Title

The Application of Seasonal to Interannual Climate Forecasts Based on El Niño - Southern Oscillation (ENSO) Events: Australia, Brazil, Ethiopia, Peru, and Zimbabwe

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THE APPLICATION OF SEASONAL TO INTERANNUAL CLIMATE FORECASTS BASED ON EL NIÑO-SOUTHERN OSCILLATION (ENSO) EVENTS:

LESSONS FROM AUSTRALIA, BRAZIL, ETHIOPIA, PERU, AND ZIMBABWE

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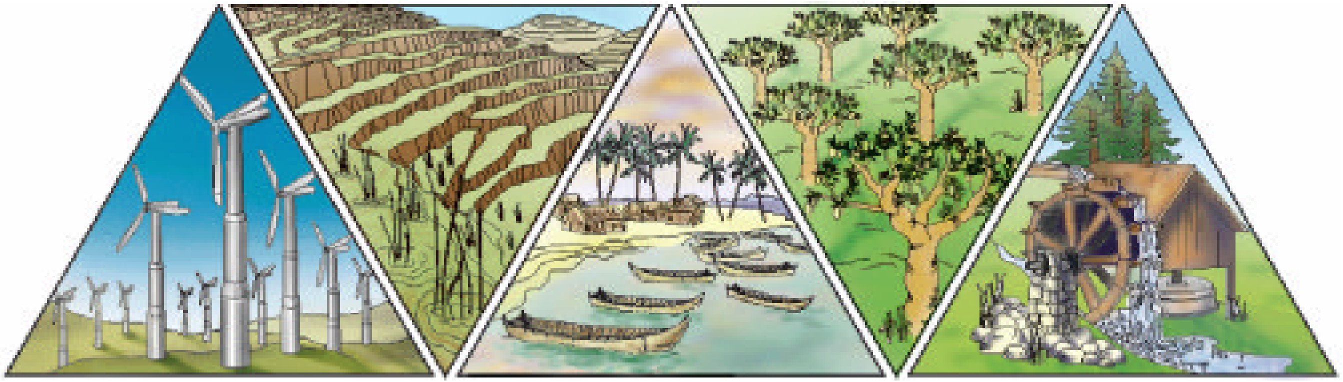

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INSTITUTE OF INTERNATIONAL STUDIES, UNIVERSITY OF CALIFORNIA, BERKELEY

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LIST OF ACRONYMS

ABARE (Australia): Australian Bureau of Agricultural and Resource Economics

BoM (Australia): Bureau of Meteorology

CAC (United States): Climate Analysis Center

CFU (Zimbabwe): Commercial Farmers' Union

DHNM (Peru): Hydrology and Navigation Bureau (Dirección de Hidrografía y Navegación de La Marina)

DMC (Zimbabwe): Drought Monitoring Centre

DPI (Australia): Department of Primary Industries

DPPC (Ethiopia): Disaster Prevention and Preparedness Commission

ENSO: El Niño Southern Oscillation

FAO (United Nations): Food and Agricultural Organization

FEWS (Zimbabwe): Famine Early Warning System

FSTAU (Zimbabwe): Food Security Techinical and Administrative Unit

FUNCEME (Brazil): Ceará Foundation for Meteorology and Water Resources (Fundação Cearense de Meteorología e Recursos Hídricos)

GMB (Zimbabwe): Grain Marketing Board

IGP (Peru): Peruvian Geophysical Institute (Instituto Geofísico del Perú)

IMARPE (Peru): Peruvian Marine Institute (Instituto del Mar del Perú)

INDECI (Peru): National Civil Defense Institute (Instituto Nacional de Defensa Civil)

INPESCA (Peru): Peruvian Institute of Fisheries Research (Instituto Peruano de Investigaciones Pesqueras)

IRI: International Research Insititute for Climate Prediction

ITCZ: Intertropical Convergence Zone

NASA (United States): National Aeronautical and Space Administration

NEWU (Zimbabwe): National Early Warning Unit

NGO: Non-Governmental Organization

NMSA (Ethiopia): National Meteorological Services Agency

NOAA (United States): National Oceanic and Atmospheric Administration

QCCA (Australia): Queensland Center for Climate Applications

RCOF: Regional Climate Outlook Forum

REWS (Zimbabwe): Regional Early Warning Systems

RRSP (Zimbabwe): Regional Remote Sensing Project

SADC (Zimbabwe): Southern African Development Community

SARCOF (Zimbabwe): Southern African Regional Climate Outlook Forum

SDR (Brazil): Department of Rural Development (Secretaria de Desenvolvimento Rural)

SENAMHI (Peru): National Meteorological and Hydrological Service (Servicio Nacional de Meteorología e Hidrología)

SOI: Southern Oscillation Index

UNCED (United Nations): United Nations Conference on Environment and Development

WFP: World Food Programme Food Supply

WMO (United Nations): World Meteorological Organization

WWW: World Wide Web

ZFU (Zimbabwe): Zimbabwean Farmers' Union

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1. INTRODUCTION

1.1 Overview

In this paper we present case studies of the efforts of five nations, Australia, Brazil, Ethiopia, Peru, and Zimbabwe, to use climate forecasts based on the El Niño-Southern Oscillation (ENSO) system to plan in advance of anticipated anomalous climatic states. We treat the variable use of climate forecasts among these nations as a problem of "fit" between the nature of ENSO, a persistent variability in the ocean–atmosphere system of the tropical Pacific which produces climate variability at local and regional scales around the world, and the human institutions and actors that make and use the forecasts. Our examination of patterns of use of forecasts indicates constraints and suggests opportunities for the useful application of climate forecasts in the future.

Over the past 15 years, interest and expertise has grown in developing forecasts of ENSO events. This interest was spurred largely as a result of the well-known 1982-83 ENSO event, which is reported to have caused at least $8 billion in losses worldwide and up to 2000 deaths (NOAA 1994). In the intervening years, international and university-based research programs (in particular, the Tropical Ocean/Global Atmosphere program and its successor, CLIVAR; WMO 1985) have helped to uncover the basic mechanisms of ENSO events, and enabled the development of predictive models (e.g., Zebiak and Cane 1987, Chen, et al. 1995, or see Barnston, et al. 1994 for a review). Complementing this physical science research, social scientists have come to understand better the social, cultural and economic impacts of and vulnerabilities to ENSO and climate variability (e.g., Glantz 1996, Magalhaes and Glantz 1992). Emerging from this work is an integrated picture of how natural variability in the Earth's physical climate system interacts with different human societies, cultures, and economies.

These developments in the physical and social science aspects of ENSO offered the hope that the impacts of climate anomalies on agriculture, water resources, fisheries, and human health might be mitigated or avoided through the application of ENSO forecasts. This concept of going "end-to-end" from climate forecast to application was formally discussed at the United Nations Conference on Environment and Development (UNCED) in 1992, and resulted in the development of a new International Research Institute for Climate Prediction (IRI), sponsored by the Office of Global

Programs of the National Oceanic and Atmospheric Administration (NOAA) and housed at Columbia University and Scripps Institute for Oceanography.

The idea of harnessing our increasing capacity to predict global climatic anomalies for improved management of agriculture, fisheries, and water resources is both conceptually appealing and socially compelling. It joins together the physical, biological and social sciences, brings together nations who share a common problem, and applies the tools of the modern scientific enterprise for the benefit of society. However, the conceptual attractiveness of going "end to-end" belies the complexity of the human enterprise. As Folke et al. (1998) observe, ecosystem properties that are linked across scales cause the most problems for human management. We now recognize that interannual climate variability affecting fisheries, agriculture, and water resources at local and regional scales in particular areas of the world is driven by a tropical Pacific-scale phenomenon. Information about ENSO, and the institutions that produce it, may or may not translate usefully down to the scales at which farmers, fishermen and water resources managers make decisions (Farmer 1988). The problem of applying ENSO forecasts, therefore, is a problem involving the "fit" between the characteristics of the biophysical phenomenon (which is linked across spatial scales, and which produces impacts across sectors) and the information and institutions that are mobilized to deal with the impacts of the climate variability.

This paper explores the dynamics of information flow, institutional learning, and innovation that are involved in fitting ENSO forecasts to the functions, structures, and wider social environments of would be "end-users." The goal is to provide an initial stock of empirical detail that might be of value to researchers and analysts, and to document patterns in the endeavor of nations to utilize climate information for decision making. In the first section of the paper we present our conceptual framework and outline the research methods. This is followed by a presentation of the five cases. The paper concludes with a discussion and synthesis of the cases, and with suggestions for further avenues of research.

1.2 Conceptual framework

In the five cases we examine, interannual variability in air temperature, sea-surface temperature, and precipitation is a persistent feature of the human management of agriculture, fisheries, water resources, and livestock. In these countries, what is new is the realization that the climate variability is at least partly driven by variability in the ocean–atmosphere system at the scale of the tropical Pacific. In other words, there is a "top-down" control exerted by variations in the tropical Pacific ocean–atmosphere system upon the functioning of the managed ecosystems, variations that may now be forecast (Shukla 1998). Following on the work of Gunderson et al. (1995), Berkes and Folke (1997), and Folke et al. (1998), we view "use of forecasts" as an endeavor to generate, diffuse, modify, and apply a new form of scientific information, set within the context of historically, scientifically, and culturally contingent human–environment relationships. In this approach, management of the environment and its resources is seen as a process of mutual interaction between the structure and function of institutions on the one hand, and the structural characteristics of the biophysical environment on the other. Effective management—i.e., management that secures the flow of the natural resource in a sustainable manner—is considered to be a function "of the fit between the institutions themselves and the biophysical and social domains in which they operate" (Young and Underdal 1997).

Complicating the analysis are the difficulties in specifying what activities and actors/institutions constitute "uses" and "users" of forecasts. For example, the incorporation of predicted sea-surface temperature fields from a coupled ocean-atmosphere model into a simulation model of the seasonal climate of Northeast Brazil, may be considered a "use" of a forecast. The use by smallholder farmers of that seasonal climate information to plant drought-tolerant crops on their family plots would constitute another use. A useful distinction might therefore be made between "upstream" and "end" uses of an ENSO forecast, which we define here as a predictive numerical model of tropical Pacific sea-surface temperature (El Niño) and/or atmospheric pressure (Southern Oscillation) fields. A similar distinction might be made between "apparent" and "actual" motivations for using forecast information. For example, government institutions may issue forecasts to gain social legitimacy or authority, even if no resources are actually invested in making behavioral responses to the anticipated climate anomaly. Linking these diverse uses, users, and motivations, however, is the flow of information about the future state of the climate.

We have chosen the five countries in this study because each is known to have had at least some experience with climate forecasts, and because they represent a diversity of environmental, political, economic, ethnic and cultural, and scientific milieus. Three of the nations (Brazil, Peru, and Australia) are directly affected by the changes in sea-surface temperature and atmospheric pressure associated with ENSO. The African countries are "teleconnected" to the tropical Pacific through not fully-understood physical mechanisms. While some nations still wrestle with the lingering effects of colonialism, civil war, and extreme poverty, others are politically and economically stable. Therefore, any framework to identify, understand and explain variable patterns of use of climate forecasts among these nations must account for a diverse array of possible explanations, ranging from the degree of strength of the ENSO "signal" within the spatial-temporal domain of the forecast application, to the relative resources available to would-be "end-users."

1.3 Hypotheses

Therefore, characterizing the dynamics of that information flow may be a useful starting point for analysis. The metaphor of "signal transduction" is one way to represent the endeavor to use climate forecasts (Figure 1). In this model an initial signal, the ENSO forecast, is sent along the transduction pathway—usually by an international forecast-issuing agency such as the IRI. Along the pathway, regional, national and subnational institutions reshape and re-communicate the climate information—"upstream" uses, as discussed above. As this reshaping takes place, the original "signal" is modified to produce regional to subnational-scale climate forecasts that are relevant for sector-specific planning activities. Finally, behavioral changes are either undertaken—to varying degrees—or not, representing the final signal output ("end" use). Along the pathway from forecast to end-use, therefore, the nature of the signal changes as it is transferred and transformed from institution to institution.

We propose that patterns of information flow from forecast to end-use should be shaped by the degree of "fit" between the climate information itself, and the social-institutional environments through which the information flows and by which it is reshaped. At least two aspects of this "fit" may be salient. The first, which we term "scale fit," refers to the degree of fit between the spatial and temporal scales over which forecast information is available, and the spatial-temporal characteristics of the "use" to which the information would be applied. For example, if farmers make planting and crop management decisions based on expectations about the timing of rains at particular points during the rainy season, a climate forecast of the probability of receiving average rainfall for the whole season would likely be of little use.

We also postulate the importance of what we term "organizational fit." Specifically, the climate information must "fit" the problem-frame, decision-making processes, and capacity for adaptive response of the users. If users are not familiar with the nuances of probabilistic information, do not trust scientific information, or simply do not think of the climate anomalies as linked to a global phenomenon, a lack of fit between the climate information and the social-institutional "structures of signification" (Giddens 1984; Collins 1981) should constrain the flow from forecast to application. Though these questions of familiarity, trust and perception might be viewed as cultural or psychological issues, we frame them in terms of organizational fit because they typically play out within patterns of institution-level behavior. Further, even if would-be users of climate information can interpret the information, entrenched patterns of information flow and decision making—the "structures of legitimation"—can also limit the use of climate information. In other words, the "signal" can be damped or routed away from its potential output in the form of behavioral response. Finally, institutions and actors who lack the resources to respond in advance to an anticipated climate anomaly would not have the capacity to utilize any climate information to which they are exposed. Here, the "structures of domination" would constrain the use of climate information and damp the signal output (i.e., behavioral changes).

It is important to bear in mind that the international institutions that develop ENSO forecasts (e.g., NOAA, IRI, US National Weather Service) do not necessarily have a great deal of experience working with social planning institutions around the world. Similarly, as suggested in the discussion above, the modifiers and "end-users" of forecasts constitute a diverse group of regional, national and subnational meteorological agencies, resource management agencies, food security planning agencies, and others that have not traditionally made use of seasonal to interannual climate forecasts. In other words, all of these institutions have made changes to their structures and functions (or "learned") in order to incorporate climate information into their range of activities. The outcome of these structural and functional changes represents the design of the pathway of information flow from forecast to end-use.

Functional changes to the institutions might include the development of forecast dissemination strategies, development of forecast and application products, or working with "end-users." Structural changes, which must accompany the functional changes, can include the organizing paradigms of the institution ("structures of signification"), the structures of information flow and decision making ("structures of legitimation"), and the allocation of resources ("structures of domination"). As noted in the social science literature, these three aspects of social and institutional structure need to reinforce one another in order to optimize conditions for social action (Giddens 1984; Collins 1981; Westley 1995). "Barriers and bridges" to learning and innovation within both forecast-generating and forecast-utilizing institutions should, therefore, provide important fundamental constraints on the patterns and extent of use of climate forecasts. Figure 1 summarizes these propositions.

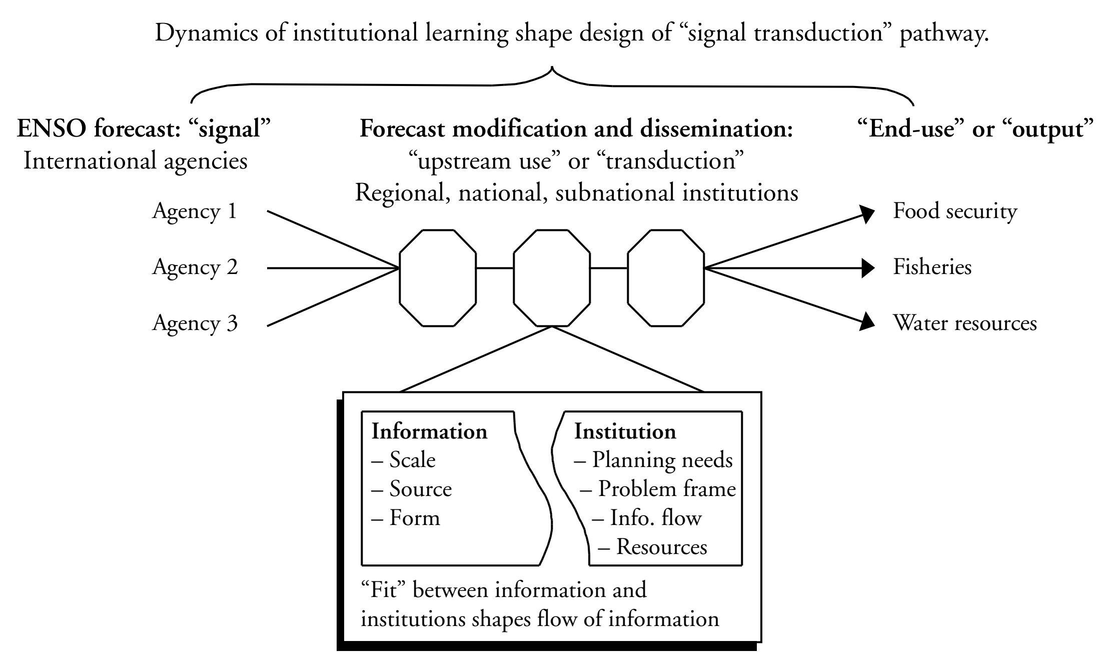


Figure 1: Conceptual model of information flow from ENSO forecast to application

1.4 Research methods and structure of cases

In order to explore the above propositions further, the cases were examined through published literature, the "gray literature" of reports, websites and other on-line documentation and extensive face-to-face and telephone interviews. Given these propositions, each case examines the biophysical and social backdrop within which climate information has emerged, outlines the relevant institutions involved in generating and applying climate information, and presents a historically-based narrative discussion of how these institutions have "learned" to develop and use climate forecast products. Each case concludes with a summary discussion. While we do attempt to present the cases in a relatively consistent manner, our goal is not to test rigorously an *a priori* set of hypotheses, but to explore and extend them from a critical mass of empirical detail. Therefore, we do allow the nuances of each country's experiences to guide the presentation of the cases. One element of consistency is our rough terminology for spatial scales. We use the word "international" to refer to scales of a number of countries on more than one continent, or of the entire globe; "regional" to refer to a number of contiguous countries on a single continent; "national" to a single country; "subnational" to a region within a country; "state" to a province or other large administrative unit within a single country; "local" to a county, village, or other small area. We do not, however, formally match these scales, which are made in reference to political boundaries, to scales of relevant atmospheric phenomena and ecosystem processes (e.g., Clark 1985); this is planned for future work.

The case studies are presented in alphabetical order.

2. CASES

2.1 Australia

This section presents the case of Australia's endeavor to utilize ENSO forecasts. In particular, we focus on the state of Queensland, where the impacts of ENSO are strongest and where the efforts to apply forecasts have been most concentrated. Initial work on developing useful climate forecasts began in the early part of the century, and has been led by the national Bureau of Meteorology (BoM). Through interactions and collaboration between BoM and the state-level Department of Primary Industries, Queensland has developed expertise in the generation of climate forecasts and applications for a variety of agriculture-related sectors. The high level of integration among relevant experts, and between experts and ground-level end-users, is unique among the cases.

2.1.1 Climate and society

The climate of Queensland shows a high degree of interannual variability. The Southern Oscillation has a strong influence in this region. By increasing atmospheric pressure during El Niño years, it leads the summer storms—the principal source of precipitation—to decrease in frequency and intensity. However, other factors also influence precipitation, notably temperature anomalies in temperate and sub-tropical regions of the southwestern Pacific.

Located in northeastern Australia, Queensland is a large state (1,727,200 km^2) featuring a variety of climate regimes. Some portions of the northeast coast receive an annual average of over 2400 mm of rainfall, while the driest stations in the arid southeast interior have less than 200 mm. Though the precipitation is sufficient for some form of agriculture or livestock raising in most of the state—1,497,000 km^2 reported in 1996—much of this is unimproved rangeland, with cattle raising in the more humid north and sheep-raising in the drier south. There are pockets of highly productive sugar cane cultivation on the coast, and sections of wheat, cotton and sorghum production in the semi-arid southern portions.

2.1.2 Forecast development and institutional learning

Through the mid-1980s, BoM released informal media briefings and advisories regarding their ENSO and precipitation forecasts for Australia, and by 1989, BoM began formally issuing seasonal climate forecasts based on ENSO. Complementing the forecast work, BoM researchers also began to integrate the climate forecasts with crop models (Nicholls 1985; 1986), and the DPI began to explore how farmers might make best use of this integrated information. In their initial efforts they focused on very fine scale decision alternatives, such as the selection of particular wheat varieties or of levels of fertilizer application to optimize production for particular climate scenarios. The growers, however, expressed more interest in broader decision alternatives in their interactions with the scientists and extensionists (e.g., should we plant cotton or sorghum?). DPI researchers then began to test experimental models, that evaluated the relative profitability of different crops and of the choice between cropping and pasture. In 1991, DPI released their first model that indicated the areas within the state for which rainfall would be sufficient for wheat cultivation. These models allowed them to obtain a three-year grant from the Grains Research and Development Corporation, which led in turn to the formation in 1997 of a new Queensland Center for Climate Applications (QCCA). The QCCA has a total budget of $5 million (FY 1997/98) and a staff of 55 people featuring experts in atmospheric and climate science, crop and grazing systems management, computing, water resources management, and agro-climatology extension (QCCA 1997).

Work in developing climate forecasts began as early as 1910 in Australia's Federal Bureau of Meteorology (Quayle 1910a, 1910b). Researchers within BoM, in particular Neville Nicholls, built upon this work in the late 1970s and early 1980s. This work began to confirm the strong link between the Southern Oscillation and seasonal rainfall patterns in Australia (Nicholls and Woodcock 1981; Nicholls 1983; McBride and Nicholls 1983). By 1982/83, the BoM had established that Australian droughts were in fact predictable, and Nicholls issued an ENSO forecast, including discussion of its possible agricultural impacts, at a September 1982 meeting (Nicholls, personal communication).

A 1983 meeting was later convened in Sydney to examine associations between weather and farming in the wake of the 1982-83 ENSO event. This meeting was attended by Nicholls and two scientists, Graeme Hammer and Greg McKeon, from the Queensland Department of Primary Industries (DPI), a rural economic development agency for Queensland state's agriculture, forestry and fisheries industries. Hammer and McKeon had begun as early as 1978 to develop pasture and crop simulation models, and were seeking approaches that could help them deal with the extreme climatic variability of the Queensland region (Hammer, personal communication). It was through this contact that Queensland, where the impacts of ENSO are most pronounced in Australia, began to take interest in applying climate forecasts (Nicholls, personal communication; Hammer, personal communication).

In the mid and late 1980s, the BoM continued its work in improving climate forecasts, while the DPI began to develop systems for disseminating forecasts and making them useful to farmers and graziers; interestingly, this work was undertaken within the context of climate change rather than climate variability (Hammer, Woodruff and Robinson 1987; Hammer, McKeon and Clewett 1988). Strikingly, the BoM's progress did not stem directly from the incorporation of the dynamical models of coupled ocean–atmospheric interactions that were pioneered during that decade. Instead, they relied on statistical models that explored quantitative data for significant patterns. They discovered relatively weak correlations between the Southern Oscillation Index (SOI) and precipitation at the Queensland regional scale. However, when BoM scientist Roger Stone, while on extended study leave at the University of Queensland, divided two-month periods into five categories of trends in the SOI (heavily decreasing, decreasing, steady, increasing, heavily increasing), he was able to discover much stronger correlations with precipitation at a high degree of spatial resolution. Stone worked in-house in the DPI during the 1990s, providing in situ climate expertise to the DPI that had not previously been available. His presence within the DPI "enabled (them) to focus the forecasting techniques in a way not possible by interaction with BoM" (Hammer, personal communication). Stone's unique meteorological work came to serve as the basis for ENSO forecasts and application products in Queensland.

The source of funding for these activities is noteworthy. A group of industry-government corporations, including the Land and Water Resources Research and Development Corporation, the

Grains Research and Development Corporation, the Meat Research Corporation, and the Rural Industries Research and Development Corporation, helps to provide funding for the climate forecast and applications work. These corporations are statutory organizations, supported by the government and by the stakeholders involved. They invest on the order of tens of millions of dollars to support research and development related to the future growth of the industry in question.

In summary, Australia's long-standing national level expertise in meteorology coalesced with Queensland state-level efforts to assist growers and graziers in managing the effects of persistent climate variability. In 1983, institutional bridges were informally built through "link-forming" activities in the wake of the 1982-83 ENSO event. Through the 1980s, the state-level DPI began to hire climate experts from the national BoM, leading to the development of forecast products that were tailored to farm and pasture-scale end users. (We would like to indicate a specific terminological usage at this point: we use the word "entrain" to refer to the process by which an agency or organization draws new kinds of personnel into itself.) In parallel, BoM continued to develop forecasting capacity and began to issue formal forecasts, and the DPI began to work closely with end users to build their capacity to make use of climate information. By 1997 these activities culminated in the birth of a new institution (QCCA), in which the relevant suite of experts—from meteorology to agricultural extension—were brought together from the beginning. These developments were consistently enabled by the financial support of the government and the rural industrial corporate entities.

2.1.3 Forecast products and applications

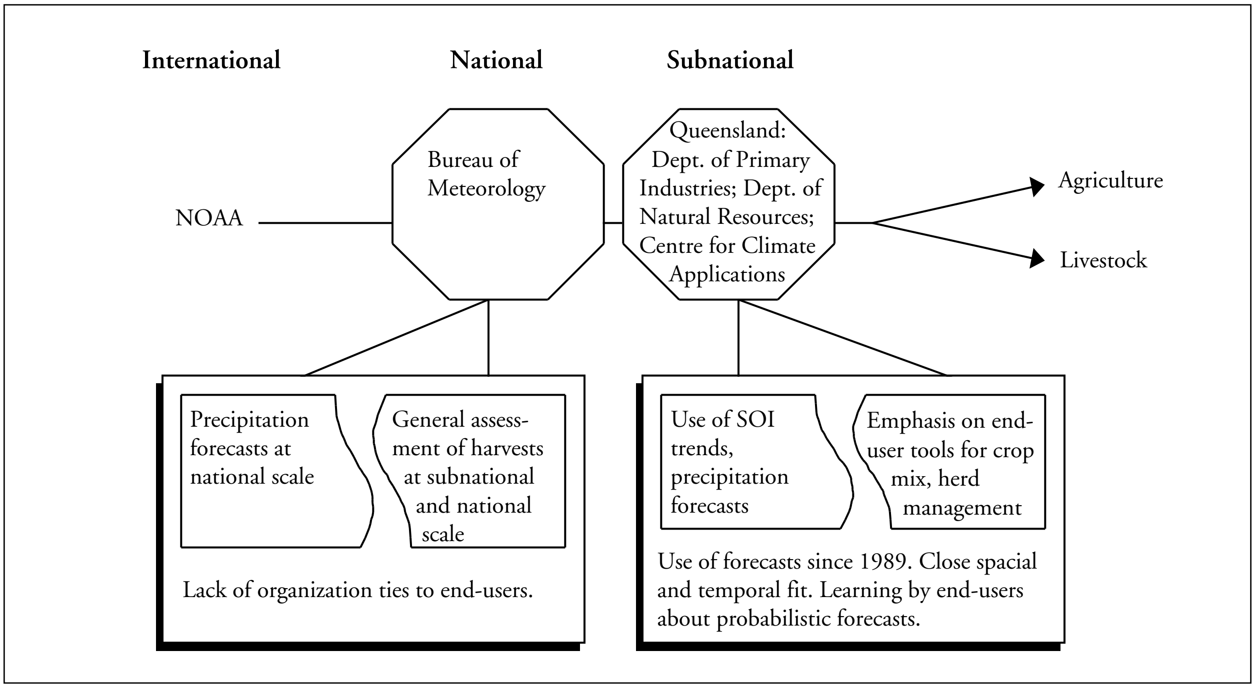
Queensland's climate forecast and application products reflect the tightly integrated institutional arrangements that underlie their development. Forecast products have taken four forms: 1) on-line resources, 2) stand-alone software packages, 3) telephone and fax hotlines, and 4) education and training materials and activities. A least three world wide web sites feature access to a rich array of ENSO forecast data and information, the Long Paddock and the QCCA web site. On the Long Paddock site, for example, current climate and Southern Oscillation Index phase data are posted each weekday evening, along with a current SOI message. Additionally, users can, through an interactive interface, obtain total monthly rainfall, rainfall percentile, SOI, SOI phase, and sea-surface temperature data from 1900 to the present.

A stand-alone software package, Rainman, was developed by the DPI, BoM, and the Western Australia Department of Agriculture and funded by the Rural Industries Research and Development Corporation and the Meat Research Corporation. It is designed for graziers, farmers, and other users (e.g., students and educators), and enables the user to examine daily, monthly and seasonal rainfall, apply current SOI data to assess the probability of seasonal rainfall, and analyze historical SOI and rainfall data for 4000 locations in Australia. Along with these crop-related products, a spatial modeling system was developed for pastures that linked to the SOI phase forecasting system (Brook 1996).

Further complementing the development of these tools, applications delivery specialists developed case studies to bring to groups of farmers. These efforts have been built upon with the development of on-line supplemental educational materials, training courses and resources, all with a goal of providing end-users with basic knowledge about meteorology and the nature of probabilities and forecasts, in order to make the most effective use of the forecast products. Through these efforts, growers have come to appreciate the nature of production risks and the statistical/probabilistic nature of the climate forecast products.

Although we do not treat the emerging efforts to utilize seasonal to interannual climate forecasts elsewhere in Australia, it is worth noting that resource managers in other Australian states are following the example of Queensland. For example, managers of hydrological resources in particular watersheds in Western Australia are developing their own models that integrate Pacific and Indian Ocean data to forecast precipitation.

Figure 2: "Fit" between institutions and information in Australia



2.1.4 The 1997-98 event

With respect to the 1997-98 ENSO event, in June 1997 the Australian Bureau of Agricultural and Resource Economics (ABARE) began to issue media releases with forecasts of projected impacts on crops and exports. The June 17 media release forecast a 5% drop in the value of Australia's farm exports to $20.2 billion in 1997-98 (ABARE, 1997a). They projected winter crop yields to decrease, especially in the eastern states, with wheat expected to fall 30% (16.2 million tons). The July 2 media release (ABARE, 1997b) echoed this concern. but again noted the conditional nature of the forecast: "Each El Niño event is unique. Therefore it is not possible to be precise about the areas that will be most affected...(I)t is still possible to achieve above-average yields. For example, for two recent years with El Niño patterns in June, wheat yields were 35% below average in one and just above average in the other." By October this caveat was realized as good seasonal conditions in Western Australia boosted the wheat crop; ABARE's October 21 media release revised its projection of 1997-98 wheat production to 17.6 million tons, and also noted improved conditions for summer planting in Queensland (ABARE. 1997d).

As for livestock, graziers initially reacted to the 1997 ENSO forecasts by increasing slaughterings. Slaughterings in Queensland during July were up 17% from the previous year, and were up 19% for Australia as a whole (Westpac, 1997). In total, the ENSO event was projected to result in a total decrease of farm GDP by $1.4 billion over 1997-98, a 6 percentage point drop through the national economy.

2.1.5 Summary

Queensland's close integration of Southern Oscillation Index data with farm-scale climate and crop forecasts is unique among the cases. This cross-scale information integration reflects the close institutional arrangements among the DPI, BoM, and corporate associations representing economically important resource managers in the state. These arrangements in turn reflect the economic importance of the rural industries to the overall economy of the state, the sophistication of Queensland's scientists and resource managers, and the education and technical capabilities of the end-users. These conditions, combined with the commitment and talents of the scientists involved, help to explain the observed pattern of institutional learning, in which climate experts from the BoM first initiated awareness of climate forecasting in the DPI, engaged in cross-institution collaboration (or "link forming"), and were finally entrained by the regional DPI. This process culminated in the eventual birth of a new institution (QCCA) that, from its outset, reflects the diversity of expertise that is required to make forecast products usable across a wide range of sectors. In this case, the Australian tradition of scientific excellence, many opportunities for cross-institution flows of information and expertise, and significant available resources have successfully reinforced one another.

2.2 Brazil

Climate forecasts have been made and utilized since at least 1991 in the Nordeste region of Brazil, where persistent periodic droughts have caused great hardship for poor smallholders and landless peasants. Similar to the Australian case, a state-level institution—Fundação Cearense de Meteorología e Recursos Hídricos (the Ceará Foundation for Meteorology and Water Resources, FUNCEME)—has led the effort to develop and apply climate forecasts for agriculture and water resources planning. The evolution of FUNCEME from a cloud-seeding to a climate forecast and applications institution contrasts with the more gradual development of DPI/DNR in Queensland. Although FUNCEME has entrained much of the climate forecast and applications experts into the institution itself, it works with the Secretariat of Agriculture and the Extension Service to assist producers in making decisions about when and what to plant. Some well-publicized missed forecasts have eroded FUNCEME's credibility in recent years, illustrating the importance of public trust in, and understanding of, the benefits and risks of climate forecasting.

2.2.1 Climate and society

The Brazilian Nordeste is typically divided into five major ecosystem types: 1) the *zona da mata,* a humid coastal area extending along the coast from Bahia to Rio Grande do Norte, with average precipitation of 2000 mm/year; 2) the *cerrado* region in western Nordeste, where annual precipitation averages at least 1000 mm; 3) a transition zone *(pre-Amazonia)* between Amazonia and the semiarid *sertão* (see below), with high precipitation; 4) *agreste,* the transition zone between the coast and the *sertão,* an area of high population density that receives ~800 mm/year of precipitation; and 5) the semiarid *sertão,* the least-developed region of Nordeste—and the hardest hit by drought events (Magalhães and Magee, 1994). This analysis focuses on the *sertão* region of Nordeste, and in particular on Ceará state.

While mean annual rainfall for the *sertão* is about 700 mm, the spatial and temporal variance in precipitation patterns is great. Precipitation varies from 1,000 mm/year in the *serras* to 250 mm/year in the *caatinga.* The rains themselves are also strongly seasonally distributed: 80-90% of the annual rainfall falls during the wet season between February and May. Superimposed upon this seasonal and within-region climate variability are ENSO-driven climate anomalies that occur over interannual time scales across the *sertão.* Precipitation comes to the region when the Intertropical Convergence Zone (ITCZ) reaches its southernmost position. During ENSO events, a warming of the eastern Pacific sea surface moves the ITCZ northward and enhances atmospheric convection off the western coast of South America. This increased convection is balanced by the subsidence of dry air (as is true in the Western Pacific over Australia), and produces drought in Nordeste with an average periodicity of five years or so (Uvo, 1993). Severe drought events of the recent past have occurred in 1951, 1958, 1970, 1982-83, and 1993.

The *sertão* was developed later than some areas of the Nordeste. Its abundant land made it attractive to cattle ranchers, and cattle and subsistence agriculture (rice, beans, corn, manioc) have come to dominate land-use activities in the area. Cotton, a relatively drought-resistant crop, is the largest cash crop. About 7 million people live in Ceará state, which occupies 148,000 km^2 in area within the *sertão.* Per capita income remains low, and land and income distribution are unevenly divided. While large farms (>100 Ha) represent only about 20% of the total number of farms, they cover about 95% of the land in the *sertão* (Kutcher and Sandizzo, 1981). Owners of smaller plots, who mainly raise crops for subsistence (and some cotton for cash) typically live on the more marginal lands of the region. Approximately 225,000 families do not own land at all (Magalhães and Glantz, 1992); these people either work as laborers on the large landholdings or squat, providing some of their harvest as rent to the landowners (Hall, 1978). With increasing growth and development in the region, demand for food and raw materials has put increasing pressure on the already-marginal land. The more marginal lands are increasingly cultivated, while fallow times decrease on the better lands—reducing soil quality and increasing the vulnerability of the land to drought (Magalhães and Magee, 1994).

The social impacts of drought in Nordeste have been documented since at least the 1580s, when Cardim first described the coastal migration of indigenous tribes during periods of low rainfall (Hall, 1978, p. 2). Since then, increasing population growth and settlement in the arid sertão, coupled with the socioeconomic arrangements that have governed land and water use, have made the people of the Nordeste extremely vulnerable to the regular droughts that plague the region. If faced with the prospect of drought, many of them migrate to the cities of Brazil's more prosperous southern states, adding to the social and economic hardships already facing these urban centers. In more recent years, displaced peasants are also moving to the larger cities of the northeast and placing additional pressures on the regional economies at the time when they are already impacted by drought.

Over time, the state and national-level governments have taken a variety of strategies to deal with the problem of persistent drought in Nordeste and the *sertão.* From the late 1800s through the mid 1900s, the main goals were to increase the retentive capacity of the hydrological system through technological interventions (building dams and irrigation systems). These goals were accomplished through a permanent institution, the Superintendency for Studies and Drought Relief Works (now known as the National Department for Drought Relief Works). From the 1950s through the 1970s, attempts were made to further decouple the social and economic welfare of the region from drought, through industrial development and increased irrigation. These strategies, and the institutions that were deployed to promote them, reflect an engineering paradigm: The objective of minimizing the impacts of drought was pursued through direct interventions in the biophysical system, with the social and economic system receiving increasing attention beginning in the 1970s.

2.2.2 Generation of forecasts: FUNCEME

This engineering paradigm also drove the creation of FUNCEME. The Governor of Ceará state established FUNCEME in 1972. Its objective was to increase precipitation, especially during dry years, by a cloud-seeding program. This development took place during the peak period of optimism (and federal funding) for weather modification in the US, in the 1960s and 1970s. Funding began to decline in late 1970s, with very little money allocated to this program after mid-1980s. After several failures, FUNCEME abandoned its artificial rain program by the mid-1980s, changed its name in 1987 to the Ceará Foundation of Meteorology and Hydrology, and quickly began to develop and promote the use of climate forecasts. The governor-appointed President of FUNCEME at the time was an innovative water resources engineer who developed links to the academic and scientific community in Brazil and internationally and built a strong in-house group of meteorological researchers. At the same time, he created a water resources management group, which developed management strategies for the operation of dams and optimal use of water resources. The goal was to understand and monitor drought in Nordeste, and develop better ways of using water resources to mitigate drought impacts. Through the efforts of its new president, FUNCEME shifted its organizational paradigm, from biophysical "engineering" (i.e., increasing precipitation through cloud seeding) to integrated understanding and management (i.e., improving the use of water and agricultural resources through forecasts and management strategies).

Three changes outside of FUNCEME complemented and influenced the internal shift in direction. First, interest in climate forecasting was growing in Brazil, linked to the expansion of Brazil's space program, collection of satellite data, and increase in computational equipment and skill. Second, there was a shift in the governing political party at the state level. The governors of Ceará in the 1970s and early 1980s were associated with one party that had been dominant under the military. Around 1984, the governor switched to the opposition party.which won the election in 1986 and has held the governorship since then. The new parties reoriented government programs towards medium- and long-term poverty alleviation projects. This return to electoral democracy led to higher level of activity of print and radio journalism, providing contexts for FUNCEME to present its forecasts. Third, a switch in cotton varieties increased the demand for climate forecasts. Boll weevil outbreaks in the 1980s reduced cotton yields markedly, and led to a switch from the traditional low-yielding drought resisting perennial cotton, a kind of tree crop, to annual cotton varieties that are less susceptible to weevils but also less tolerant of drought. The use of this crop increased vulnerability to, and awareness of, rainfall variability. Finally, the expansion of agricultural credit and the agricultural extension service, associated with these new varieties, provided further conduits for information about the use of forecasts.

Starting in 1989, FUNCEME worked with the state Department of Rural Development (Secretaria de Desenvolvimento Rural or SDR) in its Planting Time Program, called "Hora de Plantar" in Portuguese—literally, "hour of planting." The participants in this program are poor farmers, who register with the agricultural extension service. In exchange for a portion of their harvest, farmers receive high-quality seeds. The extension service does not distribute the seeds until the "hour of planting" has been declared by SDR on the basis of advice from FUNCEME. This advice rests on the climate forecasts that indicate a likelihood of sufficient precipitation. In 1992, FUNCEME added a second source of information for the determination of this date: a soil moisture model, based on surveys of soil characteristics and on real-time monitoring of precipitation. The planting dates were issued with great specificity; the state was divided up into many small zones, each with a particular date for particular crops.

In addition, FUNCEME took on other activities in the late 1980s. It coordinated with Civil Defense Coordinating Committee to anticipate droughts and to plan emergency measures such as public works projects distributions of water and food. In addition, it works with the Department of Hydrological Resources for the management of reservoirs—an issue of considerable importance locally, since the capital of Ceará, Fortaleza, is one of the largest cities in Northeast Brazil and has a history of water shortages. Moreover, the president of FUNCEME provided FUNCEME's forecasts personally to the Ceará governor, giving him *ad hoc* reports on an emerging situation, providing analysis, and making recommendations; additionally, landowners and local politicians would informally contact the president to receive assessments and seek advice.

2.2.3 Initial successes

The Planting Time Program got off to a good start. It operated effectively in 1990 and 1991. The organization's moment of most visible success came in association with its role in managing the 1992 drought, which was associated with the 1991-92 ENSO event. In December of 1991 FUNCEME issued a forecast of drought, using a U.S. National Weather Service El Niño forecast (Glantz 1996). The Ceará governor traveled the state to warn growers about the predicted drought, and get them to plant crops better suited to drought conditions. Complementing the governor's efforts, newspapers and radio stations also discussed the forecasts in detail. Warnings were issued in the capital of Ceará, Fortaleza, of potentially severe water shortages, which led the government to ration water supplies and construct a new dam (Glantz 1996). Grain production in 1992 fell only 18% while only 73% of average precipitation fell; in contrast, grain production fell by 85% in 1987, a year with 70% of average precipitation when climate forecasts were not applied (Golnaraghi and Kaul 1995). It should be noted, though, that some observers dispute these figures, since they find that many farmers save seed from previous harvests rather than obtaining it from government sources, thus limiting the influence of the Planting Time Program (Finan 1998).

By this time, FUNCEME received a great deal of public attention, much of it positive. Some officials in the agency began to criticize openly other providers of forecasts. They attacked as backward and superstitious the local "rain prophets" (*profetas de chuva*) who drew on local beliefs about meteorological phenomena and the timing of flowering of certain trees and bushes. They also challenged local scholars associated with a university in Fortaleza who had constructed historical time series of precipitation in the region. This adversarial tone offended many local people, who took the criticisms—that these scholars represented an outdated form of research—as a kind of snobbery, with regionalist and racist overtones, based on the belief in the inferiority of northeast Brazil and the superiority of southern Brazil, where many FUNCEME scientists were born and had studied.

2.2.4 FUNCEME's failures

FUNCEME stumbled later in the 1990s. In 1992, it offered a false negative forecast of drought for 1993, predicting normal rains that did not materialize. Individuals close to FUNCEME in that year state that the agency's climate forecast division had argued that precipitation would be well below normal, but that top officials were concerned that a second drought forecast would create a political situation unfavorable to the current state governor, up for reelection in that year. Though other factors, such as the inherent uncertainty in all forecasts, may also have operated, this account seems plausible. In 1994, FUNCEME gave a preliminary forecast of drought in 1995. Though it later modified this forecast to a more moderate one, the local perception remained that FUNCEME had forecast drought. When rains fell at moderate levels, some farmers blamed FUNCEME and the Planting Time Program for the income that they lost by planting lower-yielding drought-resistant crops. These failures gave fodder to the local groups that had resented FUNCEME's disparaging comments in earlier years. Some newspapers gave extensive coverage to the rain prophets and to the local university scholars, claiming that the people of the northeast understood their own problems better than outsiders. It is noteworthy that FUNCEME's contributions to limiting water shortages in Fortaleza received very little attention; the residents of the city—at least those outside the poor neighborhoods without adequate infrastructure—simply took steady water deliveries for granted.

2.2.5 FUNCEME's reorientation

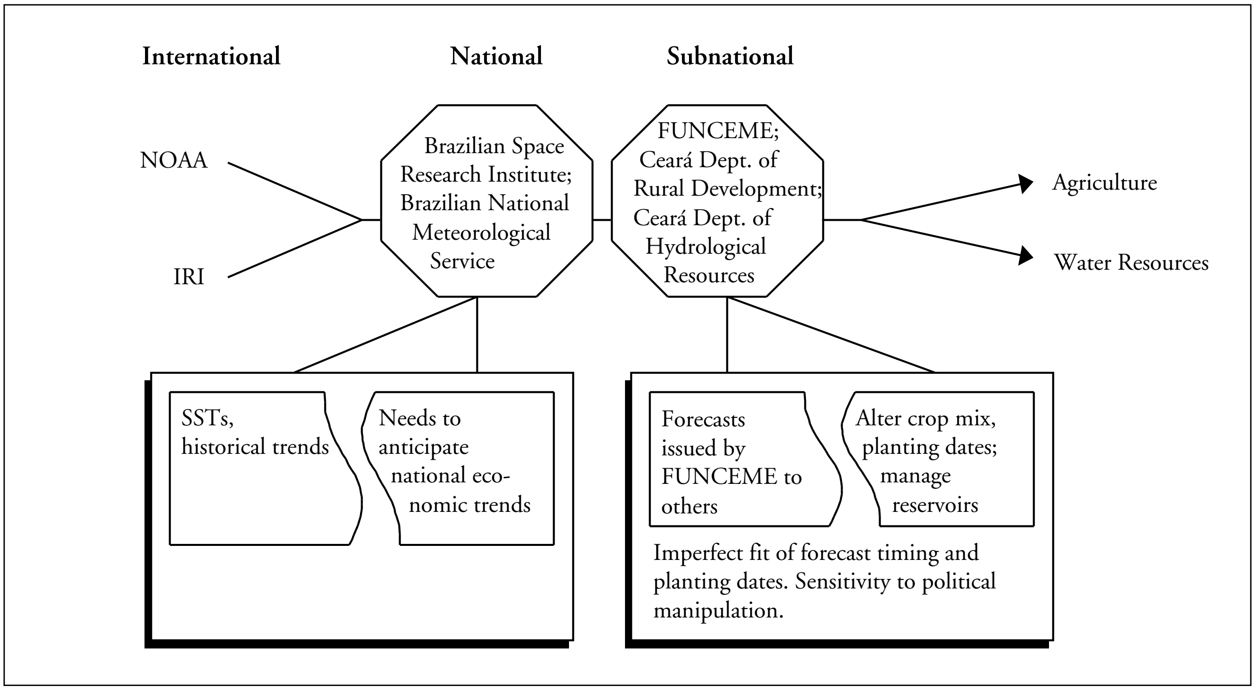
In 1995, the president of FUNCEME was transferred to another state agency. The new president has sought to provide more accurate forecasts through the use of recent advances in understanding of the linkages of regional climate anomalies to ENSO and to SST variability in the Atlantic. He has begun a series of cautious initiatives to restore ties to the SDR, Department of Hydrological Resources and Civil Defense Coordinating Committee. In December 1996, he and a few technicians met with the leaders of these agencies before speaking openly to the press about their forecasts. He also restored contacts with meteorological services in other northeastern states. He arranged for regular meetings among their staff and coordinated their local forecasts..

The rainy season early in 1997 proved to be a difficult one to predict. FUNCEME forecasted a year of below-average rains. The rains began early and in normal quantities, leading many people to criticize FUNCEME for issuing an incorrect forecast. This criticism stuck, even though the rains ended in mid-season and FUNCEME's forecast proved correct. Frustrated by this public misperception, FUNCEME has decided to limit its contacts with the media, and has begun to rely on press releases rather than interviews and conferences (Maria Carmen Lemos, personal communication).

Later in 1997, contacts with climate scientists in international agencies and in the Brazilian Space Research Institute alerted FUNCEME scientists to the development of the 1997-98 El Niño event. The awareness of this event grew in January 1998, when the second Regional Climate Outlook Forum for northeastern South America (most of Brazil, Venezuela, the Guyanas, and portions of Colombia) was held in Fortaleza. In conjunction with discussions at that conference, FUNCEME scientists reviewed ocean and atmospheric data, integrated temperature anomalies in the Pacific and the Atlantic, and anticipated a drought. They issues their forecasts only after the RCOF held its final press conference, attended by local and national print, radio and television journalists. Despite this international support, the FUNCEME forecast was met with skepticism, since some rain had already fallen, creating the public perception that the rains would be normal. The projected drought did materialize, as one of the most severe of recent years. Though the agricultural and hydrological sectors made relatively little use of the forecast, it seems at least to have restored some of FUNCEME's reputation. The officials in the SDR decided not to wait for FUNCEME's approval before releasing seeds in their "Time of Planting Program"; they felt pressure from farmers, eager to begin planting with the first rains. The rain prophets had also forecast normal rains, and publicized their views in a First State Congress of Popular Prophets sponsored in part by the SDR. (Cortez et al., 1998) Beans and corn production fell by 70%, and rice by 50%.

Though FUNCEME might recover some of its former prestige through these accurate, less politically motivated forecasts and this failure of their local rivals, it is faced with two severe challenges. Firstly, tight national and state budgets in an period of neo-liberal economic restructuring have led to severe cutbacks in the size of the scientific and technical staff of FUNCEME. In this context, the government encourages FUNCEME—with little guidance—to seek financial support from its clients through the sale or rental of its services. It has made contacts with the Department of Hydrological Resources and with some private water users, but these seem unlikely to compensate for the budget cuts or to restore the public favor to FUNCEME. (Maria Carmen Lemos, personal communication). Moreover, this privatization turns the meteorological services of the other northeastern states into rivals, rather than allies, of FUNCEME. Secondly, the public perception of incorrect forecasts in recent years has led FUNCEME to couch their forecasts in technical probabilistic terms; this choice, though it may help avoid risks, makes the forecasts less accessible to the public.

Figure 3: "Fit" between institutions and information in Brazil



2.2.6 Summary

FUNCEME, a state-level agency originally created to increase precipitation through cloud seeding, evolved in the late 1980s into a climate forecast and applications center with strong connections to the national and international scientific community. Through informal ties with the governor, landowners and local politicians, its dynamic first president provided assessments and forecasts—as did various news media. The rapid transformation of FUNCEME and its early successes were tempered by a series of missed forecasts, which eroded the credibility of the institution. Although FUNCEME has attempted to restore its credibility in the face of dwindling resources, the recent 1997-98 ENSO event indicates that end-users are still not confident in the forecasts (despite their accuracy in this event). This erosion, even with more formalized institutional links to seed distributors, suggests that the public does not accept or fully understand the probabilistic nature of forecasts. Further work is required to fully uncover the dynamics underlying public attitudes toward FUNCEME and climate forecasts, and FUNCEME's responses to its erosion of credibility.

2.3 Ethiopia

As a consequence of political instability, increases in human numbers, the expansion of agriculture onto marginal drylands, and unproductive and environmentally degrading agricultural and grazing practices, the direct dependence of most of Ethiopia's 57 million people on rain-fed agriculture makes the nation exceptionally vulnerable to naturally recurrent meteorological droughts. This vulnerability, and the disastrous 1984 famine, spurred Ethiopia to explore and utilize ENSO-based climate forecasts from as early as 1986-87. ENSO forecasts are received from a variety of international sources, and the National Meteorological Services Agency (NMSA) issues national and subnational climate forecasts to the Disaster Prevention and Preparedness Commission (DPPC) and the Ministry of Agriculture for food security planning efforts. More recently, the Greater Horn of Africa Regional Climate Outlook Forum began issuing consensus three-month climate forecasts in 1998, and international relief agencies such as the United States Agency for International Development's (USAID's) Famine Early Warning System (FEWS) have begun to pay note of seasonal climate forecasts. However, functional integration of climate forecasts into regional and international food security planning efforts has had mixed results. While the national Ministry of Agriculture has successfully capitalized on ENSO-based seasonal climate predictions in its work with farmers, the international relief community has thus far been less responsive to the possibilities for early action that are enabled by climate forecasts.

2.3.1 Climate and society

The area of Ethiopia is 1,235,000 km^2. The country is located in the northeastern section of Africa, commonly known as the Horn of Africa. The central topographic feature of the country is a high central plateau, with elevations between 1500-3000 meters (with some peaks over 3500 meters), that is divided by the East African Rift Valley that runs from northeast to southwest through the country. Surrounding the plateau and mountains are the lowlands, with elevations below 1500 meters. This topographical diversity sets the stage for great heterogeneity in climate and other important elements of the biophysical environment.

Rainfall varies enormously across the country. While precipitation in the lowlands in the south/southeast, east, and north averages below 500 mm/year, some areas of the highlands average over 2000 mm/year (McCann, 1994). In addition to this spatial variability, rainfall is highly variable over seasonal and interannual time scales. In most of the country, there are two rainy seasons—the short spring rains (February-May) known as *Belg,* and the main rainy season (June-September) known as *Kiremt.* In the western part of the country, however, there is only one rainfall peak during the year. High interannual variability in precipitation is characteristic of both the *Belg* and the *Kiremt,* though the spring rains tend to be less reliable.

The large-scale atmospheric dynamics that affect the Ethiopian climate are quite complex. During *Belg*, atmospheric dynamics important to precipitation include the Arabian anticyclone, low-latitude penetration of large amplitude troughs in mid-latitude westerlies, and the southward movement of the subtropical jet. During *Kiremt,* the ITCZ, the southwest Indian Ocean anticyclone, the South Atlantic anticyclone, and other atmospheric features control precipitation (Bekele 1997). During periods of drought, the states of and relationships among these atmospheric systems change.

Ethiopia has experienced droughts for hundreds of years, with major events (i.e., ones involving famine or documented suffering) including 1888-92, 1899-1900, 1920-22, 1933-34, 1973-74, 1983-84, 1987-88, 1990-91, and 1993-94 (Wolde-Georgis, 1997).

It is not fully understood how ENSO events influence precipitation patterns in Ethiopia. It is thought that ENSO affects precipitation in Ethiopia by displacing and weakening the major rain-bearing systems through its influence on the general circulation of the planetary atmosphere (Haile, 1988). Studies of drought events in Ethiopia indicate that the tropical easterly jet and Tibetan high become weakened, and the ITCZ both weakens and shifts to the southeast during times of drought (Krishnamurti and Kanamitsus 1981). The physical connection between these changes in the atmospheric general circulation and ENSO is complicated and not well understood. Other factors, such as southern Atlantic and Indian sea-surface temperatures, also influence the rain-bearing systems in Ethiopia (NMSA 1987), and not all ENSO events correlate directly with drought in Ethiopia. The 1982-83 El Niño, for example, did not cause a particularly dry *Kiremt* (Ward and Yeshanew, 1990; in Bekele, 1997), although one of the worst droughts in Ethiopian history occurred over 1983-84.

Despite this complexity, Ethiopian researchers have developed a system for identifying when an El Niño event is likely to produce climatic variations in Ethiopia, and for forecasting ENSO-induced climate anomalies. The NMSA, based on criteria that define particular types of ENSO events, has concluded that negative SST anomalies are strongly associated with below-normal rainfall during *Belg*; positive SST anomalies are often correlated with good rainfall during *Belg* and poor *Kiremt* rains. However, while some ENSO warm events (e.g., 1972, 1987) are associated with severe, countrywide droughts during *Kiremt,* others (e.g., 1982-83) are less strongly associated with precipitation anomalies during *Kiremt* (Bekele 1993).

Ethiopia's major food crops include maize, teff, barley, sorghum, wheat, and pulses, with 69% of the total caloric intake met by cereals. Agriculture provides for about 45% of GDP and 85% of exports, and rainfall-dependent smallholder farming accounts for over 90% of total output (Thomson et al. 1998). The Ethiopian people are exceptionally vulnerable not only to low total amounts of rainfall, but to fluctuations in the timing of precipitation. Severe drought events, perhaps linked to ENSO (Wolde-Georgis 1997), have over the past century wiped out food production and caused famines of disastrous proportions: One third of the population perished as a result of the 1888 drought, and 90% of livestock died; 200,000 people died in the wake of the 1972-73 drought, and one million people died as a consequence of the 1983-84 famine. The more recent famines, 1983-84 in particular, were as much the consequence of war and political instability. Although crop failure was caused by the drought, the fighting in the northern part of the country and Eritrea stifled the movement of relief supplies to stricken areas, and exacerbated the disaster.

In 1993, after the 1991 fall of Menghistu, the Transitional Government of Ethiopia promulgated a National Policy on Disaster Preparedness, Prevention, and Management, which developed the institutional infrastructure for dealing with the country's chronic food insecurity. The focus of the policy is on "building up capabilities before a disaster situation prevails in order to reduce impacts," and it sets forth a number of initiatives aimed at decentralizing the early warning systems for food security and reducing dependence on food relief. Similar to Northeast Brazil and

Peru, the policy called for relief to be provided through employment in public works projects. It also placed primary responsibility for monitoring local conditions in *woreda*-level committees (the smallest government administrative unit in Ethiopia), with linked regional and national committees above them (Thomson et al. 1998).

However, lack of confidence in local-level assessments has led to the establishment of a series of assessments that are carried out during the long rainy season, with the final assessment provided by the Commission on Disaster Prevention and Preparedness, or DPPC (Wolde-Georgis 1997). The DPPC coordinates the national government's early warning activities and makes official appeals to the international community. However, although the DPPC conducts its assessment during October (before and during the harvest), formal appeals to (and relief pledges from) the donor community typically occur only after the Food and Agricultural Organization conducts its post-harvest assessment in late November (Thomson et al. 1998).

An important resource under the jurisdiction of the DPPC is the Food Security Reserve (FSR), which is managed by a joint committee of donors and the government (Thomson et al. 1998). The target level of the FSR is 307,000 metric tonnes (MT), a level designed to meet the needs of 4.2 million people for four months; loans from the Reserve are made only against established pledges. However, as discussed below, the entrenched process of early warning assessment, coupled with inaccurate assessments of relief needs during the Spring of 1997, led to a risky depletion of the FSR during the 1997-98 ENSO event, despite the many early warnings issued.

2.3.2 Institutional interactions and preparation of forecasts

Within Ethiopia, the DPPC receives climate information from the NMSA, which began to include ENSO information in its preparation of seasonal agroclimatic forecasts in 1986-87 (Wolde-Georgis 1997; Glantz 1996). In preparing their seasonal forecasts, NMSA draws from climate bulletins issued by the Climate Prediction Center of the U.S. National Weather Service (the Climate Diagnostic Bulletin and the Weekly Climate Bulletin), the Drought Monitoring Center (Kenya), the South African Weather Bureau, the African Center of Meteorological Applications for Development, the Hadley Center for Climate Prediction and Research (U.K.), and the Australian Bureau of Meteorology (Bekele 1997).

Four complementary methods are used to prepare the forecasts: the analogue method, trend method, statistical method, and teleconnection. In the analogue method, researchers find a historical year that closely resembles the current year with respect to various atmospheric variables; based on the observed precipitation of the analogue year, the current year's precipitation is forecast. In the trend method, the current pattern of the atmospheric system's development (for example, the warming pattern of the eastern equatorial Pacific) is extrapolated and used to forecast the pattern of precipitation on the upcoming season. In the statistical method, statistical techniques based on past connections between ENSO and Ethiopian rainfall are used to project upcoming precipitation. The teleconnection method is, in essence, a more qualitative cousin to the statistical method. Bekele (1997) highlights as an example of this method the knowledge that ENSO events are always associated with the overturning of the Walker Cell, such that the descending limb of the Cell, rather than the ascending limb, sits over Africa (WMO 1985).

More recently, the NMSA and DPPC participated in the first Horn of Africa Regional Climate Outlook Forum, held in February 1998. This group issued a forecast for the March-May period, and (in a September 1998 meeting) for the September-December period. The forecasts are expressed as the probability of receiving above, normal, or below-average precipitation for the upcoming three-month period. The forecast, issued via world wide web and other media, explicitly warns potential users about the limitations of the information:

> This Outlook is relevant only to seasonal time scales and relatively large areas; local and month-to-month variations may occur. Users are strongly advised to contact their National Meteorological and Hydrological Services for interpretation of this Outlook and for additional guidance. (http://iri.ucsd.edu/forecast/sup/text/feb98/nairobi.html)

This regional activity is relatively new for Ethiopia, and parallels similar developments seen in the Zimbabwean case. Importantly, the regional-scale activity appears to be less driven by external pressure than in Zimbabwe, and as much driven from the "bottom up" as the top down. Below we discuss initial experiences in the use of forecasts from this regional-scale institution.

2.3.3 Initial use of forecasts

Ethiopian use of climate forecasts began in 1986-87, when the NMSA began to issue seasonal-scale climate forecasts (NMSA 1987). The first experience is considered to have been extremely positive. The NMSA forecast a drought for the 1987 *Kiremt* season and alerted national authorities. They also forecast an abundant and long-lasting *Belg* rain (Glantz., 1996b). With the famine of 1983-84 fresh in the minds of government officials, creative steps were taken to prepare in advance of the onset of drought conditions. The government recommended that farmers attempt to maximize the amount of land sown during *Belg*, and the Ministry of Agriculture released seeds and fertilizer; the goal was to try to produce as much as possible before *Kiremt,* when dry conditions were feared to result in huge crop losses. Additionally, the government warned farmers to decrease the amount of land sowed during *Kiremt,* sow only short-term crops, and conserve food and water. Ethiopia also made early requests to the donor community in anticipation of the expected food shortages. Significantly, despite the severity of the drought, it is reported that no human life was lost as a consequence of the 1987 event. The large *Belg* harvest and early action from the donor community were successful in averting the potential disaster (Glantz 1996b).

Wolde-Georgis (1997) reports that in 1988-89 the government used ENSO information to guide their recommendations regarding how much land to cultivate, how much seed and fertilizer to release, and the appropriate water and food conservation policies. He also reports that, after the establishment in 1991 of the Transitional Government of Ethiopia (which operated from 1991-95), the DPPC utilized ENSO information from 1993 to avert famine conditions in 1994. Finally, he reports that NMSA forecast floods after heavy *Belg* rains in May, 1996, a forecast that was used by DPPC in an early warning issued in June, 1996.

2.3.4 The 1997-98 event and beyond

For the 1997-98 ENSO event, news reports and other sources indicated an increasing public awareness of the links between ENSO and Ethiopian drought. In June 1997, the NMSA issued a climate forecast of "generally deficient and irregular" *Kiremt* rains because of El Niño. By August, the office of the Prime Minister had issued a statement that late rains in surplus-producing areas of the country would cause a drop in agricultural production, and that the Federal Government was considering various measures to deal with the situation (Africa News Online, August 29 1997). Shortly thereafter, the NMSA reported rainfall deficiencies in various parts of the country, particularly in Tigray (60% below the mean), North Shoa (30%), eastern Oromia and Southern Ethiopia National State (40-50%); they attributed these shortages to the developing ENSO event (Africa News Online, September 2 1997). In addition to these initial precipitation deficiencies, the Food Security Reserve was at less than 25% of its normal level because of loans to other programs, raising additional food security concerns (FEWS Bulletin, August 1997). During August 1997, cereal prices rose steadily, partly out of concern that the emerging ENSO event—coupled with the low grain reserves—would result in a poor harvest. This is an indication that one Ethiopian institution, the market, rapidly incorporated information concerning ENSO during the 1997-98 event.

Although the long season rains appeared to resume in late summer, unusually heavy rainfall hit much of the country in late September and October. This flooding was unusual, since ENSO events are typically associated with drought during the long rains. Such variability reflects the complexity of the factors that shape the climate of Ethiopia. In September, the DPPC concluded that significant food aid would be required, and signed an agreement with USAID to transfer 20,000 MT of U.S. wheat for emergency food aid. The Technical Committee of the Food Security Reserve subsequently approved the emergency distribution of food totaling this amount, so that relief could be provided before arrival of the U.S. wheat. Additionally, the European Union agreed to provide about 53,700 MT of wheat to replenish the reserve and assist in relief operations.

However, these appeals were not commensurate with subsequent assessments of food needs. In December the Food and Agricultural Organization (FAO) estimated that 300,000-400,000 MT of food aid would be required. At the time, only 84,000 MT were held in eight warehouses around the country, insufficient to meet the anticipated needs. Based on appeals by the DPPC, repayments of grain loans were pledged, and 150,000 MT were pledged from foreign governments, still insufficient to replenish the FSR or meet anticipated relief needs.

By January 1998, the FAO World Food Programme (WFP) Food Supply Assessment team revised its estimate, projecting that Ethiopia would need approximately 420,000 MT of relief food aid in 1998 (for 5.35 million people). This amount represents an increase over its preliminary estimate of 300,000 to 400,000 MT (FEWS Bulletin, February 1998). These estimates were further revised, however, as farmers took advantage of the unanticipated fall rains and planted off-season crops; harvests from these crops were expected to diminish somewhat the need for food aid in some regions of the country.

In summary, it appears that climate forecasts—coupled with a weak *Belg* harvest that predated the 1997-98 ENSO forecasts and low strategic food reserves—did motivate the DPPC to make early appeals to the donor community to boost its stocks of emergency supplies. However, these appeals were still subservient to the entrenched process of food security planning, as evidenced by the late and generally insufficient pledges of the donor community. Ethiopia still struggles to replenish its emergency food reserves, and as of August 1998 still had not boosted the stock above 66,000 MT

(FEWS Bulletin, September 1998).

The only evidence that forecasts were used for any early planning was again in the Ministry of Agriculture extension department, which in October 1997 developed a contingency plan for the 1998 *Belg* rains—anticipating both the poor *Kiremt* harvest in 1997 and the possibility of good rains in the spring (Thomson et al. 1998).

One unanticipated consequence of the climate anomalies tied to the 1997-98 ENSO event was the effect of Rift Valley fever outbreaks on exports of livestock. Pastoralists in the southeastern lowlands of Ethiopia depend on livestock exports to Somalia, which in turn exports the livestock to Saudi Arabia. Outbreaks of Rift Valley fever in east Africa, tied to the anomalous fall 1997 rains, led Saudi Arabia to ban imports from eight nations, including Ethiopia. Even though there were no reported cases of Rift Valley fever in Ethiopia, an estimated 3 million pastoralists were severely affected by the Saudi import ban (FEWS Bulletin, March 1998).

Moving into the 1998 growing season, the Greater Horn of Africa Regional Climate Outlook Forum issued its first forecast in February for the spring rains. The group indicated that north and northeastern Ethiopia would receive normal to above-normal rainfall, while western Ethiopia was expected to receive slightly less than normal precipitation (http://iri.ucsd.edu/forecast/sup/text/feb98/nairobi.html). While farmers sought to take advantage of the favorable conditions present in the early part of the *Belg* season, many lacked adequate inputs to do so. The torrential fall rains caused a shortage of seed; furthermore, many farmers were unable to repay loans from the previous year because of the crop failure, preventing them from receiving further loans under current government policy (FEWS, March 1998). Despite the forecast, precipitation was erratic over the course of the spring season, with a mid-season drought lasting from mid-March to mid-April. Production was highly variable across the country as a result, with highland regions less adversely affected than the lowlands.

2.3.5 Problems and limitations

ENSO and seasonal climate forecasts have been issued and utilized in Ethiopia for national-scale famine and disaster planning and relief efforts. However, in order to have a significant impact on food production at the farm scale, and thus directly address the food security problem, ENSO forecasts need to be “tailored” and provided to the needs of small-scale producers. This first requires that the information itself be of sufficient resolution to deal with the many microclimates that characterize Ethiopia’s meteorological situation. The many crops cultivated in Ethiopia reflect this climatic diversity, with different planting and harvesting dates and maturation periods (Wolde-Georgis 1997). Because of the complexity of smallholder farming in Ethiopia, generic forecasts and recommendations such as those issued by the Regional Climate Outlook Forum are probably insufficient to meet the needs of farmers at this scale. Additionally, the end-users at the district and farm scale must trust the forecast information, possess the capacity to interpret it in light of its uncertainties, and have resources available to plan in advance of a drought.

However, as Haile (1997) reports, even district-level agrometeorological data, from which more spatially-resolved forecasts might be constructed, is difficult to obtain; long records from many locations, such as those in Australia, are simply unavailable. Even the more recent record of precipitation for the past 30 years is punctuated by long periods of no data. The NMSA does not operate branch offices at the district level (although it does at the provincial level), hindering the gathering of data and development of forecast products that would be more useful at the farm scale. While the DPPC does have offices at the district level, only the Ministry of Agriculture (which also operates its own meteorological stations) has extension agents who work at the village scale. This cross-scale institutional presence may help explain why, even in the absence of high-resolution forecasts, the Ministry has been able to make creative use of the NMSA's knowledge of ENSO impacts.

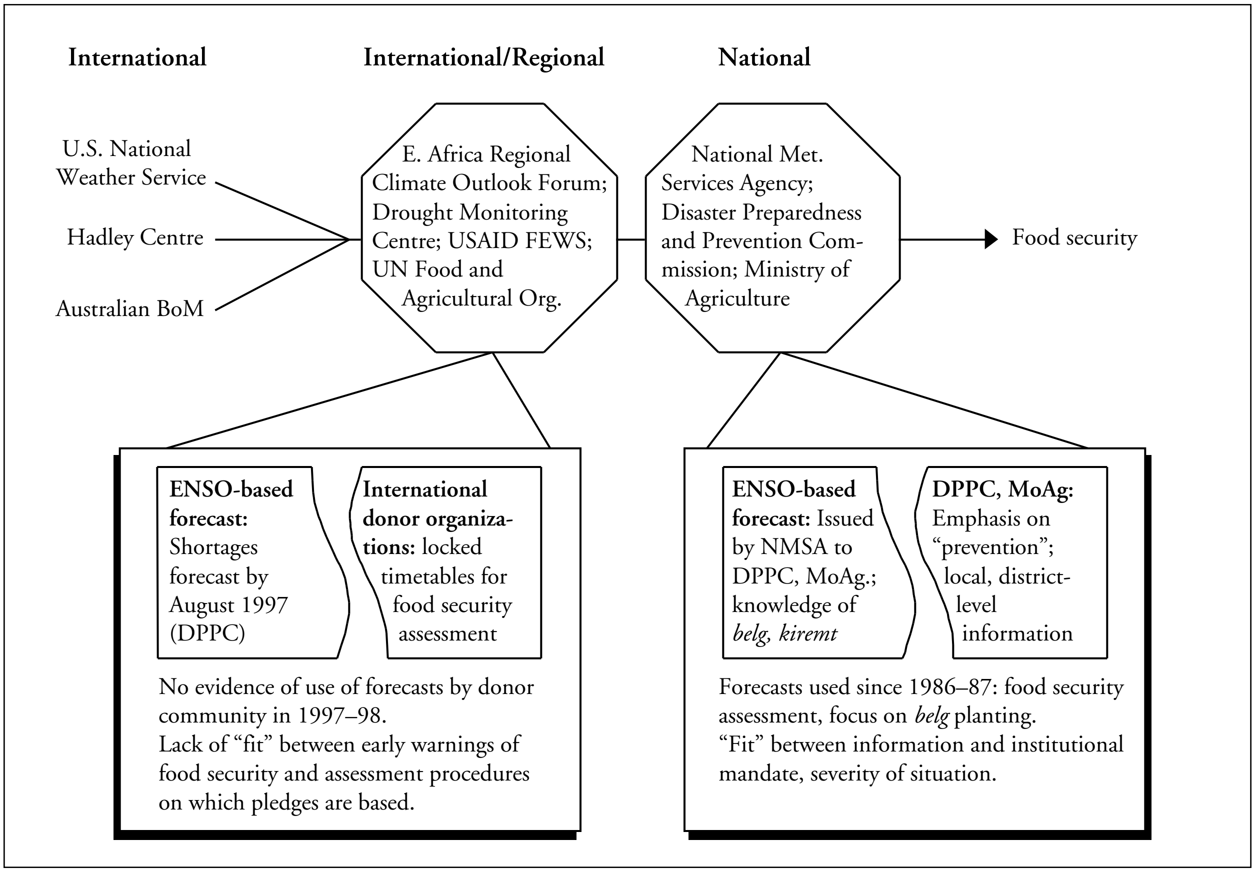
The Greater Horn of Africa Regional Climate Outlook Forum has provided a context in which the issues surrounding the use of climate forecasts may be addressed. In a follow-up to the first meeting of the Forum in February 1998, the group of international climate forecasters, national meteorologists, and food security planners evaluated how climate forecasts and food security planning might co-evolve in the future. Among the recommendations, the group noted that the timing of forecasts needs to be geared toward the planting calendars of the region. They observe that "the current consensus forecast covered March-May 1998. For Ethiopia, Eritrea, and Somalia, however, an April-June forecast would have been more useful. Rolling 3-month forecasts, issued monthly, better fit the varieties of agricultural calendars within the region" (FEWS Bulletin, March 1998). Additionally, the group observed that the timing, duration, and intensity of midseason dry spells, as well as the timing of initial rains, usually have a greater effect on agricultural conditions than total or mean rainfall.

In addition to these comments regarding the nature of the forecast information itself, the group also commented on the dissemination and application of the forecasts. They made specific recommendations to national governments and forecast-issuing agencies, including: 1) clarifying which agencies within the government are responsible for what aspects of climate forecasting and utilization; 2) disseminating clear and simple climatological information that users can integrate into their activities as they see fit; 3) emphasizing flexible strategies that minimize climatic risks for all actors groups that might alter their behavior in response to forecasts; 4) developing strategies that diminish farmers' exposure to climatic extremities; and 5) understanding climate forecasts in the context of the larger food security situation.

Importantly, the Forum may begin to provide a context in which forecasters and users can continue to exchange ideas regarding the content, dissemination, and application of forecasts. As evidenced by its initial findings, the Forum may emerge as an important vehicle for regional and national-scale institutional learning in the generation and application of climate forecasts.

Ironically, the international famine early warning community appears to be less ready at present to incorporate climate information into their strategies for promoting food security than the resource-strapped Ethiopian national government. As Thomson et al. (1998) observe, there is no evidence that, aside from noting the existence of forecasts for the 1997 *Kiremt*, these groups undertook any meaningful action in advance of the post-harvest assessment—despite the DPPC's early awareness of the likelihood of crop failure. The reactive nature of the famine early warning culture, reflected in the established timetables for conducting food security assessments which are prerequisites for official appeals and commitments of aid, does not appear to "fit" with the nature of early warning information based on climate forecasts. Instead, it appears that greater responsive capacity exists within the NMSA, DPPC, and Ministry of Agriculture, even despite limitations in the forecast information.

Figure 4: "Fit" between institutions and information in Ethiopia



2.3.6 Summary

An institutional infrastructure is in place at the regional and national scales to integrate ENSO and climate forecasts with food security and disaster planning and relief efforts. The exceptional vulnerability of the Ethiopian people to meteorological drought, as much the consequence of political instability and economic underdevelopment as drought itself, clearly underlies these efforts. Even despite ongoing political trouble in the mid-1980s, the NMSA, DPPC and Ministry of Agriculture combined to make use of ENSO forecasts as early as 1986-87—among the earliest examples of the successful application of ENSO forecasts documented. However, there is a mismatch of scales in the institutional linkages that bind the meteorologists (NMSA) to the food security planners (DPPC) and agricultural extensionists (Ministry of Agriculture). NMSA has no district-scale offices, and the DPPC only operates down to the district scale; only the Ministry of Agriculture has offices at the scale of the village. Because of this mismatch, the data that are required to tailor ENSO forecasts to the diverse microclimates of Ethiopia, the communications pathways to provide such forecasts to the villages, and the outreach required to assist them in assessing how to use the information, are not fully present. However, these shortcomings have been recognized in the context of the Horn of Africa Regional Climate Outlook Forum, an institutional vehicle that may prove to be a catalyzing source for institutional learning in the near future. And despite these limitations, the national institutions have demonstrated a relatively high degree of responsiveness (tied to the more decentralized early warning system) and innovation, as evidenced by the creative activities of the Ministry of Agriculture in response to climate forecasts. This innovation is in contrast to the apparent non-responsiveness of the international famine early warning community, which appears to be bound to an entrenched pattern of assessment activities that have not functionally integrated ENSO-based climate information.

2.4 Peru

In 1986, the Peruvian Geophysical Institute began providing forecasts of El Niño-related fluctuations in precipitation and temperature to farmers on coastal Peru. Several forecasts proved to be incorrect. In recent years, the Peruvian Marine Institute, which has monitored ocean variability and its impact on fisheries since the 1960s, has begun using El Niño forecasts to advise fisheries regulators. In addition, civil defense efforts have started to operate disaster mitigation efforts, reinforcing the physical infrastructure of flood-prone areas. Nonetheless, Peruvian responses to El Niño events have been weakened by competition between agencies and by the shift of focus from one sector to another.

2.4.1 Climate and society

The Andes Mountains that run from north to south divide Peru (1,285,000 km^2) into three zones: a narrow coastal desert to the west, the Andean highlands in the center, and the Amazonian region to the east. The adjacent waters of the Pacific Ocean may be considered a fourth natural region of this country. The vast bulk of the precipitation comes from the east, so that the desert, in the rainshadow of the Andes, is ordinarily very arid. Its resident population is concentrated in the narrow valleys of the rivers that bring water down from the second zone, the Andean highlands. In this coastal zone, which contains the capital city of Lima and a number of other large cities, are concentrated a number of economic activities: highly productive irrigation agriculture, marine fisheries and industry. The portions of the Pacific Ocean closest to the coast ordinarily contain large fish populations, since the dominant currents lead to the upwelling of cool, nutrient-rich waters. This upwelling into the shallow waters where light can penetrate permits the growth of phytoplankton, the basis of the food chain that supports commercial fisheries.

El Niño events bring a number of changes to the climatic and oceanographic regimes of Peru. One set of changes affects the ocean directly. During El Niño events, the pool of warm water that is ordinarily concentrated in the western Pacific begins to move east, while the atmospheric winds that create the upwelling tend to weaken. Though complex in spatial and temporal terms, these shifts generally lead to an increase in the temperature of marine waters at and near the surface. These warmer temperatures cause declines in the populations of certain fish species, important both in natural food webs and in commercial fisheries. The second set of shifts consists of temperature and precipitation anomalies in the coastal desert region. The warmer surface waters in the ocean lead to higher air temperatures and relative humidity and to greater precipitation. This increased rainfall often leads to flash flooding and massive mudslides, because of the scanty vegetative cover and poor soil development in much of the coastal region. However, these rains can also increase the volume of water that is stored in reservoirs in the adjacent highlands and that can be used for irrigation and for the generation of electricity.

These fluctuations have been recognized in Peru for centuries, though their onset has not been predictable. Small-scale artisanal fishermen in Peru have known that the surface waters of the Pacific Ocean can wane, especially in December. They were the ones who first applied the name “El Niño” to this anomaly, because it often comes close to Christmas, associated in Peru with El Niño Jesus, the Christ Child. Archaeologists have traced the consequences of massive floods and landslides in pre-

Columbian civilizations in coastal Peru. Local leaders appealed for relief to colonial Spanish authorities only a few decades after the Spanish Conquest. (Keefer, et al. 1998; Nials et al., 1979a,b; Craig and Shimada 1986)

In contrast with the other countries included in this study, Peru has a number of different institutions that monitor the atmosphere and ocean and that detect and forecast anomalies. Peru has a long-established national weather service, the National Meteorological and Hydrological Service (SENAMHI or Servicio Nacional de Meteorología e Hidrología), which dates back to 1922. The Peruvian Geophysical Institute (IGP or Instituto Geofísico del Perú), established in 1947, drew its initial stimulus from the high risks of earthquakes in this seismically active part of the world, but began to study ocean currents as well. The Hydrology and Navigation Bureau (DHNM or Dirección de Hidrografía y Navegación de La Marina), a branch of the Peruvian Navy, has monitored oceanographic and atmospheric phenomena since the 1920s. It has represented Peru in the Permanent Commission of the South Pacific, an organization formed in 1952 which also includes Colombia, Ecuador and Chile, the other nations on the west coast of South America. This Permanent Commission took on the task of forecasting El Niño events in 1974, following the major 1972-73 event. The Peruvian Marine Institute (IMARPE or Instituto del Mar del Perú) was established in 1963, when the Food and Agricultural Organization of the United Nations perceived the danger that overfishing posed to the stability of Peruvian fish stocks and to global fishmeal markets. This organization was charged with conducting research on fisheries and providing advice to policy-makers and regulators, especially with limiting overall capacity in the fishing fleet and establishing closed seasons. It began the serious study of El Niño events during the 1976-77 event.

2.4.2 The use of forecasts

El Niño events have a strong influence on economic production in Peru. Scientific attention in Peru has focused on the variability in the ocean and its impact on fisheries since the 1960s and on the variability in climate and its impact on agriculture since the 1980s. However, it was in agriculture, rather than in fisheries, that the first uses of El Niño forecasts were made. To explain this apparent paradox, several characteristics of the two sectors should be mentioned, before the specific history is traced. Firstly, the links between anomalies in the ocean (sea temperatures) and fish stocks are more complex and less well understood than the links between anomalies in the atmosphere (temperature, humidity and precipitation) and crop growth. Secondly, a fishing fleet can respond much more quickly to forecasts than agricultural units. Ships can be called back to shore or sent out to fish within a few days or weeks, unlike a farm, where a decision to plant a crop commits a piece of land for several months, until the harvest. (Long-term decisions, such as investment plans, in both sectors operate on a longer time horizon than the scale of interannual variability such as El Niño events.) For this reason, the fishing sector can use real-time monitoring of environmental parameters to modify its operations, but the agricultural sector requires medium-term forecasts. Thirdly, the alternation of years of high and low profit, and the overall high levels of profit have encouraged a speculative attitude in the fisheries; the coastal agricultural sector, with lower overall rates of profit has adapted a more conservative risk-management approach in the latter. Fourthly, the fisheries sector has often sought to avoid government restrictions and control, while the agricultural sector has tried to obtain government loans and support. Though Peruvian nationals rather than foreign capital dominate both sectors, government control is stronger in fisheries, because the fleet operates in waters controlled by the national government, rather than farming on private or corporate land as in the case of agriculture (Cameron 1997; Hunefeldt 1997).

El Niño events also have a strong influence on physical infrastructure in Peru. Heavy precipitation leads to flooding and landslides that destroy houses, roads and bridges. Though precipitation forecasts have been used in agriculture since the 1980s, it is only in the 1990s that they have been directed to civil defense projects to mitigate flooding and landslides. This difference in timing also can be explained by specific characteristics of different sectors. Crops are planted every year on the Peruvian coast, so there is a clear deadline—the time of choosing crops—when forecasts can be used each year. The heavy rains that destroy infrastructure, by contrast, occur infrequently, perhaps once a decade or less often, so that a number of years might pass without an occasion to issue a forecast. Moreover, the floods tend to be spatially concentrated; a particular El Niño event can hit some valleys heavily and have a milder impact on others. Current models do not allow great spatial resolution of precipitation forecasts, so forecasts of flooding cover large areas, and hence are often correct for some valleys and incorrect for others. However, there are lower costs to false positive forecasts for floods, since such forecasts usually lead to public expenditures to strengthen bridges, reinforce flood diversion channels and the like. Even if the floods do not appear, local inhabitants often are employed in these projects or in providing services to project personnel. The costs are felt only indirectly, in the activities and projects that would have been funded if resources had not been allocated to civil defense. False negative forecasts may also seem to be lower in cost in civil defense than in other sectors, because emergency disaster relief is often forthcoming.

Nonetheless, the use of forecasts in these sectors can be understood not only by their structural characteristics but also by their specific histories, to which we now turn.

2.4.3 Fisheries

The early scientific attention effort to maritime fisheries can largely be explained by the growth of maritime fisheries in Peru in the 1950s and 1960s. After World War II, there was an increase in global demand for fishmeal, a component of poultry and animal feed. Productive capacity, particularly in the critical anchovy fishery increased sharply, since capital and equipment was readily available. (A number of different species are targeted in Peru. The anchovy catch is usually the largest and economically most important; several other important species, such as the sardine, resemble it. For reasons of space, we will focus on anchovies alone.) The annual catch of anchovies, less than 0.5 million metric tons in 1955, reached 1 million metric tons in 1958. It rose fairly steadily through the 1960s, though research biologists noted that the 1965 El Niño temporarily reduced anchovy stocks. By the time the catch reached its peak of over million metric tons in 1970, the marine fisheries were a major component of the national economy (Thorp and Bertram 1978). The catch began to decline in 1971, due in part to excess capacity in the fishery, and plummeted to less than one-eighth of its peak by 1973, an El Niño year. It recovered somewhat, but showed other sharp declines during El Niño events in 1976-77 and 1982-83.

The Fisheries Division of the Ministry of Agriculture has set up fisheries regulations since the 1950s. Many of these, aimed at preventing overfishing in the long run, sought to regulate the total capacity of the fishing fleet through licensing rules. To prevent overfishing in the short term, the government introduced closed seasons in 1958 and total allowable catches in 1966. These regulations were aimed to keep fish stock size from falling below certain levels, rather than to respond to interannual variability. Between 1966 and 1990, catch limits were established each year, though the timing, duration, and levels of allowable catch varied. These limits were based, not on forecasts, but on real-time observations of conditions of the fish stock and the ocean. The regulatory efforts were particularly active in the 1970s, following the creation of the Ministry of Fisheries in 1969, and were more sporadic in the early 1980s. A decline in anchovy catches after the strong El Niño event of 1982-83 led to tighter regulation in 1984, when an unusually long, closed season was declared. Though the anchovy stocks recovered, the owners of fishing fleets and fishmeal-processing plants, who were oriented towards short-term profits, pushed for weaker regulations. In 1991, a new law set the regulatory process on firmer grounds. Two closed seasons were set for each year: one in February at the time of spawning of anchovies and another in August, when the juveniles reached catchable size. The duration of the closed seasons and the total allowable catch would vary from year to year according to the size and age composition of the stock; it is very unlikely that government officials and the public, who had little awareness or understanding of El Niño forecasts, would have accepted them as a basis for regulations. The anchovy catch exceeded 7 million metric tons every year between 1993 and 1996.

After the closed season of February 1997 was lifted, anchovy catches were high at first. By April 1997, the 1997-98 El Niño event was well established and brought warm sea temperatures that threatened the stock, even though the fishing fleet continued to land large quantities of anchovies by targeting the schools of fish that were concentrated in the remaining pools of cool water close to shore. There was some debate within IMARPE and the Ministry of Fisheries at this time. Some scientists and officials took seriously the threat of the impending El Niño event, while others, less disposed to impose tight regulations, thought that it might be a mild and brief event. The tense atmosphere was heightened by a meeting of the Permanent Commission of the South Pacific, which convened in July rather than at its usual time of November. The August closed season was established several weeks early, and, unlike other years, was set for an indefinite period. This relatively strong regulatory effort bears a complex relation to forecasts. Most directly, the projections for further increases in sea surface temperatures suggested the vulnerability of the fish stocks. In addition, the growing public awareness of the El Niño event strengthened the hand of the regulators.

At this point, the politicking became unusually intense. The managers of fishing firms placed strong pressure on IMARPE and the Ministry of Fisheries to reopen the fisheries, in part through the Peruvian Institute of Fisheries Research (Instituto Peruano de Investigaciones Pesqueras, or INPESCA), a wholly industry-supported research organization, which offered predictions, based on scanty evidence and implausible readings of NOAA data, of a much milder El Niño event. In August, the national government, concerned that the event might bring disaster to the fisheries and to other sectors as well, established a Multisectoral Committee to study the event. Though a good deal of El Niño policy was made directly by the President, Alberto Fujimori, and was administered by the Ministry of the Presidency, an agency very close to him, this committee influenced other areas of policy. It included IMARPE, SENAMHI, DHNM, IGP, and other entities. IMARPE chaired the committee and had strong control over its bimonthly press releases and technical reports. This position, strongly favorable to IMARPE, reflected the importance of fisheries, the uneven record of forecasts by IGP, and some effective mobilizing of political connections on the part of IMARPE.

IMARPE made forecasts for the event continuing well into 1998. It based these forecasts on NOAA and other satellite data, which had been little used in Peru through the 1980s due to limitations in data availability and scientific expertise, but had become increasingly accessible through the spread of internet connections. Of considerable importance in these forecasts were IMARPE's own measurements of oceanographic data, especially vertical temperature profile. In addition, IMARPE continued its programs of real-time monitoring of stock size and population dynamics. This data source showed that fish stocks had declined sharply. With this advice from IMARPE, the Ministry of Fisheries did not reopen the anchovy harvest until in late October though with a very low level of total allowable catch, 1.5 million tons. Fisheries researchers from FAO traveled to Peru in October to advise the Minister of Fisheries personally about the dangers of allowing the fishing fleet to operate at that time. Faced with strong evidence that the El Niño event was not abating and that the stocks were threatened, the Ministry of Fisheries closed the anchovy fishery again early in January 1998, before even this low total allowable catch had been reached. They were reopened in the far south of the country in April, but have remained closed through 1998 with only brief reopenings in other areas. The anchovy stock remained at very low levels.

2.4.4 Agriculture

Climate fluctuations have a strong impact on the capital-intensive commercial agriculture in the northern coastal region of Peru. Warm and moist years favor rice, a crop that requires a great deal of irrigation water and that grows more rapidly at higher temperatures. The other major cash crop in the region, cotton, has higher yields in cooler, drier years; under such conditions, plants produce larger cotton bolls and insect pests fail to thrive. Peruvian forecasters attracted a good deal of attention in December 1982. At that time, a representative of the Peruvian Geophysical Institute correctly forecast the 1983 El Niño event, even though the US National Oceanographic and Atmospheric Administration forecast normal conditions. Agricultural production was low in 1983, due to flooding, storm damage and rapid growth of insect pest populations, which devastated crops. If the forecast had been made earlier and if it had been followed, crop choices and planting dates could have been modified, and emergency measures could have been taken.

For a number of years since that event, the Peruvian Geophysical Institute has offered forecasts in September of each year that serves as the basis of planning by the Ministry of Agriculture. IGP scientists, who had earlier training in the use of NOAA datasets than their counterparts in other Peruvian agencies, take the NOAA forecasts of sea surface temperatures off the north coast of Peru, usually with six months' lead, and then compare these forecasts with historical correlations of sea surface temperatures with temperature and precipitation. The model is a simple one: if the temperatures are projected to rise to 28°C, heavy rains are predicted; if they are expected to reach or exceed 29°C, the rains will be very heavy.The Ministry offers advice to growers' associations and to banks, and encourages different proportions of rice and cotton, depending on the forecast. These forecasts have only a moderate level of accuracy, since the NOAA forecasts are coarse in resolution and the correlations between sea surface temperature and weather are not very strong. (This case shows that local historical information that offers statistical correlates of climate anomalies is not always a useful complement to model-based forecasts.) However, the IGP forecasts do have the lead time necessary for actors in the agricultural sector to select crops. This program had an important early success when it correctly forecast the 1987 El Niño event. Its failures in 1994 and 1996 weakened its reputation. Though it recovered some prestige when in September 1996 it correctly forecast a warm moist season early in 1997, it issued word that rains would not be above normal in 1998.

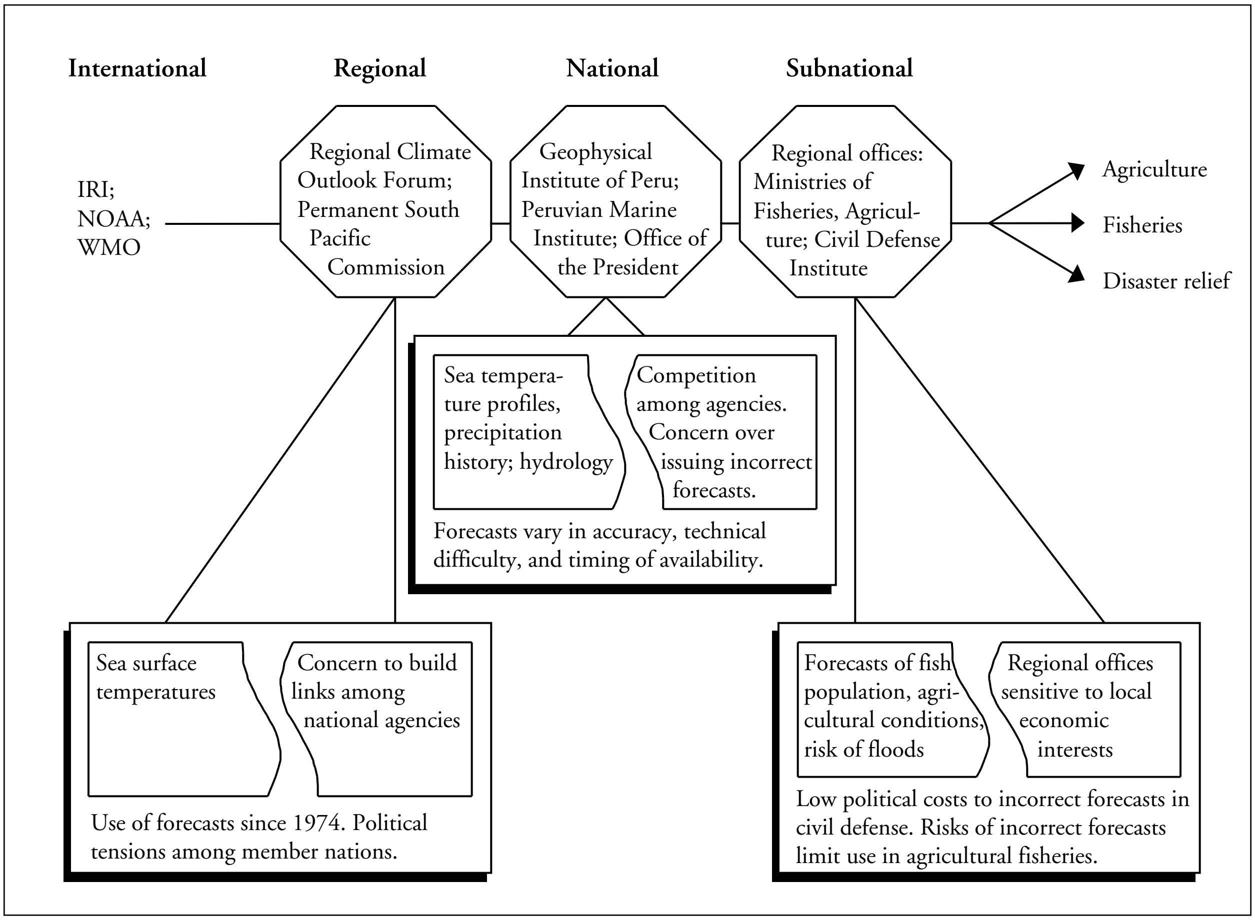
This incorrect forecast came strongly to the public eye during the Regional Climate Outlook Forum held in Lima in late October 1997. It offered a precipitation outlook for Colombia, Ecuador, Peru, Bolivia and Chile for December 1997 through March 1998. This conference was sponsored by the IRI, the WMO, NOAA and the Inter-American Institute for Global Change Research. There was extension participation of the leading climate-related research institutes in Peru, such as IMARPE, IGP, DHNM, SENAMHI and INPESCA. The industry-based INPESCA and the IGP had prominent positions in the organization of this event. (In the eyes of many observers and participants, the RCOF was not as much about generating consensus forecasting as a kind of show, in which different agencies jostled with each other for a more prominent place in this visible international forum.) Prodded by international climate scientists, the IGP and INPESCA claims for a short, weak El Niño event were rejected. Once the heavy rains began in 1998, the IGP lost—irrevocably, it appears—its standing among Peruvians, already well aware of the event from its extensive treatment in the national media. Since the IGP was the principal provider of agricultural forecasts in Peru, the critical agricultural sector was heavily impacted in the 1997-98 event. (It also suffered from the president's lack of support of the Ministry of Agriculture in normal years as well.)

2.4.5 Civil defense

The President of Peru, Alberto Fujimori, seems to have made three decisions in the first half of 1997: that a major El Niño event was on its way, that he would undertake a program of mitigation on his own rather than operating through ministries, congress and NGOs, and that civil defense would be his principal priority. According to people close to his administration, this first decision was based on research which his immediate advisors conducted on websites of international agencies, rather than on advice from Peruvian agencies, who disagreed so strongly among themselves. His plan to operate directly rather than through other channels is consistent with the political style of his current and previous presidencies and his apparent desire to seek election to an unprecedented third term. (He has made use of the Ministry of the Presidency, a new ministry created under his administration, to bypass existing administrative structures so that he can channel funds directly to a variety of projects.) Fujimori seems to have been drawn to civil defense as a sector on which to focus for a number of reasons: his experience with the severe flooding in the 1982-83 El Niño event, his background as an engineer, his desire to have highly visible programs in operation. Moreover, this choice allowed him to focus on a few cities, where many voters were concentrated; rural areas did not benefit as much from these projects. Whatever his personal political motivations, this decision was a forward-looking one. It marked a shift from after-the-fact disaster relief to proactive disaster mitigation.

In this effort, a principal actor was an autonomous governmental agency, the National Civil Defense Institute (Instituto Nacional de Defensa Civil or INDECI), founded under the military government of the late 1960 and 1970s. Coordinating with the Ministry of the Presidency, it has carried out extensive works to prevent the damage that could be caused by flash floods and landslides. INDECI has supported the maintenance and improvement of protective walls along river courses, cleaning of existing storm drains and the construction of new ones and the maintenance of bridges and roads. The match between the areas of protection and the areas of impact, though fairly good, was not perfect. INDECI officials expected that the areas that flooded in the 1982-83 event would flood again. This belief led them to concentrate their efforts on the north coast and hence to fail to protect areas further south, such as the Ica valley, that did flood. Nonetheless, the president received a good deal of support for these advance measures. The civil defense projects served as a kind of public works and relief program that created support in the local areas, whether or not the disasters did materialize. In the few areas where unanticipated disasters did occur, local populations tended to accept them as acts of fate, and welcomed the food relief and emergency shelter construction that came soon after.

Figure 5: "Fit" between institutions and information in Peru



2.4.6 Summary

The very different uses of forecasts in agriculture, fisheries and civil defense demonstrate several points. Firstly, the availability of forecasts and the need for forecasts differ from sector to sector, depending on the ecosystemic consequences of climate variability for the sectoral activity, the nature of the activity itself, and the necessary lead time for action. Secondly, the actors in sectors vary in their willingness to use forecasts, depending in part on their sensitivity to risk and their relations with regulation at large. Thirdly, some sectors are particularly sensitive to incorrect forecasts. Since agricultural production strategies cannot be modified rapidly, the actors in this sector perceive greater losses due to incorrect forecasts. Moreover, we see a degree of institutional learning on the part of some agencies. IMARPE shifted from providing real-time environmental data to managers and fisheries agencies to the incorporation of forecasts in their information; they found ways to downscale global forecasts and to incorporate locally-generated data, such as the vertical temperature profiles in the ocean. However, the IGP failed to modify its strategy when its forecasts proved incorrect, leading them to fall from their position of wide acceptance.

There are other lessons to be drawn from the Peruvian case. The country seems to have lost, rather than gained, from having a number of different agencies that offer competing forecasts. The competition and disagreement among the agencies may have contributed to the president's decision to turn away from all of them for advice (and hence to rely on the ad-hoc belief of INDECI officials that floods would recur in the areas where they taken place before). The lack of coordination also impeded the Regional Climate Outlook Forum.

2.5 Zimbabwe

Zimbabwe, like Ethiopia, has developed an institutional infrastructure for forecasting drought and famine. Much of this effort has taken place through the regional-scale institutions of the Southern African Development Community (SADC), including the Regional Early Warning System (REWS), as well as Zimbabwe's National Early Warning Unit (NEWU). While climate forecasts, crop forecasts and food security warnings were issued prior to the severe 1991-92 and 1994-95 droughts by a variety of international organizations, these warnings had little impact in spurring preventative measures. Since that time, the ENSO teleconnection has been greatly publicized in the media and through meetings of scientific experts, which has raised awareness in Zimbabwe that ENSO forecasts might be utilized with greater confidence. Activities undertaken in response to forecasts of the 1997-98 ENSO event, including the rapid formation of a new Southern Africa Climate Outlook Forum, suggest some progress in the willingness and capacity of Zimbabwe to utilize climate forecasts. However, a number of constraints remain that may limit the applicability of the forecasts.

2.5.1 Climate and society

Climate and ecology in Zimbabwe, as in Ethiopia and the Nordeste region of Brazil, are highly variable over different scales of space and time. The country is commonly divided into five Natural Regions on the basis of rainfall patterns, ranging from Natural Region I, with annual precipitation over 1050 mm, to Natural Region V, with annual precipitation usually under 500 mm and uneven distribution during the rainy season (Muir 1994). The dryland savanna environments of southern Zimbabwe, where 90% of the nation's communal farming areas are located, are located in Natural Regions III, IV and V, with annual precipitation below 600 mm and frequent droughts.

Major drought events have occurred many times this past century, with especially severe events in 1916, 1922, 1926-27, 1946-47, 1967-68, 1972-73, 1982-83, 1986-87 and particularly 1991-92. In these cases, rainfall has dropped to as little as 30% of the annual mean. Within years, rainfall is also highly variable as well. For example, the coefficient of variability for rainfall in Chivi District of Masvingo Province (Natural Region IV) during the month of January is 78%, with about 45% of years experiencing rainfall at least 25% lower than the long-term average (Scoones, 1996b).

Drought has been a perpetual feature of life in the Zimbabwean savanna, and the entire southern African region. The cyclic nature of drought, with periodicities cited from 13 to 19 years, has been recognized for some time in the scientific community (Zimbabwe Department of Meteorological Services, 1981; Tyson, 1986; Mazvimavi, 1989). However, the connection between these recurring drought events and the ENSO phenomenon has only recently been highlighted in the scientific literature (e.g., Downing; 1992, Cane, Eshel and Buckland, 1994). Currently, the teleconnection is understood as a statistical correlation rather than from a process-based perspective. Cane et al. (1994) note that the Niño3 index can account for 64% of the interannual variation in precipitation, and—curiously—for 78% of the variation in maize yields (see Rosenzweig, 1994 for discussion). However, the question of how ENSO events influence precipitation at finer spatial scales (e.g., at the level of the communal farming area) is not yet resolved. An operational understanding of the complex interactions that produce recurring drought in southern Africa therefore remains elusive.

As in the Brazilian Nordeste, land is unevenly divided. From the beginning of colonial rule in 1890, white settlers forced the native population onto the communal areas in marginal drylands of natural regions III-V, where subsequent population growth and poor land-use practices have further degraded the already-poor land. The power of these commercial farmers has continued under the neo-colonial rule of the settler-dominated Ian Smith government (1965-1979) and has been only partially challenged after independence in 1980. At present, about 4,500 commercial farmers (4,000 of European origin) occupy about 40% of farming land in the moist fertile regions of the country (natural regions I and II), while 90% of the communal area population live on the driest, least fertile lands (natural regions III, IV, and V. The state plays a major role in agriculture through the Grain Marketing Board (GMB), an agency which, since its inception in 1931, has dominated purchasing, transporting, storage and marketing of grains and other crops such as coffee. Though some private trading in grain has developed in recent years, following neo-liberalization programs, the GMB continues to control all imports and exports of grains and coffee. Other marketing boards play similar roles for cotton and tobacco. The Commercial Farmers' Union (CFU) and the Zimbabwean Farmers' Union (ZFU), partially autonomous of government control, represent the commercial and communal farmers, respectively.

Communal farming, centered on maize cultivation for subsistence consumers, is the largest source of employment. Despite this focus on small-scale subsistence production, Zimbabwe has also been a net exporter of agricultural products for about a century. In addition to exporting maize in years of good rainfall, it is also the largest exporter of tobacco (accounting for Z$3.4 billion in 1994) and is the world's third-largest exporter of roses. Though the large-scale commercial agriculture is highly productive, Zimbabwe's smallholders remain vulnerable to droughts. Recent efforts at land reform have accomplished a limited Africanization of the commercial sector and have redistributed a small portion of the large landholdings to poor African farmers. Nonetheless, the vast majority of the subsistence producers of Zimbabwe lacks the means to invoke their traditional drought-coping strategies, and are at constant risk of famine when droughts occur.

2.5.2 Early Developments

The 1982-83 famine, associated with a strong El Niño event, was the independent government's first experience with a major drought. It created a National Civic Protection Council that sought to coordinate the efforts of different ministries. This council was relatively inactive. Dissolved in the mid-1990s in a period of budget cuts, it was reorganized in 1997 under the name of the National Policy and Programme for Drought Management (Jayne 1998). However, the greatest activity has come from international organizations, especially regional organizations that address disaster issues in southern Africa and foreign assistance programs of wealthy industrialized nations. In the years after the 1986-87 El Niño-related drought, three regional organizations opened offices in Zimbabwe. These organizations, all with funding from international donor organizations, seek to mitigate the impact of drought-related famine in Southern Africa. In their early years of operation, they based their efforts on real-time monitoring of weather and agriculture, and sought to coordinate disaster relief. Their use of forecasts began in 1993 and accelerated after 1995. They began programs to alter production strategies to mitigate the impacts of drought. We focus on these agencies: The Regional Early Warning System (REWS), the Regional Remote Sensing Project (RSSP) and the Drought

Monitoring Centres (DMC).

Early warning systems for coping with food shortages in Southern Africa began in 1987 as a regional effort of the ten nations of the Southern African Development Community (SADC) when the SADC's Food Security Technical and Administrative Unit (FSTAU) initiated the Regional Early Warning System (REWS). The objective of the REWS system is to "provide member states and the international community with advance information on food security prospects in the region through assessments of expected food production, food supplies and requirements" (SADC, 1997a). Complementing the REWS are National Early Warning Units (NEWUs) in each of the ten SADC member states; the REWS acts as a coordinating body for the NEWUs.

The head office of the Regional Early Warning System for 10 nations in Southern Africa is located in Harare, the capital of Zimbabwe. Foreign assistance has been important to both the national and regional early warning units. The former has received funds from Danish foreign assistance agencies and from the Food and Agriculture Organization of the United Nations, and the US Agency for International Development has supported the latter.

The REWS provides specific information, both for the region and for each member country, on food crop performance and the likelihood of crop failure; food supply and demand assessments and projections (including imports and exports); and areas and people at greatest risk of suffering food shortages (SADC, 1997a). Its activities include producing Quarterly Food Security Bulletins (with monthly updates), which are distributed through fax and electronic mail to member states. The Bulletins typically include information on rainfall data and crop conditions during the growing season (agrometeorological bulletins are also released every ten days); remote sensing images and outputs of maize yield forecast models from the Regional Remote Sensing Project (to assess yield potential while the crop is still growing); projections of crop harvests and supplies, estimates of available cereal stocks and anticipated demand (using national annual food balance models, a regional food balance model, and a monthly food balance model); and marketing and price information. Additionally, the NEWUs are "encouraged to include in their food security assessments relevant information on the availability and accessibility of food at the household level" (SADC, 1997a). These information products are distributed to the national governments, international organizations such as FAO and USAID, and the donor community, to encourage planning in advance of drought events.

The Zimbabwean NEWU receives district-level assessments of expected harvests at different points during the growing season from agricultural extension workers in the field. These data are combined with information from the Meteorological Office and the Central Statistics Office into national maps that highlight any areas with expected shortfalls in harvests from the different agricultural sectors (communal, resettlement, and small and large-scale commercial). Finally, the projected harvests are compared with grain stocks held by the Grain Marketing Board and anticipated demand, to assess the potential for food shortages within the country (Scoones, 1996b). It is within the context of these national and regional institutional arrangements that ENSO forecasts have been issued and utilized.

The Regional Remote Sensing Project (RSSP), established in 1988, was first based in the Zimbabwean Department of Meteorological Services, but soon was transferred to the FSTAU within the SADC. The RSSP receives satellite data on cloud cover and vegetation every 10 days during the cropping season from September through April. It uses these to prepare news sheets, at the same ten-day interval, on cloud cover, rainfall, and vegetation development. It also produced monthly bulletins. These reports are based on real-time monitoring rather than on forecasts, though they serve an important function in allowing verification of forecasts that had been made earlier.

These reports are distributed through the REWS to the NEWUs within the SADC and to the national meteorological services, though they also pass by informal means to other users as well. In addition, the RSSP offers training to the staff of the national meteorological services in the 10 member nations. The RSSP has been funded by Dutch and Japanese foreign assistance and by the FAO. Though the RSSP monitors a large portion of southern Africa, the location of its head offices in Harare places Zimbabwe users in a favorable position to receive its reports.

In 1991, Drought Monitoring Centers for southern and eastern Africa were set up, with principal offices in Harare and Nairobi, with support from the United Nations Development Program and the World Meteorological Organization. The Harare center is housed under the Department of Meteorological Services. It receives climate, agricultural and hydrological data from member nations, and draws on satellite data from international centers. As "upstream organizations," the DMCs do not interact directly with governments agencies, but rather communicate with the national meteorological services. They issue bulletins, and provide pre-season forecasts in September. The location of the DMC in Harare has led some Zimbabwean to obtain the reports directly; these include NGOs, firms and individuals, though no government organizations apart from the president's office and the Department of Meteorological Services. Some observers note that the Zimbabwe Department of Meteorological Services has pressed the DMC to weaken and to postpone forecasts of drought until the government has prepared to take action (Stack 1998).

2.5.3 The 1991-92 El Niño event

The 1991-92 event provided the first test of these agencies. Though the El Niño-related drought led to poor harvests, severe famine did not materialize. The regional agencies and international donors deserve much of the credit for this averted disaster, since the government of Zimbabwe was slow to act. The government continued to make contracts to export grain despite early warnings, based on the low stocks left from the previous seasons, from REWS in March 1991, from the national Grain Marketing Board in April, and from the NEWU in July (Jayne and Rukuni 1994; Rook 1997). The NEWU warned that "if the present trend of intake, local commercial sales and export of maize continues, the stock of maize in the GMB (Grain Marketing Board) will be at a record low level by December, 1991" (Zimbabwe National Early Warning Unit, Vol. 5(7), noted in Scoones, 1996b).

The government sought to forestall concerns by pointing to the normal levels of precipitation in October and November, the first months of the rainy season. However, the REWS noted the danger of food shortages when little rain fell during December, a critical month. During this time, it is unclear when ENSO forecasts became available. The expansive study of Glantz, Betsill, and Crandall (1997) reviews the use of ENSO forecasts in Southern Africa in 1991-92, and notes that "it is difficult to say exactly when an ENSO forecast was issued prior to the 1991-92 Southern Africa drought. The answer depends on the source of the information as well as the type of information one chose to rely on." They comment that the main sources for ENSO forecasts within the SADC at the time were the Climate Analysis Center (CAC) of the U.S. National Weather Service, and the Australian Bureau of Meteorology (BoM). While the CAC forecast model began to indicate in April, 1991 that a warm episode was likely to develop in late 1991, the Australians did not forecast an ENSO until July; this forecast was still very tentative, however, and it was not really until September of 1991 that the forecast community as a whole concurred that an ENSO event was taking place (Glantz, Betsill, and Crandall 1997). Once the forecast was made, however, it appears that Zimbabwe had no processes in place to utilize the prediction. The research of Glantz, Betsill, and Crandall (1997) indicates that there was essentially no institutionalized mechanism for receiving and utilizing ENSO forecasts during the 1991-92 period. In 1991, the only Zimbabwean institution that is known to have disseminated ENSO information is the WMO Drought Monitoring Centre in Harare, which discussed ENSO model predictions in its March, 1991 Drought Monitoring Bulletin for Eastern and Southern Africa (well before consensus existed as to the likely onset of the ENSO event).

The initial reports were followed by increasingly alarming warnings regarding the year's crop. The SADC Food Security Bulletin in December, 1991 warned the member governments, the international community and donor organizations of the increasingly dry climatic conditions, and made projections of the likely grain harvests. In January 1992 the REWS alerted the US ambassador, who noted the critical situation and began to seek food assistance for Zimbabwe in February. Ministers of the SADC nations called for a rapid assessment of the likely extent of food shortages, development of a shared strategy to cope with the impacts, and the convening of a donor's conference. Between January and March, the REWS/NEWU systems initiated a series of rapid assessments to anticipate the availability of food and project the amount that would be needed to cover the anticipated shortfall. Their results were independently confirmed by a joint Food and Agriculture Organization/UN World Food Programme Crop Assessment Mission over March and April (Rook, 1997).

The national government did not declare a national disaster until March. Until this official statement was made, international donors had been unwilling to make sizeable contributions of aid (Greene and Herrick 1994). After the government's declaration of a disaster, the SADC and the United Nations Department of Human Affairs also proclaimed a drought emergency in all of southern Africa. With assistance from a number of donor countries, Zimbabwe imported grain and prevented massive famine, though American maize did not actually arrive into the interior of the country until after the first week of April 1992—a month after the country had essentially run out of grain reserves. These measures were expensive. Zimbabwe spent $340 million to import the quantity of grain that it had exported for one-quarter of that figure. This cost represented 11% of Zimbabwe's GDP over the 1992-93 marketing year (Jayne and Rukuni 1994).

A number of explanations for the delay in preventative actions are possible. First, as Scoones (1996b) argues, "the perceptions of drought on the part of scientists, administrators, and politicians were different" (p. 176). While the scientists were confident in their predictions, administrators were apparently more ambivalent and cautious. And the politicians, he claims, "refused to believe the science of prediction. (P)olitical and social process, and not rational scientific argument, provided the impetus for action" (p. 176). Reinforcing this view, good rainfall during October and November of 1991 undoubtedly contrasted with the predictions of drought, which themselves were uncertain at the time. Even if Zimbabwe had had experience in interpreting and utilizing ENSO information, the forecasts were likely not unambiguous enough, particularly given the climatic situation at the time, to be sufficiently credible for decision-making. Moreover, there were political pressures to continue exports while food stocks dwindled. The large capital-intensive farmers, represented by the Commercial Farmers' Union, may also have been reluctant to support any moves to have the government renege on contracts to export food crops, even in the face of likely shortages. Economic policymakers also seemed concerned to maintain the exports that generated foreign revenue (Jayne and Rukuni 1994).

Finally, action by government actors and donor organizations is not necessarily oriented toward cautious planning in advance of an event, but rather toward swift, heroic action once a catastrophic situation arises. Risks are high when acting in anticipation of an uncertain future, and overt political benefits low. Further, budgetary resources are often not available for preventative measures, only for disaster response. When a drought is underway, incentives are great for quick and effective action by national politicians and international donors. This point is echoed by Glantz, Betaill, and Crandall (1997), who present data from interviews with officials in other Southern African countries. Together, this analysis suggests that the absence of formal institutional mechanisms for providing the REWS and NEWU systems timely ENSO forecasts, lack of experience (and, hence, trust) in understanding and using the forecasts, and absence of political incentives for making use of forecasts interacted in the Zimbabwean non-use of ENSO forecasts in 1991-92.

2.5.4 The 1994-95 El Niño event

The nearly averted tragedy of the 1991-92 drought led to the creation of the Zimbabwe branch of Famine Early Warning System (FEWS) in 1992. This unit is supported by the US Agency for International Development and housed under REWS. FEWS coordinates with RRSP as well as with REWS issues. It aims for greater spatial disaggregation of climate, agricultural and socioeconomic data to locate specific zones of greatest vulnerability. It draws on data sources that had not been used extensively by drought monitoring agencies; these sources include water storage in reservoirs, livestock population levels, local and regional economic activity. It issues monthly Field Reports, and less frequent Food Security and Vulnerability Assessments to USAID and to other international donors; these documents circulate widely. An addition to the formation of FEWS, another change that followed the 1991-92 drought was the increased use of newer forecasting techniques in the early and mid 1990s. By 1993, the REWS incorporated early outlook information on projected rainfall.

Despite this growth in institutions and techniques, the response to the 1994-95 drought paralleled the one three years earlier. Warnings of potential shortfalls of food supplies came in early in the rainy season. Drawing on climate forecasts, FEWS, DMC and REWS warned in September 1994 of the strong possibility of an impending El Niño event These concerns, augmented by real-time monitoring of precipitation and vegetation, were reiterated in REWS reports in December and in NOAA briefings to USAID around that time as well. At a meeting held in Malawi in January, the Southern African Development Community recognized the risk. It activated a regional drought task force, which met in Swaziland in March. At this meeting, already late in the rainy season, member nations agreed to monitor their food needs; their evaluations showed the failure of harvest in many areas and a high risk of famine. In March and April, experts from the FAO and the World Food Program made on-site assessments and underscored the serious nature of the impending food shortage. The SADC appealed for international assistance in May and June (Jayne 1998).

The Zimbabwean government did not declare a national disaster until July; soon after, it requested $186 million in drought relief assistance (Jayne 1998). The international donor community had received warnings months earlier, and recalled the near-disaster of the 1991-92 famine. Aid in the form of supplies of food and seed began to arrive in August. This second narrow escape led USAID to support a NOAA initiative for the International Research Institute for Climate Prediction in November 1995.

2.5.5 The 1997-98 El Niño event

The 1997-98 El Niño event differed from the 1991-92 and 1994-95 events, since national, regional, and global organizations made greater use of forecasts, media coverage was far more extensive, and national agencies adopted proactive measures to mitigate the effects of the anticipated drought rather than merely seeking disaster relief once the drought was under way.

In the first months of the event, it appeared that there would be a repetition of the earlier pattern of early alerts from regional and global agencies, with little response from national agencies. In May 1997, the Climate Prediction Center in Washington informed FEWS that it was forecasting an impending event. FEWS circulated these warnings widely, though informally, to REWS, DMC, RRSP, and the SADC. The Ministers of Agriculture in the SADC countries met in June 1997 and recommended that close attention be paid to monitoring climate forecasts. However, the NEWU, a unit within the Zimbabwean government, was reluctant to issue a warning without formal declaration of an alert from REWS; for this reason, it did not pass word on to other ministries.

The REWS alert came at the end of June. It received a good deal of publicity in the form of newspaper coverage, inclusion in the new SADC website, and in the magazines of the Zimbabwe Farmers Union, which represents the smallholders and communal farmers, and the Commercial Farmers Union. In July 1997, a REWS report on Global Climate Observations and Trends noted the "increasing concern among international climate researchers and forecasters over the possibility that a warm ENSO could occur this year...(ENSO events) are often associated with poor rains in southern SADC" (SADC, 1997b). They cautioned the community, however, that "it is still too early to make any definite predictions concerning the next rainy season in SADC." By July/August, the REWS issued a Food Security Special Update, warning that "climate condition indicators are such that there could well be adverse impacts on food production during the coming 1997-98 growing season" (SADC, 1997c). The report warns SADC member states to consider reviewing export liabilities for existing stocks; providing drought resistant seeds to commercial and communal farmers; reviewing external financial commitments in the event of low profits due to low agricultural production; using surface water supplies carefully; and undertaking preventative maintenance of available irrigation equipment.

The Commercial Farmers Union also based its articles on ENSO forecasts that were included on the websites of global climate organizations. Nonetheless, government circles were relatively slow to respond. In August, the Ministry of Land, Agriculture and Water Development began to inform international donors of food assistance, so that the government could begin to prepare its appeal.

An important innovation in the use of El Niño forecasts took place in Zimbabwe in September. This was the first Regional Climate Outlook Forum (RCOF) held anywhere in the world. The Southern African RCOF (SARCOF) drew together representatives of global agencies (the International Research Institute for Climate Prediction [IRI], the World Meteorological Organization), regional agencies (the DMC), and national agencies (the SADC national meteorological services), with funding from the IRI and the European Union. On the basis of extensive consultation, it prepared forecasts for precipitation for the next several months across southern Africa,

These forecasts were notable in several ways. Firstly, these were consensus forecasts, agreed to in discussion at meetings open to climate specialists and some government officials, though not the media or the general public. As noted by SARCOF (1997):

> There are many institutions that are preparing forecasts, and in the past that has lead to confusion on the part of the users. To address this issue, the SARCOF initiative brings together international, regional, and national experts in order to prepare forecast guidance. It issues a deliberately general climate "outlook," intended to spur national agencies to issue forecasts and to reduce the inconsistencies in these forecasts.

Secondly, these forecasts had some degree of spatial disaggregation. In the case of Zimbabwe, they distinguished between northern and southern portions of the country.

This backing from global and regional organizations, along with greater use of forecasts and greater media involvement, encouraged the NEWU to issue drought warnings in early October. They made a number of specific recommendations, encouraging farmers to plant early, to choose drought-tolerant and early-maturing varieties, to adopt water conservation measures, and to prepare to sell animals. These warnings were widely circulated in the press and on the radio.

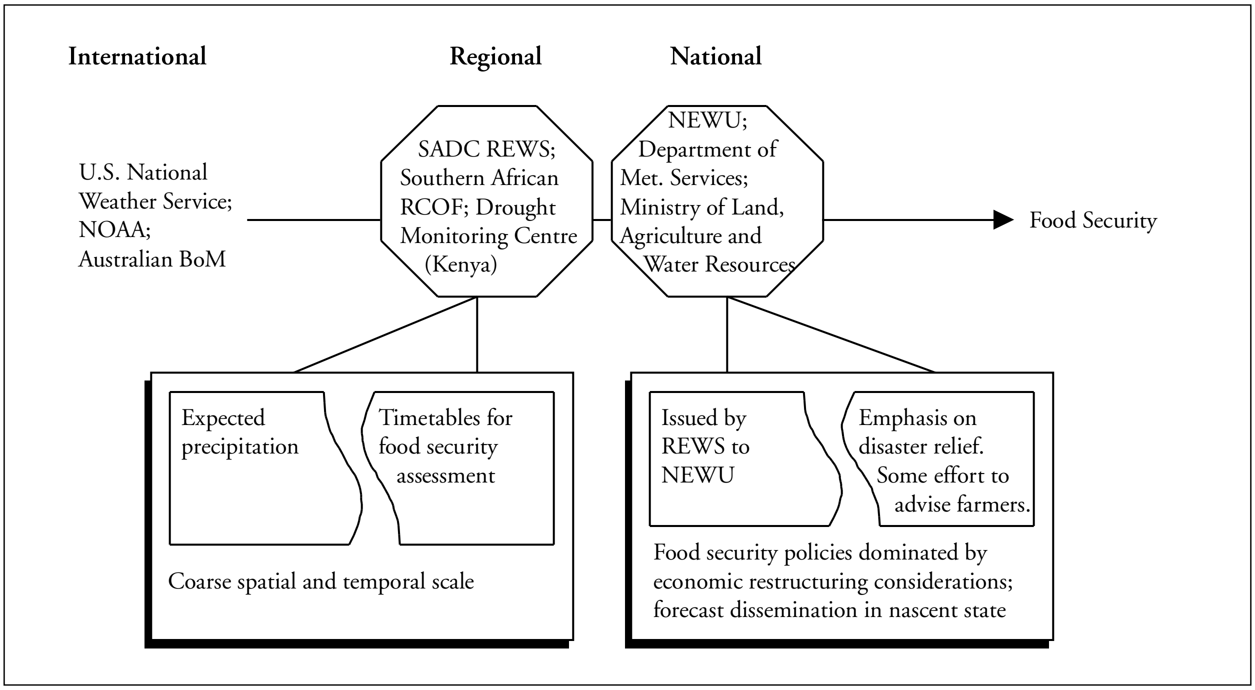
Precipitation in Zimbabwe during the 1997-98 rainy season was between 70 and 75% of average levels, a less severe drought than the one that occurred in 1991-92 (AGRITEX 1998, DMS 1998). The temporal distribution of rain was very uneven. In normal years, the rains begin in October and November, peak from December through February, and then taper off, ending in May. In 1997-98, dry and wet months alternated. November, January and March had above normal rains, with very heavy rains in January; the critical month of December was very dry, February had below normal rains, and virtually no rain fell at all in April. Moreover, the spatial distribution was uneven, with more severe drought in the Natural Regions IV and V in the south.

The commercial farmers drew on these warnings from the RCOF and the NEWU. They had also been alerted by the Commercial Farmers' Union magazine, and a number of them had international websites. They planted early, shifted to drought-tolerant crops, and stored fodder for their animals. They passed through the drought with relatively minor impacts (DMS 1998).

Though the reporting of agricultural statistics makes it difficult to determine precise responses, it appears that the area planted by communal farmers was about 20% to 30% below average, and yields declined about 40%, reflecting the shifts to drought-tolerant varieties and the lower levels of inputs. Some of this decline reflects the lesser availability of credit, since banks were concerned that farmers would not be able to repay loans. As much because of this timing as because of the overall levels, some farmers who followed government recommendations and planted early obtained adequate yields. However, many farmers who reduced their planted area were very discontent, because they blamed their lower overall harvests on poor advice. As a leader of the Zimbabwe Farmers' Union stated, “Seasonal forecasts of the 1997/98 season resulted in overwhelming panic in the farming fraternity due to the deficiencies of the forecasts’ information.” (DMS 1998, p. 24). The communal farmers felt strongly that they could have achieved higher yields if they had received advice to stagger their planting dates and to adopt moisture conservation techniques. They also may felt that the tone of the alerts was exaggerated; the 1997-98 El Niño, billed as “the event of the century” did not lead to droughts as severe as the ones earlier in the decade.

These problems were exacerbated by the inconsistent policies of the Grain Marketing Board. The GMB established strategic grain reserves to cover 5 months of consumption and set up a cash fund to purchase 3 months’ worth of food imports(SADC, March 1998). However, this agency offered varying reports on the prices that it would set for the purchase and sale of maize (UNDP 1998). These inconsistencies made it difficult for farmers who had surpluses to decide at what time and at what levels to sell their surpluses; farmers whose crops failed were uncertain whether to sell animals to purchase grain. With a total grain deficit of 1.1 million tons), 1.3 million people had applied for famine relief by March 1998 (SADC, March 1998; DMS 1998). Discontent was also strong in urban areas, where food riots broke out.

Figure 6: “Fit” between institutions and information in Zimbabwe



2.5.6 Summary

Although Zimbabwe has only recently begun to utilize ENSO forecasts, it appears to be bound to a set of regional institutional arrangements that are heightening awareness of ENSO and assessing the real usefulness of ENSO forecasts for planning at the national scale. During the 1991-92 and 1994-95 events, low awareness of ENSO, a lack of institutional pathways for providing forecasts and understanding their implications and limitations, and possible lack of political incentives prevented potentially available forecasts from being used. Since that time awareness of ENSO’s impacts on

Southern Africa and Zimbabwe, through scientific publications and improved international diffusion of ENSO predictions, have helped to improve the conditions for the use of climate forecasts in Zimbabwe. Both the REWS and NEWU systems have incorporated ENSO forecasts into their regular bulletins, and the SARCOF has begun to provide an important institutional bridge between international and U.S. climate forecasters, and the national meteorological services and early warning units. ENSO information, though still only available at a coarse spatial resolution for Zimbabwe, is now considered useful and credible enough for the NEWU to issue advice to farmers, and for the Grain Marketing Board to undertake some preventative measures. These measures, particularly in contrast to the near-disasters of 1991-92 and 1994-95, indicate a rapid (if late, relative to the other cases) co-evolution of information and institutions that have made the climate more favorable for application of ENSO forecasts in Zimbabwe. However, greater efforts must be made to assure closer articulation with end-users. In the 1997-98 event, commercial farmers draw information not only from REWS and NEWU but also from their producers' association and from individual efforts to browse international websites. These efforts allowed them to bypass some constraints within the national political systems, but also prevented them from drawing on the accumulated knowledge and experience of the climate experts. Many communal farmers are very disappointed by the coarse spatial and temporal scale of forecasts and by foregone harvests. Their first contact with forecast-based drought warnings may have left them less rather than more willing to heed alerts in the future.

3. DISCUSSION AND CONCLUSIONS

3.1. Fitting forecasts, institutions and societies

Despite the diversity of sociocultural, institutional and environmental settings across the cases, some broad patterns emerge. In all of the cases, institutions that did not originally develop, disseminate, or use climate forecasts evolved, or "learned," to do so. For example, the Department of Primary Industries in Queensland began in 1983 to explore the possibility of using climate forecasts after interactions with officials from the national Bureau of Meteorology, and by the early 1990s had added forecasting to the array of services it offered its clients. In 1997 the Peruvian agency IMARPE included forecasts as a tool to advise fisheries managers only after years of using real-time monitoring. The clearest case is in Brazil, where FUNCEME in 1987 abandoned its efforts to make rain by cloud-seeding, and transformed itself into an integrated climate forecast and water resources management institution.

We wish to underscore the fact that, in this process of cross-scale institutional change, national and subnational agencies in the four developing countries are not simply passive recipients of forecasts from international sources. Many of these institutions generate their own forecast products, downscale ENSO forecasts from international sources, and/or provide national or subnational-scale interpretations of internationally generated forecasts. The integration of Pacific and Atlantic data in Brazil takes place partly in national research centers and partly in FUNCEME in Ceará. IMARPE collects data on sea temperature profiles, which it then integrates with other forecasts from the United States and elsewhere. The NMSA in Ethiopia draws on local knowledge of the two rainy seasons. Only in Zimbabwe, the most recent case of use of forecasts, is this modification of forecasts not apparent. Even here, however, the new southern Africa Regional Climate Outlook Forum has begun to develop subnational scale precipitation forecasts for Zimbabwe, although these likely remain too coarse in resolution to aid farm-scale decision making at present.

As suggested in the introduction, the spatial and temporal characteristics of ENSO forecasts do shape patterns of use across the nations. In Ethiopia and Zimbabwe, only broad, province-scale forecasts are available for the upcoming season. Consequently, forecast application efforts have been focused on national and regional scale food security and disaster planning, and less for local agricultural planning. In contrast, Queensland farmers and graziers, with statistical forecasts available at the farm scale and tools and training to assist them in their application, have utilized forecasts for crop and livestock planning. In Brazil, difficulties in using forecasts for agricultural and water resources planning can partly be explained by the timing of forecast release; as Lemos (1998, personal communication) notes, planting and water resources management decisions are often made well before FUNCEME actually releases its forecasts. As intuition would suggest, in no case do we see ENSO forecasts either applied for activities occurring at a finer spatial scale than the available forecast information, or—obviously—used if the forecast information is available only after planning decisions need to be made.

Drawing on the notion of "organizational fit," we also find that a lack of fit between forecasts and institutions can constrain forecast use and, in some cases, challenge institutional viability. In the Brazil case, for example, methods for both disseminating forecasts and encouraging their application among smallholders are incongruent with the ways in which they make planting decisions, and with the limited options available to them for coping with drought (Lemos and Tucker 1998). Competition with other traditional methods of forecasting drought in Northeast Brazil indicates that FUNCEME, and by extension modern science, does not yet “fit” the ways in which the people of Ceará frame the problem of drought. Finally, end users have little concept of the meaning of probabilistic technical information, and at any rate lack the resources to alter their behavior significantly in anticipation of drought. Even if more spatially and temporally resolved forecasts were available, these points suggest that the sociocultural elements of “fit” would continue to constrain the use of climate information in Nordeste. In the Zimbabwe case, early forecast information may not have “fit” the incentive structures for national politicians and famine relief organizations. As Glantz et al. (1997) have observed, politicians may accumulate less capital from averting disasters before they start than responding heroically to them as they begin to unfold. Although it does not seem probable that such motivations could constrain the use of climate information for long, this lack of “fit” between climate information and political incentives appears to have been among the initial constraints present in the Zimbabwe case. In Ethiopia as well, the entrenched institutional culture of famine relief, in which both the government and involved NGOs are together embedded, places constraints on adaptive response through the still-rigid procedures for assessing relief needs and delivering food aid. The timetables associated with these procedures limit the extent to which forecast information can stimulate responses before the imminent onset of famine (Thomson et al. 1998). Even in Peru, the focus on civil defense as the major sector of state activity in the 1997-98 event shows the utility of disaster relief as a politically advantageous response to environmental variability.

3.2. Dynamics of institutional learning

In the cases, institutions that were originally developed to conduct resource management, food security planning, or other activities evolved, or “learned,” to generate and/or make use of climate forecasts. The case studies provide a wealth of empirical detail relevant to this theme of institutional learning. Here we provide a first-order analysis of four aspects of institutional learning: 1) what types of institutions are involved, 2) the substance and patterns of institutional learning across the cases, 3) the time scales over which learning takes place, and 4) the wider milieu of science-society relations within which efforts to utilize climate forecasts take place. Table 1 summarizes much of the information on which the analysis below is based.

3.3 Which institutions “learn”?

Interestingly, while in some cases (e.g., Zimbabwe) regional or international agencies have provided the impetus for the use of forecasts, we find that the subnational institutions have been particularly active in reaching outward and upward to forge institutional ties to end-users and international agencies, and in modifying and downscaling forecasts (see 3.2). This is in slight contrast to national meteorological agencies, which in some cases (e.g., Ethiopia, Australia) have been active sources of learning and innovation, but in others (e.g., Peru, Brazil, Zimbabwe) have been relatively inactive.

Also of note is the relative absence of private sector institutions. Though the free market is often receptive to potentially relevant information, in the nations studied here the generation and use of ENSO-based climate information by private sector institutions has been limited. Although this is changing rapidly, particularly in Australia (and potentially in Brazil), the initial investments in climate forecasting and application have been directed toward sectors and actors groups that have typically been under the social jurisdiction of government.

	AUSTRALIA	BRAZIL
DATE OF FIRST AWARENESS OF ENSO	1910	1987
DATE OF FIRST FORECAST APPLICATION	1989	1992
APPLICATION SECTOR(S)	Commercial farming; livestock; water	Commercial and subsistence farming; water resources
FORECAST-GENERATING INSTITUTIONS	**National:** BoM	**International:** IRI **Regional:** Regional Climate Outlook Forum **Subnational:** FUNCEME
FORECAST-UTILIZING INSTITUTIONS	**Subnational:** Queensland DPI/DNR (state); QCCA (state)	**Subnational:** SDR (state); SAS (state); SRH(state)
MODE OF INSTITUTIONAL CHANGE FOR FORECAST INCORPORATION	"Link forming" then "entraining" Also "de novo birth" of new institution (QCCA)	"Transformation"

Table 1: Summary of cases

3.3.1 Subnational institutions

As shown in Table 1, two subnational-scale institutions (FUNCEME in Brazil and IMARPE in Peru) are actively involved in generating climate forecasts based on ENSO. The remainder, including the Queensland DPI/DNR and SAS, SDR, and SRH in Brazil, are both resource management agencies that modify forecasts, broker the flow of information between forecast-generators and end-users, and act as end-users themselves. Interestingly, while much discussion in the ENSO forecast community centers on local-scale end-users (such as subsistence farmers) who do not make climate-related decisions through the vehicle of an institution, very little data exist regarding their "learning" processes in using ENSO-based climate forecasts. While some studies have investigated the use of climate information by smallholders in Zimbabwe and Brazil (see Lemos 1998; Phillips 1999;) and by commercial farmers in the United States (e.g., Mjelde et al. 1988), complete data on the actual use of forecasts by end-users in the five nations (i.e., what specific behavioral changes were undertaken in response to a forecast), even within institutional settings, are limited. This data gap poses serious constraints on our understanding of the total process of going "end-to-end" from forecast to end-use.

ETHIOPIA	PERU	ZIMBABWE
1986	c. 1600	1991
1986	1987	1997-98
Food security	Commercial farming; fisheries; infrastructure/public works	Food security
International: US National Weather Service; Australian BoM; Hadley Centre for Climate Prediction **Regional:** Greater Horn of Africa RCOF; African Center for Meterological Applications and Development; South African Weather Bureau; Drought Monitoring Center (Kenya) **National:** NMSA	**International:** NOAA **National:** IGP; SENAMHI **Subnational:** IMARPE	**International:** US National Weather Service; NOAA; Australian BoM **Regional:** SARCOF
International: USAID FEWS **National:** DPPC; Ministry of Agriculture	**National:** Ministry of the President; Ministry of Agriculture (Fisheries Division); National Civil Defense Institute	**Regional and international:** SADC REWS; USAID FEWS; FAO GEWS **National:** Zimbabwe NEWU
"Link forming" and "entraining"	"Entraining"	"Entraining"

3.3.2 National institutions

An array of national-scale public sector institutions has been involved in generating and applying forecasts. In three of the five nations (Australia, Ethiopia, Peru), national meteorological agencies issue their own climate forecasts. In Peru, however, IGP is one of a number of agencies that issues competing forecasts with the subnational-scale IMARPE and other organizations; as discussed below, this competition bears important implications for how the forecasts are actually utilized in that nation. In Ethiopia, Peru, and Zimbabwe, national-scale institutions utilize climate forecasts for disaster preparedness and prevention (Ethiopian DPPC, Peruvian Ministry of the President and National Civil Defense Institute), food security and agricultural planning (Zimbabwe NEWU, Ethiopian DPPC and Ministry of Agriculture, and Peruvian Ministry of Agriculture), and fisheries regulation (Peruvian Ministry of Fisheries). As discussed below, the subnational agencies have been somewhat more proactive, in general, than the national-scale institutions in developing innovative forecast products and application strategies.

3.3.3 Regional and international institutions

Organizations at the supra-national scale have also played a significant role in promoting the use of climate forecasts. On the one hand, we do not find that the push to use forecasts has been simply driven from the top-down by institutions such as the WMO or IRI. On the other, our fundamental capacity to forecast ENSO events and their global impacts has been developed by these institutions, and they have played the critical role in catalyzing global awareness of the potential uses for seasonal-to-interannual climate forecasts. As noted in Table 1, almost all of the countries make use of forecasts issued by NOAA, IRI, the US National Weather Service, the UK Hadley Centre for Climate Prediction, and others. (Australia is an exception, but its Bureau of Meteorology is a long-lived institution with a worldwide reputation for excellence; it can itself be considered an "international" agency, as its forecasts are also utilized by other nations in this study.) Additionally, the Regional Climate Outlook Fora, which encompass three of the five countries, appear to be playing a catalytic role in developing consensus forecasts and providing opportunities for national meteorological agencies to gain experience in issuing forecasts and working with end-users. Regional and international organizations such as the US Agency for International Development, the FAO, the Southern Africa Development Community, and NGOs that operate famine early warning systems and provide relief, have also played a role in utilizing forecasts. However, as the Ethiopian and Zimbabwean cases highlight, it is unclear whether the traditionally reactive institutional culture of the donor/relief communities has changed sufficiently to utilize climate forecasts in a proactive manner.

As noted above, we find that subnational organizations have been active catalysts for learning and the forging of cross-institutional ties. For example, FUNCEME evolved from a cloud-seeding agency to a climate forecasting and water resources management agency in 1987. FUNCEME also established strong ties with the Brazilian space agency INPE and, through them, with the international climate forecast community. IMARPE and Ministry of Fisheries personnel in Peru have actively sought out advice from United Nations specialists in the FAO. In contrast, national agencies appear, on the whole, to have been slightly less catalytic and innovative. While the possibility of utilizing forecasts in Australia was initially introduced by an informal transfer of information from the national BoM to the state-level DPI, the pioneering statistical method on which the forecasts and application products are based was developed by a BoM scientist while on leave at the DPI. The relative inactivity of the Zimbabwean national meteorological agency contrasts with the international scientific attention paid to the links between ENSO and drought in southern Africa (Cane and Buckland 1990; Anyamba and Eastman; Eastman and Fulk). One exception is Ethiopia, where the NMSA, DPPC, and Ministry of Agriculture have made innovative use of nationally tailored ENSO forecasts since 1986, based on the different impacts that ENSO appears to have on the spring and summer rainy seasons.

3.4 What do these institutions learn to do, and how do they learn to do it?

The process of institutional learning within public-sector institutions, as we consider it here, involves the initiation of changes in the structure and/or function of the institutions so that they can make use of climate information. For international organizations, primarily agencies that issue climate forecasts, the functional changes consist of building ties with national meteorological services and regional coalitions of these (e.g., RCOFs), developing dissemination strategies using various media (press releases, faxes, and Internet), and issuing forecasts in ways that are understandable by nonexpert audiences. For national and subnational agencies that conduct forecasts, the learning involves downscaling ENSO forecasts, developing public and cross-institution dissemination strategies, and building ties upward (with regional and international meteorological agencies), and laterally/downward (with agencies that either directly use forecasts or work with end-users). For end-users, the learning consists of building ties laterally, upward, or downward (depending on whether the "end-user" is a subnational, national, or regional/international entity), and gaining capacity to make behavioral changes—based on the climate information—that make them better off than they would otherwise have been. In all of these cases, the functional changes require some degree of structural changes to the organizations. We note characteristic ways in which the organizations in these cases appear to undertake such structural changes.

3.4.1 Forecast modification and downscaling

The national and subnational agencies described in the five countries are not simply passive recipients of forecasts from international sources. Instead, they modify these international forecasts by downscaling them to regional, national or subnational scales or by interpreting them in ways that are signficant to users. In some cases, they generate new forecast products on their own. For example, the integration of Pacific and Atlantic data for development of climate forecasts for northeast Brazil takes place partially in national research centers and partly in FUNCEME. IMARPE collects data on sea temperature profiles, which it then integrates with other forecasts from the United States and elsewhere. The Queensland DPI has developed software tools that enable farm-scale end-users to make their own probabilistic climate forecasts based on the Southern Oscillation Index (developed by a BoM scientist), and to explore optimal cropping and pasture management strategies based on the forecasts. The NMSA in Ethiopia draws on local knowledge of the two rainy seasons, as well as on forecasts issued by international organizations. Only in Zimbabwe, the most recent case of use of forecasts, is this modification of forecasts not apparent. Even here, however, the new Southern Africa Regional Climate Outlook Forum has begun to develop subnational scale precipitation forecasts for Zimbabwe, although these likely remain too coarse in resolution to aid in farm-scale decision making at present.

3.4.2 Modes of learning

We note three patterns of structural change that accompany the functional changes discussed above: i) "link forming," in which the institution forms cross-organizational ties to gain meteorological, forecast application or other relevant expertise; ii) "entraining," in which the institution enfolds meteorological or other relevant experts that were previously external to the institution; and iii) "transformation," in which the institution entirely reorganizes itself (see Table 1).

Link forming is seen particularly clearly in Australia, where informal ties between Bureau of Meteorology and Department of Primary Industries effectively initiated the integration of climate and agricultural information. Later, the DPI entrained some of BoM's climate experts, resulting in even more productive activity that, in the end, led to the birth of a new, fully integrated institution (Queensland Centre for Climate Applications). In the case of Zimbabwe, a similar pattern appears to hold. Regional and global-scale institutions (FAO and the SADC) entrained climate information and expertise into their assessments of food insecurity and planning of relief efforts, in conjunction with link forming activities such as the Southern Africa Climate Outlook Forum. In Peru, IMARPE had made use of ocean temperature data for some time, so it was not a large change to begin making use of forecasts of ocean temperature. The use of climate forecasts in Ethiopia has occurred within the wider transition of the country toward "preparedness and prevention" efforts, rather than "relief and rehabilitation." Functional changes related to climate forecast application in the NMSA, DPPC, and Ministry of Agriculture were thus "entrained" within larger structural changes in the nation's approach toward the problem of chronic food insecurity. In contrast, FUNCEME in Brazil completely abandoned its cloud seeding mission in 1987 and transformed itself to incorporate climate information for drought management. This change was tied both to the persistent ineffectiveness of other government strategies for dealing with drought in Nordeste, and to larger political changes at the state and national levels.

3.5 On what time scales do institutions learn?

The pace of institutional learning appears to be quite variable across the cases. In some cases (e.g., Ethiopia and Brazil), ENSO-based seasonal forecasts were utilized essentially as soon as they became available. In both of these nations, the climate anomalies linked to ENSO—droughts—are tied to massive human suffering. The incentives to try any promising new means to lessen this vulnerability are high, particularly given the many historical failures of other strategies. In the other nations, the pace of change has been much slower, with first forecast application lagging initial awareness of the ENSO teleconnection by five to ten years (Table 1). The pace of learning and innovation appears to be constrained both by the rate at which understanding of the local and regional climate impacts of ENSO events can develop, and the rate at which end-users come to trust and understand how to use the climate information. The rapidity of scientific progress in understanding the ENSO phenomenon itself has not been matched by progress in understanding its impacts at smaller spatial scales. Both the physical mechanisms and the statistical relations that link the state of the ENSO system to climate anomalies outside the tropical Pacific (i.e., with the exceptions of Australia and Peru) are complicated and subtle, and the robustness of these associations is hindered by lack of data. Another constraint is the great deal of time it can take to introduce end-users to the nature of probabilistic information, a task that is complicated by variability in understanding and credibility of science and scientific information around the world. Even in the most data-rich and developed country, Queensland, which is directly affected by atmospheric pressure changes associated with the Southern Oscillation, it took about a decade for the institutions involved to develop robust forecast products and strong ties to forecast end-users.

In other cases, the pace of innovation and learning can be limited by a lack of resources or political incentives. In the Zimbabwe case, early forecast information may not have "fit" the incentive structures for national politicians and famine relief organizations. As Glantz et al. (1997) have observed, politicians may accumulate less capital from averting disasters before they start than responding heroically to them as they begin to unfold. Although it does not seem probable that such motivations could long constrain institutional change if the climate information were truly able to help mitigate human suffering, this lack of "fit" between climate information and political incentives appears to have been among the initial constraints present in the Zimbabwe case. In other cases, particularly Peru, there is evidence that pace of learning may also be slowed by an overabundance of forecasts issued by competing agencies. This theme is discussed in some more detail below.

3.6 Within what science/society contexts does the learning take place?

Regarding the first aspect, if the behavioral response to an incorrect forecast can be modified mid-stream, users are more likely to tolerate incorrect forecasts. In the case of Peruvian fisheries, ship owners will lobby to have a closed season lifted if a predicted decline in fish stocks does not occur; their displeasure is directed at the regulator, not the forecaster. In contrast, one cannot replant a field with new crops once the growing season is underway. A missed forecast in the agricultural sector could threaten profits and food security; this may be one reason why FUNCEME has come under such harsh attack for its missed forecasts.

In cases where forecasts have been used for some time (for example, Brazil), a second phase of learning takes place as end-users respond to the inevitable missed forecasts, and those responses feed back to impact the functioning of the forecast application institutions. Once agencies have begun to issue and/or use forecasts, they become accountable for the accuracy of their forecasts and, in the eyes of some end-users, for the consequences of any activities undertaken in response to the forecast. The issue of missed and misused forecasts lies directly at the complicated interface between science and society. The cases suggest that the tolerance of end-users for incorrect forecasts may be quite variable. Three aspects of the problem appear salient: 1) the ability to modify one's response to a forecast "mid-stream," 2) who wins and loses when a behavioral change is made in response to an incorrect forecast, and 3) the relationship between the kinds of information a society wants, the kinds of information that science provides, and how that information is communicated.

Additionally, if the behavioral response to an incorrect forecast is not costly—or profitable—to the end-user, users are more likely to tolerate incorrect forecasts. The individuals who were hired to build protective works against floods in Peruvian valleys did not complain when the floods did not materialize. Moreover, flood victims in areas where excessive precipitation was not predicted seemed to tolerate these incorrect forecasts, in part because they received disaster relief after the fact. Although public works and disaster relief projects are costly in monetary terms, government actors can gain valuable political capital by promoting them—even if a climate anomaly does not materialize. In such cases, as seen in Peru, the political benefits of such responses to climate forecasts can outweigh the monetary costs.

We also note the importance of the forms of interaction and participation that permit forecast-issuers and forecast-users to recognize each other as legitimate and to trust one another. On one hand, society demands accurate and precise information. On the other, many sources of information of varying accuracy compete for credibility and social acceptance, as well as for channels for dissemination. This competition places enormous pressure on scientific institutions to downplay the abundant uncertainties and make categorical forecasts (e.g. "there will be a drought" or "there will not be a drought"). Both the risk and the benefit of doing this are apparent in the Brazil case, where FUNCEME's often-cited success in 1992-93 built the institution's credibility on a foundation of weak public understanding and lingering mistrust of authority. FUNCEME's difficulties in weathering the public reaction to subsequent missed forecasts are in part a consequence of their overstating the certainty of the forecasts. The Brazil case illustrates the fact that the information sources that persist are those which "work," although they may "work" by providing culturally acceptable justifications for inaccurate and imprecise information. The Australia case, in contrast, illustrates what can occur when "scientific uncertainty" and "probability" become such culturally acceptable justifications. As Hammer (1998, personal communication) observes,

> ...we nearly suffered the Brazil syndrome in 1997 because...the forecast was wrong! Fortunately, I think we had built a degree of credibility by not going the categorical [forecast] path. But [we] only just [maintained our credibility], because the media was bombarded by categorical forecasts of gloom and doom from every international climate agency on the planet...[Because] we had spent years talking about risks to users in Queensland, they [mostly] understood but it was a continual battle against outpourings of ridiculous categorical forecasts.

The cases illustrate the fact that climate forecast application is only one arena in which science competes for social and cultural legitimacy against other ways of knowing. The longer-term dynamics of institutional learning and climate forecast application will continue to be governed by this complicated interface between science and society.

A related aspect of this issue is intra-national competition among different forecast-issuing and utilizing agencies. In Ceará, Brazil, forecasting at the state level was dominated for a decade or longer by a single institution (FUNCEME). This monopoly allowed forecasters and researchers to learn from early errors. It also, in theory, gave users the chance to develop a trust for the forecasting agency, much as it did in Queensland. In addition, it seems to have allowed agencies to broaden their set of users—as in the case of FUNCEME working first with agriculture, and later with urban water supply. However, FUNCEME by no means enjoys a wider social monopoly on climate forecasts, and still competes with "rain prophets" and other groups for social legitimacy. As noted above, this competition may have pushed FUNCEME to issue categorical forecasts, a move that may have cost them long-term credibility when their forecasts failed. In Peru and Zimbabwe, many different agencies issued forecasts. Though these were national and subnational agencies in Peru, and regional agencies and their branches in Zimbabwe, the effects appear to be similar. Users in government agencies and in producer associations were uncertain which of the competing forecasts to rely on. In the case of Peru, this competition seems to have undermined the exchange of information between forecasts-issuers and between forecast-users, with little communication between agricultural, fishing and civil defense sectors. Moreover, this competitive environment introduced complications to the decisions of the timing of issuing in forecasts: in some cases, forecast-providing agencies rushed to issue the first forecast of an impending event, while in other cases, the considerable finger-pointing among rival agencies provoked a strong spirit of caution. Though this competitive environment can have salutary effects—it led to an awareness of the weakness of IGP forecasts in Peru, for example—its overall consequences seem, on the basis on these cases at least, to be negative. Ethiopia is an intermediate case. Through the mid-1990s, the NMSA benefited from its monopoly, and experimented with different forecast models. In 1997, however, the regional FEWS in East Africa issued a different assessment of the ENSO forecast for Ethiopia, muddying the message to government planners and to farmers (Thomson et al. 1998). It remains to be seen whether other regional forecasts, issued by Regional Climate Outlook Forums, will reinforce or undermine national forecasts. In the case of Brazil, the former seems to be the case, perhaps because of strong networking between FUNCEME and global agencies such as NOAA and IRI.

4. AFTERWORD

We have outlined a hierarchy of constraints on the use of forecasts, in which the dynamics of institutional learning and change shape institutional arrangements that, in turn, underlie the development of forecast products and dissemination strategies. The "fit" between these products (in particular, their scale and data characteristics, methods of dissemination, and institutional source), relative to sector-specific planning needs and the institutional milieu (mental models, or the "structures of signification"; decisionmaking norms and processes of institutions and actors, or the "structures of legitimation"; and the availability and allocation of resources, or "structures of domination"), guide the extent and manner of use of climate forecasts.

The continued use of climate forecasts in these and other nations will depend on the extent to which the forecasts actually make the users better off than they would otherwise have been. In this respect, tolerance of the inevitable missed forecast, which to a great extent depends on the level of trust and understanding of the climate forecast enterprise (and science in general), will be a crucial variable. Toward this end, continuing efforts to educate would-be users about science and the benefits and risks of forecasts, and increase their capacity for resilient responses to climate variability, may provide the best long term pay-offs to the climate forecast community. Regardless, all involved organizations need to develop a long-term view, and a sense of patience, in promoting the further development of climate information and its use across diverse national and sectoral settings.

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Founded in late 1996, the **BERKELEY WORKSHOP ON ENVIRONMENTAL POLITICS** emerged from a long-standing commitment to environmental studies on the Berkeley campus and from the presence of a core group of faculty whose research and scholarly interests linked environment, culture, and political economy. The workshop draws together over fifty faculty and doctoral students from San Francisco Bay Area institutions (the University of California campuses at Berkeley, Santa Cruz, and Davis, and Stanford University) who share a common concern with problems that stand at the intersection of the environmental and social sciences, the humanities and law. The Berkeley Workshop on Environmental Politics has three broad functions:

- to assist graduate training and scholarly research by deepening the theoretical and methodological toolkit appropriate to understanding environmental concerns in an increasingly globalized world;
- to bring together constituencies of local and international scholars, activists, and policy makers for transnational conversations on environmental issues; and,
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