lack of access to drinking water, toilets, bathing, and laundry facilities are common problems associated with farm worker housing.

In addition, farm workers' children face formidable challenges in accessing a relevant education. The national high school graduation rate for children of farm workers is 55 percent, compared with the overall national average of 88 percent (National Center for Farmworker Health 2001). The lack of physical stability inherent to the migrant lifestyle is a major concern as children are frequently moving and changing from one school to another. The consequence is that students often either repeat, or completely miss large sections of the curriculum (National Commission on Migrant Education 1992).

Thus, before even considering the obstacles created by climate, it is apparent that farm workers are already a vulnerable population. Their vulnerability is connected to such factors as poverty, health problems, inadequate housing, educational obstacles, frequent mobility, lack of proficiency in English, undocumented legal status, a lack of awareness of rights, and limited means of transportation. As a consequence of their disempowered position, climatic conditions have an increased impact on this group of stakeholders.

7.2.2 Case Studies: Migrant Workers in the Sulphur Springs Valley

Among Mexican farm workers in the SSV, there is substantial variation with regard to home bases, migratory circuits, immigration status, and work patterns. There are approximately 1,780 people employed in the agricultural industry in Cochise County. This includes 330 seasonal orchard and packing plant workers, 300 permanent greenhouse workers, 350 permanent field hands, and an additional 800 migrant farm workers (Clark and Dunn 1997). To this must be added an unknown number of illegal workers that arrive to the area during the harvest season. Among farm workers in Cochise County, a distinction is made between migrant and seasonal workers. Migrant laborers typically have legal immigration status, are bilingual, and maintain a home base within the United States, often near the border. Some migrant workers follow the harvest within Arizona, typically traveling between Yuma, Eloy, and the SSV, while others travel to New Mexico, often to work on chile farms near Hatch and Deming. Still others travel as far as Colorado, California, and Montana, following different crops including beets, potatoes, squash, pumpkins, cantaloupe, chiles, apple, and radish. Some circuits extend as far as Texas and the East Coast, including citrus farms in Florida.

By contrast, seasonal laborers in the SSV are predominantly undocumented workers who maintain a home base in Mexico, often in Agua Prieta, where they return each day. Although their number is unknown, they constitute the majority of farm workers in the valley. Typically, a labor contractor picks them up at 3:00 or 4:00 a.m. at the border, and they are taken to the fields where work starts at sunrise. They are returned to the border in the afternoon, usually by 3:00 p.m. They spend the night in Agua Prieta, living either in a home or temporarily in hotels while the season lasts. Seasonal workers usually do not speak English and come from all over Mexico including Oaxaca, Chiapas, Chihuahua, Sonora, Jalisco, Sinaloa, and Zacatecas.

Local farm workers acknowledge a tension between migrant and seasonal workers. Undocumented seasonal workers, they argue, often agree to work under poor conditions and for lower wages than documented workers. As a result, standards for working conditions and payment are lowered for all workers. As one migrant worker explained, “Many people come to work without papers. There are too many and the work gets finished faster and then we are struggling to make ends meet.” He continued by describing the situation on one farm in the region, “The *patrón* hires about 300 people during the peak of the chile harvest. But imagine he [the farm owner] hires on average 220 to 240 illegals [sic] because they are willing to work for such low wages and under such poor conditions. So that only leaves about 60 to 80 jobs for us with the papers. And with 300 of us working in the fields that will mean only four or five hours of work a day.”

Case Study: Interactions with Migrant Workers*

The workers start coming about three to five days before the chile harvest, between the 10 and 15th of August. They come from all over Mexico: Oaxaca, Veracruz, Mexico City, Guadalajara, and Sinaloa. A lot of them come to work for one specific grower. They live in the fields—in cardboard boxes, tents, or in the farm sheds if the owners will allow it. Sometimes after walking across the border for two days or so they will pass by my house and ask for a cup of coffee or something and I’ll usually give them something to eat. A lot of old-timers come from their little towns, they’ve been coming here for years, they already know when and where there is work. They start bringing the younger guys with them to work. A lot of them work the season here and then they have enough money to go back home to their little town and can live off of the money they made here until next season. Some of them hold their money to take home, some of them send it home directly, and some drink it away (Female farm worker, personal communication 2000).

They are really immobile and have to stay in the fields all the time. Sometimes they’ll ask me if I can go grocery shopping for them and they’ll give me the money and the shopping list and it’s not like I’m going to say no and let them starve in the field. Sometimes they’ll ask me to get them blankets or whatever they need and they pay for everything. When they want to go home a group of about 10 of them will offer me $20 each to take them down to Agua Prieta, but Immigration could put me in jail for doing that so I don’t do it. But usually I’ll hook them up with someone that can (Female farm worker, personal communication 2001).

*Composite of multiple stakeholder experiences. Names have been omitted to protect privacy.

For both migrant and seasonal workers, the process of labor migration from Mexico to the United States typically follows one of three patterns. Workers can be contracted through formal farm labor contractors, informal contractors, or simply through social networks and word of mouth. There are five formal contractors, or Farm Labor Contractor Employees, operating in the region. Workers also can be contracted through informal contractors, of which there are an unknown number. Local residents estimate that there are at least 11 informal labor contract "companies" operating in southeastern Arizona. The agencies are described as fly-by-night operations and residents note that it is very easy to sign up, get a license, and call yourself a contractor. A farm owner who employs undocumented workers can incur substantial fines. Ultimately, it is the farmer, and not the contractor, who is responsible for any legal violations.

Contractors provide the link between growers and farm workers. For a specified amount of money paid by the farm owner, contractors locate farm workers, arrange contracts, check immigration papers, and even drive vans to transport workers to and from the fields. Farm owners depend on labor contractors, especially in the fruit and vegetable sectors, to fulfill their labor needs by providing sufficient workers in a timely manner. Seasonal laborers traveling from southern regions of Mexico are often in contact with labor contractors from their home base. A local labor contractor explains, "As soon as the chile season is about to begin, at the beginning of August, people start calling me from their homes in Oaxaca, or from the fields in other parts of the United States. In August they call me to see when the chiles will be harvested and in May they call me again to see when there is work thinning and weeding."

Most farm workers rely on social networks and word-of-mouth to secure employment.[15] Ties to current or former U.S. migrants, including bracero-era workers, are a valuable social asset that can be used to reduce costs and minimize risks through information and assistance, especially related to employment opportunities. Workers often learn about jobs from friends or family, or directly from relationships with individual farm owners, especially with Hispanic growers. One male migrant worker offered an example of the impact of the development of social networks among farm workers employed in the SSV, "This is the way it works," he explains, "Let's say an old guy from a small town in Zacatecas comes here to work, he first figures out where to stay and when to come and work. Then the next year he'll bring like 10 guys from the same little town and then the year after that 40 of them will come together."

While they are working in the SSV, farm workers often stay in cheap, local motels that have been converted into mini apartments with kitchenettes. Some laborers will camp out in the fields or in ditches. Farmers often report seeing evidence of workers living in the fields, including personal items, footprints, and soap near the irrigation pivots where people bathe. Many workers stay overnight in Agua Prieta, Mexico because the cost of living is much cheaper. Still others have settled in the region and have homes in the SSV. Despite lower job opportunities, these workers generally decide to settle in order to provide stable schooling for their children.

The most obvious obstacles for farm workers in improving their economic situation are the low wages and unstable work. Typically workers are paid on a daily basis because, according to locals, "Workers never know if they are going to be picked up by the INS." While some workers are paid an hourly wage, many receive payment based on a per piece system. As an example, workers in the SSV are typically paid $.60 per bucket of chiles. One worker fills an average of five to seven buckets per hour, meaning she earns between $3.00 to $4.20 an hour. On an excellent day, however, a worker could earn $50 to $60 harvesting chiles. When considering wages, it is important to remember that the work, especially harvest work, is dependent on the production of a viable crop, and on weather conditions that permit the work to occur.

7.2.3 Weather and Climate: Impacts and Adaptations

Farm workers adjust their work strategies to seasonal changes and crop production. Demand for labor concentrates in the harvest season, from August to December. The rest of the year work is sparse and unstable. The months of January to March are particularly difficult. A few workers are employed by lettuce growers for the weeding and thinning of winter lettuce fields, and by pecan growers for orchard pruning. During this time, farm workers typically try to find nonagricultural employment, often in either Douglas or Sierra Vista. From April to June there is some work thinning peach and apple trees. In May, the demand for agricultural labor increases somewhat. The harvest of winter lettuce

Case Study: Impacts of Weather and Climate on Migrant Workers*

J is in his mid-50s and was in Willcox for the chile harvest in September 2001. We met him in the parking lot outside the rundown hotel where he was renting a room for the harvest season. On that day he had left early in the morning to harvest chiles at a nearby farm. However, because of high summer temperatures and low rainfall, the chile crop was very poor. The entire crop was harvested in a few hours and by the time the work was complete, J had earned only seven dollars. With no other options, he returned to his hotel to await better luck the next day. Sitting in a lawn chair in front of his room, J explained that because of the poor chile harvest, he did not have enough money to buy food and had to go to the local Food Bank for free handouts. Nor had he been able to pay for his hotel room for the past three weeks. Furthermore, J has a chronic illness. He rarely earns enough money to buy the medicines he needs or to see a doctor.

After finishing with the chile harvest in the SSV, M couldn't find employment locally. M resides in the SSV, where she is raising her three children by herself. Because she wants stability for her kids, she does not consider the option to migrate elsewhere. She decided, then, to commute on a daily basis to Rodeo, New Mexico. She leaves her home at 2:30 a.m. and arrives in Douglas at 3:10 a.m. From there she rides with 13–14 other workers on the free van to Rodeo. There are other vans but each laborer must pay the contractor $5 for the ride. Work starts at 5 a.m. However, when it drizzles, work has to be stopped and workers have to wait until the weather improves. At times, because of the weather, they can only work for an hour. Their entire day is lost, and they return to Douglas having earned only one hour's pay. Work in Rodeo lasts until the end of July. Then M starts going to Animas, New Mexico, on one of three vans that take workers from Douglas to Animas to harvest jalapeño peppers.

*Composite of multiple stakeholder experiences. Names have been omitted to protect privacy.

employs some farm workers, usually 40 to 50 in a large field. There also is some work thinning and weeding chiles. During June and part of July the onion harvest provides some work opportunities that can last from 5 to 10 weeks. However, the onion harvest does not require a large number of workers and is at constant risk of rain damage. Many workers have a hard time finding jobs in the valley and most look for employment outside of the SSV, in the Eloy, Phoenix, or Marana area, or in non-agricultural jobs.

The peak of activity occurs during the harvest season. Starting in August, fruit orchards hire large numbers of farm workers (more than 200). The chile harvest requires a large pool of workers and with it, migrant workers begin their "corrida," moving along a circuit through Elfrida, Kansas Settlement, Bonita, and then to San Simon in Graham County. Summer lettuce, squash, and other vegetables also are harvested in the fall and require a large labor pool. At this time, workers also are hired to pick, sort, and shell nuts.

Savings acquired during the agricultural season are important to subsist during the off-season. During the fall harvest, farm workers are able to buy extra supplies, such as food, which they save for use during other periods of the year when work is harder to find. Workers also typically save money to cover other expenses during low employment times. As one migrant worker commented, "Savings are important during this time of the year [the fall and winter], also storing food. Starting in about September we start buying large quantities of beans, rice, flour, lard, and vegetables. We go to the places across the line in AP [Agua Prieta] where they sell you things wholesale." Another worker further emphasized the point, "When I'm working and I have a bit of money left over I start buying extra food for the winter months when there is no work. I'll buy extra canned food and big 50 pound bags of flour, beans and rice. When I'm working in the fields I'll bring home some of the food from the fields. Like I'll bring home big sacks of pounds of onion. Girl, you don't even know how tired we get of eating onion."

Even when there is work in agriculture, some workers will seek to supplement their income by pursuing entrepreneurial endeavors, such as selling food to other farm workers during the lunch break. Sometimes one of the household heads will find work in agriculture and the other one will seek employment elsewhere, possibly cleaning houses, for example.

A limited number of farm workers use government aid programs to lessen the effects of seasonality in crop production. As one woman reported:

> I do get food stamps sometimes during the winter months and I get WIC for the little girls. They have had WIC since they were born and will get it until they are five years old. They give me milk, cheese, juices, peanut butter, and cereal. But I have to miss work when it's time to go and get the WIC checks because they give you an appointment to go pick up the checks. In order to qualify for WIC you have to go every three months and take all of your check stubs to prove you still qualify for WIC.

However, use of government aid is not typical among farm workers in the SSV, even among those with eligible immigration status. Many migrant workers also are eligible to collect unemployment pay between January and March, but the general consensus is that it is more productive to find a job because unemployment checks are so small. For example a family of four may only receive $75 per week in unemployment compensation.

The impact of unforeseen climatic events that negatively affect the harvest of crops can be devastating to farm workers, particularly for those who migrate from distant areas in southern and central Mexico. These laborers incur considerable expenses to arrive at the agricultural region where they expect to find work. When climatic conditions delay or damage the harvest, their wages are compromised, they are unable to send remittances to their families in Mexico, and they must continue to pay for their living expenses while away. The heavy rains in October 2000 resulted in substantial damage to the chile crops. Because of the sudden onset of the rains, farm workers did not have time to travel to another region to find work, but instead were stranded in the SSV as the rains destroyed their work opportunities. As one migrant worker said, "If I had climate information that told me it was going to rain most of the harvest, I might just have gone to work at Burger King."

Climate and weather also have a dramatic impact on the health and well being of farm workers. Because they work and often sleep outside, workers and their families are more susceptible to the dangers of rain, floods, lightning, extreme heat, cold temperatures, and Valley Fever. The severity of these climatic threats is augmented by the fact that farm worker housing often lacks safe drinking water, bathing, or laundry facilities and even adequate sanitation (National Commission for Farmworker Health 2001). The health dangers of constantly working and living outside during periods of extreme heat, for example, are intensified if workers do not have access to safe drinking water to avoid dehydration.

The only health services available to farm workers in the region are provided by the Chiricahua Health Center, which opened near Elfrida in 1996. Prior to 1996 there was no health center in the region. Migrant workers do not often go to the center itself (perhaps, in some cases, because it is located near a Border Patrol checkpoint). Since 2000, health care workers have gone out into the fields in a van to provide services to migrant workers. They bring clothes, basic medicines (i.e., Tylenol), and water to the workers as well as providing them with both flu and tetanus shots. Additional medical care is typically limited to emergency cases.

Furthermore, because of limited transportation and in some cases fear of the Border Patrol, many farm workers do not have regular access to food supplies, further magnifying the health threats of negative climatic conditions and events. At times severe weather conditions make the dirt roads in rural areas impassable, leaving farm workers unable to relocate to regions with more work opportunities. One Mexican farm worker with official work authorization documents commented, "The illegals do have it pretty bad, they really can't move around or else Immigration might get them. So if there is a lot of rain or something they have to either wait for it to pass or else go to another area like Eloy or Pearce. When they need groceries they have to count on a documented worker to go to the store for them."

Despite the multiple limitations created by economic constraints, farm workers have developed strategies intended to minimize their vulnerability to weather and climate. Social networks, for example, play an important role in the transmission of critical information on climate and crop conditions. Farm workers are constantly exchanging information regarding which regions and even which farms have good crops, and where production is poor. Social networks tend to be well established, especially within a particular geographical circuit. As one farm worker explained, workers who live in Mexico or other regions of the United States hear about the harvest conditions from workers who have already passed through a given area. For example, the number of farm workers in the SSV in the fall of 2001 was significantly less than usual because many workers had already heard about the April frost (discussed in chapter 5) and the damage to the fruit crops. Many decided not to go to the SSV at all, but rather looked for work in Texas, Colorado, or other regions of Arizona. Such travel decisions are critical in determining their economic well being as an uninformed decision can result in significant transportation, housing, and food costs without generating any income.

In general, social networks are most effective in mitigating the impact of climatic events when they are forecasted more than a week or two in advance. Advance warning allows workers to pursue alternative strategies, such as finding work outside agriculture. As one worker told us, “Everyone, but I mean everyone, tries to get work in either the stores or McDonald’s or wherever you can work for a little while. I’ve worked cleaning hotels for a couple of days or weeks at a time. There is a cannery around here called Fiesta Canning and they can artichokes, green chiles and tomatillo. Sometimes they guarantee you a full five days of work, which can be better than going three days to Animas [to harvest].”

The availability of more permanent employment in local greenhouses has been an important strategy to minimize the negative impacts of climate variability. One man who worked as a migrant laborer for over 15 years, obtained year-round employment at a local tomato greenhouse. He described the stability of the greenhouse position, noting that he now earns much more money, enough to buy a house and a nice car, and he has health and dental insurance. Other workers find more stability in year-round maintenance jobs. One farm worker who is employed by a local orchard for year-round tree maintenance (i.e., pruning, etc.) explained that the April frost did not have nearly as much of a negative impact on him compared to the workers who depend solely on the harvest for employment. However, year-round jobs are very difficult to find in the SSV.

While the entire agricultural industry in the SSV experiences vulnerability to climate conditions, Hispanic farmers and farm workers are at a greater risk. Throughout this chapter we have emphasized how lower access to adaptive resources (e.g., technology, government support, credit) results in greater vulnerability to climatic variability. A focus on the relationship between ethnicity and vulnerability has been instrumental in highlighting the factors that limit the capacity of specific groups of stakeholders to buffer against climate variability. Our analysis in both cases, however, is preliminary and more in depth case studies on vulnerability and adaptation are required. While already existing social networks are central to the dissemination of improved climate information, more formal mechanisms need to be established.

8. Conclusions

Groundwater-dependent agriculture in the U.S. Southwest has undergone profound transformations over the past 50 years. These transformations reflect a process of adaptation to the range of factors that define the vulnerability of different livelihood to climate variability. In the assessment presented here, we have emphasized how farmer responses to climate variability are intertwined with such variables as input prices and markets, agricultural policy and financing, hydrological conditions, crop choice, access to technology and climate information, and the managerial skill of individual farmers.

This report documents the nature of vulnerability to climate variability in a groundwater-dependent agricultural valley. The history of the SSV reveals that climate vulnerability has changed through time. Current farming livelihoods are the result of decades of adaptation to a semiarid natural environment characterized by low and erratic annual precipitation, strong seasonal variation, frequent droughts, and occasional floods. The process of agricultural adaptation has been cumulative and has engendered a complex set of public and private strategies for mitigating climate impacts. This iterative process has led to the development of important buffering strategies, which have changed farmer perceptions of their own vulnerability and of the importance of climate in decision making.

8.1 General Adaptations

Today, as in the past, access to water continues to be the principal limiting factor for farm owner/operators in the region. Because the availability of irrigation water is largely determined by the depth from which it has to be pumped and associated costs, technological innovation has focused on the efficiency of water extraction and use. Since the beginning of commercial farming in the region, farmers have struggled, with varying degrees of success, to keep water costs down in order to remain competitive. Today, center-pivots, sprinklers, and drip irrigation devices lead to a more efficient use of water and allow farmers to better regulate irrigation schedules in response to plant requirements. Such technological innovations as frost-control technologies buffer farmers at critical times against the possible devastating effects of extremely cold temperatures. Diversification in crop production and marketing strategies also are important adaptation strategies. By using crops that require less water, for example, farmers are able to decrease production costs and may fare better during periods of extended drought.

Larger societal-scale adaptations also influence farmer perceptions of their own adaptive capacity. Decisions to diversify or adopt new technology may be influenced by government programs that include low-cost loans, market-loss assistance, and subsidy programs. Hail insurance, government-subsidized crop insurance, and disaster payments further help mitigate risk. The cumulative impact of the different buffers provided by technology, policy support, and industry-wide market forces has contributed to a general sense that the vulnerability of irrigated agriculture to climate variability is substantially reduced.

This report emphasizes that climate and weather information also play a role in reducing farmer vulnerability and that it has the potential to become an increasingly important part of decision-making processes. Although we found that stakeholders generally are skeptical about the reliability of weather and climate forecasts, they are still a part of farm management strategies, and the tendency is for farmers to combine information from forecasts with their own personal experience. In this sense, those who have been in the region for a long time and have come from farming families are at an advantage, as are those with access to the Internet. We found that most farmers subscribe to the DTN service and obtain 24-hour and up to 90-day forecasts. The National Weather Service web site is visited often, and satellite images on the web are monitored frequently. Farmers interested in frost forecasts have grouped together to purchase information from a private meteorological service. Most farmers consult the Weather Channel every night, and others simply call neighbors to find out about the latest forecast.

8.2 Particular Vulnerabilities

The diversity in agricultural systems in the SSV has allowed us to explore the vulnerabilities of different types of farmers and agricultural workers. Excessive rain can make fields inaccessible for harvesting, prolonged drought can make irrigation costs exorbitant, rains can affect decisions about when to plant and harvest, and climate patterns in other parts of the United States can affect the profitability of local agriculture. However, the impact of climate variability is not uniform, because some farming livelihoods are more vulnerable than others. Each crop is susceptible to particular climate and weather-related events throughout its life cycle. Frosts and warm winters are a problem for orchard growers, whereas low summer precipitation is a major concern of corn farmers. Vegetable growers prefer aridity to rain so that they can control pests, molds, and disease, and greenhouses are mostly concerned about solar radiation. Labor requirements also vary significantly depending on the crop, available technology, and the timing of very specific climate-related events.

An emphasis on ethnicity, especially in a society where the dominant culture provides most of the climate information, helps explain how and why some sectors have been more successful than others in buffering against the vagaries of climate. This study underscores the disadvantaged position of Hispanic farmers and migrant workers relative to Anglo farmers. In the case of Hispanic farmers, we looked at social class, language/literacy, migration, and age as variables that impact their vulnerability. The Hispanic farmers in our sample were mostly low-technology, resource-scarce producers, with less access to land, forecasting information, government aid, and other forms of institutional support. Farm workers were identified as an even more vulnerable group. Climate extremes generally limit their mobility, undermining one of their key strategies for mitigating the negative impacts of climatic variability. The reduction of work hours, due to extreme climatic events, is a constant threat, and long-term exposure to the elements can result in both illness and injury. This vulnerability is magnified by the lack of secure housing, inadequate sanitation, and inconsistent access to medical services.

Despite multiple limitations, Hispanic farmers and farm workers rely on complex social networks as coping mechanisms that help them deal with climate variability. For farm workers, the use of informal weather forecasts transmitted through social networks is a key strategy. There also is a constant exchange of information on crop conditions by region and even by farm. These networks tend to be well established, especially within a particular geographical circuit and encompass geographic regions in Mexico and in the United States.

8.3 Buffering and the Physical Environment

Another theme explored in this assessment is the impact that current buffering strategies might have on the physical environment. Even though the future of the industry is contingent upon the continual recharge of the regional aquifers, groundwater withdrawal rates continue to exceed recharge. Little is known about the impacts of overdraft in the region, or about how much water is available and how long it will last at the present rate of exploitation. Farmers point to advances in irrigation efficiency as a critical component of the future of agriculture in the SSV. But while technology has reduced short-term vulnerability to drought, it also may be increasing vulnerability to multiyear droughts, which lower the water table and substantially increase pumping costs. At the same time, government assistance programs have led to a perception of decreased risk. We question the viability of such adaptations and their long-term impact on the natural environment. Are these programs, in fact, buffering farmers to the point where they discourage adaptations to changing natural conditions at the farm level?

The longer-term sustainability of currently successful buffering mechanisms requires further review and a great deal of further research. However, the lack of information on regional aquifers makes it difficult to determine whether or not there is a real divergence between stakeholder-perceived vulnerability and actual vulnerability. Currently potentially cultivable land in the valley is estimated at more than twice the actual cultivated land, suggesting there is not much concern about climate and its impact on the water table. A few farmers, however, did express interest in longer-term changes in climate that would affect the water table and, thus, the overall profitability of agriculture in the region.

8.4 Stakeholder Needs for Climate Information

For the most part, however, stakeholders expect and have adapted to changes in annual average climatic conditions and concern about these changes is relatively low. Unexpected and short-term extreme climatic events, however, are a common preoccupation. Frost, heavy rain, strong winds, hail, and floods can be more damaging than a season-long drought. There is great interest in better forecasts of an unusual event and forecasting information that ties climate to specific events. Stakeholders also emphasized the need for climate information, including historical data, more finely tuned to the local area.

Stakeholders also expressed interest in understanding monsoon variability and onset of the monsoon precipitation. A 90-day outlook of a wetter-that-normal summer, for example, may lead a diversified farmer to plant more corn and less chiles or a farm worker to change his/her migration schedule. Knowing climate forecasts for competing agricultural regions around the world also is valuable information because it might impact marketing decisions at critical times. Also, there is particular concern about winter precipitation and snow in the Pinaleño Mountains, which are perceived by local farmers to be the main source of aquifer recharge. Farmers would like to know what the outlook is for winter precipitation in the next five years. This knowledge would have direct relevance on their decisions to deepen wells, continue to improve the efficient irrigation technology, or to change cropping strategies.

8.5 Constraints to the Use of Climate Information

Throughout this report we have identified a number of constraints to the use of climate information. These can be summarized as follows:

1. Forecasts are perceived in many cases to be irrelevant at the local level. Farmers often point out that the SSV falls in between the locations typically given by the prediction models (Tucson, AZ and El Paso, TX) and that the valley's 4,000-foot elevation results in significant differences in temperature from Tucson and El Paso.

2. There is a general perception by stakeholders that climate forecasts are unreliable. This perception comes from a combination of factors. Farmers generally do not make a distinction between climate and weather and they often attribute the inaccuracies of a given weather forecast to climate forecasts. We found cases in which farmers made decisions based on a forecast that turned out to be incorrect. These decisions were generally costly and led to a loss of trust in the use of future forecasts. We also identified cases in which forecast uncertainty was undermined, especially by the media, leading to unrealistic expectations and, again, a loss of credibility in forecast information.
3. Another important constrain refers to stakeholder decision-making capacity. It may simply be too costly to change strategies based on climate information, or it may be technologically impossible. In this case, the availability of climate information becomes irrelevant. In this regard, we also found that greater vulnerability to climate variability does not always lead to an increase in the use of climate information. The most vulnerable stakeholders (Hispanic farmers and farm workers) tend to use basic information and most do not have Internet access or may not have the capacity to integrate climate information into their decision making.

8.6 Recommendations

Based on the concerns and suggestions of stakeholders, we have the following specific recommendations to the scientific forecasting community, institutional stakeholders, policymakers, and NOAA.

1. For climate researchers, it is strongly recommended that they address the following concerns:

    - Apply forecasting knowledge to predict the probabilities of short-term extreme events. This is a significant challenge to the current state of climate forecasting but the predictability of these events lies at core of farmers' decision making.

    - Make better linkages between climate, climate forecasting, and the consequences for local hydrological processes.

    - Downscale climate information to fine spatial resolution (a few kilometers). Farmers often comment on their willingness to work more closely with forecasters to obtain more accurate predictions specific to their area of interest and to particular hazards. Long-term resident farmers can be a particularly important source of knowledge on climate variability at the local level.

    - Address the fact that different sectors require different types of forecasts, it is important to develop an Internet-based interactive forecast evaluation tool that decision makers can tailor to their specific interests.[16]

2. Given the diverse interest for weather and climate forecasting information found among the different

stakeholders, we recommend the recruitment of local and state agencies and universities as the most cost-effective way to reach this diverse group of stakeholders. Agricultural Cooperative Extension, for example, could become a key conduit through which to channel climate information to farmers and farm workers in the SSV. This would entail the training of extension personnel and other agriculture agents in seasonal climate forecast interpretation. Also, through Risk Management Education, crop insurance agents have the potential to assist farmers in incorporating climate information in their risk assessment decisions.

3. For social scientists involved in climate research, there is a need to assess the role of social networks in the transmission of climate information among migrant farm workers and Hispanic farmers. Because these groups of stakeholders have been identified as the most vulnerable, it is important to understand the mechanisms through which they obtain climate information. In the specific case of migrant farm workers, access to improved climate forecasts in different regions of the Southwest would clearly allow them to better plan the timing and trajectory of their seasonal migrations. Already existing social networks are central to the dissemination of improved climate information, but more formal mechanisms need to be established.

4. For federal policymakers, it is important to understand that different agricultural systems have varying vulnerabilities and potentials to adapt to climate variability. Policies should encourage adaptation to a semiarid environment, for example, by increasing the ability of all farmers to obtain credit in order to purchase water-conservation devices.

5. There were two frequently heard requests that can be addressed directly by NOAA:

   - Stakeholders would like an easily accessible list of available climate information web sites. In the words of one farmer: “In the NOAA website you have to stumble around for a couple days to find what you really need. It would be nice if NOAA had a link on their home page for agricultural predictions.”

   - Stakeholders would like NOAA to reinstate the agricultural forecasting service that it provided in the past through the National Weather Service office in Phoenix.

Endnotes

[1] Agricultural price support payments to U.S. farmers increased from $5.8 billion in 1995 to .$22.4 billion in 2001 (http://www.fmsnbc.com/news/749038.asp?0dm=C15PN accessed 5/8/2002). In May 2002, the Farm Security and Rural Investment Act of 2002 was passed by both the House and the Senate, and, as of this writing, it was expected to be signed into law by President Bush. This legislation will increase federal spending on farm programs by nearly 80 percent over current program costs (Associated Press May 8, 2002).

[2] "The Commodity Credit Corporation (CCC) is a Government-owned organization created to stabilize, support, and protect farm income and prices; to help maintain balanced and adequate supplies of agricultural commodities…and to help in an orderly distribution of these commodities." (http://policy.nrcs.usda.gov/scripts/lpsiis.dll/M/M_440_503_A_0.htm).

[3] For more information on this program, see http://www.fsa.usda.gov/pas/publications/facts/sdaloan01.pdf.

[4] In 2001, the FSA interest rate for Farm Operating loans was 5 percent.

[5] NAP has been available since at least 1996 (when records become available), but a revised pilot program in year 2000 has since been enacted into law and appears likely to be retained in the 2002 Farm Bill legislation.

[6] A state FSA official observed that a declaration of disaster can be a political act. Release of CDP funds, for example, is often announced near election day. Also, states which have agricultural lobbies with clout on Capitol Hill, can exert pressure for a disaster declaration in their region more readily than a relatively small agricultural state such as Arizona.

[7] National figures are illustrative of the importance of crop insurance for current U.S. agriculture. For crop year 2001, the RMA estimated that crop insurance protects approximately 216.1 million acres nationwide, for total insurance protection of an estimated $37.3 billion (Catalog of Federal Domestic Assistance, http://www.cfda.gov/public/viewprog.asp?progid=76).

[8] For protection at 50 percent of yield, the government now subsidizes 67 percent of the premium, in contrast to 55 percent subsidy under old law; at 75 percent yield coverage, the subsidy rose from 23.5 percent to 55 percent, and at 85 percent coverage, the subsidy increased from 13 percent to 38 percent (Shelden 2000).

[9] Codling moth is the largest insect threat to apple orchards and, although it is always present, if unchecked, it can infect 95 percent of the fruit.

[10] About 240 pounds (at a cost of approximately $6,000) are applied per center-pivot, or 120 acres. A farmer that has 10 pivots will spend about $60,000 in fertilizer.

[11] Phytophthora blight is caused by the fungus *Phytophthora capsici.* It can attack the roots, stems, leaves, and fruit, depending upon which stage plants are infected.

[12] One farmer lost at least $1,000 per acre. With the heavy rain, the chiles were full of water. During the heat of the day they rotted. At some point there was a freeze that cracked the waterlogged chiles. If this farmer had known it was going to rain he would have harvested earlier. Those who had harvested their green chiles were not affected.

[13] As defined by Bourdieu and Wacquant, social capital refers to "the sum of the resources, actual or virtual, that accrue to an individual or a group by virtue of possessing a durable network of more or less institutionalized relationships of mutual acquaintance and recognition" (Massey 1999)

[14] According to data from the Department of Labor for all farm workers (foreign and domestic), 20 percent received unemployment insurance; 10 percent received assistance from the Women, Infant and Children (WIC) program; 13 percent received Medicaid and 10 percent received food stamps.

[15] Massey (1999) explains that migrants gain access to social capital through social networks that connect migrants, former migrants, and non-migrants in sending and receiving areas through ties of kinship, friendship, and shared community origin. Migrant networks "lower the costs and risks of movement and increase the expected net returns to migration" (Massey 1999:44). Such networks represent a form of social capital that can be converted into financial capital in the form of foreign employment, higher wages, and the possibility of accumulating savings and sending remittances.

[16] This tool is being developed in partnership with the NASA-funded Hydrologic Data and Information System (HyDIS) project (http://hydis.hwr.arizona.edu/) and a NOAA OGP-funded project under the GEWEX America Prediction Project (GAPP). Through this partnership, CLIMAS researchers initiated outreach activities with stakeholders through participation in the SSV's annual "Ag Day," held in February 2002. Activities included inviting stakeholders to participate in a user test of the newly developed CLIMAS web site and of the forecast evaluation web tools maintained on the HyDIS web site.

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Appendices

A. Farming Sector Interview Guide

Date_______________
Code ________________
Informant _____________________
Address and phone number _________________
Interviewer______________________

I. The first set of questions is about your family's history in farming in the SSV and also about your farming operation.

1. What is the history of your family farm?

2. What did you do before becoming a farmer?

3. What prompted you to farm in the SSV?

4. What was here when you started farming? (Is the previous owner still living around here?)

5. How much land do you own?

6. Have the number of acres that you own increased or decreased since you have been farming?

7. How many acres do you plant?
   a. Has that number changed? Why?

8. What do you produce?
   a. How many acres of land do you have for each crop?
   b. Has this changed?

9. What other tracts of land do you own?
   a. What are you doing with them?

10. Do you cultivate land that you rent from someone else?
    a. How much land?

11. What is your primary source of income?

12. Do you have other sources of income? What are they?

II. The questions in part two will help me get an idea of what you do in the farm throughout the year.

13. What do you do during each season? What type of technology (irrigation, computers, machinery) do you use during each period? What are the most important climatic factors that affect you during that particular season? How do these specific climatic factors affect your decisions?

Season	Activity	Technology	Climate factors	Decisions
Summer				
Fall				
Winter				
Spring				

14. What type of irrigation system do you use?
    a. Has that changed over the years?
    b. Why?
    c. Do you use natural gas, diesel, or electricity for irrigation water?

15. How many wells do you have?

16. When are peak times in terms of water usage?

17. Costs of irrigation during peak times?

18. Have you noticed a change in well depths during the past 10 years? 5 years?

19. What is the depth of your wells? Has that changed over the years?

20. Are you ever concerned with depletion of the aquifer?

III. The third set of questions is related to climate. Here I want to identify key areas of sensitivity and vulnerability to climate.

21. What is the approximate average yearly rainfall on your farm?

22. Have you noticed a difference in seasonal rainfall? (Probe winter and summer rains)

23. Did the 1983 flood impact you in any way?

24. What is the climatic factor that has the greatest effect on your operations?
(Ask about ENSO)

25. Was your farm affected by drought conditions during the past six years?
    a. If so, what were the impacts?
    b. Impact of 1996 drought?
    c. 1999 drought?
    d. Did you have to sell farmland/change production?

26. Do you have an emergency drought plan? Describe.

27. Rank the following factors in terms of their importance in agricultural production for you:
    - cost of pumping
    - markets
    - climate
    - labor
    - government policy
    - access to credit

28. What are the economics of farming during climate stress?

29. In your experience as a farmer, how would you define drought?

30. Do you think that climate has changed in the region?
    a. How is that changed perceived? (i.e., fauna and flora, land productivity, change in irrigation?)

31. Did you receive or applied for emergency low-interest rate loans or any other government programs?
    a. Have you ever benefited from any government programs?
    b. What type of insurance do you use, if any?

IV. The fourth set of questions is designed to assess your access and needs to weather and climate information

32. Do you consult weather and/or climate forecasts?
    a. What kind of service do you use?
    b. How did you find about it?
    c. How do you access this service?

33. What are your forecasting needs? (temperature, precip, relative humidity, frost, wet periods, etc.)

34. What forecasting periods do you use? (days, weeks, months, years)

35. When, within the agricultural cycle, do you most use this information?

36. Are you paying to obtain weather information?
    a. How much?
    b. What other types of information do you get through this service?
    c. For how long have you used this service?

37. Are you satisfied with the kind of information that you are getting? How good are existing forecasts? How relevant is this information at a local level?

38. Can you recollect a specific time when forecasts worked well for you?

39. Can you recollect a specific time when making a decision based on forecasts actually made more damage than good?

40. What would you like to have in terms of weather or climate information? How could it best be presented?

41. How do you see the future in the SSV?

42. Do you do any record keeping of precipitation or daily temperatures? Could we have access to that info?

B. Farm Subsidies and Crop Insurance in Cochise County, AZ

Table B.1. Payments by Cochise County FSA Office to Producers, 1999 to 2000.

Program	Total Payments
MLA - Market Loss Assistance	$ 4,942,861
EQIP - Environmental Quality Incentives Program	$ 452,291
NAP - Non-Insured Crop Disaster Assistance Program	$ 137,804
LAP - Livestock Assistance Program	$ 417,951
LDP - Loan Deficiency Payments	$ 16,645
LDP-CORN - Loan Deficiency Payments, Corn	$ 2,613,682
AMTA - Agricultural Marketing Transition Act	$ 2,752,910
MILK - Dairy Marketing Loss Assistance Program	$ 3,442
TOTAL	**$11,337,586**

Source: Cochise County FSA office.

Table B.2. Crop Insurance in Cochise County, 1989 to 2001.

Year	Subsidies (a)	Premium Discounts (b)	Indemnities (claims) paid** (c)	Total received (b+c+d)	Total premium (paid by farmer + gov't)	Liabilities (insured value of crops)	Policies sold	Policy Prem (active policies, subset of policies sold)
2001	$294,462	$0	$282,577	$577,039	$455,593	$6,170,341	180	76
2000	$175,007	$31,640	$28,110	$234,757	$301,539	$4,451,490	147	73
1999	$145,984	$32,807	$111,342	$290,133	$255,337	$3,025,186	115	62
1998	$135,363	$0	$35,522	$170,885	$160,376	$2,484,655	123	62
1997	$156,675	$0	$148,971	$305,646	$227,873	$3,196,000	132	93
1996	$84,496	$0	$64,082	$148,578	$126,258	$1,714,132	161	60
1995	$86,925	$0	$134,855	$221,780	$175,109	$2,232,669	144	65
1994	$32,864	$0	$141,832	$174,696	$137,797	$1,457,920	58	35
1993	$46,276	$0	$564,095	$610,371	$212,489	$2,445,235	63	59
1992	$56,602	$0	$1,191,187	$1,247,789	$271,305	$2,687,791	58	49
1991	$35,397	$0	$1,435,877	$1,471,274	$207,216	$2,584,757	45	42
1990	$38,802	$0	$429,171	$467,973	$222,485	$2,218,084	41	34
1989	$68,444	$0	$636,923	$705,367	$385,522	$3,544,227	39	39
Subtotal	$1,357,297	$64,447	$5,204,544	$6,626,288	$3,138,899	$38,212,487	1306	749

Source: Risk Management Agency (2001b).
**Indemnity payments are funded by both premiums and government funds.

C. Crop Production in Cochise County

Table C.1. Changes in Corn Acreage, Yield, and Production for Cochise County, AZ, 1994 to 2000.

	1994	1995	1996	1997	1998	1999	2000
Acreage planted	11,500	9,500	18,000	18,500	15,000	18,000	25,600
Yield per acre (Lbs)	9,700	10,790	10,640	10,580	10,640	11,600	11,600
Production (tons)	49,000	50,680	93,100	97,900	80,330	99,740	141,570

Source: Data obtained through U.S. Department of Agriculture (1997).

Table C.2. Apple production in the SSV*: Acreage, Yield, Production, and Value, 1994 to 2000.

	1994	1995	1996	1997	1998	1999	2000
Bearing Acreage (acres)	4,400	4,200	4,000	3,700	3,800	3,900	3,900
Yield per acre (lbs)	14,500	2,620	25,000	12,200	12,100	8,790	24,400
Utilized Production (Millions lbs)	59	11	100	44.1	45	32	94.5
Value of utilized production ($ 1,000)	4,621	782	12,432	4,724	6,628	4,054	6,834

Source: U.S. Department of Agriculture (2001a).
*Includes Graham and Cochise counties.

Table C.3. Chile Production in Cochise County, AZ, 1987 to 1997.

	1987	1992	1997
Chiles, harvested (farms)	11	20	28
Chiles, harvested (acres)	343	1581	3696
Percent of AZ production	96.1%	85.0%	90.8%

Source: Data obtained through U.S. Department of Agriculture (1997).

D. Meteorological and Climatological Forecast Wishes of SSV Farmers

D1. Fruit orchards

Spring

March

Climate/weather:	Frost in Spring: fruit matures uneven. Temperature (lows), dew point, wind, cloud cover, and relative humidity.
Lead time:	A week in advance preferred, a few hours desired.

March–May

Climate/weather:	29°F can result in 10 percent crop loss. Below 27°F kills 90 percent of crop. Dew point and relative humidity. Temperature: blossoming sequence begins at 50°F.

Summer: June pheromone application

Climate/weather:	Heat changes the structure of pheromones and destroys them.
Lead time:	1–2 weeks in advance to plan pheromone application.
Climate/weather:	Hail and high winds damage fruit and can be devastating to crop.
Lead time:	Not much can be done, except hail insurance.
Climate/weather:	Temperatures and timing of monsoons affects timing of fruit maturity and harvest periods.
Lead time:	30–60 days, percent increase in temperature relative to year before. 90-day, advertisement for U-pick opening season have to be printed. When spraying chemicals, need to know 1 or 2 weeks in advance strength of monsoons because heavy rains washes chemicals off.

Fall

Climate/weather:	Frost in fall kills fruit.

Winter

Climate/weather:	Cold temperatures promote more consistent bloom.
Lead time:	Forecasting will not make a difference in decisions.
Buffering technology:	Frost alarm, wind machines, propane line heaters. March–May wake up every hour to check temperature. Drip irrigation: long term adaptation to deal with natural arid conditions. To minimize climate impacts trees are planted from north to south so that wind flows downhill through the orchards Trees planted close together to provide shade and prevent damage from excessive solar radiation.
F**orecast use and needs:**	Meteorological service in Seattle costs $500 (temperature and humidity to predict night temperatures). The guy has a remote station through the valley for Willcox, Bonita, Winchester, Dragoon, and Bowie areas. Consult everyday. Weather bureau web site, satellite is more accurate. They used to consult NOAA's ag forecasting service but the service stopped four years ago. They would like to have that back. No system in place to update info quickly.

D2. Corn

Spring

April planting

Climate/weather:	Rains affect decisions of when to plant.
Lead time:	Knowing 1 or 2 weeks in advance allows for time to prepare to seed right after rain, helps conserve water.
Buffering technology:	Center-pivot irrigation to deal with decline in water table and high cost of water caused by prolonged drought and increased energy prices.
Forecast use and needs:	DTN service (national weather info and commodity prices), satellite dish, and weather channel.

May–June

Climate/weather:	Hail.
Lead time:	30 days in advance, allows to buy hail insurance.
Buffering technology:	Hail insurance prevents losses from hail.

Summer (deep irrigation)

Climate/weather:	Timing of beginning and end of monsoons. Temperature, wind, and cloud cover (affects soil moisture).
Lead time:	2 weeks. Allows to adjust irrigation schedule. High winds, cloud cover, and temperature has important effect on soil moisture and water use.

Early fall

Climate/weather:	Timing of end of monsoons or tropical storms.
Lead time:	Knowing 1–2 weeks in advance if there are going to be heavy rains will help in harvesting decision. Harvesting may be done earlier.
Buffering technology:	Corn dryers allow for early harvesting in case of fall storms.
Forecast use and needs:	Use of forecasts in other corn producing regions to make better marketing decisions.

Winter

Climate/weather:	Winter drought: no snow on surrounding mountains means a decline in water table and increased costs of production.
Lead time:	Will not affect decisions but will give indication of what to expect.

D3. Chile

Spring

March–May planting

Climate/weather:	Frost.
Lead time:	Will plant based on frost forecasts.
Forecast use and needs:	DTN gives info by radar. Channel 9 ABC are good, NBC are not good. Weather channel from Tucson, meteorologist don't realize how important the information is to farmers.

April–May

Climate/weather:	Critical time for possible wind damage, plants are very vulnerable when they are first emerging from ground. Big difference between 30 mph wind and 35 mph wind. The latter will pick up sand and burn the plants.
Lead time:	Detailed wind prediction. If season is going to be too windy, preferred 60 days in advance. But also useful short-term (1–2 days predictions).
Buffering technology:	To prevent wind damage through the season: plant barley with chile plants. Short term prevention: irrigate or mix up dirt pushing loose sand underneath.

Climate/weather:	Precipitation for fertilizer application.
Lead time:	2-week (fertilizer must be applied right away and ordered 2 weeks in advance).

Summer

Climate/weather:	Timing and amount of precipitation.
Lead time:	24–48 hours. To cut back on irrigation or increase irrigation. Standing water will cause disease.
Buffering technology:	Forecasting info is fed into computer to decide the speed at which to irrigate with center-pivots, speed puts more or less water in certain areas (can't control amount of water). Can change nozzle to a smaller size when the pressure goes down. If it is going to be dry, need to have ground very wet.
Forecast use and needs:	Use of forecasts in other chile producing regions to make better marketing decisions (Hatch, NM, from the Rio Grande Valley to El Paso).

Fall

Sept–Dec

Climate/weather:	Hail.
Lead time:	Little can be done in advance.
Buffering technology:	Hail insurance.

Harvest

Climate/weather:	Fall storms get chiles waterlogged. Frost, crack chiles after heavy rain.
Lead time:	30 days in advance to harvest earlier. Labor issues.

D4. Nut orchards

Fall

Sept.–Nov.

Climate/weather:	Early arrival of cold weather will cause nutmeat to stick to shell.
Lead time:	Several hour lead-time allows growers to turn on sprinklers.
Buffering technology:	Sprinkler irrigation is a cheap and effective way to mitigate damage from frosts and freezes.
Forecast use and needs:	Some pistachio growers obtain frost forecast information from a private firm in Seattle. They would like to get local forecasts again because they had great confidence in local meteorologist, Craig Ellis.

March–April

Climate/weather:	Frosts cause reduced blooms and freezes can ruin harvest [happened last April, 2000].
Lead time:	Knowing that freezes and frost will be more likely or severe could induce growers to invest in sprinkler technology—need six months to a year for installation.

Winter Nov.–Dec.

Climate/weather: Excessive rain from frontal storms can delay harvesting and decrease value of nuts.
Lead time: With 1–3 month lead-time, growers can arrange machinery for early harvesting.

Summer and Fall

Climate/weather: Flooding or droughts in Georgia and Texas.
Lead time: Three-month lead-time will allow pecan and pistachio growers to arrange to have their nuts refrigerated and stored in anticipation of better prices due to scarcity of nuts.

D5. Alfalfa hay

Spring through Fall (May–Nov)

Climate/weather: Too much rain reduces number of cuttings and quality of hay [the Monsoon of 1999 lasted an extra month which cost them 3 cuttings or approximately $798,000 per farmer]
Lead time: Little can be done to offset this risk because alfalfa is perennial. Need to know one week in advance approx. timing, amount, and location of precipitation. This impacts decisions about cutting and baling.
Forecast use and needs: Watch [and laugh] at local weather on TV. Watch Weather Channel out of Chicago for weekly forecasts. They have looked at 30-, 60- and 90-day forecasts on DTN, but regard them with skepticism.

Summer

Climate/weather: Droughts are good because the increased cost of irrigation is offset by the increased number of cuttings.
Buffering technology: Center-pivot irrigation has reduced water use and mitigated drought danger.

Winter

Climate/weather: Drought is bad because of its effect on recharge.
Lead time: If they knew in Nov. that the winter was going to be dry, then they might deepen wells.

D6. Vegetables

Summer through Fall (July–Dec)

Climate/weather: Excessive rain prevents harvests and precludes tourists from picking produce [crop losses from tropical storms can amount to $120,000 per farmer or force people out of production such as in 2000 for pumpkin and lettuce harvests].
Lead time: Six-month forecasts for fall precipitation may help U-pick farmers to decide whether or not to plant that year. If excessive rain appears likely, they may not plant in April.

Climate/weather: Summer rain leads to standing water and threat of Phytophthora infestation.
Lead time: Drip irrigation mitigates possibility of standing water. Fungicide spraying prevents Phytophthora.
Buffering technology: Drip irrigation.

Spring March and April

Climate/weather: Frosts and freezes damage seedlings.
Lead time: If they know one week ahead of time when the last spring frost is, they can outplant seedlings later.

Fall

Sept.–Oct.

Climate/weather:	Frosts and freezes damage mature fruit and reduce its marketability.
Lead time:	Three-day to a week frost forecasts can allow large-scale squash growers to spray “frost guard” on their fields or to turn on sprinklers for reducing frost.

Oct.–Nov.

Climate/weather:	Excessive rain in Salinas, CA 1998
Lead time:	If farmers know one month ahead of time that excessive Nov. and Dec. rains are going to hit California, they may plant lettuce in fallow fields which can be very lucrative but also risky.
Forecast use and needs:	Local television forecasts. Their use of word-of-mouth in 1998 was unreliable.

D7. Greenhouses

Summer (July – first planting)

Climate/weather:	Sunlight is critical for maturation of plants.
Buffering technology:	Computer system controls temperature, humidity, irrigation and fertilizer application schedules. Planting north-south direction allows for even sunlight, especially in winter. Whitewash to block excessive sun during the summer.

Fall (August and September)

Climate/weather:	Cool nights are important, good for pollination, so the drier the better.
Lead time:	Cucumber: an accurate long-range forecast of temperatures may impact decision to change cucumber variety because different varieties have different sensitivity to nighttime temperatures.

Winter

December (second planting)

Climate/weather:	Radiation and cloud cover are important as well as temperature. Prefer cold winters and less cloud cover. Light can be a limiting factor.
Lead time:	Cucumber: needs 90-day lead-time to select different varieties. Needs a week in advance for control strategies.
Buffering technology:	Cold winters lead to higher costs of heating.

December–March

Climate/weather:	Cucumber: El Niño means more storms and less sunlight.
Lead time:	With a three-month warning of the severity of El Niño, cucumber growers would be able to change their strategies to reduce the impact of reduced sunlight.

D8. Labor

Spring (April–May)

Climate/weather:	Frost that hurt fruit orchards will decrease demand for labor in the fall .
Lead time:	Not a problem, need to know about the frost when it already has passed.
Buffering technology:	Social capital in the form of information networks. Climate and weather information is passed by word of mouth or through phone calls to contractors or farm owners.

Summer

Climate/weather:	Timing and amount of precipitation can prevent harvesting of onions.
Lead time:	At least one week to look for employment elsewhere .
Forecast use and needs:	Use of forecasts in other producing regions would help in deciding migration cycle.

Fall (August–December)

Climate/weather:	Hail, fall storms during harvest time, flooding, high temperatures, frost (anything that interferes with harvesting).
Lead time:	At least four weeks in advance to look for employment elsewhere.
Forecast use and needs:	Need to know precipitation forecast for other agricultural regions in order to choose migration strategy most efficiently.