Adaptation to Climate Variability and South African Livestock Systems: Lessons for Long-term Climate Change

Kathleen A. Galvin[1,2], Philip Thornton[3] and Randall Boone[2]

1 Department of Anthropology and 2 Natural Resource Ecology Laboratory, Colorado State University, Fort Collins
3 International Livestock Research Institute, Nairobi

Introduction

Adaptation

Adaptation is a concept derived from evolutionary biology, which, in its strict biological sense refers to the ability of organisms to pass on their genetic material to the next generation. It is measured through genetic fitness. Another, broader view of adaptation refers to the ability of individuals or groups to respond to changes in their environment. Until the last decade or so, adjustments to changing environments were generally viewed as positive, but we now know that adjustments are a series of trade-offs, that there are costs and benefits to choices that individuals and groups make. We must therefore ask the question, who is benefiting from the adjustment and who is not. An example from biology is that a population that lives in an energy deficient environment may "choose" to have a large population supported under these conditions which is good at the population level, but at the individual level, there are costs, such as lowered fecundity, low nutritional status and a deficient cognitive development.

These concepts in biology carry over to human-environment problems today especially when addressing issues of adaptation and adaptive capacity in human populations coping with climate variability and climate change. People, societies and cultures must still make adjustments and the adjustments are intended to reduce vulnerability. But we additionally must ask the question, what are the costs and benefits of adjustments and for whom.

Adaptive capacity is the ability to cope with the impacts of climate variability and change, that is the ability to make adjustments (Smit 2001). Capacity varies among individuals, communities, socioeconomic groups and regions. Those with the least capacity to adapt are generally the most vulnerable to the negative impacts of climate variability and change. Issues of policy, growing populations and low agricultural and livestock production, contribute to adaptive capacity and ultimately, vulnerability (Finan and Nelson 2001, Lamb 1995, Little et al, 2001). Developing countries are dependent on climatic resources and because of growing populations and lower technological capabilities, they generally have lower adaptive capacity (Downing 1997, Magistro and Roncoli 2001). This is true for small-scale farmers who are dependent on the seasons for their livelihoods. This is especially true for pastoral people, who inhabit the arid and semi-arid regions with high climate variability. Most adaptations to climate variability are socio-cultural (that is, changes in management), usually a series of reactive responses to a climate event such as drought (Galvin et al 2001, Little et al. 2001).

But how do we assess capacity? It has to do with flexibility and choices. Those individuals and communities who can be flexible in their responses and have a range of choices usually have greater capacity to deal with change. For myriad reasons people can become vulnerable (the risk of negative outcomes as a result of climatic changes that overwhelm the adaptations they have in place) to environmental changes due to changes in frequency or duration of those changes or because they are constrained economically, socially or politically from responding adequately to those changes. Thus, human derived and ecological processes as well as historical contexts structure coping ability.

In this paper we briefly describe the coping strategies of commercial and communal livestock farmers in the North-west Province, South Africa for dealing with climate variability. We then use integrated modeling to link current strategies of coping and to scenarios of long-term climate change. We then develop a conceptual model of the household and the factors that its adaptive capacity.

Climate Variability and Adaptive Strategies in South African Livestock Systems

Interannual climate variability in the form of frequent droughts is one of the major driving factors that differentiate the function of dryland ecosystems from the more predictable patterns seen in more mesic environments. In southern Africa in general, as in many other parts of the continent, the probability of occurrence of extreme events is predicted to increase, and one manifestation of this is changes (increases, often) in the year-to-year variation in rainfall. A more complete analysis of this with respect to our modeling application (below) would include a study of the changing frequency of ENSO events and the household impacts of more frequent dry years. Currently we do not know how climate change will affect the frequency of ENSO events, and the analysis below relates to changing the coefficient of variability of rainfall alone.

The South African Weather Bureau regularly produces seasonal climate forecasts that consider long-term climatic patterns such as El Niño / Southern Oscillation. These forecasts are a potentially important information source available to people living in drylands. But in general, the implications and possibilities associated with this new information are not well understood. We assessed the potential value of climate forecasting to livestock producers (called farmers in the region) in a semi-arid zone of South Africa, where drought-induced losses of secondary production and livestock mortality are major threats to economic stability and human well-being. Our work focused upon five districts in the North-West Province, an area with a variety of socioeconomic groups, all facing some level of political or economic change. In general groups may be defined as commercial livestock farmers and small-scale communal farmers. Commercial farmers produce young stock for market, whereas communal farmers maintain animals as a capital asset.

We used field studies within commercial and communal districts in the North-west Province , and ecological and economic modeling of farms, to identify responses to drought and to assess the current and potential utility of seasonal forecasts. Field study methods combined survey research, formal and informal interviewing and in-depth ethnography. SAVANNA, a process-based ecosystem model focusing upon water availability, was adapted to represent five commercial farms and five areas managed communally, where interviews were conducted. The model was linked with a mathematical programming module to optimize income from farms under different seasonal climate forecasts. Workshops in the North-West Province were used to gather stakeholder information and regional support early in the project, and to disseminate results and gather feedback near the completion of the project.

Commercial and communal farmers coped with drought in qualitatively similar ways. Main responses included selling animals, buying fodder, or taking no action (Hudson 2002). Commercial farmers were more likely to have sold animals outright, whereas communal farmers sold animals to buy fodder for remaining animals. Whereas few (4%) commercial farmers reported that a single-year drought would be difficult to cope with, 37% of communal farmers said that a single-year drought would cause great difficulty. Eight percent of commercial farmers believed their production systems could survive four years of consecutive drought, but no communal farmers predicted surviving more than three years of drought.

Many commercial farmers (72%) and communal farmers (40%) have some access to climate forecasts through television, radio, telephone, or other means. Weekly or monthly forecasts are available to 68% of commercial farmers, and 25% of communal farmers. In general, farmers considered seasonal forecasts valuable, but not accurate. This disjunct is likely related to a seasonal forecast for a severe drought in 1998, which did not come to pass. Overall, about 29% of livestock farmers reported using seasonal climate forecasts in their management, with more farmers likely to adopt their use when the predictive power of forecasts improves. Results and feedback from South African livestock producers suggest that a real-time farm model linked with climate forecasting would be a valuable management tool. Whereas we used several rainfall scenarios to assess farmer responses to drought in the project, the scenarios used for this paper is new and one developed for looking at climate change.

Modeling Scenarios

For use in this modeling exercise, we sought to create precipitation data sets with variability from the observed coefficient of variation (29.6%) to 46% while maintaining the observed average annual rainfall (391 mm yr^{-1} from 1900 to 1994). To maintain average rainfall but increase variation essentially required that values above the mean rainfall be increased, and those below the mean be decreased. In conducting this exercise we discovered that the coefficient of variation in rainfall has changed over the last 100 years. The CV of rainfall from approximately 1900 to 1960 was about 24.8% and from 1960 it has been about 36.3%, a huge change (Figure 1). It appears that South African livestock farmers have already been coping with increased variability, and for quite some time!

A series of runs were carried out to investigate what happens to farm income as the coefficient of variation of rainfall increases. We ran a number of runs, but the set described here was used to investigate the impacts on farm income of culling livestock at different rates, triggered by the SOI falling to values below minus one. The question asked was, in seasons when the SOI falls below the trigger, indicating an increased probability of an El Niño season, what proportion of the herd should be culled to maximize long-term income? This "heavy culling" was simulated to take place in the July before the "forecast" indicating El Niño conditions in the coming months. Five runs were done for each rainfall scenario: the proportion of the herd culled in years when the SOI fell to below minus one ranged from 90% to 50%, in increments of 10%. In other years, the herd was culled in accordance with the standard culling rule. As in the original runs of Thornton et al. (submitted), cattle prices were assumed to decrease by 50% in El Niño years, corresponding to the pessimistic impacts reported by both communal and commercial farmers in the survey of Hudson (2002).

Figure 2 shows the mean and variance of returns at the optimal forecast culling rate (which, like the set stocking rate, did not stay constant across all rainfall scenarios). Except for two scenarios, forecast culling generally increased the variance of returns, and in half the cases this was accompanied by an increase in mean returns.

Set stocking and forecast culling are compared in Figure 3, in terms of the mean income per year for the nine rainfall scenarios. Culling according to the forecast resulted in higher mean income in all cases.

But there is a cost involved in this. Figure 4 plots the CV of income against the nine rainfall scenarios, and it can be seen that the CV is sharply increased in the forecast culling cases, compared with the set stocking simulations.

Discussion

There seems to be substantial benefits to be gained from culling in the face of increasing the CV of rainfall. Mean income may be increased, but the variance of income is almost always increased too, and while the effects of increased rainfall CV are not entirely straightforward to interpret, it is clear that there is a general tendency for the high CV scenarios to increase the downside risk of inadequate household income, particularly with regard to the "cashing in" syndrome, when herd numbers may in fact decrease to levels that cannot be easily built up again. There are highly personal trade-offs involved in these stocking and culling decisions. For risk-averse farmers who need as steady an income stream as possible, they may be unlikely to take on the added risk of using the forecasts, and the possible future situation where rainfall CV increases is going to make steady income streams increasingly difficult to obtain. For farmers who are more interested in ranching as an investment and are able and prepared to take on more risk, then the rewards of using forecasts may be substantial over the long-term. But in a climate characterized by increased rainfall CV, it looks as though the downside risk is greatly increased compared with the extra benefits that might be expected from some wetter years.

In summary, increasing rainfall CV increases both downside and upside risk, but not symmetrically – in semi-arid environments, ecologically, probably, and economically, definitely, the downside far outweighs the upside. In any case, the upside risk does not matter much, because most livestock producers are risk-averse, with the result that their economic utility will be decreased with increasing rainfall CV and resultant increasing income CV.

Adaptation under Climate Variability and Climate Change

In areas of high climate variability where the future is intrinsically unpredictable households are doing two things: they are trying to maintain their livelihoods in such a way as to be able to deal with unpredictability, that is, their livelihood strategies are by definition, able to deal with a certain amount of variability. Thus, livestock owners may sell their livestock, move their livestock or provide inputs onto their livestock management system as needed. These management strategies are institutionalized into the culture. They also try and reduce the effect of climate variability when it occurs such as diversification of livelihood strategies in ways that are, again, institutionalized for that society. Both of these strategies are important and they work as long as the system is not subject to significant changes such as a large-scale disturbance.
The increased climate variability (as measured in an increased CV of rainfall) that has been increasing steadily for South African livestock keepers appears to be "weathered" by farmers satisfactorily. However, if large climate scale changes occur, people and institutions may not be able to respond because there is a lack of fit between existing knowledge and the new disturbance. Thus, their capacity to adapt, that is, their ability to be flexible and have choices may diminish. Among livestock farmers in South Africa, increasing rainfall CV increases downside and upside risk; the downside risk far outweighs the upside. Since most livestock farmers are risk averse where the upside does not matter much, their economic returns may decrease with increasing rainfall CV.

Household decision-making under uncertainty functions within a complex system of human-environment interactions with many socio-economic, policy and institutional forces also playing an important role (Figure 5). At the core are households and communities who make decisions based on environmental conditions and a number of socio-economic factors which derive from several levels of social organization, the local, regional and beyond. The decision-making process is also influenced by specific land uses and household goals and is conducted under the different forms of severity, duration and form of the climatic perturbation. All these factors determine when, how and in what form, mitigation, adaptation and/or coping occur. These factors also determine adaptive capacity. Through time some or all of these processes can apply depending on initial conditions at the household (e.g., wealth, social networks, etc) and the nature of the climatic event (cf Galvin et al. submitted).

Processes and feedbacks involved in household decision-making evolve over long time periods, constrained by environmental and socio-economic factors. At a given point in time, these processes and feedbacks may be viewed as initial conditions of households. Adaptive management of livelihoods may ameliorate effects of climate change (including increased variation in climatic factors) over time, so that households adapt to climatic uncertainty in an incremental way, diverging from initial conditions slowly. Such adaptation may be less effective or absent when change is rapid.

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Figure 1

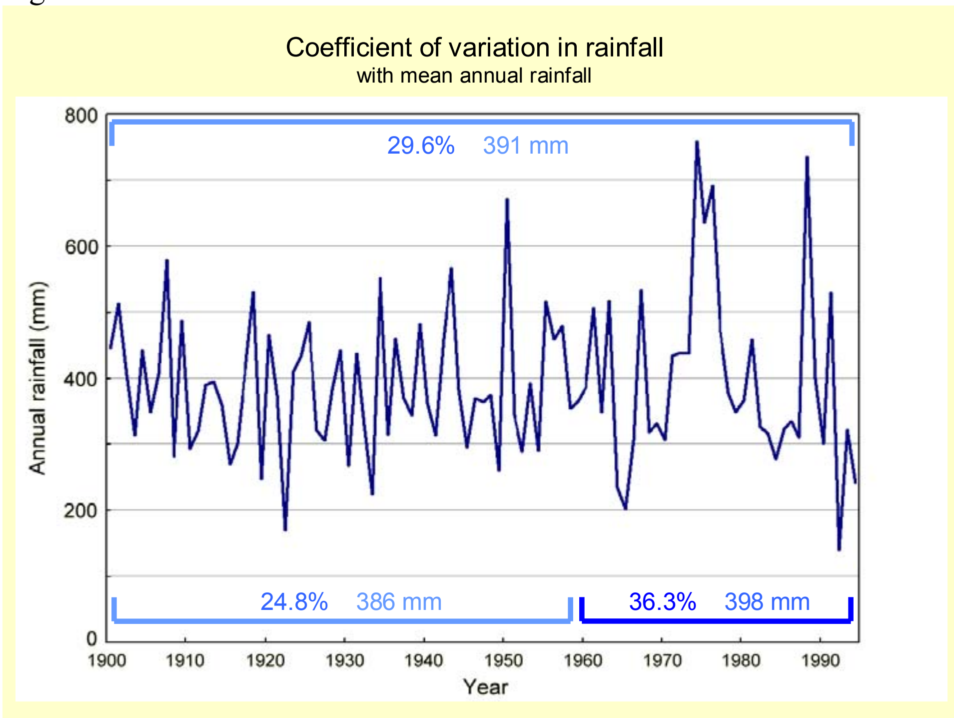

Figure 2

Mean and variance of returns at the optimal forecast culling rate for different CVs of rainfall: Vryburg, farm V112, 1971-1995

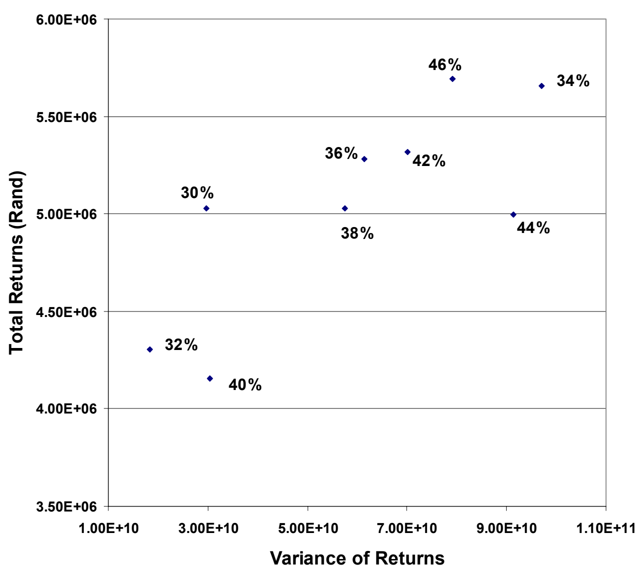

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Figure 3

Mean income per year at the optimal stocking rate and the optimal forecast culling rate for different CVs of rainfall: Vryburg, farm V112, 1971-1995

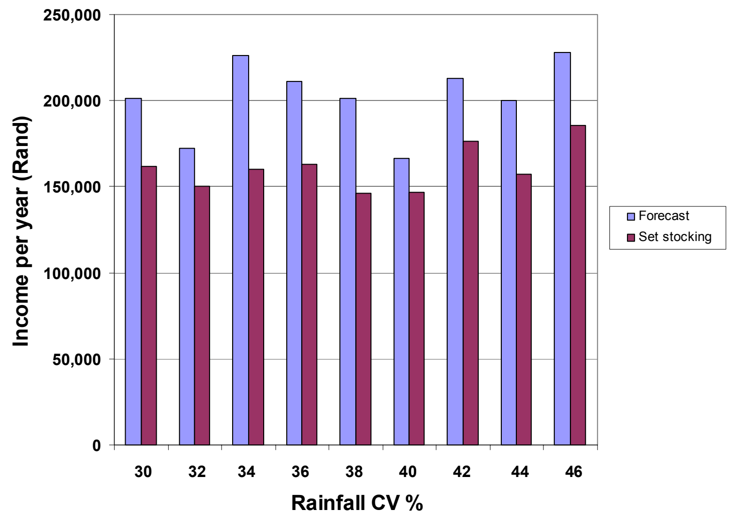

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Figure 4

CV of income of the optimal strategy for different CVs of rainfall: Vryburg, farm V112, 1971-1995

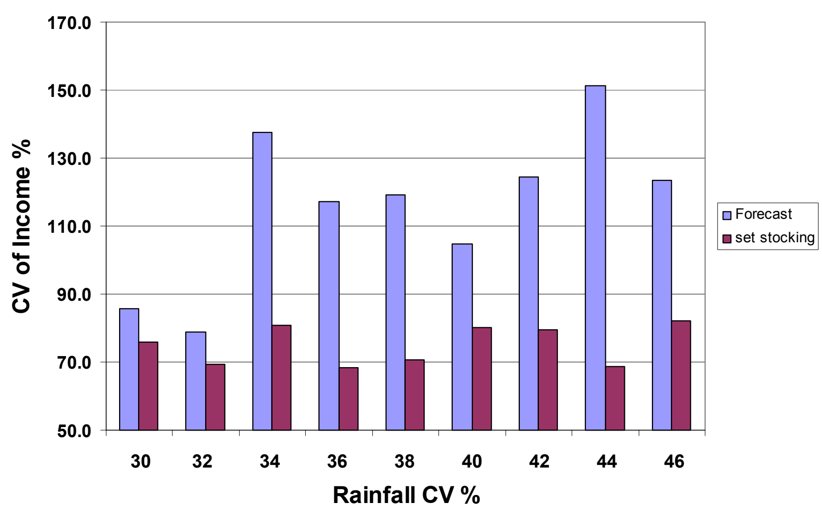

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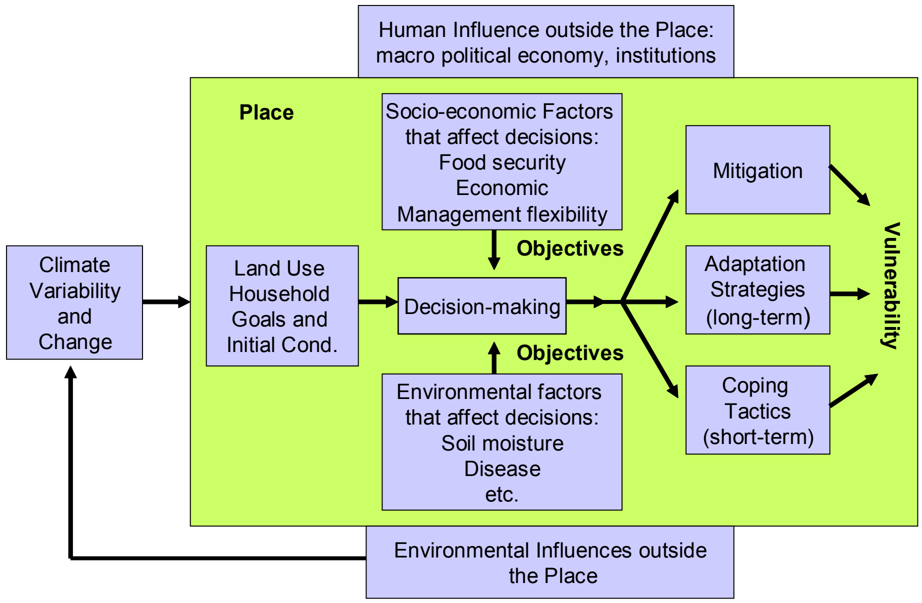
Figure 5


Human Influence outside the Place:
macro political economy, institutions
Place
Socio-economic Factors
that affect decisions:
Food security
Economic
Management flexibility
Objectives
Climate
Variability
and
Change
Land Use
Household
Goals and
Initial Cond.
Decision-making
Objectives
Environmental factors
that affect decisions:
Soil moisture
Disease
etc.
Mitigation
Adaptation
Strategies
(long-term)
Coping
Tactics
(short-term)
Vulnerability
Environmental Influences outside
the Place