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Climate variability and the vulnerability of ranching in southeastern Arizona: a pilot study

Hallie Eakin[1,*], Julie Conley[2]

[1]Department of Geography and Regional Development, and [2]School of Renewable Natural Resources, The University of Arizona, Tucson, Arizona 85721, USA

ABSTRACT: For ranchers in the Southwest, unanticipated droughts pose serious management challenges. Social and economic factors combine with the physical impacts of drought to render ranchers more vulnerable to climate variability. Using agricultural census data and interviews with ranchers, we analyze ranchers' responses to drought events in 1996 and 1999. From this analysis we develop an initial assessment of the principal factors contributing to the vulnerability of ranching in southeastern Arizona to climatic variability, and we make some preliminary determinations regarding the potential use of climate information in mitigating this vulnerability. During drought, climatic conditions can combine with poor cattle prices and high feed costs to strain ranchers' resources. The ability to cope with drought is further complicated by changes in environmental policy and pressure from urban growth. In these circumstances, ranchers reported being tempted to sell their private ranch property to development interests. Although our pilot study identified smaller operations as the most vulnerable to climatic variability in the context of policy and economic uncertainty, these operations reported less utility in climate information. The multidimensional nature of vulnerability suggests that climate information will be most useful to ranching operations of all sizes if it is integrated with market, policy and other economic information and if existing information distribution channels are used to reach ranchers.

KEY WORDS: Vulnerability · Ranching · Drought · Rangeland management

1. INTRODUCTION

The vulnerability of agricultural production to climatic variability and change has been explored in other regions of the United States and Canada (e.g. Rosenburg 1993, Cross 1994, Easterling 1996, Smit et al. 1996, Chiotti et al. 1997), but ranching has not been a focus of this work. Using the 1996 and 1999 droughts as analogies, the objective of this study was to provide an initial assessment of the principal factors contributing to the vulnerability of ranching in southeastern Arizona to climatic variability, and to make a preliminary determination of the potential use of climate information in mitigating this vulnerability.

One of the defining features of ranching in the desert Southwest is the dependence of ranchers on the productivity of the desert's natural vegetation for cattle forage, and the extreme sensitivity of that vegetation to climatic variability. While desert plants are relatively well adapted to fluctuations in precipitation and temperature, the decisions of ranchers in relation to environmental change are in a large part influenced by complex interactions between economic, social and political institutions. While this reality can pose serious management challenges, one advantage of human systems is the capacity to plan and take anticipatory action in face of risk (Smithers & Smit 1997). Climate information potentially can improve the capacity for such planning, facilitating difficult production decisions during periods of climatic stress. A rancher's failure to respond rapidly to drought conditions can compromise both economic returns and the long-term sustainability of the range on which ranchers depend. The cumulative effects of poor management decisions

*E-mail: heakin@email.arizona.edu

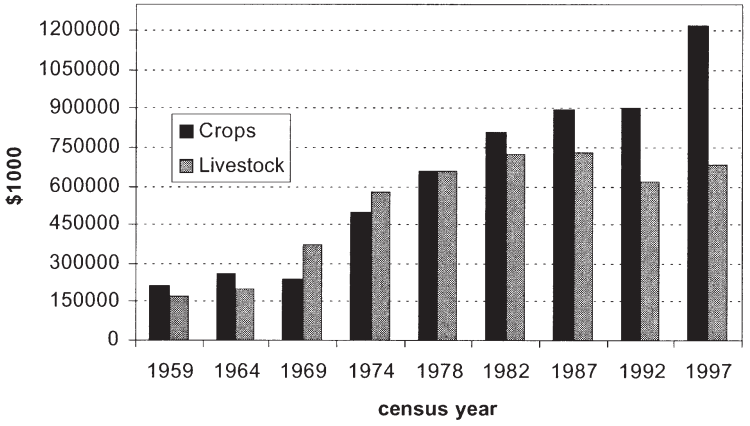

Fig. 1. Market value of Arizona crops and livestock, 1959–1997 (USDA 1999). The value of livestock products has declined in relation to crops

on rangelands can increase the sensitivity of rangeland ecosystems to climatic stress, and, in turn, exacerbate ranchers' vulnerability. This study draws from theoretical approaches to vulnerability analyses that emphasize the political-economic, social and environmental dimensions of vulnerability (Blaikie et al. 1994, Liverman 1994, Parry & Carter 1998). The vulnerability of a population to climatic variability or change cannot be measured uniquely through an analysis of the impact of changes in climatic conditions (Liverman 1994, Parry & Carter 1998). The vulnerability of an agricultural operation needs to be understood in relation to the interaction of climatic and political-economic stresses in the decision-making of the farmer or rancher (Cross 1994, Smit et al. 1996, Chiotti et al. 1997, Parry & Carter 1998). As Smithers & Smit (1997) argue in their study of Ontario farmers' vulnerability to climatic change, the farm household is the intersection of the multiple institutions—economic, social, and political—that affect both the impact of climatic events on the household and the capacity of the household to adjust to environmental changes.

In Arizona, together the US Department of Agriculture Forest Service (USDA FS), the US Department of the Interior Bureau of Land Management (BLM) and the Arizona State Land Department (ASLD) administer 28.6 million acres (approx. 11.6 million ha) of grazing lands (Ruyle 1991). Outside of the Indian Reservations, 85% of grazing land is under public management. Urban and suburban growth in Arizona is now posing considerable challenges to the current patterns of land and water use, stimulating changes in the policies of administering agencies. In the last decade sub-urban 'ranchette' developments have proliferated in Arizona, accommodating populations of retirees from outside the state and in-state populations fleeing the rapid growth of Phoenix and Tucson (Ingely 1998). With the changes in land use policies, the real estate projects now compete with Arizona's ranchers for land and water resources and provide additional pressure for ranchers to 'sell out' in periods of high stress. Change in the values and priorities of the rural populations of Arizona also have meant increased concern over species preservation and the ecological implications of different forms of land use. Ranchers are increasingly finding themselves embroiled in these conflicts.

Perhaps partly in response to these circumstances, in the last 30 years the number of cattle operations in Arizona has declined by approximately 25%, and cattle ranching has assumed less importance in the state's agricultural economy (Fig. 1). Today, as in the past, ranching is almost entirely dependent on the natural vegetation of the low- and high-desert ecosystems, with very few ranchers relying on irrigated pasture. The Arizona Agricultural Statistics Service reported an inventory of approximately 810 000 cattle and calves in the state held by 3300 cattle operations in 1998 (USDA/AASS 1998). The vast majority of these ranches are cow-calf operations that maintain a breeding herd of cows and sell a crop of calves yearly to feedlots, typically out of state (Krause 1991).

2. METHODS

2.1. Data collection

In order to provide the detailed, ranch-level analysis necessary for understanding the complexity of ranch decision-making, this study relied on in-depth interviews with a total of 16 ranchers: 10 in the spring of 1997 and 6 more in February 1999. These interviews took place both during and following periods of medium to severe drought in the region (NOAA 2000). The ranchers were contacted through a database of ranchers holding permits for use of land administered by the state of Arizona and through lists of ranchers provided by area livestock auctions. The majority (72% in 1997) of Arizona's cattle operations are very small scale, with herds of less than 100 head. Most, if not all, cattle operations in Arizona with less than 100 head are supported by income from non-livestock sources (Ruyle et al. 2000). For this reason the principal investigators of this project decided to focus on those ranchers with more than 100 head of cattle in an attempt to capture those operations not buffered by other income sources and thus most vulnerable to climatic variability.

During the interviews, the respondents were asked to expound on the following themes: their characterization and perception of the drought as it had affected the rainfall and vegetation in their area; their general production practices and the timing and nature of their principal production decisions (e.g. cattle sales, pasture rotation, water supply management); the impact of recent drought conditions on these practices and operations (e.g. perceptions of pasture productivity and water supply, cattle deaths, effect on calf crop and cattle weight at time of sale); their strategies for coping with this impact; and finally, the type, form and content of any external information (whether relating to climatic, market or policy issues) they considered important in their decision-making. Ranchers were also questioned about their knowledge of the El Niño-Southern Oscillation phenomenon and whether, and in what way, climate information might be useful to their operations.

As in some other studies of vulnerability of agricultural systems to climatic hazards (see, e.g. Smit et al. 1996, Chiotti et al. 1997), our interviews were designed to determine in qualitative terms the sensitivity of ranchers to climatic hazards and to elucidate how climatic uncertainties interacted with other pressures in the ranchers' decision-making during drought years. For this reason, ranchers were also requested to elaborate on their relationships with the various public land-administrating agencies, their perceptions of urban growth and development in their area, their interpretation of the implications of changes in land use policy in the state for their operations, and their perspectives on the market conditions for their livestock at the time of the droughts. None of the respondents were directly asked about NAFTA (North American Free Trade Agreement), although they were prompted to discuss the influence of international trade on their operations.

Additional interviews were conducted in 1997 and 1999 with range management specialists in the USDA FS, the BLM and the ASLD and the managers of 4 livestock auctions. Questions in these interviews covered the impact of the droughts on the ranching community and the livestock market, the problems and challenges of ranching in the state, and the potential use of climate information in ranch operations.

The interview data was coded thematically to facilitate a comparative analysis of the respondents (Crang 1997). The responses of the interviewed ranchers were contextualized with an analysis of geo-spatial and socio-economic data acquired from the AASS, the USDA Agricultural Census, the BLM, the USDA FS and the ASLD. We characterized the number, size and economic contribution of ranching operations in each county, and the role of public lands in the ranching operations of the study area.

2.2. Study area

The study area was in southeastern Arizona, encompassing Cochise, Pima and Santa Cruz counties, east and west of a meridian running from the towns of Catalina to Nogales, and ranchers living in the vicinity of Benson. The study area was chosen to facilitate the integration of the findings with the initiation of the Southwest Integrated Assessment Project at the University of Arizona, and was readily accessible in the time frame allocated for the project.

3. RESULTS

3.1. Ranch characterization

Of the ranchers interviewed for this study, 56% had herds between 100 and 500 head, 13% between 500 and 800, and 19% over 800 head. Two ranchers declined to specify their herd size. In comparison, at the state level approximately 20% of Arizona's ranching operations had herds of 100 to 499 head in 1997 and only 8% over 500 head, with the majority (72%) of operations reporting less than 100 head (USDA 1999).

All of the respondents classified their operations as cow-calf operations in which they bred calves for sale in feedlots (typically in New Mexico). Two of the respondents interviewed in 1997 also raised stocker cattle when the forage conditions permitted and sold these 1 yr old cattle directly to pack houses. Sixty-nine percent of the respondents considered their livestock operations their primary source of income.

3.2. Impact of drought

3.2.1. Drought severity

Crop moisture indices and the Palmer drought severity index measured both the summers of 1996 and 1997 and the fall and winter of 1998-1999 as drought periods in southern Arizona, with conditions ranging from moderately to severely dry. The drought was particularly severe in 1996 and 1997 as it hit during the months of July and August which normally bring as much as half of southeastern Arizona's annual rainfall (USDA/USDC 1996–1998; Fig. 2). Although the winter of 1998 was unusually wet as a result of El Niño-related precipitation, this moisture was not enough to compensate for the dry summer that followed. The ranchers interviewed perceived the direct impacts of the drought primarily through their observations of changes in the productivity of the vegetation on their grazing land. Because 9 out of the 16 ranchers kept

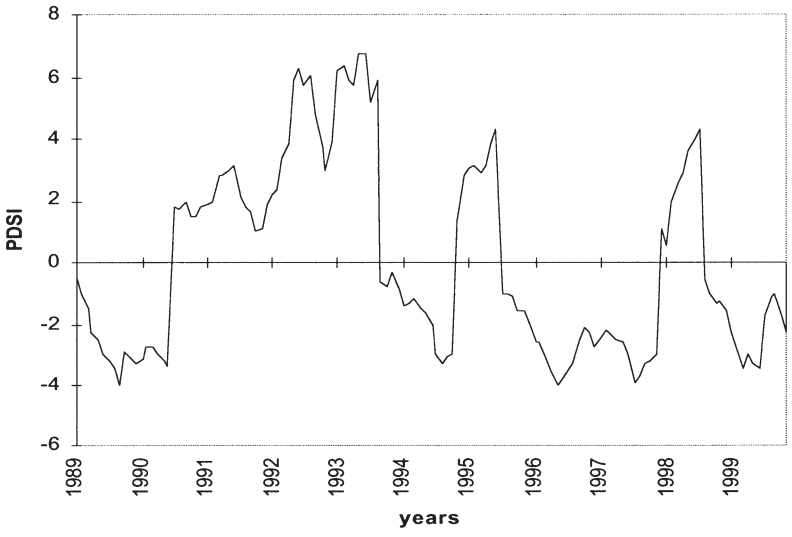

Fig. 2. Palmer Drought Severity Index (PDSI) for southeastern Arizona (climate division 7) from 1989–1999. Values less than –1.5 are indicative of moderate to severe drought conditions (NOAA 2000). Drought conditions in 1996 and 1999 coincided with our interviews of ranchers

records of the rainfall on their property, impacts were also visible through changes in the quantity of rainfall each property received in the months of the drought.

3.2.2. Pasture productivity perceptions and water supplies

All of the interviewed ranchers reported poor forage quality and quantity on their ranches at the time of the interviews. Two ranchers in 1997 reported permanent damage to their pastures as a result of the drought. Ten out of the 16 ranchers interviewed relied on earthen dams in their pastures as primary water sources, with well water as secondary sources. All but 1 of the ranchers had some access to ground water for their herds. Six ranchers relied primarily on well and spring water, and of these, 4 used wells and springs as sole water sources. The wells in all but 2 cases were, according to the ranchers interviewed, not affected by the droughts. Nine ranchers reported that the water levels in their dams, however, were well below normal or completely dry, rendering many pastures useless for cattle regardless of the presence of forage. Of these ranchers, 2 had been dealing with water shortages for several years.

3.2.3. Impacts on cattle health and productivity

The lack of spring rain in 1996 delayed the breeding for some cows that normally give birth in the early spring. Four ranchers had completed their count of the calf crop at the time of the 1997 interviews and reported significant declines in productivity (10 to 40%). The remaining ranchers were in the process of conducting a count of their calves during 'roundup' and thus did not have a calf-crop estimate.

One of the impacts of the drought and general lack of forage was the resulting lighter weight of cattle on the market in 1996. In 1996, half of the respondents reported selling their calves 10 to 100 pounds (4.5 to 45 kg) lighter than normal. One respondent's calves were at half their normal weight at the time of sale.

3.3. Response strategies

3.3.1. Pasture and forage acquisition

Half of the ranchers we interviewed had a specific grazing strategy that involved rotating the use of different pastures within a single year, or, in some cases, rotating pastures on a yearly basis in order to rest some pastures and improve animal distribution. While each rancher had his/her own grazing management strategy, 80% of the ranchers in 1997 and 83% in 1999 reported that the drought conditions had forced modifications of their land use strategies and rotation schedules. Those ranchers practicing yearlong continuous grazing were forced to supplement, acquire more pasture, and/or destock, as their pastures became depleted of forage or inaccessible due to lack of water.

Four of the ranchers interviewed had access to larger land areas that, according to their own evaluations, enabled them to move their cattle from one area to the other in response to the variable ecological and microclimatic conditions of these dispersed pastures. Ten of the ranchers interviewed, who lacked the diversity of land, were forced to rent additional pasture (at costs reportedly ranging from \$900 to >2000 mo^{-1}) because of the lack of forage on the land they had available. In some cases this strategy involved transporting cattle at considerable cost. All of these operations had <800 head.

3.3.2. Water supply

As a result of dry dirt tanks, 40% of ranchers in 1997 and half in 1999 reported having transported and/or purchased water in metal tanks to supply pastures that lacked well infrastructure. The purchase and transport of this water entailed additional production costs of \$40

to 1500 mo^{-1} and additional labor time. Other ranchers drew more heavily on 'city water'—the water supplied by the municipalities to which they belonged for domestic use—at additional cost. All of the ranchers interviewed in 1999 reported taking decisions to invest in more long-term water supply strategies that would reduce their reliance on rainfall, and increase their use of ground water resources. These ranchers hoped that larger storage tanks (as large as 50 000 gallons [1.9×10^5 l]), pipelines and wells would increase their accessibility to water should the dry years continue.

3.3.3. Supplemental feeding

Sixty percent of ranchers in 1997 and 83% in 1999 resorted to supplementing natural forage with alfalfa hay, grain or minerals as a result of the decline in quantity and quality of range vegetation. The cost of the supplemental feeding programs implemented by these ranchers varied considerably, ranging from $12 to 100 $head^{-1}$ yr^{-1}. Two of the ranchers who increased their supplemental feeding were owners of irrigated pastures in which they grew alfalfa, and by increasing their acreage during the drought periods they were able to offset some of the additional expenses by selling the surplus hay at elevated prices.

3.3.4. Destocking

All the ranchers we interviewed in 1999 and 8 of the 10 ranchers interviewed in 1997 reported cutting back on their herd size as a way to cope with the drought. Sixty-nine percent of the ranchers interviewed reported culling rates of 15 to 50%, a significant increase from the average annual rates of 10 to 15%. One rancher interviewed in 1997 had liquidated his herd. Those ranchers who had significantly culled their herds were waiting for a decided improvement in climate conditions before risking re-stocking. Two of the ranchers who did not increase the culling of their herds during the drought of 1997 produced their own irrigated alfalfa hay that enabled them to maintain their stocking rates.

Other than the more routine support ranchers acquired for pasture improvements, only 6 ranchers said that they had taken advantage of feed cost-sharing programs instituted by the federal government in the drought years. These ranches were also those who reported taking the most severe destocking measures (25 to 50% of total herd). Of the remaining ranchers who did not use the federal assistance, 6 resorted to bank loans as a means of meeting the extra costs associated with the drought's impacts.

Despite the number of ranchers who requested bank loans, almost all the ranchers we spoke with were negative about resorting to loans to carry them through a drought period. They viewed debt as a sure way to increase vulnerability to both weather and market fluctuations. Indeed, agricultural debt has been identified as a contributor to farmers' vulnerability to climatic change in Mexico, given that during subsequent drought years a debt burden can become insurmountable (Liverman 1990, 1994).

3.4. Economic factors contributing to the vulnerability of ranchers

3.4.1. Livestock market

Our pilot interviews confirmed that vulnerability in the 1996 and 1998-1999 drought periods was not simply a function of diminished rainfall, but rather the combined effect of ecological, market and financial factors. The ranchers and livestock auction managers interviewed in 1997 reported cattle price declines of 30 to 50% from previous years (Fig. 3). The stockyard managers interviewed in 1997 reported that the number of head of cattle going through their auctions had increased by 15 to 35% in 1996-1997, and that the quality was considerably lower than in previous years. In the Marana stockyards near Tucson, data collected by the auction showed elevated cattle sales all year, with record sales in the late fall of 1996, a fact which the auction manager interpreted as the final culling of herds as ranchers realized they could not keep their stocking rates through the winter. USDA statistics for the state of Arizona indicate the average number of cattle sold increased by 45% from 1993 to 1996, and by 10% alone from 1995 to 1996.

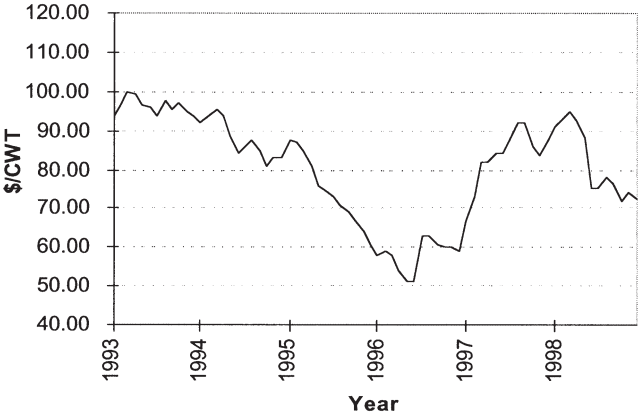

Fig. 3. Average monthly calf prices in Arizona, 1993–1998 (USDA/AASS 1998). Low prices between 1996 and 1997 exacerbated the plight of drought-stricken ranchers. Calculated as dollars per hundredweight ($/CWT). 1 CWT = 45 kg

3.4.2. The impact of NAFTA

Ranchers mentioned NAFTA frequently in their explanations for the low cattle prices of 1996. In 1997, 80% of the ranchers interviewed believed that NAFTA, in combination with drought conditions in northern Mexico and the devaluation of the Mexican Peso in 1994, was driving cattle into the US markets and pulling the price down. This phenomenon has been documented by Peel (1996), who showed that Mexican feeder imports had the greatest impact on 181 to 227 kg steer prices, reducing the price on average by $1.98 head^{-1} from 1988 to 1992. Forty percent of ranchers in 1997 also commented that climatic crises (heavy snows) in the Midwest had also contributed to the cattle glut as ranchers in those states liquidated their herds. Three ranchers also observed that the devaluation of the Mexican Peso and the drought in Mexico was depressing the demand for replacement heifers.

The managers of the livestock auctions interviewed in 1997 and the range management professionals interviewed in the 3 government agencies concurred that cattle prices in 1996 initially reflected the fact that the industry was at a cyclical peak in inventory, and that the cost of production in the Midwestern feedlots (the principle buyers of Arizona cattle) had increased because of the high cost of grain. The effect of these factors was exacerbated by the drought and adverse economic conditions in Mexico and the Southwest.

Cattle prices had improved in 1998-1999, but still concerned many of the ranchers interviewed. Two of the ranchers interviewed in 1999 said they had anticipated the meager winter rains and had sold earlier to avoid a glut at the market. However, in contrast to the drought of 1996-1997, most ranchers did not as readily associate the market prices for livestock with the impact of the drought.

3.4.3. Public land use policy and land development

Land use policies and leasing arrangements are a source of uncertainty for ranchers that also appears to affect their vulnerability to drought events. Arizona ranches are a patchwork of tenure arrangements. A full third of livestock operations include a combination of 2 or more agency-administered grazing allotments, of BLM, USDA FS, and/or ASLD land (Ruyle 1991), and would not be viable without access to public forage resources. Cattle graze more than 90% of ASLD lands.

In southeastern Arizona, private and state administered land is particularly important to grazing. For example, the ASLD owns approximately 34% of the land in Cochise County (Table 1). Only 1 rancher of those interviewed did not lease land from any government agency. Sixty-nine percent leased some land from the ASLD, 45% leased from BLM and 18% from the USDA FS. In 1997, 40% of the ranchers interviewed reported that they ranked the land use policies of the BLM and the USDA FS as high concerns in managing their cattle during drought periods, referring specifically to the strict requirements to destock on federal lands.

Nine of the 16 respondents were also preoccupied by what they feared would be the implementation of new regulations relating to the Endangered Species Act on the land they leased from federal agencies. These ranchers expressed fears that implementation of the Endangered Species Act would mean a loss of access to public ranching allotments they have relied on for decades. They were particularly concerned with those allotments that contained riparian areas—areas that could be critical during drier periods. In the more recent interviews 4 of the ranchers expressed concerns about the recent attempts to put ASLD grazing leases up for competitive bidding and to lease BLM lands for conservation purposes. They feared that they would be outbid and evicted from their traditional grazing lands.

Thirty-one percent of the respondents also felt that their operations were threatened by urban development. Arizona is one of the most rapidly growing states in the nation. The state's population increased 30.4% between 1990 and 1999 (US Census Bureau 1999). Many of the newcomers are retirees or professionals who seek scenery and recreation opportunities. The demand for 'ranchette' properties and suburban expansion have put land prices at a premium, increasing property taxes and inheritance taxes at a time when many older ranches are about to change generational hands. Ranching at the urban-rangeland interface can also result in 'culture clash' and an increase in nuisance issues such as trespass, vandalism, stray dogs, and carelessness with gates (Huntsinger et al. 1996).

Over half of the ranchers interviewed had been approached to sell their deeded land, and several had already considered the idea given the current challenges faced by the livestock industry. One of the respondents interviewed in 1997 had already sold

Table 1. Land ownership and administration (as % of total land area) for selected counties in southeastern Arizona (USDA/AASS 1998)

County	USDA FS	BLM	ASLD	Reservation	Private	Other
Cochise	12	9	34	0	41	3
Santa Cruz	53	<0.5	8	0	39	0
Pima 7	6	15	42	11	19	
State 15	20	13	28	16	8	

some property at a considerable profit in an attempt to recover from a significant loss of cattle in 1994. This action had the effect of reclassifying his property as development real estate for tax purposes and had substantially increased the burden of inheritance taxes. This rancher was considering additional sales after having lost financially during subsequent years of drought.

3.5. Planning practices and climate information needs

3.5.1. Planning practices

To better understand where climate information might fit into ranchers' decision-making, we asked ranchers to outline a rough schedule of their annual activities and decisions. From these discussions we were able to identify some relationships between size and scale of operation and planning practices. Smaller operations were more likely to breed and/or sell cattle year-round rather than controlling the timing of breeding and selling their cattle all at once as a package to 1 buyer. Six of the 10 operations with <500 head bred or sold cattle year-round, while only 1 of the larger operations did so. Four of the 16 operations engaged in yearlong continuous grazing of pasture as opposed to a rotational grazing system. Three of these operations were small-scale, <300 head, and the herd size of the fourth was unknown. Two of the ranchers who continuously grazed their pastures expressed a desire to implement a rotational system but claimed that they did not have the financial resources for additional pasture fencing.

3.5.2. The value of forecasts

Ranchers were also asked about their current use of climate information and, more specifically, whether or not they thought that weather and climate forecasts could be useful in their decision-making. One half of the respondents thought that climate forecasts would be valuable to their operations, with the other half perceiving them to be of limited value or not at all helpful. Reliability, timeliness and accuracy were expressed as the primary concerns related to forecasting. The majority of the ranchers interviewed were aware of sources for both daily (24/48 h) and long-range forecasts, and most believed the short-range forecasts to be more reliable than longer-range forecasts.

Of the ranchers who perceived limited value in the forecasts, the majority of these were small- to medium-scale operations. These ranchers believed forecasts to be generally unreliable. They also noted that forecasts seldom accounted for the local (spatial) variability in weather, and that they failed to accurately predict the summer storms in the desert area. Winter weather was perceived as more predictable, but even then the forecasts were considered unreliable. These ranchers preferred to 'wait and see' before making any significant management decisions, even at the risk of facing unfavorable market conditions should they need to cull.

While only half of the smaller-scale ranchers thought that the forecasts might be valuable in their operations, 4 of the 5 ranchers with >500 head, and one-half of the smaller scale ranchers felt that forecasts could be valuable to their operations if they were >50% reliable. These ranchers felt that the availability of long-range forecasts might change their decisions on the timing of cattle sales and purchases. They would be able to avoid drought-induced market gluts and make better decisions regarding spring culling prior to the summer rains. The 2 ranchers who cultivated their own forage saw the daily weather forecasts as particularly important, as they felt that the forecasts could be effectively used to plan their forage production in anticipation of the market's demand for forage.

The ranchers who believed long-range forecasts to be potentially useful were already users of climate information. One rancher paid close attention to weather information broadcast at a special frequency from the National Weather Service (WXL30), others watched the daily TV broadcasts and read long-range forecasts in livestock journals. Those ranchers who reported receiving long-range forecasts received them primarily from livestock and agricultural journals such as the Farmer's Almanac and Drover's Journal. Only 1 respondent reported that he received long-range forecasts from the National Oceanic and Atmospheric Administration via the National Weather Service radio broadcast. In marked contrast to comments on other sources of long-lead climate information, this source of forecasts was considered nearly 80% reliable. These ranchers were also relatively articulate and informed about meso-scale and global atmospheric influences on local weather conditions. Several ranchers volunteered explanations of the predictability of winter rainfall in the state and the influence of the jet stream's position for winter precipitation.

3.5.3. Climate information needs

The timing of both winter and summer rainfall was a common priority in information needs among the ranchers interviewed. Summer rainfall patterns were of particular interest, given that the production of the

major forage grasses depends on available moisture in the months of July, August and September. Two ranchers indicated an interest in climate forecasts for the Midwest, where most of the feedlots are located. They understood the relationship between climatic events, grain prices, calf demand, and cattle prices and thought that having these forecasts would help them in their planning. Those ranchers less interested in forecasting still expressed an interest in other forms of weather and climate information, particularly in information about climatic trends and patterns such as might be provided from tree-ring data and remotely sensed data. They said they would use such data to confirm their own perceptions of precipitation cycles and changes.

3.5.4. Additional information used in decision-making

To determine how climate information might best be disseminated to ranchers, we assessed how ranchers received and incorporated information into operational decisions. Publications containing market data were some of the most important sources of decision-making information that the ranchers regularly used. Most ranchers, regardless of resources and scale, kept track of local and regional cattle prices through ranching periodicals such as The Drover's Journal and The Western Livestock Journal. For local price information, several ranchers received faxes or mailings from the local cattle auctions announcing sales and past trends in prices. Because these periodicals and reports are so widely read by ranchers, incorporating climate information into them could prove to be an effective way of improving the base of information on which ranchers make decisions.

4. DISCUSSION

The 4 livestock auction operators interviewed in 1997 shared the perspective that the smaller ranches—those with 50 to 200 head—were the hardest hit by the drought, and that many of these ranches liquidated their herds because of the economic burden of the drought. While there was a difference of opinion among livestock experts in Arizona on the range of herd sizes necessary for an operation to be commercially viable, there was a consensus that the smaller operations—those with <200 head—would face greater economic challenges than larger ranches if they operated without substantial investment from other non-ranch income sources (Ruyle et al. 2000). Theoretically, economically marginal agricultural operations are thought to be the most vulnerable in the face of the extra expenses often associated with overcoming the impact of climatic stress (Parry 1990, Downing et al. 1996).

Land area also appeared to be important in the interviewed ranchers' strategies for coping with drought. Precipitation in southeastern Arizona is typically more reliable on mountain slopes and upland areas than in the semi-arid grasslands and desert scrub, where rainfall can be more dispersed in space and time. In addition, the normally low levels of forage productivity in desert grasslands means that as many as 60 acres (approx. 24 ha) of range in good condition may be required to support one 1000 pound (454 kg) cow for the year (Martin & Ward 1976). Managing these constraints entails having access to a large area of land, carefully managing animal distribution and grazing intensity, and making clear management decisions as early as possible (Vallentine 1990). Failure to do so can lead to long-term deterioration of rangelands, placing further stress on ranchers, rangeland wildlife, and the hydrologic system. Those ranchers who had access to larger land areas, particularly those who had spatially dispersed land, did not destock as much as other ranchers and did not report dramatic declines in calf weights and calf crops. These ranchers also did not have to devote resources towards the lease of additional land allotments during the drought periods. If the current trend of 'ranchette development' continues in rural Arizona, ranchers may find it more difficult to maintain access to the quantity and diversity of land needed during drought periods.

Shortages of water and forage in ranchers' pastures exacerbated the economic burden of the drought. Many of the ranchers in the 1999 sample discussed infrastructure changes to their water supply system as a response to experiencing several years of drought—namely, digging new wells and investing in water storage tanks to diminish their reliance on rain water.

Supplemental feeding was another important strategy of the interviewed ranchers during the drought periods for coping with declines in forage quantity and quality. The BLM, ASLD, and USDA FS actively discourage supplemental feeding on leased land in order to force ranchers to adjust their herd size to the natural production of the land. Not only does supplemental feeding complicate a rancher's relationship with the government agencies from which he or she leases land, but it also increases a rancher's sensitivity to volatile grain and feed markets. Grain and hay prices during the drought of 1996 were the highest in many years as a result of increased demand for corn-derived industrial products and grain to feed burgeoning cattle inventories in Asia, along with poor grain harvests in Argentina and the United States (FAO/GIEWS 1996, available at

www.fao.org/DOCREP/004/W1690E/W1690E00.HTM, Hargreaves 1996).

Timing of culling is critical, not only to minimize economic losses, but also to prevent irreversible damage to the range. Interviews with range managers in the USDA FS, BLM and ASLD confirmed that the agencies often demand that ranchers reduce their stocking rates during drought periods, forcing ranchers to move their cattle to non-agency land or to cull their herds. With the possibility that weather and forage conditions will improve, pro-active culling was not a strategy that all the ranchers interviewed viewed with enthusiasm. Yet these ranchers also are cognizant that those who wait until their cattle exhibit drought stress risk poor livestock weights and consequently poor prices, or unfavorable market conditions, not to mention pasture damage.

This outcome, according to the ranchers interviewed, is what made the 1996 drought particularly severe for area ranchers. The problems with forage and water supplies were translated into declining cattle productivity and low calf weights, which in turn had direct economic implications for the ranchers at the time of sale. As more ranchers culled their herds, the possibility of remuneration from their sales diminished. Ranchers who were forced to sell off a large percentage of their herd, particularly when prices were unfavorable, cut deep into their assets and may not recover easily from the drought's impact. The regional effects (Southwest US and northern Mexico) of the drought, combined with cattle losses to severe winter conditions in the Midwest, illustrates the importance of linking the vulnerability of ranchers to climatic events in one particular locale with climatic events and rancher responses in other regions and nations.

Our interviews confirmed that the long-term vulnerability of the ranchers was influenced not only by complex market circumstances but also by land use policy. The ranchers' perceptions of the stability of their land tenure depended in part on the land management policies of the different public agencies from which they lease. Because deeded land is often isolated and surrounded by agency allotments, the loss of access to public allotments through changes in bidding procedures or stocking regulations could also jeopardize the ability of the ranch to operate efficiently, and constrain the management flexibility of ranchers in times of drought. Grazing restrictions may also be imposed by legislation such as the Endangered Species Act, the National Environmental Policy Act, and the National Historic Preservation Act. Requirements under these laws create complex procedures for approval of range improvement projects and management plans (Ruyle et al. 2000). The ranchers' concerns over the new environmental regulations were difficult to assess at the time of the interviews. However, whether it represents a real or perceived threat, the ranchers viewed environmental policy as a major source of uncertainty and anxiety in their operations, and this perception undoubtedly had some influence on the ranchers' land use decisions during periods of economic stress.

In contrast to those ranchers who were preoccupied with the policies of the public land agencies, the ranches composed of large tracts of private land reported being under pressure to sell this land for suburban development. Economic difficulties for ranchers arising from either climatic or other events may accelerate this form of land use change, with potentially serious implications for future natural resource use in Arizona. While leaving ranching may actually improve the livelihood stability of some ranchers, the shift in land and water use entailed in suburban expansion may exacerbate the aggregate vulnerability of Arizona's population and economy in the longer term.

In terms of climate information needs and demand, the data from our pilot study suggests that information use may be linked to the capacity of a ranch manager for advanced planning, and the flexibility of decision-making of the manager. While ranch size does not necessarily imply resource constraints, the consensus of the range managers interviewed in this study was that ecological and market conditions in Arizona make it difficult for smaller ranchers (in both area and herd size) to operate effectively. The smaller ranches of our sample were also those that were less likely to follow a seasonal breeding and culling schedule and that were less likely to engage in rotational grazing plans. Ranchers who have developed systems for organizing their production activities are more likely to undertake proactive measures to avoid the ecological damage that can exacerbate climate stress and thus may be in a better position to make use of climate forecasts. These proactive decisions help ranchers avoid the adverse economic effects of crisis response and improve their economic returns in the long run (Thurow & Taylor 1999). The importance of planning and decision-making structures is also emphasized by Chagnon et al. (1988) and Sonka et al. (1986) in their earlier studies of forecast use in US agriculture.

5. CONCLUSION

By definition, rangeland livestock production is extremely sensitive to temporal and spatial variability in precipitation and temperature. However, as our research has shown, the sensitivity of ranching to climatic variability is not the only factor in the vulnerability of ranchers in southeastern Arizona. It is the combi-

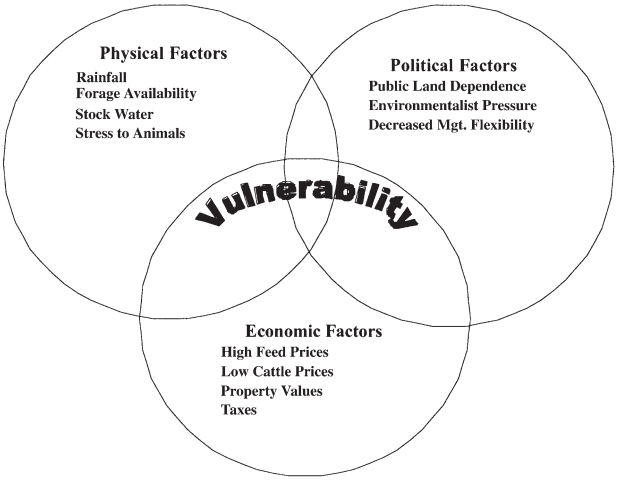

Fig. 4. Combined factors contributing to the vulnerability of southeastern Arizona ranchers to climate variability

nation of adverse market conditions, land use policies, political pressures, and individual management strategies and resource access that affect not only the impact of a drought event, but also the ways in which a rancher can adjust to the impact (Fig. 4). This not unexpected conclusion underlines the importance of integrated approaches to understanding vulnerability and the capacity of individuals to adapt to risk. An assessment of the physical sensitivity of livestock and forage to climatic stress cannot serve, in itself, as an indicator of vulnerability, nor can the vulnerability of the ranching sector be understood in isolation from the broader picture of policy change and economic development in Arizona.

While 16 interviews remain a small number from which one may generalize findings, our research suggests some hypotheses for further study. First, smaller-scale operations on the edge of economic viability in which ranching plays a significant role in the household income may be the most vulnerable to 'going out of business' as a result of a drought event. This vulnerability may increase if the operation engages less in advanced planning and does not have the resources for land improvements, such as pasture fencing and water development. As a result, when drought hits, these operations risk permanent damage to rangeland resources if destocking measures are not undertaken in a timely manner. These ranchers may have the most difficult time recovering from economic losses as a result of forced cattle sales during drought periods. Indebted ranchers in this category would be most at risk to losing property during drought and economic crises.

Ironically, these smaller operations, while perhaps most vulnerable to climate variability, also appeared to be the less likely to use new climate products to mitigate their risk. Although the small sample size of this pilot study precludes any definitive conclusions, other studies of climate forecast use in agriculture have focused on resource constraints and the flexibility of decision-making as inhibiting factors in integrating forecasts effectively into decision-making (Eakin 2000). It may be that without a structure for decision-making that facilitates advanced planning and the systematic incorporation of information from a variety of sources, climate products—particularly forecasts—can have only a limited application. Improving the capacity of the more marginal ranchers to develop and systematically implement drought management plans and structures for decision-making may be initially more important for mitigating vulnerability to climate than the provision of climate information.

Climate information may be useful to ranchers only to the extent that they can operationalize the information. Our findings suggests that for climate information to be of use to smaller producers as well as larger ranchers, the information must be provided within the decision-making structure that ranchers employ for their operations. In addition to making use of popular periodicals, current efforts of extension programs and public agencies to improve planning in smaller scale operations can serve as vehicles for introducing climate products and information into management practices.

Once a structure for the use of the information is in place, the information will need to be packaged and communicated to ranchers in a manner that will be accessible for those who may not rely on electronic data sources or for whom climatic concepts are relatively foreign. Many ranchers expressed interest in participatory workshops in which they could speak directly to climatologists. This form of information exchange will be critical in developing useful products for Arizona ranchers. Not only can such fora permit ranchers to gain an understanding of the scope of information that might be available to them, and the uncertainties and risks entailed in its use, but climatologists can also refine their understanding of product demand and applications. Finally, the multidimensional nature of vulnerability suggests that climate information will be most useful to ranchers if it is integrated with market, policy and other economic information and using existing information distribution channels to reach ranchers.

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