HARVARD UNIVERSITY
JOHN F. KENNEDY SCHOOL OF GOVERNMENT

Communicating Probabilistic Forecasts to Decision Makers: a Case Study of Zimbabwe

Anthony Patt

Global Environment Assessment Project

Environment and Natural Resources Program

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The Global Environmental Assessment project is a collaborative team study of global environmental assessment as a link between science and policy. The Team is based at Harvard University. The project has two principal objectives. The first is to develop a more realistic and synoptic model of the actual relationships among science, assessment, and management in social responses to global change, and to use that model to understand, critique, and improve current practice of assessment as a bridge between science and policy making. The second is to elucidate a strategy of adaptive assessment and policy for global environmental problems, along with the methods and institutions to implement such a strategy in the real world.

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Publication abstracts of the GEA Project can be found on the GEA Web Page at http://environment.harvard.edu/gea. Further information on the Global Environmental Assessment project can be obtained from the Project Associate Director, Nancy Dickson, Belfer Center for Science and International Affairs, Kennedy School of Government, Harvard University, 79 JFK Street, Cambridge, MA 02138, telephone (617) 496-9469, telefax (617) 495-8963, Email nancy_dickson@harvard.edu.

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FOREWORD

This paper was written as part of the Global Environmental Assessment Project, a collaborative, interdisciplinary effort to explore how assessment activities can better link scientific understanding with effective action on issues arising in the context of global environmental change. The Project seeks to understand the special problems, challenges and opportunities that arise in efforts to develop common scientific assessments that are relevant and credible across multiple national circumstances and political cultures. It takes a long-term perspective focused on the interactions of science, assessment and management over periods of a decade or more, rather than concentrating on specific studies or negotiating sessions. Global environmental change is viewed broadly to include not only climate and other atmospheric issues, but also transboundary movements of organisms and chemical toxins. (To learn more about the GEA Project visit the web page at http://environment.harvard.edu/gea/.)

The Project seeks to achieve progress towards three goals: deepening the critical understanding of the relationships among research, assessment and management in the global environmental arena; enhancing the communication among scholars and practitioners of global environmental assessments; and illuminating the contemporary choices facing the designers of global environmental assessments. It pursues these goals through a three-pronged strategy of competitively awarded fellowships that bring advanced doctoral and post-doctoral students to Harvard; an interdisciplinary training and research program involving faculty and fellows; and annual meetings bringing together scholars and practitioners of assessment.

The core of the Project is its Research Fellows. Fellows spend the year working with one another and project faculty as a Research Group exploring histories, processes and effects of global environmental assessment. These papers look across a range of particular assessments to examine variation and changes in what has been assessed, explore assessment as a part of a broader pattern of communication, and focus on the dynamics of assessment. The contributions these papers provide has been fundamental to the development of the GEA venture. I look forward to seeing revised versions published in appropriate journals.

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ABSTRACT

Seasonal climate forecasts offer the possibility of helping people to change their decisions in response to scientific information. With an improving ability to model and predict the El Niño / Southern Oscillation, climatologists are able to issues seasonal forecasts that in some places are quite reliable. One such place, is Zimbabwe, lying in the semi-arid tropics of southern Africa, and with an economy highly dependent on rain-fed agriculture. Starting in 1997, there have been efforts to apply seasonal forecasts to decision making in Zimbabwe. The success of these efforts has been mixed. This study examines these efforts, and attempts to explain why they may have been more or less successful. Drawing off literature in environmental assessment, risk communication, and behavioral economics, this study offers guidance for ways to improve the forecast applications process, particularly with respect to the communication of probabilistic information. Additionally, this study seeks to test whether the recommended course of action—a highly participatory assessment process examining uncertainties in great detail—could succeed, through the undertaking of a behavioral economic experiment in rural villages throughout the country. The experimental results suggest the approach could work.

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ACRONYM LIST

AEZ	Agro-Ecological Zone
Agritex	Zimbabwe Agricultural Extension Service
CFU	Commercial Farmers' Union
CNN	Cable News Network
DJF	December, January, and February
DMC	Drought Monitoring Centre
DSW	Department of Social Welfare
ENSO	El Niño / Southern Oscillation
FANR	Food, Agriculture, and Natural Resources Section
FEWS	Famine Early Warning System
FSTAU	Food Security Technical and Administrative Unit
GEA	Global Environmental Assessment Project
GMB	Grain Marketing Board
ICRISAT	Institute for Crops Research in the Semi-Arid Tropics
IRI	International Research Institute for Climate Prediction
ITCZ	Intertropical Convergence Zone
JFM	January, February, and March
NEWU	National Early Warning Unit
NOAA	National Oceanic and Atmospheric Administration
OND	October, November, and December
REWS	Regional Early Warning System
REWU	Regional Early Warning Unit
RRSP	Regional Remote Sensing Project
SADC	Southern African Development Community
SARCOF	Southern African Regional Climate Outlook Forum
SST	Sea Surface Temperature
UNDP	United Nations Development Programme
USAID	United States Agency for International Development
WFP	World Food Programme
WMO	World Meteorological Organization
ZFU	Zimbabwe Farmers' Union
ZW	Zimbabwe

INTRODUCTION

Nothing in life is certain, and anything is possible. People make decisions based on what they think is likely to occur, and sometimes based on what they fear, or hope, might happen. I bring an umbrella to work if I think rain it will probably rain. I wear a seatbelt because there is a small chance I will get in an accident. I buy a raffle ticket because I might win a nice prize. Implicit in all of these decisions is some assessment of what might happen, with what likelihood. I plan my actions accordingly.

Responding wisely to global environmental change requires the same sort of consideration of possible events, except that unlike the raffle ticket decision, good environmental decision making requires a sophisticated appraisal of complicated natural systems. Over the last twenty years, government and academic scientists have joined forces to produce a number of environmental assessments: social communication processes, usually centered around a written report, that coalesce the relevant knowledge about a problem in order to guide decision making. One example of this is the Intergovernmental Panel on Climate Change, which has produced a dizzying array of reports about possible global warming and climate variability, in order to guide policy makers deciding issues at the national, regional, and global levels.

Assessment authors and participants face a number of challenges, increasingly documented in a growing social science literature. As Patt (1999) shows, the scientists participating in assessments have their own strategic concerns, such as promoting policy change, or arriving at consensus, and these are likely to enter into assessment design decisions. Some ways of communicating scientific information are more likely to lead to policy change than are others (Patt, forthcoming). Policy makers are likely to consider some but not all information to be legitimate bases for decision making. As van der Sluijs (1997) shows, the fact that assessments take place within the political world leads to interesting results, such as anchoring on particular numeric estimates (e.g., the range of anticipated temperature chance as a result of a doubling of greenhouse gas concentrations), even when the scientific understanding that gave rise to the original estimates changes. The social science literature can draw specific lessons, and offer general guidance to future assessors about how best to overcome their challenges.

This paper examines the forecasting of seasonal climate in Zimbabwe, an assessment effort designed to mitigate food insecurity resulting from drought. The assessment effort has its roots in the discovery that crop yields in Zimbabwe correlate highly with El Niño, the changing temperatures of tropical Pacific surface waters and patterns of atmospheric circulation that accompany those changes. I examine this particular assessment for two reasons. First, it is an important assessment. People's lives depend on making good decisions that reflect their beliefs about the likelihood of drought; assessments can help them to understand what might happen, and how they can react. Second, it is a case study that can improve the general understanding of what works and doesn't work in trying to communicate uncertainty to decision makers. The relationship between El Niño and rainfall in Zimbabwe is not absolute, and there is a significant chance of error associated with using the former to predict the latter. In Zimbabwe, scientists have made a deliberate decision to forecast seasonal climate in probabilistic terms—to quantify their uncertainty—something rare among environmental assessments. Because it is rare, the existing social science literature on assessments, such as the GEA (1999) framework that I will explore in depth, offers little guidance how best to incorporate quantified uncertainty into an assessment. Another set of theory, in the related field of risk communication and behavioral economics, has examined issues of

communicating uncertainties, although in the different context of more local risk assessments. The Zimbabwe case can show whether this theory ought to fill in the gap in the existing assessment literature.

Traditionally, environmental assessments have expressed uncertainty in vague terms, or not at all, reflecting the difficult—perhaps impossible—task of quantifying the likelihoods of different outcomes. Unfortunately, decision makers could usually use more precision, in order to gauge the importance of the new information coming in. In this paper, for example, I explore the decisions that farmers face in response to climate forecasts. Doing a good job of incorporating new information is not an easy task. Farmers are already responding to a variety of price signals, food requirements, and cash flow challenges. They can change their decisions in response to a climate forecast, but that change is likely to prove costly if the forecast be wrong. Ignoring the uncertainty, or treating it in vague terms, trivializes the importance of the other information which farmers must also consider. While communicating quantified uncertainty has its own special challenges, the risk communication literature argues strongly that it is a task worth undertaking.

I suggest this argument is correct, based on the analysis of two very different sets of data. First, I trace the historical events that occurred in Zimbabwe during the 1997-98 El Niño event, when seasonal climate forecasts first reached a diverse set of users in a systematic way. Through a review of documents, newspaper articles, existing literature, and interviews with key players in the assessment and decision making institutions in Zimbabwe, I evaluate the relative success of the forecast in different sectors of the economy and different groups of decision makers within those sectors. I observe a complex set of decisions, made in response to numerous pieces of information, in which actors hesitated to incorporate new types of information out of fear that it would be wrong. Second, I analyze the results of a behavioral economic experiment, designed to test a critical assumption necessary to apply the existing risk literature to the Zimbabwean context: whether Zimbabwean subsistence farmers follow the same patterns of thinking about probabilistic information that researchers have observed over and over in the west. My results suggest that they do.

This paper is structured as follows. In Section 2, I trace the events that unfolded in Zimbabwe during the 1997-98 growing season. I focus on the relationships between decision makers and the scientists who provided news of the growing El Niño in the Pacific, and its likely impact on Zimbabwe. I present this information first in order to provide a set of examples to use in the later discussion of theory. In Section 3, I discuss the existing theory on assessment effectiveness, and how it is consistent with observations in the Zimbabwe case study. In Section 4, I discuss relevant theory on risk communication and behavioral economics that I suggest can augment the assessment literature. Again, I show how observations in the Zimbabwe case study are consistent with this body of theory, and thus suggest that the theory, developed to understand the dynamics of more localized risk assessment, can also help for designing better global environmental assessment. In Section 5, I discuss an experiment I undertook in order to test a critical assumption: whether Zimbabwean farmers understood probability well enough to take part in a participatory assessment process. I wrap up the paper in Section 6, suggesting general lessons learned, and ideas for the future.

ZIMBABWE 1997-98 CASE STUDY

Since the 1980's, when the words "El Niño" started becoming a household term, the business of seasonal climate forecasting has grown into a minor industry (Mason et al., 1999; National Research Council,

1996). One region where the potential for useful climate forecasting is highest is southern Africa, and Zimbabwe in particular, where both the weather and the economy correlate highly with El Niño cycles (Watson et al., 1997; Rowlands, 1998). A 1994 article in *Nature* noted a correlation in excess of 0.5, and approaching 0.8, between SST's in the NINO3 region of the tropical Pacific, and maize yields in Zimbabwe (Cane, Eshel, and Buckland, 1994). Coming on the heels of the 1991-92 drought, probably the worst in a century, the article suggested that "long-term forecasts, although hardly infallible, are sufficiently reliable to be useful inputs to the SADC [Southern African Development Community] Regional Early Warning System. The article promised that better communication between climate forecasters and policy-makers would allow the country "to anticipate and react early to minimize the cost and damage to the community" (Cane, Eshel, and Buckland 1994, 205).

Why is there a correlation between ENSO and Zimbabwean rains and maize yields, when the two events are on opposite sides of the planet? El Niño is the warm phase of the El Niño / Southern Oscillation (ENSO) phenomenon. During an El Niño, surface water in the eastern tropical Pacific is warmer than usual, and ocean and atmospheric circulation patterns are different. Since the tropical Pacific is one of the Earth's major heat repositories, the change can have global repercussions. Zimbabwe is located in the semi-arid tropics, at about 20° south of the equator. In "normal" years, the Intertropical Convergence Zone (ITCZ), a band of converging winds centered near the equator, tends to move southward over Zimbabwe during the summer months (November through March). This means that more of Zimbabwe's air blows in from the warm waters of the tropical Indian Ocean, rather than from the colder waters of south Indian and Atlantic Oceans, and is thus relatively wet. Additionally, the convergence of winds is associated with the development of storm clouds, and thus frequent localized events of heavy rain. The location of the ITCZ depends primarily on where there is the greatest surface heating due to solar radiation, but it is also influenced by ocean currents and winds. Over Africa, the ITCZ often stays further to the north, spending less time over Zimbabwe, during El Niño years. Since the summer rainfall of Zimbabwe is so dependent on the ITCZ's moving significantly south of the equator, El Niño can have a large impact.

Why does Zimbabwe depend on predictable rain? Close to 70% of Zimbabweans are subsistence farmers on communally owned land, and rely on rain-fed crops—principally maize but also sorghum, millet, groundnuts, cotton, and squash (National Economic Planning Commission, 1999; Policy and Planning Division, 1999). The country's economy depends on agriculture, not just for meeting its internal food requirement but also because of large cash crop industries, such as cotton and tobacco. There is little irrigation infrastructure in place.

It is no surprise, then, that forecasters and crop modelers have focused attention on Zimbabwe in an effort to be useful (e.g. Phillips, Cane, and Rosenzweig, 1998). This is a good case to study because there has been, and continues to be, a systematic effort to communicate the forecasts, with different strategies employed. During the last eight years, an extensive institutional infrastructure has developed for just this purpose. I examine the results of these efforts, out of a desire to understand what makes for a successful forecast. In this section, I begin by cataloguing the institutional structure for forecast production and dissemination. I then turn my attention to events during the 1997-98 season, comparing the usefulness of forecasts across different user groups. Finally, I discuss the implications of this case for a model of forecast effectiveness, and the implications of the model for this case.

Institutional Landscape

In 1991-92, a major drought caught the Zimbabwean government unprepared, and the process of importing large quantities of food at the last minute proved harrowing and costly (Scoones et al., 1996). The government came under criticism for failing to heed the warnings of climatologists, who had predicted the drought based on their El Niño modeling (Glantz, Betsill, and Crandall, 1997). Between 1992 and 1997, the Zimbabwean government made an effort to coordinate their drought management policies (National Economic Planning Commission, 1999). When news of a possible upcoming El Niño started to appear in early 1997, many Zimbabwe institutions were more prepared, with formalized systems for responding to the information (Stack, 1998). Examining the flow of information allows one to see which users received what information when and from whom, and this is essential background information for understanding the effectiveness of forecasts. In this section, then, I map out the institutional connections present in Zimbabwe during the 1997-98 ENSO event and through which information about the climate forecast passed.

I classify the institutions into three distinct groups: meteorology, food security, and agriculture. In general the meteorological institutions are responsible for translating information produced at the international and national level into useful forecasts for different economic sectors in Zimbabwe, as well as the functions of monitoring the climate within Zimbabwe, and hence gathering much of the data that serve as input into climate models. I then examine two of these specific sectors, and how they move the forecasts along to key decision makers. The food security sector comprises those institutions and actors concerned about hunger and famine in Zimbabwe, i.e. correcting any mismatch between food supplies and food demand. While making sure that Zimbabwean farmers grow enough food to feed the country is important to this sector, it is just one concern among many. These people worry about the distribution of food throughout the country, and if there are local or national shortfalls, the logistics of acquiring food and moving it to where it is needed. The agricultural sector comprises the country's farmers, as well as their sources of farming inputs, financing, and information. Within the agricultural sector there are two main groups—large-scale commercial farmers and small-scale communal farmers—as well as a number of small-scale commercial farmers. I do not discuss two other sectors that might potentially use climate information: water resources and health. The water resources sector worries about providing adequate supplies of water to Zimbabwean cities, and to those farmers who irrigate, as well as generating electricity at the nation's hydropower dams. The health sector worries about the spread of diseases, which in the case of malaria can respond to rainfall. I do not discuss these sectors not because they are unimportant, but because from interview data in Zimbabwe it still appears that there are very few, if any, decisions that they have make in response to climate forecasts. Certainly, exploring how these sectors can incorporate forecasts in Zimbabwe, as they have successfully done elsewhere, will be a fruitful area for future research.

Meteorology

The Zimbabwe Department of Meteorological Services, institutionally located within the Ministry of Transportation and Energy and physically based at the edge of downtown Harare, forms the heart of a network of organizations generating and interpreting climate information. Originally existing to aid air transportation, it was founded by the British in then Rhodesia, and passed through transitions in the country's government while maintaining its core facilities. The Met Service, as it is known, generates forecasts based on its network of monitoring stations throughout the country, incorporates data and

forecasts from foreign meteorological organizations, and disseminates its forecasts and its monitoring data directly to a network of users and indirectly via the national media.

Figure 1 summarizes the relevant structures of the Met Service and the organizations with which it interacts, based on interviews with members of the Met Service staff. The Met Service receives information from a host of foreign organizations such as those shown in the top of the figure, primarily through their internet sites although also via direct communication. It also exchanges information from the Drought Monitoring Centre for southern Africa (DMC), located in the same building as the Met Service, in Harare, and sponsored by the World Meteorological Organization (WMO) and United Nations Development Programme (UNDP). The DMC is in constant communication with SADC's Regional Remote Sensing Project (RRSP), which also sends information to the Met Service. The function of the RRSP is to monitor satellite images so as to generate information on vegetation growth and potential cloud development (Stack, 1998). The Met Services operational component relevant for seasonal forecasting is the Climate Services Branch.

The DMC and RRSP join with all southern African met services, as well as the relevant foreign meteorological organizations such as the US National Weather Service (part of the US National Oceanic and Atmospheric Administration, or NOAA) and new international climate research and prediction centers such as the IRI, to organize and fund the Southern African Regional Climate Outlook Forum (SARCOF). The first SARCOF occurred in September 1997, in Kadoma, Zimbabwe. SARCOF has occurred two or three time per year since then, and is the place at which meteorologists generate a consensus climate forecast for the region. Immediately following the September SARCOF, the Zimbabwe Met Service organizes its own workshop to develop a Zimbabwe-specific forecast consistent with the SARCOF results. Present at the Zimbabwe meeting are local stakeholders, the media, and political leaders. The Met Service issues its seasonal forecast after this workshop. In 1997-98 the Zimbabwe forecast was exactly the same as the Zimbabwe region of the SARCOF forecast. It supplements this forecast with monthly updates. During the growing season, the Met Service also issues ten-day and daily forecasts. Since 1998 the ten-day forecasts have come weekly, with a three-day overlap. With the exception of the daily forecasts, the Met Service sends all of these to a long mailing list of users and the media, via fax and email. The daily forecasts go to the media and the airports. Representatives from the Met Service are available to meet with users directly; occasionally users have organized training workshops.

Most of the foreign meteorology institutions at the top of Figure 1 also generate some sort of seasonal forecasts, which appear on the internet and in the foreign press. Climatologists at the DMC and the RRSP do monitor these forecasts, but generally do not take any action or make public statements until the SARCOF forecast has been issued. Interviews with farmers revealed that other users do not receive these outside forecasts, with two main exceptions. First, subscribers to satellite television service in Zimbabwe—most commercial farmers and many urban residents—have access to South African Weather Bureau forecasts, which are broadcast during the popular evening news show. Second, the Commercial Farmers' Union monitors the internet site of Professor Mark Jury at the University of Zululand. Professor Jury prepares his own seasonal forecast for southern Africa; unlike the government affiliated institutions in Figure 1, Professor Jury does not change his forecast to make it conform to the SARCOF forecast, and its predictions are sometimes different.

Food Security

The food security sector was the driving force behind efforts to apply climate forecasts to Zimbabwe decision making, and the methods of application reflect this fact. Food security implies an absence of famine, and one important feature of famine is that it builds up slowly in response to a number of factors (Ayalew, 1997). Within the food security sector are thus a number of organizations concerned with early warning: the monitoring and communication of information indicating the presence of factors leading toward famine (Dilley, 1997). An early warning allows relief organizations to prepare ahead of time, and thus makes their job easier and less expensive. Traditionally, the early warning indicators have included rainfall distribution and foliage and crop development during the growing season. The seasonal climate forecast, introduced as an additional piece of information in 1997, arrives before the growing season, and hence in advance of the traditional early warning indicators. Thus, the response of the food security sector to the climate forecast is to pay more attention to the other early warning indicators, the "hard evidence" of impending famine (Stack, 1998). If these indicators show that food insecurity is likely, then the relief agencies can go about the business of distributing food where it is needed.

Figure 2 maps these institutions. At the heart of the early warning system is the SADC Food Security Technical and Administrative Unit (FSTAU), which maintains two floors in an office building (Merchant House) in downtown Harare. The FSTAU is part of SADC's Food, Agriculture, and Natural Resources Section (FANR). The two main branches of the FSTAU are the Regional Remote Sensing Project (RRSP) and the Regional Early Warning Unit (REWU). As discussed above, the RSSP monitors satellite data and communicates information about foliage development and short-term rainfall expectations to a number of institutions, including the DMC, the Zimbabwe Met Service, and the REWU. The REWU publishes a quarterly food security bulletin for the entire SADC region, and assists national early warning units in the SADC countries, which along with the REWU make up the Regional Early Warning System (REWS). The Zimbabwe National Early Warning Unit (NEWU) is located within Agritex, the national agricultural extension service, which is part of the Ministry of Lands and Agriculture. They are located in another building, several blocks away. In terms of connections between these organizations and those of Figure 1, all of the organizations shown in Figure 2 receive the seasonal, monthly, and ten-day forecasts from the Zimbabwe Met Service. All of them also send a representative to the SARCOF meetings.

The regional office of the Famine Early Warning System (FEWS) is also in Merchant House, and so is in constant communication with the other FSTAU groups. The regional FEWS office reports to the Harare mission of the United States Agency for International Development (USAID). During non-emergency times, the FEWS regional office writes a monthly update covering southern Africa for the FEWS main office at USAID in Washington, DC, which publishes (over the internet and through the mail) a monthly bulletin for all of sub-Saharan Africa. In 1997, with the first major application of ENSO information to famine early warning, the FEWS regional office also prepared an information packet for the Zimbabwe NEWU and Agritex, to assist them in educating Agritex employees about ENSO. FEWS, then, is an additional source of expertise, completely funded by the United States, to assist SADC institutions develop technical capacity and respond to crises.

The institutions at the bottom of Figure 2, and not the early warning system, are the end users of information in the food security sector. The USAID mission in Harare is directly involved through its involvement with the FEWS regional office, and operates via the United States Office of Foreign Disaster Assistance. The World Bank is involved, both as a food relief donor and as a party interested in

the effects of drought on its structural adjustment program. The Department of Social Welfare (DSW) in the Ministry of Public Service, Labour, and Social Welfare within Zimbabwe is the local coordinator of food distribution efforts, and works with the Ministry of Lands and Agriculture and the Ministry of Health and Child Welfare to determine the shortfalls throughout the country. Indeed, in most years the DSW operates a modest food assistance program at the local level, and it is only in disaster years that it gets a helping hand from the other organizations (National Economic Planning Commission, 1999). The Zimbabwe President's Office is involved in budget allocations for food relief, and assists in the planning effort. The Grain Marketing Board, a quasi-governmental organization that, among other things, controls the national Strategic Grain Reserve, is responsible for stockpiling grain, and making it available in times of need. Finally, a large number of non-governmental and intergovernmental organizations such as Christian Aid and the Food and Agricultural Organization of the United Nations World Food Program (WFP), and governmental donors such as the Canadian Development Organization, also work to mitigate any food emergency. Nearly all of these organizations also receive the Met Service' seasonal, monthly, and ten-day forecasts, but rely on the early warning system to translate the climate and weather forecasts into the potential for food insecurity.

Agriculture

The final sector I consider is agriculture, illustrated in Figure 3. I group farmers into three categories: communal land farmers, small-scale commercial farmers, and large-scale commercial farmers. The boundaries between these groups are fuzzy, however. Communal land farmers have relatively secure *de facto* tenure on their land, which is legally owned by the President (Muir, 1999). As of 1991-92, there were 1.5 million households cultivating 4.5 million of their 16.4 million hectares (Mudimu, 1998). They face many financial and technological constraints; for example, most cultivate using draft animals, rather than tractors, and few can afford to apply fertilizer during the season. Small scale commercial farmers own a total of 1.2 million hectares, are generally black, and face many of the same financial constraints as communal farmers. The Agricultural Finance Corporation, a quasi-governmental organization is responsible for providing credit to both groups, which together are often described as the small-holder farmers. Large scale, white commercial farmers own 11.2 million hectares, and have greater access to capital, with both cash reserves and access to commercial bank loans. Commercial farmers use tractors and other machinery, and this allows them to respond quickly to information. They typically apply fertilizer throughout the season; in a drought year, they might decide to apply less fertilizer, or none at all. As a group, they are economically if not politically empowered. They get their news from CNN and the internet, in addition to the Zimbabwe media, and they also receive a number of agricultural magazines. Many have attended agricultural university in Zimbabwe or South Africa, and are receptive to new technologies.

What crops do these farmers grow, and why? Communal farmers' principal crop is maize, augmented by sorghum and millet in the driest regions of the country. Most of their grain goes for their own consumption, and what they do sell goes to cover the cost of inputs, such as seed. They round out their food production by growing groundnuts, squash, soybeans, and sunflowers, as well as raising goats, cattle, and chickens. For cash crops, they and the small-scale commercial farmers grow cotton and paprika. Nonetheless, it is very difficult for small scale farmers completely to feed themselves, let alone sell enough cash crops to meet their financial wants and needs; most rely on money sent "home" from relatives working in the city (Scoones et al., 1996; Gundry et al., 1999). Commercial farmers have traditionally grown the same crops, but as the Zimbabwean dollar has fallen compared to foreign

currencies, they have focused more attention on cash crops for export: cotton and tobacco. All of these crops grow during the summer months—November through March—and rely on rain. Additionally, many commercial farmers grow winter wheat, requiring irrigation.

There are two members' organizations. The Commercial Farmers' Union (CFU), based in Harare, serves the large commercial farms. It includes a number of smaller associations, such as the Cotton Growers Association. The CFU has been active in disseminating climate and weather forecasts. When they receive the Met Service seasonal, monthly, and ten-day forecasts, they distribute them immediately to their membership. Those farmers who have email access, roughly 20%, receive the information directly. The others receive it via the CFU regional offices, which broadcast at regular times over ham radio. The forecasts that the farmers receive are the exact ones put out by the Met Service, with supplemental analysis, often highlighting the uncertainties, coming from the CFU head office. The CFU also puts out a monthly newsletter to its members, which contains the forecast information, and a monthly magazine ("The Farmer"), which contains more in-depth articles, often with analyses of the forecasts. In 1997, prior to the growing season, the CFU made a special effort to educate member farmers about the forecasts, in particular their probabilistic character.

The Zimbabwe Farmers' Union (ZFU), also based in Harare, serves 1.1 million small-holder farmers. These include both the small scale commercial farmers and the communal farmers. Most communal farmers, however, have very little contact with the ZFU. Like the CFU, the ZFU communicates to its members via regional offices. But the ZFU has been much less active in communicating Met Service forecasts to its membership, in part because its members lack the resources (e.g. internet access, ham radios) to receive the short term forecasts quickly. In addition, the ZFU sees its role more as advocating for farmers over issues like grain prices, and relies on the agricultural extension service to educate farmers.

The agricultural extension service (Agritex) serves exclusively the communal farmers, assisting them with farming practices. Information passes from the Harare office down a chain of command that includes regional offices, district offices, and then local offices. The local offices are in larger villages and have a supervisor and one or more extension officers, who live nearby. Most farmers, but not all, have occasional contact with an Agritex extension officer. Agritex offers a training program for farmers leading to a "master farmer" certification; the certificate makes access to credit more available. For climate forecasts, the NEWU located within the Agritex head office has made an effort to educate the regional directors on the causes and effects of ENSO, along with the uncertainties inherent in forecasting seasonal climate. Agritex has deliberately tried to avoid conveying probabilistic forecasts down to the district and local level, out of a fear of confusing the farmers. Rather, they have tried to translate seasonal forecasts into deterministic terms, such as saying that it will be a good or a bad year.

Among small scale farmers, hybrid varieties of maize are the primary grains grown. Unlike traditional varieties of maize, sorghum, and millet, farmers must buy seed each year for the hybrid varieties. There are several seed houses doing business in Zimbabwe, with the largest, Seed Co Ltd., accounting for more than 50% of the market. Seed Co, like the other companies producing seed and fertilizer, communicates directly with the large commercial farmers through a network of sales representatives. They communicate indirectly to the small-holder farmers via the network of independent retailers, located in cities, towns, and large villages. The seed houses put together training sessions to help farmers select appropriate varieties, but they do not incorporate climate forecast information. In part, this is because the information arrives too late in the season, after most farmers have purchased their seed, and are starting

to prepare the ground for planting. There are also a number of agricultural research institutes, such as Institute for Crops Research in the Semi-Arid Tropics (ICRISAT), the southern African office of which is based near Bulawayo, that seeks to develop alternative grains to the seed companies' hybrid maize varieties. These institutes often meet with farmers to discuss appropriate crops for the drier regions, such as sorghum and millet, although they do not provide information in direct response to climate forecasts. Both religious leaders (including both Christian and traditional) and traditional forecasters (relying on a number of natural indicators) discuss climate issues with farmers (Shumba, 1999).

Heterogeneous climate, soil conditions, and tribal backgrounds influence the agricultural sector across Zimbabwe, especially the small-holder farmers for whom irrigation is rare. Figure 4 shows the five natural regions, or agricultural/ecological zones (AEZs) that agronomists use to describe the country. Natural region I receives the most rain, about 1,000 mm per year, with precipitation in all twelve months. By contrast, natural region V receives the least, less than 500 mm per year, nearly all of it in the summer months. Topography is the main determinant of rainfall, with the higher regions receiving more. Easterly winds prevail, so there is a rain shadow behind the mountains of the Eastern Highlands. Large commercial farms are concentrated most heavily in region II, of which they own 63% of the total land area. Seventy-four percent of the communal farming area is in natural regions IV and V; likewise over 60% of this arid land is under communal control (Policy and Planning Division, 1999).

The two main ethnic groups in Zimbabwe are Shona and Ndebele, and each has its own language. Harare and the eastern provinces of the Mashonalands, Manicaland, and Masvingo are primarily Shona, while Bulawayo and the Matabelelands are Ndebele. The Midlands province is a mixture of Shona and Ndebele. Historically, Shona people were farmers, while Ndebele people were herders, reflecting the greater suitability of Shona land for agriculture. Prior to colonization in the late-1800's, the Ndebele were under the rule of a king, with a standing army, and made frequent raids on the less centrally-organized Shona chiefdoms. Today, Shona dominate the national government. There remains distrust between the two tribal groups. Within each group, there is also a great deal of intergenerational bickering. As Bourdillon (1993) describes, the forces of urbanization and education, both accelerated since Zimbabwe's independence in 1980, have led to the younger generation's reinterpretation of many of the traditional social norms centered around patriarchal extended families working together on communally owned tribal land. There is an ongoing change in association from traditional religious beliefs, centered on ancestral spirits who provided the authority for local chiefs, traditional healers, and weather forecasters, to African "independent" churches, a mixture of Christianity and traditional beliefs, and finally to international versions of Christianity, such as Catholicism.

Summary

I have mapped out a complex array on institutions. As discussion shifts to the specifics of the 1997-98 El Niño, one should keep in mind three key features of the institutional framework. First, both the meteorology and food security sectors developed a thick network of institutions during the mid-1990s, all of which are in communication with each other about the weather. There are multiple and redundant information channels between these organizations, and they are in close physical proximity. Second, the commercial farmers, through the CFU and via the internet and satellite television, are tapped into climate and weather information coming from the Met Service and from foreign forecasters. The CFU, recognizing the confusion that comes from multiple sources of potentially conflicting information, makes a concerted effort to educate its members about the basics of weather prediction, especially the

uncertainties associated with long-term forecasting. Third and finally, communal farmers represent the largest block of Zimbabwe's population. They receive weather information from a number of sources, potentially competing: the newspaper, traditional forecasters and village chiefs, and religious leaders. Their connection to the "official" forecast coming from the Met Service is through Agritex. Agritex is a hierarchical organization, and has made the explicit decision to simplify its message to farmers, so as not to confuse them about the forecasts even more. Unlike the CFU, there are no clear pathways for information to travel up the Agritex hierarchy.

Forecasts and Response

A warm ENSO event (El Niño) became apparent in March 1997, and continued to grow for the next nine months. By December, the sea surface temperature (SST) anomaly in the NINO3 region of the Pacific was 4°C. The effects of this ENSO, the largest ever, were felt around the world. In southern Africa, however, the usual pattern of drought associated with ENSO warm events was complicated by heightened SSTs in the southern Indian Ocean, and hence more water vapor in the usually dry southeast winds. Indeed, seasonal rainfall totals for much of Zimbabwe were near average. But the rainfall distribution was far from normal: most of it fell in a short period, and caused extensive runoff and flooding rather than promoting healthy crop growth. Figure 5 shows cumulative rainfall distributions for four monitoring stations in natural regions IV and V, as well as the thirty year average for each station. There was a week of very heavy rainfall in late January, following three weeks of dry conditions, and preceding another six weeks of almost no rain. In Hwange National Park, the late January rainfall was especially heavy, enough to bring the season total above normal. Without the late January rainfall, all four sites would have had almost no rain after December.

Forecasts

Starting in April, 1997, IRI climatologists communicated directly with scientists at the RRSP in Harare, expressing concern over the warming of Pacific SSTs. The second quarter REWU bulletin (SADC, 1997a), published in May, did not report on the ENSO anomaly, and it was the June FEWS bulletin (FEWS, 1997a) that first sounded the alarm within the food security community. The bulletin devoted a page to a description of ENSO and its teleconnections, and concluded by noting that "NOAA has now issued an ENSO advisory that a warm event is developing. Having started in the April - May period and having developed quite rapidly, this may be one of the stronger episodes. FEWS and other groups are monitoring this event carefully to track its development and determine its likely effect on weather and crops." By their July bulletin (FEWS, 1997b), FEWS had begun to include a monthly "El Niño Update," and highlighted that countries in southern Africa "should be sure that structures are in place to anticipate and handle problems."

By mid-June, SADC had formed an *ad hoc* committee to monitor ENSO, made up of representatives from the REWU, FEWS, and the DMC. That same month the REWU issued a statement addressed to the SADC ministers of agriculture, advising them to prepare for a likely ENSO-related drought. The June REWU quarterly food security bulletin (SADC, 1997b) also warned of the developing ENSO warm event. In August a supplemental REWU bulletin (SADC, 1997c) was devoted to ENSO effects. By September REWU and FEWS had collaborated in preparing an information packet for the SADC-member NEWUs, describing ENSO and its effects, and had organized a special training workshop (FEWS, 1997c). Contemporaneously, the World Food Programme began cooperating with SADC and

other regional institutions to plan for a possible drought. SADC and FEWS contracted consultants to draw up plans.

Within the meteorology sector, people were busy preparing for the first SARCOF, held in Kadoma, Zimbabwe, 8-12 September. Attending were met service representatives from 11 SADC countries and the DMC, and scientists from the Universities of Witwatersrand (South Africa), Zululand, and Zimbabwe, as well as the WMO, IRI, NOAA, USAID, United Kingdom Meteorology Office, and the World Bank (NOAA, 1999). SARCOF issued a consensus forecast on 12 September for the entire SADC region, in general calling for above normal rainfall in the north, normal to below normal in the central region, and below normal in the south. The definition of *normal* was rainfall within the range of the middle tercile of the past thirty years (i.e., the ten average years). The definition of *below normal* was rainfall amounts falling within or below the range of the lower tercile of those 30 years (i.e., the ten driest years). Likewise, the definition of *above normal* was rainfall in or above the range of the ten wettest years. Figure 6 shows the SARCOF probabilistic forecast for Zimbabwe, which the Met Service adopted and reissued as its own. The verbal forecast, accompanying the weather maps, indicated that Zimbabwe would likely receive near normal rains in the early part of the season, with a high likelihood of dry conditions in the second part of the season.

The Met Service continued to issue its ten-day and daily forecasts, but these tracked local weather phenomena and did not draw from SST data. The mid-season SARCOF, (SARCOF-2), occurred in Windhoek, Namibia, on 18-19 December. SARCOF-2 produced a revised forecast for the January-February-March period, and while there were some changes for other parts of the SADC region, the forecast for Zimbabwe remained the same. The Met Service did not issue a mid-season correction forecast following SARCOF-2. As the summer came to a close in March and April, the Met Service organized a post-season review meeting, where they reviewed with stakeholders the results of the forecasting effort during the season. The conclusion of the Met Service was that the forecast of normal to below normal had been accurate. What was not accurate, they said, were the stories in the media predicting a major drought from "the mother of al El Niños," reports that most people in the country read and in part based their decisions on. SARCOF-3, the post-season international review meeting, occurred in Pilanesburg, South Africa, in May. The conclusions there were similar to those at the Zimbabwe review meeting.

Media Coverage

The media extensively covered the ENSO event and corresponding forecasts of drought, and for many people was the only source of climate-related information. People in the meteorology, food security, and agricultural sectors were highly critical of the coverage that the media devoted to the ENSO event, accusing them of blowing it out of proportion. The feeling among professionals was that the media hype contributed to a poor understanding of the uncertainties associated with ENSO. Because they felt that the media overplayed El Niño, many saw their own role as trying to downplay the significance of the ENSO warm event, urging people not to panic.

In order to understand these feelings about the media coverage, I examine a sample of newspaper articles related to ENSO or the weather, collected during the 1997-98 season from local newspapers, and analyze the type of coverage.[1] Some articles warned readers about the coming El Niño: an editorial in *The Herald* on 1 September advises: "Recent world conferences in both Tokyo and Geneva have warned of a more

severe El Nino (sic) and widespread drought in its wake. Zimbabwe is not an island. It is imperative that Government and the country's farmers meet urgently to decide on a course of action." Some articles were neutral with respect to El Niño, discussing it as context for news about ongoing preparation efforts: an article in the *Zimbabwe Independent* on 3 October, reports: "Southern Africa, bracing itself for an El Nino-inspired drought, is better prepared for the potential disaster than in previous years, the World Bank said on Tuesday." A third group of articles mention ENSO or the predicted drought, but do so to contrast these predictions with the actual rainfall, and to downplay the accuracy of the forecasts. For example, an article in *The Sunday Mail* on 1 February reads: "From climate change to El Nino, cynics are having a field day. For the climatologists and meteorologists, it looks like they are going to have to keep their computerized climate models and scientific explanations for another rainy day." A fourth group of articles cover related topics, such as the rains or food security issues, but do mention ENSO or a forecast of drought.

Figure 7 shows the distribution of articles throughout the season. There were many *ENSO warning* articles early in the season, when a drought was still news. Many of these articles also mentioned the uncertainty associated with climate prediction. By October, nearly all articles mentioning El Niño or drought were *ENSO neutral*, mentioning it as the context for other news. Contemporaneously, fewer articles discussed the drought as uncertain; most took it as a foregone conclusion that there would be drought. When the rains started out relatively normally, in October, the first of the *ENSO downplay* articles appeared. These were rare, however, until the week of heavy rains in January, when several article appeared criticizing the forecast of drought. There were several more of these articles at the end of March, after another week of rain. These later articles again discussed the uncertainties associated with ENSO forecasting. As the season progressed, and the threat of a severe drought diminished, more articles on subjects related to the weather, such as the condition of crops, made no mention of ENSO or a forecasted drought.

Another trend is also interesting. Early articles, starting in July and continuing into September, discuss mainly the relevance of El Niño for the country's food security, with less attention given to farming practices, health, or economic concerns. As the rainy season began in October, newspaper articles focused more and more on the relevance of El Niño for agricultural decision making, such as which crops to plant. This trend continued through January, at which point coverage of El Niño fell off in the wake of heavy rains.

Did the media coverage matter? Probably. For many rural Zimbabweans, newspapers such as *The Herald* are their primary source of information on the outside world. While I have not analyzed its coverage, the Zimbabwe Broadcasting Service also devoted news coverage to El Niño, not only in English but also in Shona and Ndebele. My interviews revealed that this coverage echoed the newspaper reports, in terms the type of coverage devoted to ENSO. The message, propagated by the media during the planting season, that El Niño was sure to cause a drought, was similar to that which Agritex conveyed, and contradicted the probabilistic forecasts which the Met Service sent out to its mailing list.

Agricultural Response

The agricultural sector tried to incorporate the forecasts into its decision-making, with success varying across groups. Table 1 summarizes the information received and the responses taken. The Commercial Farmers Union (CFU) had been monitoring the media reports of a growing El Niño from the beginning,

and so made a special effort to meet with forecasters from the Met Service to discuss implications, and to keep its members knowledgeable. During the winter months of July and August, the CFU incorporate discussions of El Niño into its "field day" activities in the different regions, reinforcing the probabilistic nature of the prediction. Occurring in July and August, these deliberately coincided with time at which commercial farmers were buying their seed for the upcoming season. The general advice they developed for their farmers, in coordination with the Met Service, was to plant early to take advantage of the predicted good early season rains, and to plant short season varieties to avoid the likely late season drought; specific decisions about what particular varieties to plant were generated at the field day meetings. In normal years, commercial farmers plant high-yielding varieties of maize, which carry some risk in the event of drought, but generally out perform the more drought tolerant varieties. Given a spectrum of maize varieties of different drought tolerance, commercial farmers have a wide range of choice. In 1997-98, many opted to plant a variety slightly more drought tolerant than usual, and to plant early, as soon as the initial rains arrived.

Making use of the information was more difficult in the small-holder sectors, especially among communal land farmers in natural regions IV and V. Except for a few people within the early warning unit (NEWU), most people had little idea what ENSO was, and how to interpret the seasonal forecasts. In July, Agritex organized a two-day workshop in Harare to discuss the use of seasonal forecasts with Met Service and SADC personnel. One suggestion was to educate Agritex extension officers about El Niño, so that they could help farmers make better decisions. Between 18 November and 5 December, representatives from the NEWU, Met Service, and DMC conducted a series of training sessions in the eight provinces. Present at these training sessions were the provincial Agritex staff, as well as a small number of district and local extension workers. This series of training sessions probably came too late to educate people for the 1997-98 season, since they occurred after the time for early planting (October), and well after the time when communal farmers typically buy their seed (August and September). Furthermore, the vast majority of the local extension officers did not attend training sessions, and never learned about either ENSO or probabilistic forecasts.

Even though the workshops were late, Agritex did advise farmers prior to the normal planting time, soon after the release of the Met Service Zimbabwe seasonal forecast in early October. Agritex instructed field staff to tell farmers that rainfall would be below normal. Agritex advised farmers to plant more drought tolerant varieties of maize, or extremely drought tolerant crops like sorghum and millet, to plant early (October instead of November), and to sell off draught animals, where possible. The communal farmers received this information in conjunction with the media reports. Both the media and the Agritex field staff compared the current year with 1991-92, when there was a massive drought and even drought tolerant crops had failed.

Communal farmers reacted in many different ways to the forecasts. Some, particularly among those in natural regions II and III, did plant more drought tolerant than usual varieties of maize, and did plant early. Most communal land farmers did not change their behavior in response to the forecast, and very few sold their animals. Some farmers, particularly among those in natural regions IV and V, planted millet and sorghum, and waited until December or January (i.e. late) to plant a maize crop, after having seen early season rainfall to be relatively normal. These farmers fared poorly when the rains ended early, as predicted. In total, the area of land the small-holder farmers planted was 21.3% lower than the year before, and the total harvest was 43.1% lower (Policy and Planning Division, 1999). Those farmers who planted late suffered most.

These differences in response are consistent with the farmers' incentives and available choice set. The large majority of communal land farmers in Zimbabwe plant the most drought tolerant variety of maize, since they can not take on the additional risk associated with higher yielding varieties. Some farmers in natural regions II and III plant higher yielding varieties; these are the ones who switched to the most drought tolerant varieties in 1997-98. For the other farmers, the only remaining choice in response to a drought forecast was to plant indigenous crops, such as sorghum or millet, or to plant nothing at all. Sorghum and millet have yields that are about half those of maize, and thus the opportunity cost associated with their use is high. In the drier parts of natural regions IV and V, it would make sense to switch to sorghum or millet, since the probability of the maize crop's failure is high. Planting nothing at all made sense if a farmer anticipated the return of 1991-92 drought conditions, during which all crops failed. By planting nothing, the farmer could save on input costs, avoid having to work as hard, and count on post-season food relief. Selling animals was very difficult, as nobody wanted to buy them with a forecast of drought and the difficulty of feeding them.

Newspaper articles reported that both the Agricultural Finance Corporation and commercial lenders restricted credit; the total lent fell to 25% that of the year before. Farmers also faced another impediment to early planting, in the form of a wavering Grain Marketing Board (GMB). Typically, the GMB announces the price it will pay producers for their harvest before the season begins, and farmers can use this information to decide what crops will be most profitable. In 1997, communal farmers fearing a coming drought withheld much of the prior year's harvest from the GMB, in order to make sure they could feed themselves the next year. As a result, the GMB was having difficulty obtaining enough grain to meet its own obligations and to restock the Strategic Grain Reserve, and it delayed announcing a price increase. Many people believe that the GMB delayed the announcement because they knew that communal farmers needing money to buy seed would have to sell to them at the low price. On 15 October, a month behind schedule and with the strategic grain reserve fully stocked (acquired at the lower price), the GMB announced a price increase for maize of over 20%, the first in two years. This price increase filtered through the market, and by December the prices of many basic foodstuffs had risen significantly. Riots were widespread in Harare when the government raised the regulated price of bread and maize meal.

Summary

A number of actors devoted a great deal of attention to ENSO in 1997, starting in April and lasting through the year. Within the food security sector, many of the organizations went onto a heightened state of alert. The early warning system met frequently to educate themselves about El Niño, so that they could make sense of the mass of information coming at them from climatologists. Their main message, generally overlooked by the media, was to be prepared, but not to equate El Niño with the certainty of drought. The management of the CFU, like the early warning people, decided to educate themselves about El Niño. Starting in July and August, contemporaneous with the beginning of alarmist media coverage and well prior to the planting season, the CFU discussed El Niño with its members, highlighted the limitations of forecasting, and developed appropriate response strategies at the national and local levels. The actions of Agritex, by contrast, occurred differently and later. Agritex waited until the official Met Service forecast, coming in October, to tell communal farmers about El Niño. By this time farmers had no doubt read newspaper stories that portrayed the predicted drought as certain, comparing it to events that had occurred in 1991-92. In October and November, Agritex field staff told farmers the same message. The response of communal farmers was mixed, as most did not change their behavior, some

planted drought tolerant varieties early, and others, no doubt fearing the worst, planted nothing at all. Efforts to educate Agritex workers about El Niño occurred in December, although most extension officers were not able to attend this training, and it occurred too late in the season to affect farmers' decision making. Furthermore, by this time there had been significant early season rains, and especially heavy downpours were just around the corner. In the wake of these rains many people criticized the forecasters, while the forecasters criticized the media. The harvest was smaller than normal, with isolated pockets of food insecurity. There was no need for international food assistance.

COMPARING ZIMBABWE TO OTHER STUDIES OF ASSESSMENT EFFECTIVENESS

What, if any, lessons does this Zimbabwe case study offer? I suggest two. First, it shows relatively clearly how different user and assessment characteristics matter, consistent with the existing literature on the effectiveness of environmental assessment processes. As I show below, the Zimbabwe case provides variance in terms of the potential users of the forecasts, how intermediary institutions attempted to communicate the forecasts to those users, and finally, the extent to which users changed their decisions in response to the forecasts. The existing literature, such as GEA (1999), Orlove and Tosteson (1999), and Cash and Moser (forthcoming) predict which of these variables matter, and how. The Zimbabwe case, then, provides additional support for these models. Second, the Zimbabwe case highlights the importance of participatory communication processes when levels of scientific uncertainty are high. In Zimbabwe, there was variance in the treatment of scientific uncertainty, coupled with variance in the use of that information. The literature in risk communication and behavioral economics suggest that effective risk assessment and management requires close attention both to the presentation and framing of contingent outcomes, and to the relationships between assessors and users. Most of this empirical literature, however, has looked at examples in industrialized countries such as the United States, where risk assessment is a regular feature of life. Observing climate forecast applications in Zimbabwe allows one to see whether the challenges are different in a developing country. I propose that the challenges are the same.

The GEA Framework

The GEA framework, shown in Figure 8, suggests that it is useful to examine three proximate pathways—salience, credibility, and legitimacy—as one seeks to understand the reasons for a particular assessment's usefulness or lack thereof. Salient information is important and appropriate: it speaks to a decision that actors face. For example, if actors face a decision about what crop to plant in October, then information that arrives in November will not be salient. Even information arriving in September will be salient only if suggests that planting a different crop this year would be prudent, based on an expectation that this year will be significantly different from normal. Credibility means that actors believe the information. Forecasters may predict a drought for this year, but if they made the same prediction in past years, and were wrong, then users may not believe them. Legitimate information can form the basis for decision making, without violating social norms. For example, given some degree of animosity between Shona and Ndebele tribes, would an Ndebele farmer ever choose to base a decision on information told to him by a Shona forecaster?

An assessment that shares these three characteristics is likely to influence decision making, whereas an assessment that lacks one or more of these characteristics is less likely. But these three variables, in turn, depend on numerous interacting factors having to do with the information content, the historical context,

and the relationships between assessment producers and users. Thus, one can say that an assessment was not effective because it was not credible, and then say it was not credible because of a combination of interacting variables. Having a framework such as this one helps to organize a complex set of relationships between the different independent variables. The snapshot of Zimbabwe in 1997-98 allows me make observations about two major sets of variables: user characteristics and assessment characteristics. Without time series data (something this study essentially lacks), I can make few observations about the historical context group of variables. In this section, I discuss the influence that the various user and assessment characteristic variables can have on salience, credibility, and legitimacy.

User Characteristics

The GEA model asks one to distinguish between different users, and examine the forces that influence the likelihood of assessment uptake. *Interest* describes the objectives of the particular user. For example, a commercial farmer may want to maximize expected earnings, and may have cash reserves to allow him to take risks. A communal farmer, by contrast, may be concerned first with feeding her family, and be less willing to plant a higher yielding maize variety if it means a greater risk of losing the entire crop. One should expect *interest*, then, to affect the salience of information. As I discuss later in this paper, empirical work within behavioral economics, such as Kahneman and Tversky (1979), shows that one makes assumptions about interest at one's peril. Features of interest such as risk aversion, and indeed the relative desirability of different outcomes, are highly contingent on people's perception of the status quo: the relationship of this decision to others that have already been made.

Capacity describes the ability of a user both to interpret the information, and the choices available to him or her to respond to it. Generally, one should expect *capacity* to be positively correlated with effectiveness, primarily through the *salience* pathway. Users with a greater capacity to understand information may also be more likely to believe it. Another way of describing capacity is in terms of the fit of forecast information within the ability of people to use that information in their decisions. The greater the capacity, the more likely the fit. As the National Research Council (1999, p. 81) states, effective forecasts "[m]atch informational messages to the characteristics and situation of the target group." Orlove and Tosteson (1999) elaborate on this idea, saying "the most proximate barrier to the application of ENSO forecasts should be the degree of fit between the spatial and temporal scales at which forecast information is available, and the spatial-temporal characteristics of the planning decisions in a particular sector." They also postulate that there must be "organizational fit", namely that the forecasts be well matched to "the problem-frame, decision making processes, and capacity for adaptive response of the users."

They examined the relationship between fit and effectiveness by looking at forecasting efforts in Australia, Brazil, Ethiopia, Peru, and Zimbabwe. Not surprisingly, Orlove and Tosteson did find that spatial-temporal and organizational fits were important prerequisites for forecast effectiveness. Importantly, however, they pointed to the importance of the users learning how to incorporate the forecasts into their decision making as a key ingredient. Thus forecast fit is not simply the product of a predetermined set of users' potential decisions and a particular information set that is the forecast. Rather, fit results from the interaction over time between forecasters and users, in which users learn to expand their choice set in response to the availability of new information, and forecasters adapt their information products to the changing capacity of users.

Openness describes the extent to which users already use and incorporate different types and sources of information in their decision making. One should expect it to be positively correlated with effectiveness, through the *credibility* and *legitimacy* pathways. For example, Weber (1997) shows how the existing sources of news influence how receptive farmers can be to new information. She surveyed farmers in the United States for their perceptions of local changes in weather and climate patterns, as well as changes in farming practices made in response to those changes. As an explanatory variable, she asked farmers about their belief in anthropogenic climate change. She found that farmers who believed in climate change as a long-term global phenomenon were significantly more likely to have perceived local short-term climate fluctuations, and to have changed their farming practices in response to those perceptions. She then went on to examine why a particular farmer would or would not believe in global warming. Such a belief, she found, was not correlated with demographic variables such as age, experience, or level of education. It was correlated, however, with farmers' source of information. Farmers who received their information from more sources, and for whom agricultural newspapers was one of those sources, were more likely to believe in global warming than farmers who relied on fewer media sources, sources generally limited to the popular media (e.g. daily newspapers, television, radio). Thus, prior beliefs of the information audience are important in determining credibility and legitimacy of new information. The sources of information, as well as the consistency of information, can influence beliefs over time.

The Zimbabwe case study, as I have described it, offers four observations that are consistent with these predictions: the food security sector in 1991-92 and in 1997-98, the commercial farmers in 1997-98, and the communal farmers in 1997-98. In 1991-92 the food security sector had the capacity to act in response to climate forecasts; a few meetings undertaken when the forecasts were first received could have set the ball rolling, planning the logistics of the necessary food importation. Likewise, the sector had the interest to act. By planning early it could have carried out its objectives of preventing famine more easily and at less cost. It lacked, however, the openness to different sources and new types of information, and to admitting that a potential crisis loomed. Since its independence in 1980, Zimbabwe's government has attempted to chart its own course, and not simply follow the advice of western developed countries. Hence, in 1992 the government was not receptive to climate information coming from the west, information that predicted difficult times for the country; it may or may not have believed the information, but nevertheless was not in the habit of using foreign information. By 1997, however, the situation had changed. Institutions such as SARCOF meant that climate information was, in part, home-grown and legitimate, and also institutionalized the use of different sources of information, from satellite imagery to El Niño models. The expense of the 1992 crisis caused the government embarrassment, and made it more open to consider all available information the next time around.

The commercial farming sector in 1997-98 had the capacity to use the forecasts, by planting slightly different varieties of maize, planting quickly and early with their mechanized methods, and altering their fertilizer schedule. They had the interest to act in response to available information, since as businesses they were trying to maximize their profits. Finally, they showed a great deal of openness, already receiving information from a variety of sources: the CFU, farming magazines, satellite television. It comes as no surprise, then, that the commercial farmers responded to the forecasts by changing their behavior appropriately.

In the communal farming sector, I observe a wider variety of responses to the forecasts, consistent with variance in the three independent variables. In general, communal farmers had very little capacity to alter their choices: they typically planted the most drought tolerant variety of maize as their primary crop, and changing to millet or sorghum would involve a great loss of productivity should the rains actually arrive.

Some farmers, in the wetter regions of the country, do plant longer season maize varieties, and hence have the ability to switch to a more drought tolerant variety. The fact that some of these farmers did make this switch shows that capacity matters. I also observe some variance in openness. Communal farmers have many traditions surrounding agriculture, such as the brewing of beer in preparation for planting, and the use of traditional forecasting methods based on tree flowering and bird migrations, and these may make them less receptive to other scientific information. Furthermore, to the extent they are isolated from numerous media, they are not in the habit of paying attention to multiple information channels. At the same time, there are significant inroads of western culture, such as through Zimbabwe's excellent system of primary and secondary schools, through churches, and through communication with relatives who have moved to the urban areas. This could explain the fact that in any given region of the country, some farmers followed the Agritex advice as much as their capacity allowed them to, while other farmers ignored it. Finally, understanding farmers' interests can be problematic. On the one hand, they are trying to grow as much grain as possible, both to provide for their own needs, and to sell at market and earn money. On the other hand, they are also trying to make the best of a bad situation. When widespread drought has occurred, such as in 1992, the government has typically provided assistance. For some farmers, especially in the drier regions, it could have made sense not to waste their money on farming inputs. If crops were going to fail, then the government would provide relief, and those who had not spent their money on seed would be better off. This is consistent with the decision of many farmers in the south not to plant at all, as well as their revised decision to plant late when significant rains did fall.

Assessment Characteristics

If user variables were all that mattered, then there would be no hope of building a more effective assessment. The GEA framework, however, suggests that many of the features of the assessment itself can influence the extent to which it will influence a given user. A key feature of the GEA framework is that it does not view assessment as a single product, such as a book. Rather, assessment encompasses the entire decision-support infrastructure. Thus, the information pathways I showed in Figures 1, 2, and 3 embody many of the assessment characteristics, and are closely tied to the content of the information users received. As before, I can observe four different assessment processes at work.

The GEA framework suggests three relevant variables. The *science/policy interface* describes the extent to which institutions are in place to bridge an observed cultural divide between scientists and decision makers, well-documented in the science studies literature. For example, Wynne (1996) observes how scientists and farmers may base their knowledge on different types of observations, and that each knowledge base is legitimate. Unless the assessment process makes deliberate moves to bridge these two types of knowledge, credibility and legitimacy will suffer. Guston (1998) calls these moves *boundary objects*—because they cross the science/policy boundary—and the institutions that make them he calls *boundary organizations*. He suggests that the presence of organizations with clear lines of accountability to both scientific and policy actors increases the credibility and legitimacy of the scientific information. Others, such as Alcamo, Kreileman, and Leemans (1996) and Jasanoff, (1990), make similar arguments.

The *participation* variable is closely tied to the science/policy interface, insofar as the involvement in the assessment process of actors with clear lines of authority to a particular user group makes effectiveness more likely. VanDeveer (1998) shows how the participation of scientists representing different countries directly enhances the credibility and legitimacy of the entire assessment process in those countries' policy communities. Wynne (1996) shows how the absence of farmers from assessments can lead to the

omission of critical information, and hence reduce the salience of the scientific assessment. One indicator of participation could be the inclusion of traditional forecasts, such as those identified and explained by Orlove, Chiang, and Cane (2000), in the communication process (UNSO, 1999).

The need for participation is closely tied to the theory of *social capital*. If I trust Jack, and I know that Jack trusts Jean, then I am likely to trust Jean as well (though perhaps not quite so much as I trust Jack). Social capital is the value to society of trust networks and bridges, and describes how institutions can play an important role in enhancing the credibility, and hence effectiveness, of governance systems. In his influential study of Italian political institutions, Putnam (1993) compares results in northern and southern regions of the country. He finds those in the north to be far more effective, mainly because people there trust in government more than they do in the south. After controlling for a wide range of demographic variables, he isolates participation in civic institutions as the determining factor. By developing networks of transitive personal relationships through their participation in voluntary organizations, the northern Italians lay the groundwork for their civic trust.

Finally, the GEA framework suggests that the *scope* of the assessment, such as its treatment of *uncertainty* and *dissent*, can matter a great deal. Looking at this as a dependant variable, Patt (1999) shows how assumptions about the intended audience can cause actors to limit the scope of an assessment. In particular, he observes that many consensus assessments, not unlike the SARCOF meeting, tend to omit discussion of low probability but high consequence events. However, the assessment and forecasting literature is surprisingly silent in examining scope, uncertainty, and dissent as an independent variable influencing effectiveness.

Leaving a discussion of scope for later in this paper, Table 2 codes the two remaining variables for each of the four observations discussed above. The food security sector in 1991-92 did not contain boundary organizations with clear lines of accountability to scientists and decision makers. The Zimbabwean relief agencies, such as the Department of Social Welfare, did not have ties to climate forecasters, and indeed were suspicious of such sources of information. At the same time, there was no real participation of Zimbabwean scientists representing the interests of the national food security sector in the institutions making climate forecasts. By 1997-98, both of these variables had changed. Rather than isolated scientists or research groups in the United States and Europe making seasonal forecasts based on ENSO predictions, a set of institutions had grown up to oversee both development and the dissemination of the forecasts. The Zimbabwean food security sector was intimately involved. Participation was high, through the involvement of Met Service climatologists, and the science/policy interface was tight. Organizations such as the Drought Monitoring Centre, occupying space within the Zimbabwe Met Service offices, and the Regional Remote Sensing Project, sharing space with more decision-oriented SADC groups, made for constant communication.

For commercial farmers, one must examine the role of the Commercial Farmers' Union. The CFU obviously was accountable to its members, the actual decision makers. Was it accountable to the scientific community? I argue yes. The CFU sponsors agricultural research, and has worked hard to build close ties with the agrometeorologists, both in Zimbabwe and South Africa. I therefore code the science/policy interface as tight. While the CFU did not participate in SARCOF, and hence the development of the forecasts themselves, they did work with the Met Service to interpret the forecasts. The discussion of climate forecasts at the field days, in July and August of 1997, also was a form of member participation. I therefore categorize participation as medium.

The communal farmers did not benefit from the services of a pro-active organization such as the CFU. On paper, Agritex is accountable to the interests of communal farmers, just as it has responsibilities to the scientific community. But in practice, communal farmers have very little contact with Agritex, and often pay little attention to its recommendations (Shumba, 1999). Indeed, one can identify a distinct boundary between Agritex, with close ties to the forecasting community, and the communal farming villages. The relationship between these two groups is suspicious, in both directions, as farmers do not necessarily believe what Agritex tells them, and Agritex does not expect the farmers to offer useful information to the dialogue. Likewise, participation of farmers, or their representatives, in the forecasting process was low. Not only did farmers not participate in the development of climate forecasts (just as commercial farmers did not), the communal farmers also had no say in interpreting the forecasts for their own needs. The Agritex staff in Harare made the decision to tell farmers that there would be a drought for sure, and to give them specific pieces of advice on how best to cope. This message was passed down through the Agritex hierarchy, with little chance information to flow in the other direction.

Assessment Scale

One of the challenges in applying seasonal forecasts is the issue of scale: scientists derive information at the global scale, but decision makers must apply it at the local scale. Cash and Moser (forthcoming), working within the GEA project, examine the problem of communicating global knowledge to local decision makers in a way that they can not only understand it, but also trust it and be willing to make decisions in response to it. In Figure 9, they map out the potential pathways that information can travel as it moves from the scientific community to the decision maker, and from the global scale to the local. Citing evidence from the social studies of science literature (e.g. Alcamo, Kreileman, and Leemans, 1996; Jasanoff, 1990; Guston 1998), they suggest that some pathways are better than others because of institutional factors. For example, the institution broadly described as *science* contains mechanisms, such as peer review, for enhancing the trust among its members. Thus, we might expect a local scientist working at a land-grant university to trust the peer reviewed literature on global environmental change, even though the two scientists will never meet face-to-face. By contrast, Cash and Moser suggest, other pathways may be less effective. Organizations trying to form social networks between scientists and decision makers at the global level may be less effective than those at the local level, where personal relationships are easier to maintain. Likewise, translating information from global to local relevance can be difficult outside of the realm of science, with its built in mechanisms for enhancing trustworthiness. This scale model of assessment effectiveness does not fit neatly into the GEA framework, but it makes use of many of the same concepts and theoretical literature.

The food security sector responded to the crisis of 1992-93 by undertaking a deliberate effort to build networks between global scientists and national decision makers. The results appear to have succeeded. In 1997-98, global (e.g. American, Australian) scientists communicated directly with Zimbabwean meteorologists, at the SARCOF meeting and through frequent internet contact. These local scientists then organized the *ad hoc* meetings with decision makers, such as the NEWU, to decide an appropriate response. In the commercial farming sector, CFU staff scientists established working relationships with Met Service scientists. The CFU then passed on the information to their regional offices—we can call them analysts to fit within the Cash-Moser model. These then passed the information, along with recommendations for different planting decisions, to the local farmers who were the decision makers. While not moving down and across Figure 9 in the manner that Cash and Moser suggests would be best, this information flow still took place in the lower left half of the figure, and therefore ought to have

succeeded. Furthermore, the CFU may have worked well as a boundary organization because of its voluntary and participatory character. In the communal farming sector, the information passed from global scientists to national scientists in the Met Service, and then to national level analysts at Agritex. These then formulated the decision recommendation to plant short season varieties early, and passed this down through the Agritex chain to the local extension officers, and eventually the farmers. Hence, the information pathway was mostly in the upper right half of Figure 9, which Cash and Moser suggest is a less effective place.

Summary

In this section I have compared the observations of the Zimbabwe case study to those of the assessment literature. Operating within the GEA framework, I have seen how different user and assessment variables are good predictors of salience, credibility, and legitimacy. Likewise, the related model of assessment scale also offers predictive power. The Zimbabwe case study offers too little variance, and too few observations, to test which of the elements of these models matter most; I can explain the variance in effectiveness by looking at user variables, assessment variables, or issues of scale, but I can not tell which one set of variables proved most important. Nonetheless, in being consistent with all of these models, this case study offers further evidence for their predictive power.

I noted one variable—the handling of uncertainty—for which the assessment literature is relatively silent. In the case of Zimbabwe, there clearly was variance in this area: communal farmers received a deterministic forecast, while commercial farmers and the food security sector focused extensively on the probabilistic nature of the predictions. But for the fact that I have already explained effectiveness over and over again with the other variables, the Zimbabwe model would indicate how the treatment of uncertainty can matter. In the next section, however, I discuss a body of theory from the literature in risk communication and behavioral economics that does offer guidance. Just as with the assessment literature, the risk communication literature makes predictions that are consistent with the observations of Zimbabwe. I discuss how risk communication theory can thus make important contributions to the existing assessment literature.

COMMUNICATING UNCERTAINTY

A substantial body of theory has developed in the related fields of risk communication and behavioral economics, with roots in neo-classical economics and statistical decision theory on the one side, and cognitive psychology on the other. Back when risk communication *was* statistical decision theory—about 1975—it was dominated by assumptions of objectively consistent goals people were trying to reach, and perfectly designed behavior to achieve those goals as much as possible. The field experienced cross-pollination with cognitive psychology, beginning with a landmark paper by Tversky and Kahneman (1974), and began to revise those assumptions to reflect actual human thought processes. Since then, the literature has looked more and more at the relationships between decision makers and the emotional content of the information they must process. As I show below, the literature is in a current state of development that resembles the assessment literature quite closely. But risk communication has always focused on the uncertainty aspects of knowledge, and can therefore fill in this missing piece of assessment literature's puzzle, and provide valuable insights for the Zimbabwe case study.

What distinguishes risk communication from environmental assessment? Typically, risk communication is concerned with informing people about quantifiable risks to their health and safety, based on the measurement of past data combined with assumptions linking that data to people's behavior. Traditionally risk communication has involved trying to tell people that a new or scary technological risk (e.g., flying in an airplane) is actually safer than an existing one (driving a car). Sometimes, risk communication tries to warn people that a behavior with which they are familiar (e.g., owning a home, eating peanut butter) now appears to be more dangerous (because of radon gas, or carcinogenic fungi) than had previously been thought. In general, the focus is on comparing a new risk to others that are familiar, so people can make appropriate tradeoffs. Environmental assessment, by contrast, usually concerns events that haven't happened yet, and for which few data are available. The range of impacts goes well beyond health and safety, to include wildlife and biodiversity loss, and effects on human systems and institutions, such as cities and agriculture. Thus, it is difficult not only to decide what to quantify, but how to quantify it. Climate forecasting falls somewhere in between. There is a wide range of impacts that assessments can cover, but it is possible to link past data to future trends. To some extent, the risk communication and behavioral economics literatures ought to apply to this type of environmental assessment (Nicholls, 1999).

Development of Risk Communication

Several authors have traced the history of risk communication. Fischhoff (1995, 1996) provides a neat summary, which I show in Table 3. Leiss (1996) and Renn (1998) slice the pie differently, into three pieces, but their story is the same. In Leiss' view, the first phase of risk communication lasted until the mid-1980s, and was centrally concerned with the accurate quantification of risk. Given the propensity of economists to advocate reliance on decentralized decision making (Zeckhauser and Viscusi, 1996), risk managers assumed that people would use this quantitative information to make consistent choices about which risks to accept gladly, and which to shun (Leiss, 1996). But a number of studies (e.g., United States Environmental Protection Agency, 1987; Zeckhauser and Viscusi, 1990; Breyer, 1993) showed a sharp divergence between popular opinions of risk and the opinions of so-called experts.

With these observations, risk communication entered its second phase, in which the focus was on advertising good risks as good, and bad risks as bad (Leiss, 1996). Empirical research in behavioral economics had, by then, shown that people responded to risk and uncertainty at an emotional level (Tversky and Kahneman, 1973; Kahneman and Tversky, 1979; Covello, 1990; Kammen, Shlyakhter, and Wilson, 1994). Risk managers and communicators tried to harness what they understood about people's interpretation of risk to get them to do the right thing, using rhetorical techniques already developed within advertising, sales, and marketing (Leiss, 1996).

Just as people have learned not to trust used-car dealers, so too did a strategy based on salesmanship eventually fall short. For example, Slovic (1997) identifies a number of variables related to the information user that influence his or her risk perception. Women, generally, perceive health risks as higher than do men, whether they are scientists or not. As Flynn, Slovic, and Mertz (1994) show, in the United States there is a "white male" effect that dominates risk perception: the more socially empowered is a group, the lower the members of that group judge to be the risks associated with a particular problem, and the greater their trust in expert assessments. Thus, "[i]nasmuch as these sociopolitical factors shape public perceptions of risks, we can see why traditional attempts to make people see the world as white males do by showing them statistics and risk assessments are unlikely to succeed. The problem of risk

conflict and controversy goes beyond science. It is deeply rooted in the social and political fabric of our society" (Slovic, 1997, p. 291). Risk communication that disempowers the intended audience is bound to fail.

An interesting example of this lies in decisions to locate sites for hazardous waste facilities. Economists have suggested that the optimal procedure would be an auction (Kunreuther and Kleindorfer, 1986; Kunreuther and Portney, 1991): site the facility in the community that is willing to accept it for the least amount of compensation. This community places the smallest negative value on the hazardous waste; siting it there will reduce social welfare by the least. Furthermore, since the community would in fact be compensated by the amount they stated, even they come out winners. But Frey and Oberholzer-Gee (1999) catalogue a number of studies examining these decisions, which are marked by emotional public reactions in both directions (e.g. Kunreuther and Easterling, 1992; Oberholzer-Gee and Frey, 1995; Renn, Webler, and Kastenholz, 1994; Linerooth-Bayer et al., 1994). In all cases, the researchers observe that nobody likes the auction method of siting, for it had the usual result of placing the facility in the poorest community. People felt that such a community would accept the pollution for a small level of compensation because they were poor, and they would remain poor because they then have to live with the pollution. The researchers observe that siting methods people consider to be "fair" all include extensive two way communication between members of the communities involved and the government and industry experts, in which they jointly reach a decision about where to site the facility.

This concept of extensive participatory communication, building a partnership between experts and citizens, is at the heart of the third and most recent stage of risk communication and management. Hence, this stage "is characterized by an emphasis on social context, that is, on the social interrelations between the players in the game of risk management" (Leiss, 1996, p. 90). In their handling of uncertainty and dissent, risk communicators need to work hard at establishing their credibility and legitimacy.

Lessons from and for Zimbabwe

Examining the Zimbabwe case study, I can identify what practices for the handling of uncertainty and dissent are most likely to lead establish credibility and legitimacy and lead to an assessment's effectiveness. On the one hand, the risk literature's predictions are consistent with my observation of the Zimbabwe case study. On the other hand, the literature suggests a few ways in which the Zimbabwe could improve its forecasting system.

Communicate Uncertainty

Forecasters have a choice. They can explicitly present their information and knowledge as uncertain, or they can withhold that uncertainty and present their best estimate of what will happen. If they do the former, they can make an effort to quantify the uncertainty, discuss the systemic nature of uncertainty, or do both. If they choose to withhold uncertainty, they can communicate the most likely outcome, tell the audience what decisions to make, or do both. Figure 10 represents this as a simple decision tree.

O'Brian (1999) suggests that forecasters should follow the third route, providing users with the full range of forecast information. Consider the alternatives. Freudenburg (1996, p. 52) asks the simple question of what is wrong with public decision making based on science' best estimate of what will happen, following the bottom half of the decision tree in Figure 10? "Nothing much," he replies, "just a failure to

understand the weaknesses of the risk estimates, combined with a fundamental misunderstanding of what it means to say we live in an advanced, technological society, all brought together in a way that could well do lasting damage to the public credibility of science and technology." To the extent that forecasters present the most likely event as certain to occur, they will be wrong part of the time, and they will lose credibility. Like many before him, (e.g. Slovic, 1993), Freudenburg notes the *asymmetry principle*: trust is hard to gain but easy to lose. This echoes the findings of Orlove and Tosteson (1999) with regard to forecasting drought in Brazil, namely that a single forecast that was less than completely correct destroyed the credibility of the forecasters for years to come. In Zimbabwe, interviews suggested to me that the credibility of forecasters had fallen significantly on the basis of events in 1997-98. Part of this may be attributable to the press' representation that the forecasters' most likely event—drought—was certain to occur. In any event, many people expressed doubts that forecasters knew what they were doing, and suggested they would take future forecasts with a large grain of salt. To maintain credibility, forecasters need to emphasize to the public the systemic uncertainty inherent in the predictions; to be useful, they need to make some attempt to quantify that uncertainty.

Telling people what to do is a bad idea for reasons other than maintaining credibility. People must always make tradeoffs between expected outcome (the weighted average of possible events) and risk. The simplest, and among economists still the most prevalent, way of describing behavior is in terms of risk aversion, or decreasing marginal utility. Economists define the utility function as that which people want to maximize. By making it non-linear, they can build in risk aversion: the utility received from $10 is less than twice the utility received from $5. Hence, a person would prefer $5 for sure, rather than an even gamble between $10 and $0. Risk aversion explains the existence of insurance markets. Perhaps I am indifferent between receiving $4.50 with probability one and the receiving an even gamble between $10 and $0. I would thus be willing to pay up to $0.50 to avoid the gamble, and take the expected outcome of $5. A large insurance company, by contrast, is relatively risk neutral, and will be willing to trade me the expected outcome of $5 for the gamble at a price of something less than $0.50.

Risk aversion plays an important role in Zimbabwean farming. Communal farmers typically prefer to plant the shortest season maize variety, while commercial farmers in the same area will plant a longer season, higher yield, variety. Why the difference? The longer season varieties have a higher expected yield—even figuring in the likelihood of drought—and the commercial farmers are able to take the risk. The communal farmers, however, can not afford to lose their harvest, the food to be on their plates, should the rains be below normal. They are more risk averse, and so plant the safer, shorter season maize, despite the lower average yields.[2]

Behavioral economists have shown that one's level of risk aversion is highly context dependent, and that a more accurate model of risk aversion does not consider final outcomes—how much money a person has in the bank—but changes in relation to a perceived starting position. Kahneman and Tversky (1979) call this idea "prospect theory": emotional value is associated with the prospect of a potential gain or loss. Figure 11 shows the relationship of value to gains and losses. It captures two essential features. First, the kink at the status quo, or origin, reflects that people are loss averse: the prospect of a loss matters much more to people than the prospect of a gain. Second, people appear to have opposite attitudes towards risk when the prospects involved are gains or losses. While people appear to be risk averse with respect to gains, they also demonstrate risk taking behavior with respect to losses. Hence, if presented with a choice between losing $5 for sure, or an even gamble at losing $10 or nothing, they will often choose the latter.

Frey and Stutzer (1999) show that there are net social gains when people have the opportunity to participate in collective decision making, rather than being left in the dark: individual happiness depends not only on outcomes, but helping to make sure the decision is right for them. Given the complexity of people's value function, as shown by prospect theory, there is no way that a central decision maker can know what everybody is thinking. For one farmer, a certain level of risk may be perfectly acceptable, while for her neighbor the same risk may not. Decision making is not one-size-fits-all, even for people with similar choices to make.

Expect a Difficult Time

In an economist's ideal world, people would consistently incorporate the climate forecast into their existing set of concerns. In reality, people apply a number of decision heuristics to interpret complex probability problems, heuristics that lead to predictable biases from the rational model (Tversky and Kahneman, 1974). One of these is *representativeness*. They bring to mind specific examples that best represent a particular class of outcomes. Rather than go through the statistical process of Bayesian updating, drawing off both the vivid data and the mundane, people will selectively recall the most vivid. Windschitl and Weber (1999) note that people selectively interpret risks according to these principles even when the risks information comes in quantified format. Thus, even if a risk is given to people by experts as 10% (the people do not need to estimate the risk themselves), they may well react to it as if it were 20%. In Zimbabwe during 1997-98, the most vivid example of a year when drought had been forecast was 1991-92, both because it was a year of widespread worrying, and because it was relatively recent. People treated the forecast of below normal rains as meaning there would be a repeat of the 1991-92 event. Now, 1997-98 may be a vivid example of an El Niño year, both because there was so much media attention to the forecast, and because it was recent. We can expect that for the next El Niño, many people will react to the forecast as if it were predicting a relatively benign year like 1997-98.

An important lesson of behavioral economics is that people depart from rational action—action that maximizes expected utility—in a systematic fashion. The most systematic of these departures is the way they behave in response to probabilistic information. People like predictability, and hence place a great emphasis on probabilities of 0 and 1. Small departures from these certainties elicit a big reaction. By contrast, larger probability differences in the middle of the range receive less attention. Kahneman and Tversky (1979) describe this in terms of a probability weighting function, graphed in Figure 12. The rational actor model assumes an even weighting of different assessed probabilities, such that a change from 0 to 0.1 is of the same importance as the change from 0.4 to 0.5. The behavioral model allows people to weight these differently, and captures the greater marginal importance of differences in assessed probabilities near the ends of the spectrum.

Finally, people selectively absorb information that is consistent with their beliefs and expectations (Nisbett and Ross, 1980). Bazerman (1998) suggests that for new and different information to be accepted, it must be presented in a manner convincing enough to get people to break with their past beliefs, regardless of how those past beliefs were formed. Tversky and Kahneman (1973, 1974) describe this as *anchoring* on our prior beliefs. People will include in their decision making only a subset of the information that could be useful. A forecast, which to the outside observer appears salient, may not be so the actual decision maker. The challenge for forecasters is help people understand why a given nugget of news might be important.

Match Statistics to Local Decisions

Often, however, the news might not be important. The only way to know this, and hence to respond sensibly to the information, is to examine the information in the context of the potential decisions. One model for decision makers is the static cost-loss ratio.[3] Imagine that there are two possible outcomes for the growing season, which we will connote with the variable Θ: drought ($\Theta = 1$) and no drought ($\Theta = 0$). A farmer can plant a high yield crop, which will do poorly if there is a drought, incurring a loss L. Alternatively, the farmer can protect against drought by planting a low yield crop that is insensitive to the amount of rainfall. Relative to the high yield crop in a no drought year, this protection will incur a cost of C, whether or not the rains come. For the protection to be one worth taking given some probability of drought between 0 and 1, it must be that $0 < C < L$. The expense matrix is shown on the next page, in Table 4. If the farmer's objective is to minimize the expected expense, then the decision of whether to protect depends on the probability of drought, p_θ, and the relative magnitudes of C and L. One can easily see that the farmer should protect if $p_\theta > C/L$, and not protect if $p_\theta < C/L$.

Climatology is the long-term average value of p_θ. Imagine that this is 0.2, and that C = 0.25 and L = 1. Given no forecast other than climatology, the farmer should not protect. If the farmer received a forecast for the coming season that indicated p_θ was 0.1, then the decision not to protect would go unchanged and the forecast would be of no value. By contrast, if the forecast revealed that p_θ was 0.3, then the farmer would decide to protect. The value of the forecast would be 0.05: the difference in expected cost given a decision based on climatology (0.3) and a decision based on the forecast (0.25). Imagine a different scenario where farmers always protect (perhaps climatology p_θ is 0.3). In this case, a forecast of p_θ higher than climatology would be of no value, while a forecast indicating p_θ less than 0.25 would be useful. In the latter case, the forecast would save farmers the cost of protection.

Katz and Murphy (1997) summarize a number of prescriptive decision studies, which make use of the cost-loss ratio model. Essentially, these studies examine the choices that a particular group of farmers face, and derive monetary values for the set of possible forecasts. The exercise is both useful and difficult: useful because these studies often show the forecasts to be of no value, and thus money can be saved in their production; difficult because the economic analyst must map out the entire decision making system, value the costs of different actions, predict the payoffs in all states of the world, and identify places where the forecast could fit within it.

If figuring out whether information ought to be salient is difficult for economists, imagine how hard it must be for individual farmers. Each village, and indeed each farmer within that village, faces a different set of probabilities, constraints, and payoffs. For example, one farmer might live in a gully, while his neighbor is on top of a nearby hill. Given the same amount of rain, the first farmer's land will retain more moisture. The relevant statistic to aid decision making, as I showed in the cost-loss model, is the likelihood of loss. This in turn may be a function the rainfall probability distribution, which is itself is a function of how much rain the particular area usually gets and the chances of getting more or less in this particular growing season. Translating the seasonal forecast into useful statistics means juggling a lot of probabilistic information, something I have already argued people are not very good at. Indeed, the few descriptive decision studies that agricultural economists have undertaken have shown that most farmers do not undertake this difficult process (Stewart, 1997). An effective forecast would therefore provide the decision support to help people make this translation, avoiding the systematic pits of probability misinterpretation into which most people fall. Such a decision support process must take place at the

local level, since this is where the farmer-specific information lies, and must involve two-way communication. In Zimbabwe, the numerous workshops and crop fairs that the CFU organized provided this support. Ideally, the same process would take place with the communal farmers. However, since the Agritex extension workers did not themselves know the probabilistic climate forecast, this could not and did not occur.

Repeat Even When Not Necessary

Kunreuther (1996) discusses people's willingness to purchase flood insurance. Even when it is offered to them at heavily subsidized rates—the premium is less than the expected loss—people who have not experienced a flood do not purchase it. Right after a flood occurs, many people then buy flood insurance to cover them for the next time, and continue to purchase it. This can be caused by two factors. First, people may underestimate the probability that a flood will affect them; once they experience a flood and it becomes more tangible, they then readjust their likelihood estimate. Second, people do not want to take a sure loss—purchasing the insurance—and instead opt for the gamble that a flood will not happen to them. But once they experience a flood, their expectations change, and flood damage becomes more of the status quo. Avoiding future flood losses seems then like a gain, and they view this gain with a risk averse perspective. Better to have a certain gain—avoid flood losses for sure by spending a little money on insurance—than the uncertain gain without the insurance. Even as the flood then recedes into distant memory, purchasing insurance becomes the status quo, and they continue to do so. Kunreuther and Kleffner (1992) observe a similar phenomenon at work with people's decision to mitigate against earthquake damage. People take steps to mitigate against earthquake damage just after an earthquake, even though this is when a subsequent loss is least likely.

What does this say about forecasts? First, it indicates that after several years of good rain, people may be unwilling to change their planting decisions in response to a forecast. After a year of bad rain, however, they will be receptive to using the forecasts the next time around. Second, it is important for forecasts to be a constant feature of decision making, much like the purchasing of flood insurance becomes second nature. When forecasts only arrive in anticipation of bad years, people will not use them. When they arrive every year, sometimes telling farmers that it will likely be a good year, and sometimes telling them that it will likely be bad, farmers will have an expectation of using the forecast to influence their planting decisions. The continual stream of forecast information breaks the idea of the status quo being good years, and instead reinforces the concept of constant climate variability. This fits with our observations of communal and commercial farmers in Zimbabwe. The CFU had started passing Met Service forecasts along to commercial farmers in the mid-1990s, not only seasonal forecasts but also the weekly and ten-day ones that indicated when fronts would pass through bringing rain. Amidst this background practice of continual forecast use, it was likely that commercial farmers would pay attention to the 1997-98 seasonal forecast. The communal farmers, by contrast, do not receive forecasts on a regular basis; the 1997-98 seasonal forecast was unusual in its reaching a large number of communal farmers. One can expect them to be less likely to change their behavior in response to such a one-time event.

Summary

The discussion of the risk communication and behavioral economic literature is consistent with the observations of Zimbabwe, and offers guidance about how forecasts could be better, especially for the communal farming sector. Currently, the forecast from the Met Service provides the probabilities of

below normal, near normal, and above normal rains. Given the heterogeneity of growing conditions throughout Zimbabwe, this information is not very useful; somebody needs to translate it into probabilities more closely tied to actual decisions, such as whether to plant maize or millet. For instance, a useful statistic would be the probability that a maize crop will fail. If this number were close to 0, farmers would probably choose to plant exclusively maize, since its yields are higher. As this number rises toward 1, farmers would likely plant a greater proportion of millet or sorghum, although their response is likely to be non-linear with respect to changing probabilities. The process of translating the Met Service statistics into the probability of maize failure is not easy, and requires both analytic skill and an intimate knowledge of local meteorology, agronomic practices, and other constraints. While Agritex may be able to provide the analytic capacity, farmers themselves are likely more familiar with local conditions. Thus the two groups need to work together to make the information usable, much as the CFU and commercial farmers already do. As they continue to work together, year after year, chances are that farmers will incorporate the information into more of their decisions. The decisions that farmers do make in response to forecast information depends not only on the probability of maize failure, but also on their own preferences with regard to risk, and these are very context dependent. Each farmer, then, must make his or her own decision about how to respond to the forecast.

There is an important assumption behind the application of behavioral economic theory to the Zimbabwean context: that the findings of behavioral economic experiments conducted on Americans and Europeans, the majority of them college students, apply to communal farmers living in a pre-industrial society. Perhaps this assumption is not valid in Zimbabwe, given that levels of education are lower than in the west, and that the culture is more firmly rooted in traditional agricultural practices. Indeed, Bourdillon (1993) describes the traditional rural belief system as not incorporating the idea of chance or luck; rather, some action, such as failing to respect one's ancestors, brings about bad events. Several key actors, within Agritex and other institutions in Harare, expressed to me their belief that communal farmers would not be able to understand probabilistic information at all. This belief supports the decision by Agritex to give farmers as simple a version of the forecast as possible, and not to confuse them with all of the information that a full public participation process would require.

Whether communal farmers can conceptualize and respond to probabilistic information is important. The answer will dictate which assessment strategy—the ones I have presented here based on findings in behavioral economics and risk communication, or the one currently used by Agritex—is most appropriate. To justify the approach I have presented, I decided to answer this question. The next section describes this effort.

EXPERIMENT: A GAME OF CHANCE

As I have shown, evidence suggests that people find it difficult, but not impossible, to interpret probabilistic information. This implies that the best forecast will be one that provides probabilistic information in a form closely tied to the decisions to be made by the user. Yet in Zimbabwe, Agritex has chosen not to give communal farmers probabilistic information. Agritex believes, perhaps correctly, that communal farmers lack the ability to understand even simple probabilities.

Experimental Design and Results

What I am interested in knowing is whether Zimbabwean farmers have the capacity to take part in a participatory assessment process, discussing probabilistic forecasts and adapting the forecasts, with guidance, to their own decision needs. As I have shown, the behavioral economics literature suggests that the reason a participatory process is necessary is because most people have a difficult time, at first, with new problems involving probabilities and logic. Once they have the opportunity to learn about the problem, and compare it to problems with which they are already familiar, they do substantially better. At the same time, it is important that people not simply be told what to do; they have to decide, for themselves, what is right.

Consider, for example, a simple logic question, based loosely on Pinker (1997). I offer the proposition "If A, then B," where A and B are two different states of the world. What evidence do we need to observe to see if this is so? An easy answer is to look for cases of A, and see if B is also present. Indeed, most people offer this as the only strategy. But imagine that it is framed in familiar terms: "If this restaurant serves wine to a person, then that person must be twenty-one years old." Now an additional answer seems obvious: look for people in the restaurant who are under twenty-one, and see if they are drinking wine. Indeed, after the familiar example, it becomes easier to see why one can also look for cases of Not B, and see if that always implies Not A. The purpose of a participatory assessment is to give people the opportunity to make that kind of mental leap, seeing the new problem in relation to others which with they are familiar. One purpose of my experiment, then, is to see whether Zimbabwean farmers are able to make that leap.

The experiment consisted of five sets of "games", in which subjects had the opportunity to win money by "betting" on the outcome of a spinner, a wheel painted different colors with a wooden arrow spinning on top. Each game was repeated several times in order to allow subjects to become familiar with it, and to see if they adopted consistent strategies. The experiment was conducted in a number of communal farming villages throughout Zimbabwe. In each village five men and five women were chosen at random from a pool of people who volunteered to participate in the game.[4] They sat in a semi-circle around the wheel, with spectators gathered behind them. All subjects simultaneously indicated their bet by holding up cue cards, and were allowed to observe all bets and to talk amongst themselves; this provided them the opportunity to learn from each other. Subjects received payment, in cash, after each spin of the arrow. For the entire experiment each participant earned between ZW $25 and $65, depending on their skill and luck, and the entire experimental session lasted about an hour.[5] In addition to noting whether participants were male or female, I asked for the highest level of school they had completed.

Game 1: Simple Stochastic Dominance

In the first set, the wheel was half red and half green. Subjects could bet RED, in which case they would win $2 if the arrow pointed to red, and $0 if the arrow pointed to green. Or, they could bet GREEN, in which case they would win $3 if the arrow pointed to green, and $0 if the arrow pointed to red. I repeated the game five times. The spinner is a stochastic process, where each spin is independent of those coming before. Hence, on each spin, betting RED gives participants a 50% chance of winning $2, while betting GREEN gives them a 50% chance of winning $3. Clearly, one should bet GREEN all five times.

Experiments have long shown that most people do not see the game this way, and do not adopt this simple strategy; rather, they adopt a strategy known as *probability matching* (Estes, 1964; Myers, 1976). If the wheel is 60% red, they will predict red about 60% of the time; if the wheel is 75% red, they will predict red about 75% of the time. This behavior persists even when, as in my Zimbabwe experiment, they are paid for guessing right. While theorists have found it difficult to explain this type of behavior (Friedman and Massaro, 1998), it is likely that people are applying a simple heuristic that does not quite fit the situation: the arrow will probably point to red X% of the time, so I will do best if I predict red X% of the time, or at least my predictions will be *representative* of an ordinary sequence of arrow spins (Baron, 1994). If one were predicting how often the arrow were going to point to red, in total, saying X% of the time would be a good strategy. But the heuristic is wrong in this context, however, because each spin of the arrow is independent, and people can not predict one spin of the arrow any better than they could predict past spins (Gal and Baron, 1996).

My results, shown in Figure 13, are consistent with this behavior. The most popular strategy was betting GREEN three times out of five, followed by betting GREEN two times. Women appeared to be slightly more likely than men to adopt the stochastically dominant strategy of betting GREEN all five times, although the difference is not statistically significant. This is consistent with Odean (1999), who showed that women do slightly better in the stock market, because they make fewer trades, adopting a more long-term strategy and not trying to predict short term stock price fluctuations. Adopting the stochastically dominant strategy means letting go of the belief that one can predict where the arrow will actually point on the next spin.

Game 2: A Likely Alternative

In the second game, the wheel was three-quarters red and one-quarter green. Participants had the same choice as in the first game, the payoff structure was the same, and the game was again repeated five times. Betting RED each time maximizes the expected outcome—$1.50 as opposed to $0.75— and minimizes risk—the variance being 0.375 as opposed to 0.5625. Again, probability matching suggests that people will instead bet in response to the probabilities: RED about 75% of the time, and GREEN about 25% of the time. Such behavior indicates an appreciation of probabilities, but the application of a heuristic mismatched to the problem at hand.

This is what I observe, as seen in Figure 14. The most popular strategy was to bet RED four out of five times, the strategy most closely resembling probability matching. The two closest strategies, betting RED five times and three times, were the next most popular. It is unclear whether people betting RED all five times did so because they had figured out how to maximize their expected earnings, or simply because this was close to probability matching. In either case, the results are encouraging. Zimbabwean farmers, like other subjects of psychological experiments, do adjust their behavior in response to changing probabilities, even if the adjustment is not perfect.

Game 3: Difficult Stochastic Dominance

In the third game, the wheel was one-third red, one-third green, and one-third white. Participants could again bet RED or GREEN, and the game was repeated five times. Table 5 shows the payoff structure. The stochastically dominant strategy is to bet GREEN each time, thus facing equal chances of winning $3, $2, or $0. A RED bet, on the other hand, would give equal chances of winning $3, $1, or $0. Another

way of looking at the problem, one which Patt and Zeckhauser (forthcoming) suggest many people would adopt, would be to minimize regret avoidance. If the arrow points to either red or white, subjects would wish they had bet RED. Only if the arrow points to green would subjects wish they had bet GREEN. Thus a strategy would be to bet RED each time. Finally, subjects could adopt a strategy similar to probability matching, trying to predict the arrow each time. In this case they would likely bet RED three or four times out of five, and GREEN one or two times. In sum, this was a very complicated game. I expected very few people to adopt the stochastically dominant strategy. I played this game in order to provide a real challenge, giving people an opportunity to think hard and perhaps to learn.

Figure 15 shows the results, and the fact that no single strategy was a clear favorite. What Figure 15 does not show, however, is my observation that a lot of people were whispering to each other during the game. People appeared to be thinking hard, trying to figure out what they should do to earn the most money. In several cases, the whispering was followed a strategy of betting GREEN for all remaining rounds of the game. Perhaps these people had figured out the stochastically dominant strategy.

Game 4: Maize or Millet

In the fourth game, participants received new cue cards reading MAIZE and MILLET, replacing the RED and GREEN ones they had been using to place their bets. The wheel had two possible outcomes: one side was painted green and read "wet", while the other side was painted yellow and read "dry". Those who planted maize won $4 if the arrow pointed to wet, and $0 if the arrow pointed to dry. Those who planted millet won $2 if the arrow pointed to wet, and $1 if the arrow pointed to dry. I explained that this was because maize yielded a bigger harvest than millet in rainy years, but tended to die completely during a drought. Millet, on the other hand, still provided a small harvest even when conditions were dry.[6] I repeated the game ten times, but the probabilities of wet and dry varied, following a possible scenario of annual forecasts. In "good" years, the wheel was roughly 80% wet and 20% dry. In "medium" years, the wheel was roughly 60% wet and 40% dry. In "El Niño" years the wheel was roughly 40% wet and 60% dry. Thus in good and medium years, planting maize had the higher expected payoff, while in El Niño years the two crops had equal expected payoffs. Millet always carried less risk. The sequence of years, in all administrations of the experiment, was: good, good, medium, good, El Niño, medium, El Niño, good, medium, and El Niño.

This game was most closely tied with choices that actual farmers would have to make, and hence potentially less abstract. To the extent that participants were able to understand probabilistic forecasts, I should observe a greater propensity to plant millet in the medium and El Niño years, especially the latter. Also, perhaps this game would help them to figure out the other, more abstract games. In the more familiar context of planting maize or millet, participants might realize that each probability distribution implied a dominant bet, and that one should place this bet every time.

Figure 16 shows the proportion of people who planted maize in each round of the game. It is encouraging in two ways. First, the number of people planting maize correlated positively with the probability of a "wet" outcome. Second, people appeared to learn to be more risk neutral over the course of the ten rounds. Within both the good and medium years, the number of people planting maize increased during the course of the game; people opted for the higher expected outcome, even while taking on a slightly higher degree of risk. For the El Niño years, the expected outcome was the same for both maize and millet; no trend toward planting maize is evident. Although I do not disaggregate the results in Figure 16,

analysis shows that there was no significant difference between men and women. I also analyzed the results according to education level, comparing people who had completed O-level exams (at age 16), roughly half the sample, with those who had not. Again, there were no statistically significant differences.

The Table 6 matrix shows the consistency of people's decisions. Under the El Niño Years, the first column shows people who planted maize none of the three possible times; moving to the last column, I show people planting maize all three El Niño years. Likewise, the first data row shows people who planted maize in none of the medium years; moving to the bottom row, I show people planted maize in all three medium years. Within each cell I show the number of people, and categorize them by the number of good years they planted maize. Hence, the upper left cell shows that one person adopted a strategy of planting millet (i.e., not planting maize) in all of the medium and El Niño years; furthermore, that person planted maize in three of the four good years. Four cells are black, meaning that they contain no people. Nobody at all planted millet in all of the good years, so within each cell I omit a row for 0.

First, consider the black boxes. For someone to fall into the lower left box, he or she would have to have been very risk averse in the El Niño years, but much less so in the medium years. For someone to fall into any of the upper right boxes, he or she would have to be very risk averse in the medium years, but risk loving in the El Niño years. All of these boxes, especially those in the upper right, represent inconsistent behavior with respect to risk. The fact that they are empty is encouraging.

Next, observe that over half of the people fall into the right two boxes of the bottom row. These show people who planted maize in all three medium years and two or three of the El Niño years. Given the payoff structure of the game, the bottom row is the most sensible one for people to fall into. Furthermore, in each of these cells, people would be showing consistent behavior if they chose to plant maize in all four of the good years. Most people did so. Again, these data show consistent behavior, and are encouraging.

Game 5: Do People Learn?

The fifth game was a repetition of the first.[7] The purpose of this was to see if participants had learned about probabilities and chance by playing the games for close to an hour, especially the less abstract game involving maize and millet. To the extent that people adopted a strategy of betting GREEN all five rounds, this would show sophisticated learning.

The results in Figure 17 are the most encouraging of all. Close to half of the people adopted the dominant strategy of betting GREEN all five times. Among women, more than half did so. The difference between men and women is significant at the 90% confidence level, but not at the 95% level. Interestingly, several people (seven, altogether) decided to bet RED all five times. Of these, six of them had witnessed the arrow point to red four of the five rounds of Game 1. Perhaps these people believed that the game was not fair, and was somehow rigged. Given that belief, their strategy too made perfect sense.

Summary

The experimental results suggest that Zimbabwean farmers behave similarly to Americans and Europeans. That is, they adopt betting strategies that are reasonably successful, and responsive to

changing probabilities. The pattern of probability matching is one such strategy. If Zimbabweans did not understand probabilities at all, even matching would be difficult. Given the results of Game 4, one can be confident that farmers would respond to probability estimates of seasonal rainfall. The most exciting result of all comes in Game 5. Here, the subjects performed very well, a great many of them adopting a perfectly consistent strategy. As predicted, the more familiar problem in Game 4 seemed to have helped them figure out, without any input from me, how to maximize expected earnings in the more abstract case.

One criticism is that this was not a "controlled" experiment, in that I did not conduct the same experiment with American or European subjects, and instead compare my results to other, different experiments described in the literature. But given that the purpose of this experiment is to test whether Zimbabweans can in fact conceptualize probabilities and chance, performing the same experiment on different soil would add little value to these results. The fact that they adopt strategies that do respond to different probabilities, in ways that are qualitatively similar to those seen elsewhere, shows that there is hope for a participatory assessment process in Zimbabwe. Whether Americans college students might respond to the same assessment process more or less quickly is not a great concern.

CONCLUSION

This study has examined the process of forecast dissemination in Zimbabwe during the 1997-98 El Niño. It has found the results to be generally good, except in the communal farming sector. A number of barriers stand in the way of effective forecast dissemination to the communal farmers, such as their limited set of choice options, their lack of familiarity with scientific information, and the absence of effective boundary organizations, comparable to the Commercial Farmers' Union, to go about the task of building awareness and trust in the forecasts. All of these features suggest that the need is even greater for the communal farmers—greater than it is for others—to engage in a participatory communication process, unraveling the mysteries of the seasonal climate predictions and the implications for farmers on their four hectare plots of land.

The goal of such a process would be to encourage people, giving them the tools, to think analytically about climate probabilities and their own farming decisions. The success of such a process would depend, ultimately, on their desire and ability to do so. The current practices of Agritex are based on the assumption that communal farmers can not and will not think analytically about probabilities. My experiment suggests that communal farmers demonstrate a good capacity for thinking rationally about probabilistic outcomes. This suggest that a participatory communication process could work.

What would such a process look like? First, it would have to take place at the local level, and draw off of farmers' own knowledge base as well as scientific understandings of seasonal climate. For example, geological and topographic features of the landscape, occurring at a small scale, could in large part determine the response strategies of individual farmers. No scientist in Harare is going to know that; only by meeting with farmers in their villages will scientists or analysts come to understand what local conditions are relevant for the rational application of climate forecasts to decision making. Second, it should as much as possible provide farmers with the "raw" information. As events in both Brazil and Zimbabwe show, the credibility of forecasters declines when people perceive that their advice was wrong. Rather than give advice, they need to explain what they think, why they think it, and how certain they are of their conclusions. This of course must bring into the decision making calculus the

probabilities associated with a forecast. Third, it should be the result, in part, of farmers' own design decisions. Ideally, an organization such as the ZFU or Agritex, representing the interests of farmers and involving them in decision making, would organize and carry out the communication process. Farmers must feel that they have a stake in the process. Fourth, it must occur regularly, and not just in anticipation of bad years. If farmers are going to use climatological information to influence their decisions in bad years, it is most likely because they use the information every year.

In the end, effective forecast communication is not so much about getting people to plant different varieties of maize, as it is about offering them the ability to make better informed choices. I am excited to see this forecast communication begin, because I believe that its lessons will spill over into all aspects of people's lives. The African continent has challenged policy makers wanting to see sustainable development take hold. Giving people the tools to make well-calculated decisions improves the odds. It may mean letting go of traditional views of nature, and indeed is likely to be upsetting to many people. I believe it is a gamble worth taking.

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TABLES

Table 1—Agricultural Responses to 1997-98 Forecast

User	*Forecast Source*	*Message Received*	*Response*
Commercial Farmers	CFU, Media, Internet	High probability of drought. Plant short season varieties early.	Planted short season varieties early.
Communal Farmers	Agritex, Media	Severe drought. Plant short season varieties early. Sell draught animals.	Mixed. Mostly no response. Some planted earlier. Some planted shorter season varieties. Some planted late, after first rains. Few sold draught animals.
Grain Marketing Board	Met Service, Media	High probability of drought.	Delayed announcing new price for grain until after planting.
Agricultural Finance Corp.	Met Service, Media	High probability of drought.	Restricted credit.

Table 2—Assessment Characteristics of Four User Groups

	Science/Policy Interface	Participation
Food Security 1992-93	*Suspicious*	*Low*
Food Security 1997-98	*Tight*	*High*
Commercial Farmers	*Tight*	*Medium*
Communal Farmers	*Suspicious*	*Low*

Table 3—Developmental Stages in Risk Management

- All we have to do is get the numbers right.
- All we have to do is tell them the numbers.
- All we have to do is explain what we mean by the numbers.
- All we have to do is show them that they've accepted similar risks in the past.
- All we have to do is show them that it's a good deal of them.
- All we have to do is treat them nice.
- All we have to do is make them partners.
- All of the above.

Source: Fischhoff (1996, p. 81).

Table 4—Cost-Loss Model Expense Matrix

	Weather State	
Action	Drought ($\Theta = 1$)	No Drought ($\Theta = 0$)
Protect	C	C
Do not Protect	L	0

Source: Katz and Murphy (1997, p. 191)

Table 5—Game 3 Payoff Structure

	Outcome Payoffs		
Bet	Red	Green	White
RED	3	0	1
GREEN	2	3	0

Table 6—Maize Millet Strategies

Medium Years	El Niño Years			
	0 Maize	1 Maize	2 Maize	3 Maize
0 Maize	1 2 **3: 1** 4	1 2 **3: 1** 4		
1 Maize	**1: 2** **2: 1** 3 **4: 1**	**1: 1** 2 3 **4: 1**	1 **2: 1** 3 4	
2 Maize	1 2 **3: 1** **4: 4**	1 2 3 **4: 3**	**1: 1** **2: 1** **3: 1** **4: 3**	1 2 3 **4: 7**
3 Maize		1 2 **3: 2** **4: 5**	1 **2: 1** **3: 4** **4: 16**	1 2 **3: 1** **4: 21**

FIGURES

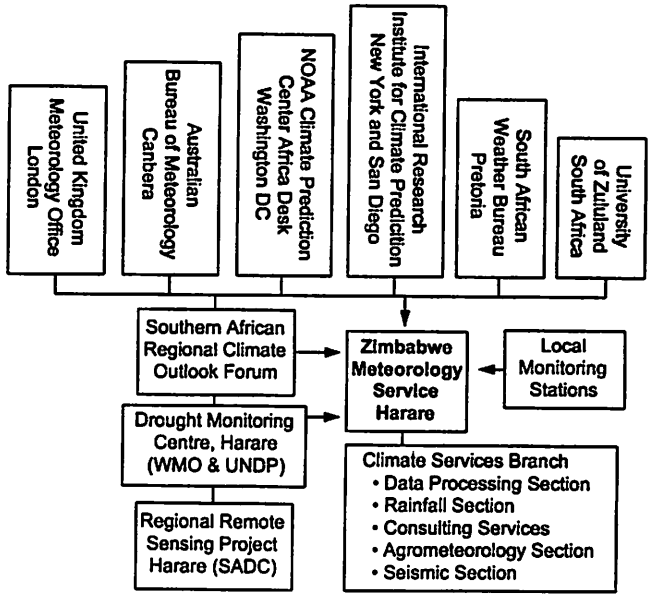


Figure 1—Meteorology Institutions Map

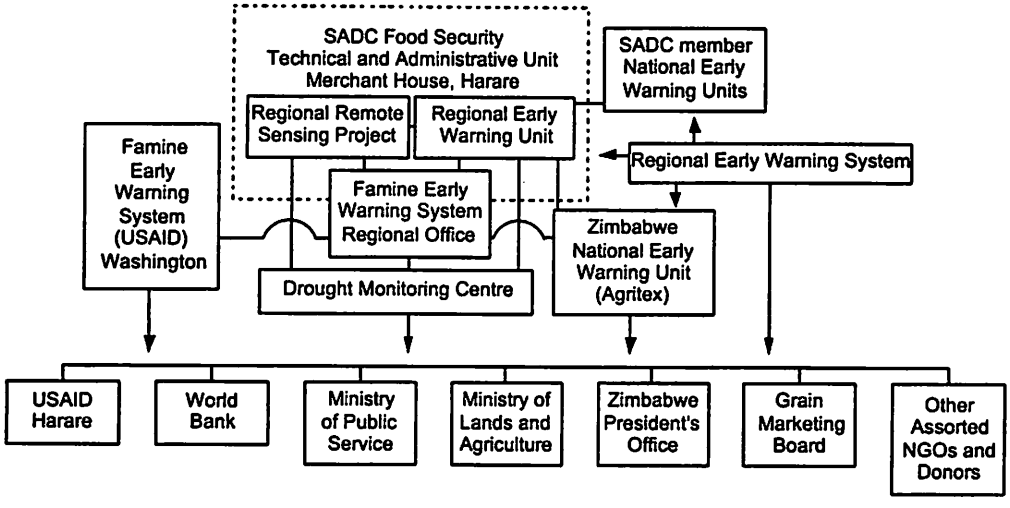


Figure 2—Food Security Institutions Map

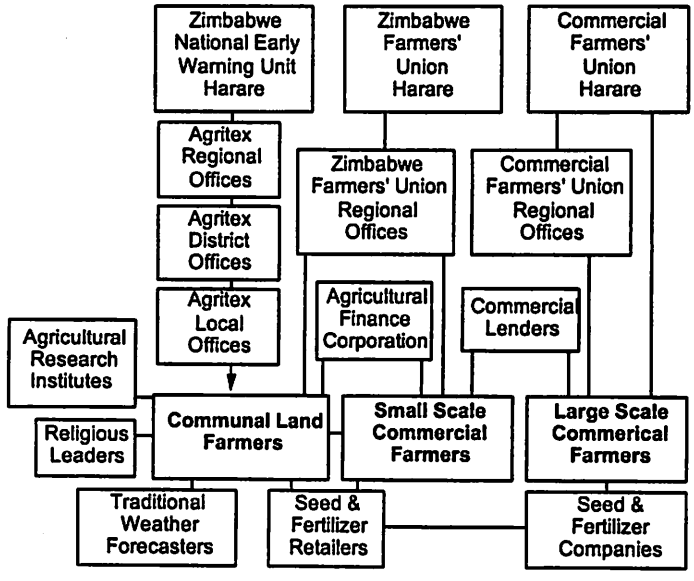


Figure 3—Agricultural Institutions Map

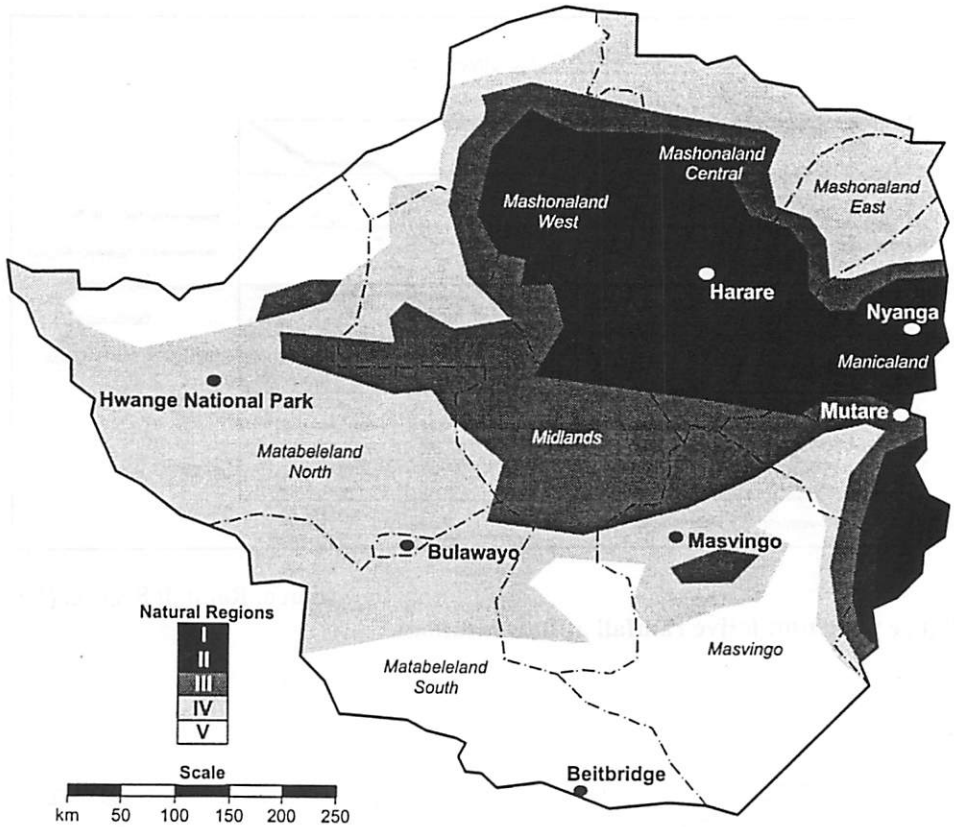
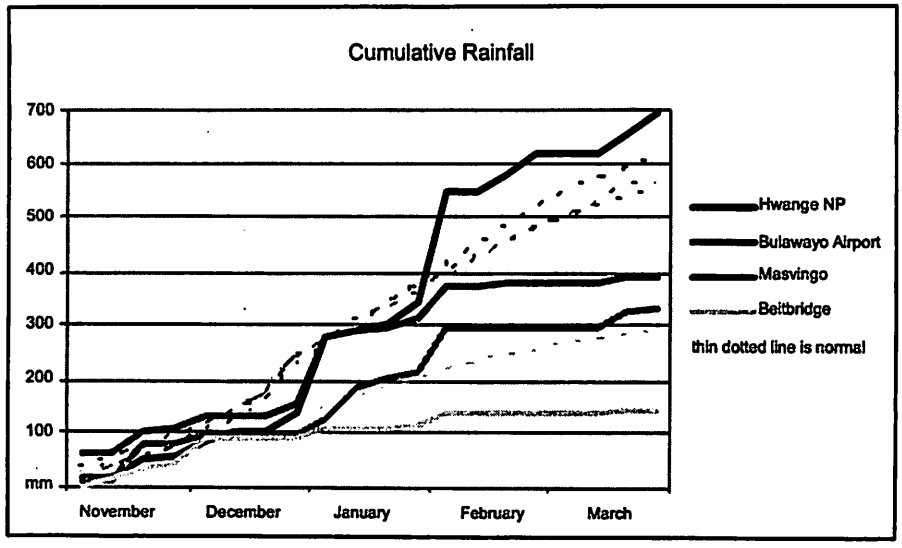


Figure 4—Zimbabwe Map



source: Rainfall Section (1997, 1998)

Figure 5—Cumulative rainfall at four locations

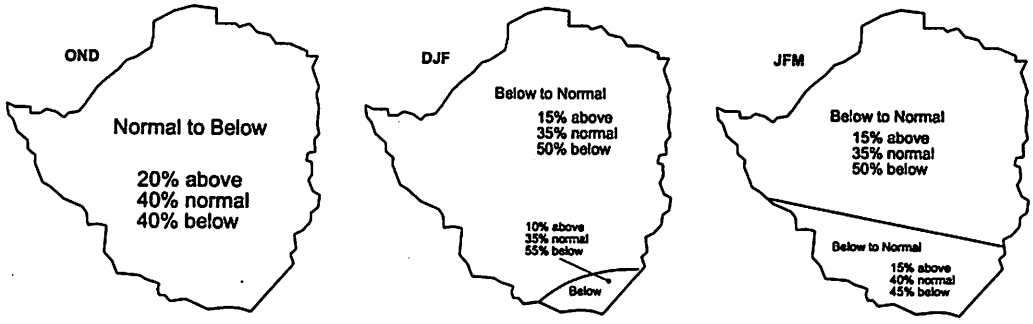


Figure 6—September Seasonal Forecast

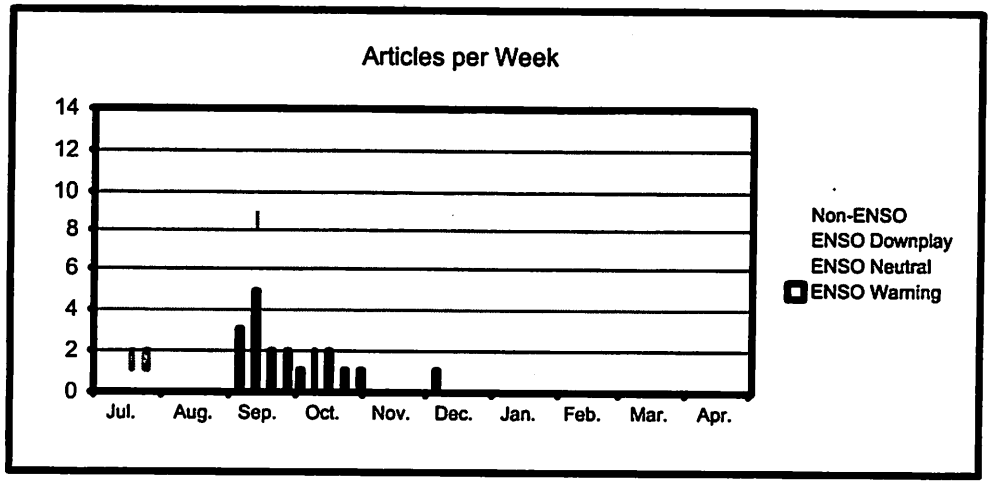
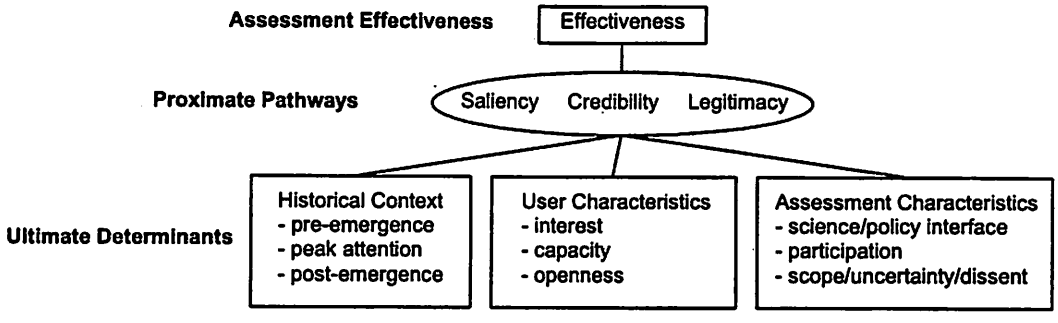
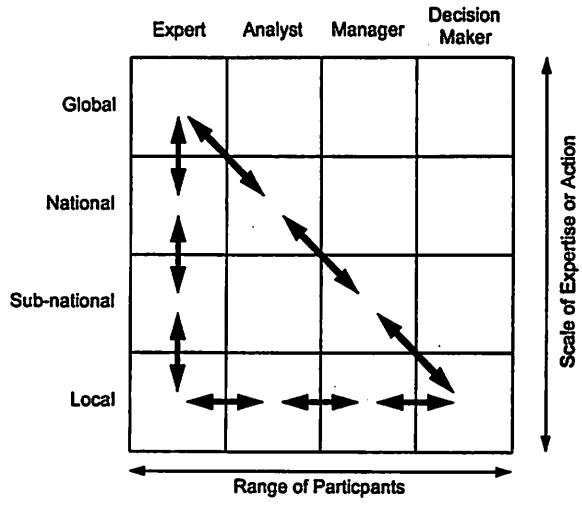


Figure 7—Newspaper Coverage of El Niño



Source: GEA (1999).

Figure 8—GEA Framework



Source: Cash and Moser (forthcoming)

Figure 9—Cross-Scale Communication Pathways

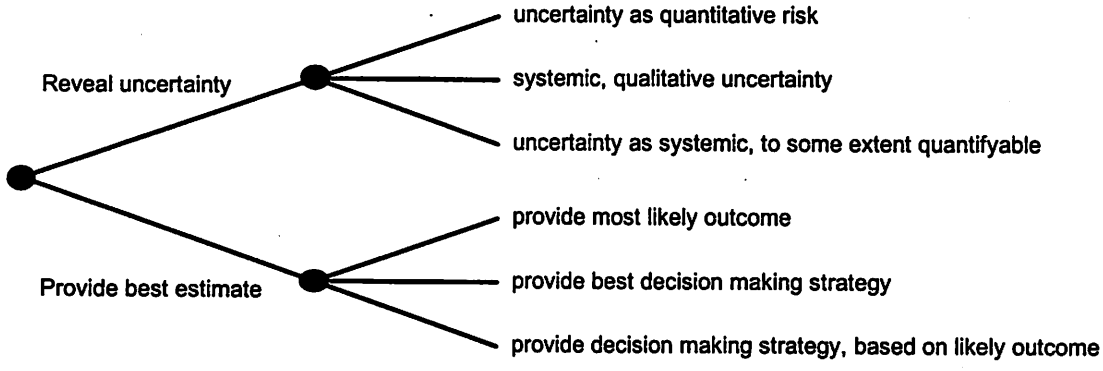


Figure 10—Assessment Alternatives

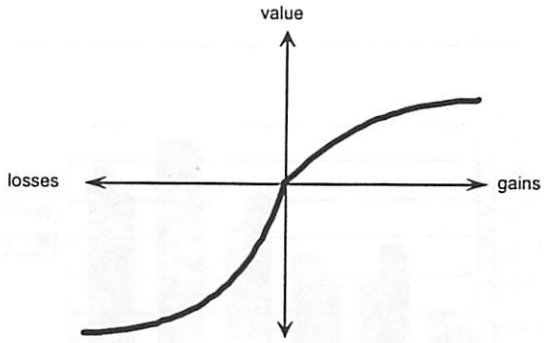


Figure 11—Prospect Theory Value Function

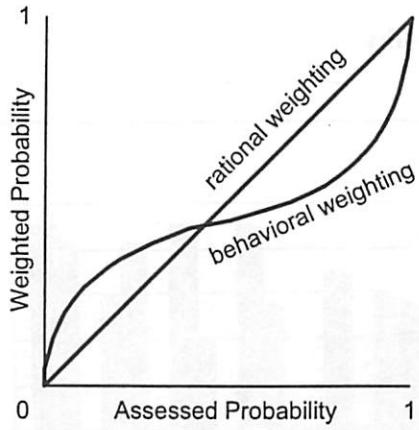


Figure 12—Probability Weighting Function

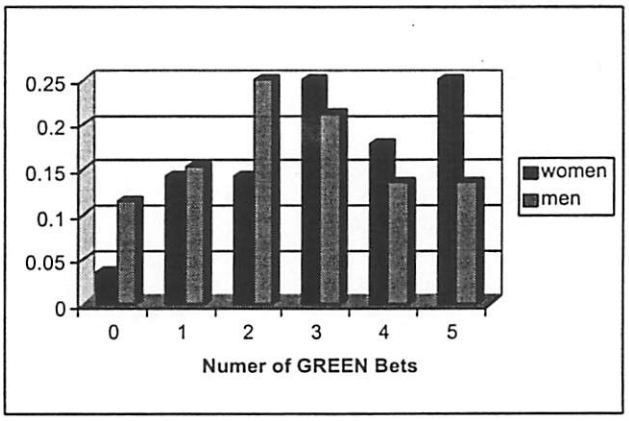


Figure 13—Game 1 Results

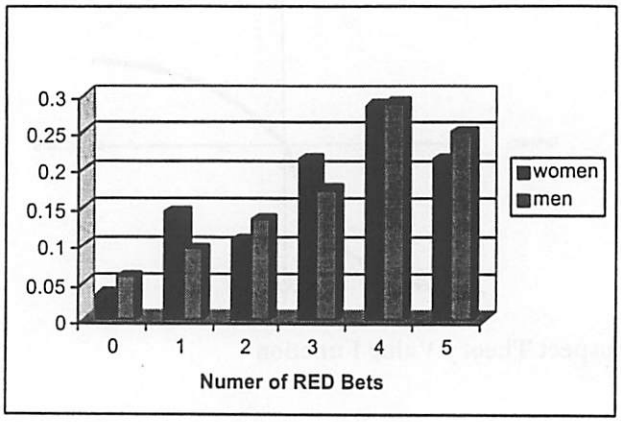


Figure 14—Game 2 Results

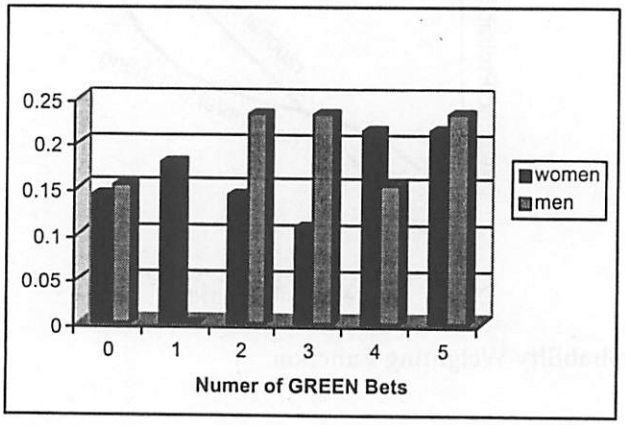


Figure 15—Game 3 Results

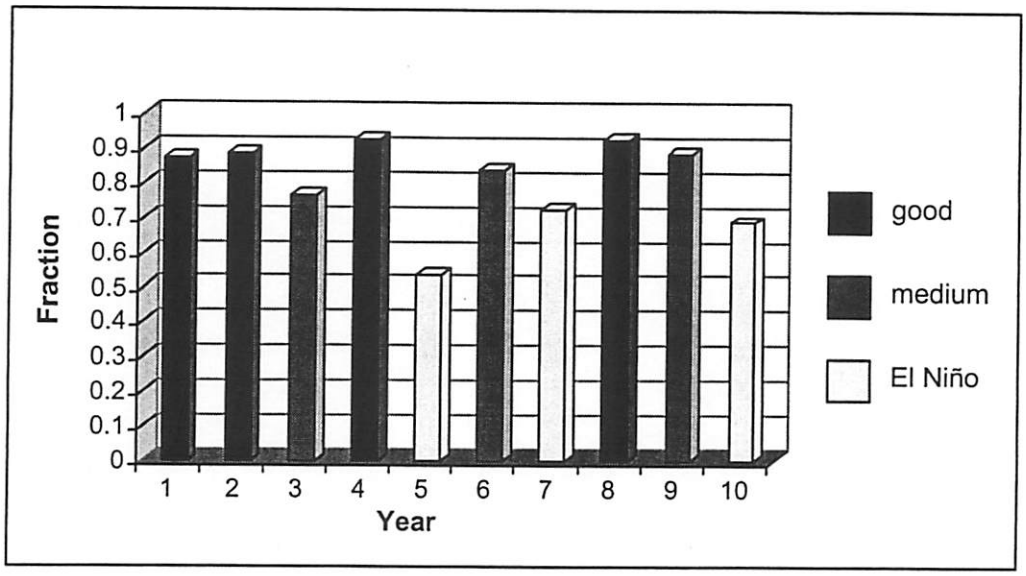


Figure 16—Game 4 Results

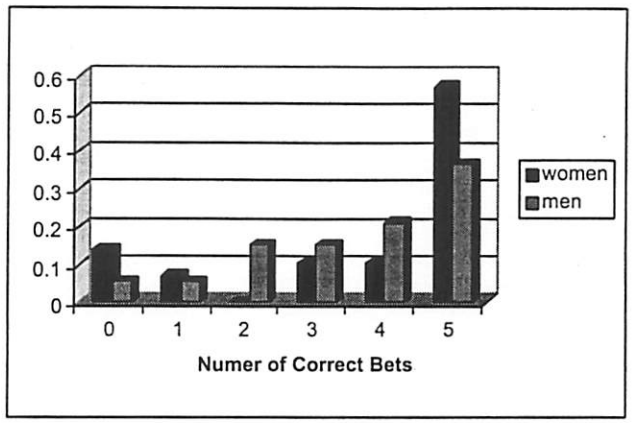


Figure 17—Game 5 Results

ENDNOTES

[1] Dr. Graham Farmer, a climatologist at the RRSP, collected the sample of 234 articles throughout the season. Most articles come from the Zimbabwe Herald, although several other newspapers are also represented. The sample is not complete, especially for newspapers other than the Herald, but gives a general picture of the type of coverage on ENSO and related issues.

[2] In Zimbabwe, a number of companies provide crop and commodity insurance to the commercial farming sector. For crops in the ground, they underwrite the risk of damage due to wind, hail, and fire. Once crops have been harvested, they insure against losses, such as fire, that occur before the crops are sold at market. Insurers have not underwritten the risk of drought, as it is too difficult to assess whether losses result from poor rainfall or from other forms of neglect, such as a lack of fertilizer. Through the 1997-98 season, insurance companies underwrote the risk of excess rains, including flooding. In 1998, a number of claims resulted from the heavy rains in late January. Many of these claims went to arbitration, since it was unclear whether the losses resulted from the excess rains in January, or the lack of rains in February. Since then, insurance companies have stopped covering the risk of excess rains.

[3] The model I present is taken entirely from Katz and Murphy (1997), who in turn credit Thompson (1952) with its introduction.

[4] It was not always possible to have exactly five men and five women participate. The experiment was pre-tested in the town of Hatcliffe, a high-density suburb north of Harare. The first two sessions took place in villages about 20 km north of Harare. The third session, in which seven men and three women participated, took place in a village just west of Masvingo. The fourth and fifth sessions took place in villages south of Bulawayo. The final three sessions took place on a commercial farm west of Harare, with farm laborers who until recently had themselves been communal farmers. Two of these three rounds involved groups of men only. The results were similar, and I present them in the aggregate.

[5] The experiments were conducted in April, 2000. At this time, the official exchange rate was US$ 1 = ZW$ 38. The price of bread was fixed at ZW$ 14.95 per 500g loaf, something many farmers but not all could afford to purchase on a regular basis. Beyond the food they grew themselves, most communal farmers received less than ZW$ 50 daily income.

[6] In several of the experimental sessions, this fourth game was changed slightly to test for the sensitivity of choice to the framing of gains and losses. In the alternate version, participants received a $10 payment lump sum payment prior to the fourth game, and told that this was to compensate them for any losses they might incur. Each of the payoffs was then $1 lower. Hence maize would win $3 or lose $1 (if the maize crop failed, they lost the money they had spent on seed), and millet would win $1 or $0, depending on whether the wheel landed on wet or dry. By the end of the ten rounds of the fourth game, participants in the alternate experiment version would be in the same financial position as those in the primary version discussed in the last paragraph. However, the outcomes they faced would include potential losses. To the extent that people are loss averse, one should expect a greater propensity to plant millet, rather than maize,

in this version of the experiment. In fact, I observed no significant difference in behavior between the two payoff systems, and I present the results in the aggregate.

[7] In the first three experimental sessions, the payoffs were as in the first set of games, with betting GREEN the dominant strategy. Since it was possible that people had learned merely to bet GREEN, and not to bet a dominant strategy, for the remaining five experimental sessions the payoffs were reversed, such that betting RED became the dominant strategy. The results—in terms of betting the dominant strategy—were similar, and I present them in aggregate, as if GREEN were the dominant strategy in all cases. Thus, what I report as a GREEN bet may have been RED or GREEN, depending on which set of payoffs I used.

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