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Ethnographic and participatory approaches to research on farmers' responses to climate predictions

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ABSTRACT: This article synthesizes the state of the art in the application of ethnographic and participatory methods in climate application research. The review focuses on 2 aspects: (1) the cognitive and cultural landscape in which farmers' understanding of climate and climate information is grounded and (2) the decision-making processes and environment which shape farmers' adaptive strategies. The first part analyzes methods to elicit how farmers perceive and predict climate events and how these perspectives relate to scientific forecasts. It addresses the long-standing question of whether and how farmers understand the probabilistic nature of climate forecasts and how they assess the credibility and accuracy of such information. The second part examines approaches to characterizing the vulnerability of decision makers and to elucidating the configuration of options and obstacles that farmers face in using climate forecasts to mitigate risk. The complexities of farmers' decisions and the difficulties of identifying the exact role that climate predictions play (and, therefore, of directly attributing impacts to them) are taken into account. Finally, the review highlights efforts to transcend the localized focus of farmer-centered approaches in order to capture interactions across sectors and scales. The review concludes by proposing that climate application research move from a 'technology-adoption' paradigm to a broader perspective on vulnerability and adaptation. This shift will entail a cross-scale, multi-sited research design and an interdisciplinary mix of interactive and structured tools and techniques. It will also require that the analytical focus be expanded to encompass local communities and their multiple action spaces as well as the higher spheres of decision-making, where policy and science are shaped.

KEY WORDS: Farmer participatory research · Ethnographic methods · Climate forecasts · Risk communication · Livelihood adaptation · Vulnerability

1. INTRODUCTION

Environmental change and economic globalization are exacerbating vulnerabilities for some areas and groups, while expanding opportunities for others (Reilly & Schimmelpfenning 1999, O'Brien & Leichenko 2000). Resilience, defined as the capacity to buffer shocks and the flexibility to adapt to changed conditions, depends, among other things, on having 'timely, accurate, and credible information' (Kane & Yohe 2000, p. 3). Information management, including the processes whereby decision makers access information, ascertain the credibility of sources, combine various types of knowledge, and learn from their experience, is critical to adaptation (Yohe & Tol 2002).

Climate predictions or forecasts relate to seasonal precipitation and other aspects of seasonal climate, such as temperature extremes (for a state-of-the art review see Goddard et al. 2001). Climate prediction is one among many sources of information that can be used by decision makers to reduce risk and to optimize gains. Among sectors, agriculture stands to especially benefit from climate information because of the close link between climatic patterns and production outcomes (Jones et al. 2000, Hammer et al. 2001, Hansen 2002). This potential has generated hope that seasonal rainfall forecasts may boost food security in highly vulnerable regions, such as Africa (Washington & Downing 1999, Dilley 2000). Yet research is still at

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an early stage as to how climate predictions can be transformed into tools for adaptive management. The way forecasts are likely to be understood depends on the way people think about climate variability, its causality and predictability, and how they assess their vulnerability to climate risk, the options and trade-offs they face, and the potential consequences of decisions (Glantz & Katz 1985, Ribot, et al. 1996, Kates 2000, Glantz 2001).

Vulnerability is not merely a function of climate but is shaped by social determinants. The latter have been conceptualized as bundles of rights and claims to resources that can be mobilized to meet livelihood goals (Blaikie et al. 1994, Bohle et al. 1994, Adger & Kelly 1999, Kelly & Adger 2000). The centrality of the social dimension of vulnerability and adaptation was affirmed by a landmark report published in the late 1990s by the Panel on the Human Dimension of Seasonal-to-Interannual Climate Variability of the National Research Council (NRC) (Stern & Easterling 1999). The Panel was tasked to review the state of knowledge and to define a priority research agenda to be pursued by the National Oceanic and Atmospheric Administration's Human Dimensions of Global Change program[1]. Among other things, the report stressed the need to improve the communication of climate information and to evaluate its impacts on different stakeholders. Recognizing the multi-faceted nature of climate vulnerability, the Panel advised that a diversity of approaches and tools be deployed, including formal surveys, qualitative methods, interactive exercises, and simulation modeling. Among them, ethnographic and participatory approaches were highlighted as ways of facilitating a better integration of farmers' concerns into the development of climate-forecast products, and a more realistic appraisal of farmers' ability to use those products to improve their livelihoods.

The present study examines the role that ethnographic and participatory methods have played in climate application efforts, particularly in light of the NRC Panel's recommendations. Many of the studies reviewed were funded by the HDGC program and informed, directly or indirectly, by the agenda laid out in the NRC report. Most of them targeted populations that are particularly vulnerable to climate variability, such as small-scale crop and livestock producers in developing countries (hereafter referred to as 'farmers'). The terms 'ethnographic' and 'participatory' are hereby used loosely to refer to methods that entail some degree of farmer involvement and mutual interaction between farmers and scientists.

While the terms are often used interchangeably, ethnography and participation have different lineages, and often different purposes. 'Participant observation' is a basic principle of ethnographic research and refers to the process of experiential learning that occurs during fieldwork, as a function of 'being there'. It is based on the recognition that engaging in daily life and social relationships provides a contextual understanding of cultural realities that cannot be captured by formal research methods (Spradley 1980, Bernard 1995, DeWalt & DeWalt 2002). But even though ethnography's goal is to understand and represent the perspective of local people, it still privileges a scientific agenda.[2] Participatory research differs from ethnography in that it seeks to change rather than to study social behavior. The approach was first developed in the 1980s in the context of farming systems research to increase technology adoption by involving farmers in developing and testing innovations (Chambers et al. 1989, Chambers 1994, Okali et al. 1994, Scoones & Thomson 1994, Martin & Sherington 1997). It was subsequently embraced by development agencies as a way of eliciting community participation in project design and evaluation, to make projects more responsive to local needs and priorities. Hence, a vast repertoire of instruments, such as matrixes, mapping, activity calendars, visual aids, group exercises, etc., was assembled under the rubrics of farmer-participatory research, participatory rural appraisal, participatory learning and action, etc. (McCracken et al. 1988 Chambers 1992, 1994, Slocum et al. 1995)[3]. Several of these tools and techniques have been used in studies reviewed here.

Following the initial enthusiasm for participatory approaches to research and development, the last 10 yr have generated a greater awareness of the limitations of such approaches, some of which also pertain to ethnographic research (Mosse 1995, Richard 1995, Nelson & Wright 1996, Peters 1996, Guijt & Kaul Shah 1998, Cornwall 2000, Brock & McGee 2002, Cornwall & Pratt 2003, Mosse 2005). In some cases, shortcomings stem from how these methods are applied. Participa-

[1]The HDGC program, together with the rest of NOAA's Office of Global Program, was incorporated into NOAA's Climate Program Office at the end of 2005

[2]Considerable debate surrounding ethnography occurred in the last 2 decades, catalyzed by Clifford & Marcus (1986) and advanced by the contributions of feminist anthropologists (Behar & Gordon 1995, Wolf 1996). Many contributions have exposed the ambiguities that underlie the ethnographic agenda and challenged many of its conventional tenets, including the validity of the insider-outsider distinction. For a critical reflection on fieldwork see Clifford (1997)

[3]Many examples of tools and case studies were published by the International Institute for Environment and Development (in 'RRA Notes', later 'PLA Notes') and by the Institute for Development Studies (as IDS Working Papers) from the late 1980s to the mid-1990s

tory rural appraisals enable the collection of large amounts of community level information in a relatively short time. However, in the context of highly constrained project timeframes, the approach is sometimes reduced to the deployment of a battery of techniques by teams of hurried consultants. Consequently, the potential for ethnographic insight and local empowerment is lost, as the research remains driven by an external agenda. The question of what drives the agenda, whether it is local demand or exogenous supply, is particularly relevant for climate application research (Broad 2002).

Another set of critiques relates to the scope of investigation. Emphasis on local context and dynamics enriches the analysis, but the particularistic focus, informal methods and non-random samples that characterize the participatory and ethnographic approaches limit their replication or the generalization of results. Reliance on casual interactions, conversational interviews, and key informants enables a deeper insight into cultural meanings, but introduces biases. Village-wide meetings and group work are likely to privilege normative explanations and produce the appearance of consensus, obfuscating difference and dissent. Western notions of participation, centered on public speaking and visible performance, tend to privilege the views and voices of the most prominent or educated members of the community, muting those of marginal groups. Even when explicit efforts are made to include them, subordinate groups may be held back by internalized cultural norms or fear of retribution. Social differentiation may be recognized, but such recognition rarely translates into an examination of the power relations that underpin differences in vulnerability. Doing so would entail a broadening of the analytical scope to the historical processes, economic forces, and policy mechanisms that link communities to regional and global systems. But the micro-level, present-oriented thrust of participatory and ethnographic methods does not facilitate this type of multi-scale analysis.

Climate prediction research has sought to capitalize on the advantages afforded by these approaches to gain insights into users' information priorities and decision-making processes. There is widespread agreement that stakeholder participation and partnerships are essential to developing relevant application tools and to sustaining viable communication flows (Hammer et al. 2001, Meinke et al. 2001, Hansen 2002, Hartmann et al. 2002, Nelson et al. 2002, Podesta et al. 2002, Patt & Schrag 2003, Patt et al. 2005). The need for ongoing dialogue between scientists and farmers has been especially emphasized (Hammer et al. 2001, Hansen 2002). At the same time, there have been efforts to overcome the limitations of participatory research, for example by combining village-level research with structured large scale surveys (Letson et al. 2001, Phillips et al. 2001, Podesta et al. 2002, Phillips & Orlove 2004, Patt et al. 2005, Ziervogel et al. 2005) and by using institutional or policy analysis to link multiple scales (Lemos et al. 2002, Ziervogel & Downing 2004). The present study examines a broad range of field-based studies on climate forecasts to assess how the methods applied capitalize or improve upon participatory research.

The review centers on 2 classic domains of ethnographic and participatory research: (1) the cognitive and cultural landscape in which farmers' understanding of climate is grounded and (2) the decision-making process and environment which shapes their adaptive responses to climate information. The first part analyzes approaches that seek to elicit how farmers perceive and predict climate events and how these perspectives relate to scientific forecasts. At its core, this section addresses the long-standing question of whether and how farmers understand the probabilistic nature of climate forecasts and how they assess the credibility and accuracy of such information. The second part examines efforts to elucidate the configuration of options and obstacles farmers face in applying climate forecasts to mitigate risk. The key challenge remains that of unraveling the sequences of steps and interplay of factors in the decision process in order to assess the precise role of climate forecasts and their relation to impacts. The present study concludes by stressing the need for climate application studies to move from a narrow 'technology-adoption' focus toward a political ecology of adaptation. This means expanding the analytical scope from the micro-dynamics of individual and household decisions to the broader framework of pressures and uncertainties that shape farmers' livelihood strategies. Methodologically, it calls for a cross-scale, multi-sited approach to research design and a multi-disciplinary mix of interactive and structured tools and techniques.

2. CULTURAL AND COGNITIVE FRAMEWORKS

Several field studies address the relation between climate, culture, and cognition. This section begins by examining efforts to uncover the basic conceptual framework that underlies farmers' understandings of climate. Such efforts center on linguistic analyses of typologies and terminologies of seasonal change and climatic events. Ethnographic research on local forecasting knowledge also highlights salient aspects of climate and common indicators used to predict it. Ethnographic approaches reveal that discrepancies exist between how farmers think and what they want to know about climate on the one hand and how forecasts are formulated by scientists on the other hand. At the same time, however, they stress the composite and changing nature of local cultural systems, showing that they are not necessarily incompatible with or vulnerable to the introduction of scientific forecasts. Interactive experiments show that farmers' ability to understand scientific forecasts can improve, particularly by integrating such forecasts with farmers' own knowledge and experience. However, attitudes towards forecasts are not only a function of what farmers understand, but also of what they believe. Confidence levels are shaped by multiple factors, including the social position and personal experience of decision makers. Cultural notions of what is true and trustworthy are also crucial in assessing credibility and accuracy both in farming communities as well as scientific circles. The uncertainty of climate predictions means that their communication and interpretation are shaped not only by cultural contexts but also by power struggles involving different intermediaries and stakeholders.

2.1. Cultural understandings of climate

Research on risk communication indicates that people filter and absorb climate information in terms of their prior assumptions and attitudes (Kempton et al. 1995, Thompson & Rayner 1998, Magistro & Roncoli 2001, Morgan et al. 2002). Thus, an inquiry into the cultural meaning that underlies farmers' understandings of climate, both its ordinary and abnormal manifestations, is a necessary first step in climate application studies. Given the centrality of 'seasons' in climate predictions, Orlove (2004) explored how different cultures divide the calendar year. Comparing data from 28 language groups, he examined terminologies used to name the seasons, their sub-components and their distinctive attributes and predictors. The analysis shows that most cultures divide the year into periods of different lengths, which are defined in terms of atmospheric and environmental observations. But the notion of the calendar year is by no means universal. In Uganda, where rainfall patterns are bimodal (two seasons per year), there is still no local language term for the calendar year, as the notion was only introduced in the 19th century by the British colonial administration.

Seasonality is an important dimension of rural livelihoods in Africa and in other parts of the world, which structures fluctuations in vulnerability and the implementation of adaptive strategies. Therefore, the study of seasonal changes in resource availability and human activity is a fertile ground for investigation. Seasonal calendars, a hallmark tool of participatory rural appraisals, have often been used in climate application studies to map out the sequencing of climate events, cropping cycles, and farm work (Eakin 1999, Bohn 2000, 2003, Vogel 2000, Letson et al. 2001, Phillips et al. 2001, Ziervogel & Calder 2003). These efforts are valuable, as they make it possible to gain insights into how local people experience climate variation over time. They do, however, have limitations. Among them is the tendency to produce normative, static models of farming systems, which hardly render the dynamic, iterative nature of agricultural adaptations. Furthermore, calendars and timelines are often patterned upon Western notions of time and climate. The study conducted by Gadgil et al. (2002) among Indian peanut farmers is a notable exception, as researchers adopted local classification of the solar calendar into 13–14 d periods (known as 'nakashatras') to structure the research design.

The study of taxonomies and typologies, using ethnographic interviewing, has contributed to climate prediction research by revealing salient principles that underpin cultural models (Spradley 1980, Werner & Schoepfle 1987). This approach was applied by the Climate Forecasting for Agricultural Resources (CFAR) project in Burkina Faso to explore how farmers distinguish different types of rain (Roncoli et al. 2002a). The research showed that rain events are classified in terms of their timing (e.g. when rain falls and how long it lasts), which translates into crop impacts. The temporal dimension was also found to be central to farmers' evaluations of seasonal rainfall, as shown by a ranking exercise, another common tool in participatory approaches (Roncoli et al. 2002b). Focus groups were asked to reach consensus about the relative performance of the last 10 rainy seasons by assigning a number of points to each. Farmers' discussions revealed the criteria whereby they evaluate rainfall in different seasons, pointing to the importance of the duration of the rainy season (e.g. timing of onset and end of the rainy season) and the distribution of rainfall during the season (e.g. occurrence of dry spells at vulnerable stages of cropping cycles). Because of the importance of the duration of the rainy season for successful crop production under Sahelian conditions, participants in the CFAR project in Burkina Faso understood forecasts for a rainy season that is drier than usual to mean that the season would be shorter than usual rather than one that produced less rainfall (Roncoli et al. 2004, 2005). This suggests that, unlike scientists, these farmers think about rainfall as a process rather than as a quantity. Yet, climate forecasts continue to be formulated in terms of quantity rather than temporal parameters, as currently available tools and models cannot reliably predict duration and distribution of rainfall.

The risk of misinterpretations or mistrust of climate forecast due to a lack of concordance between the cognitive frameworks of users and producers of climate forecasts has been long recognized, not only in relation to farmers but also to institutional decision-makers (Orlove & Tosteson 1999). Using a mental model approach (Morgan et al. 2002), Hansen et al. (2004) compared how Florida farmers and climate scientists conceptualize climate variation and its determinants. The analysis indicates that the farmers think in terms of shorter timeframe and localized scale, while the scientists have a more long-term global perspective. This methodology is useful in uncovering cultural assumptions that structure respondents' attitudes and actions, about which they are unaware, hence unable to articulate when they answer survey questions. Because it relies largely on open-ended in-depth interviews, the mental model approach is labor intensive and places high demands on farmers' time (Hansen 2002). Consequently, it tends to involve small non-random samples and its findings cannot always be generalized. As with classificatory systems, there is also the danger of representing cultural models as if they were rigid blueprints that people carry in their heads, disarticulated from the social context. The authors of the Florida study avoid this pitfall by recognizing that farmers' mental models shifted during interviews, but they report no corresponding change in the scientists' models. The goals of participatory technology development and collaborative learning would be well served by a better understanding of how scientists' cultural models may (or may not) be affected by interaction with farmers and other stakeholders, including other scientists, funding agencies, policy makers, and the media.

2.2. Local forecasting knowledge

Local predictions provide clues about those aspects of climate that are most salient for farmers and about the kinds of climate information farmers seek to mitigate climate risk. At the same time, they can help enhance the relevance of scientific forecasts by integrating them with locally-specific observations. Ethnographic and participatory methods have been deployed to identify local sources and indicators for climate predictions used by farmers. Such methods include open-ended interviews and focus groups with farmers, elders, and local experts, as well as formal surveys to determine the distribution of knowledge in the general population (Bharara & Seeland 1994, Osunade 1994, Mutiso 1997, Finan 1998, Huber & Pedersen 1998, Eakin 1999, Phillips et al. 2001, Roncoli et al. 2002a, Kihupi et al. 2003, Luseno et al. 2003). These tools have elicited a rich repertoire of shared knowledge and specialized expertise based on environmental observations and ritual practices. In some cases, however, more effort has been directed to compiling inventories of signs and beliefs than to gaining insight into the cultural meanings and social life that such knowledge is embedded in. For example, the quantity of leaves and fruits produced by certain local trees are among the most common indicators mentioned by African farmers (Phillips et al. 2001, Kihupi et al. 2003). However, based on in-depth interviews in rural communities of Burkina Faso, researchers show that farmers do not rely on generic observations of any tree of a species. Rather, farmers base their predictions on specific trees located near their farms or homes, which have been objects of sustained monitoring over a lifetime of farming decisions (Roncoli et al. 2002a). Fieldwork among Andean farmers also found that forecast meanings are firmly grounded in locality, being considered valid only for the specific site where they are produced (Valdivia et al. 2003).

Researchers have used ranking matrices to elicit farmers' views of the relative importance of different indicators in order to identify which information parameters are most salient to them (Eakin 1999, Phillips et al. 2001, Luseno et al. 2003). These rankings, however, should be interpreted in the context of the variability of microenvironments, seasonal climate, and crop outcomes. For example, farmers may rank as highest those indicators that were most noticeable in the recent past or information about aspects of climate that have just occurred (e.g. end of the season) or that have had a particularly severe effect on crops (e.g. occurrence of dry spells). Significance of different forecast parameters also varies for different crops or activities (Ingram et al. 2002, Ziervogel & Calder 2003).

Given the diversified nature of rural livelihoods, farmers' knowledge sources and needs are likely to encompass a mix of parameters which may be significant for different types of producers or production systems. Field research among African farmers shows that they do not generally rely on a single forecasting indicator. Rather they consider signs and clues that arise at various times and from multiple settings, without striving to fit them into one coherent scenario (Roncoli et al. 2002a, Luseno et al. 2003). In farming, they combine their own experience with agricultural extension advice. To predict the future, they rely on traditional diviners as well as prophesies derived from Christian and Islamic scriptures (Roncoli et al. 2002a). This eclecticism is a reflection of both cultural frameworks and environmental processes. Among the Mossi of Burkina Faso, it epitomizes an understanding of human knowledge as always contingent and incomplete, and therefore inherently unable to convey the full truth based on any one source or indicator. Likewise, the experience of devastating fluctuations in climate that have occurred in the Sahel in the last 30 yr has made farmers in that region less confident in their own predictions and keen to obtain externally-produced forecasts (Roncoli et al. 2002a). Such findings have led some to question whether the introduction of scientific knowledge is contributing to the demise of local culture (Roncoli et al. 2000a). But anthropologists have stressed that such threat may rather stem from the pressures that climate change, environmental degradation, adverse economic conditions, unfavorable policies, and political instability place on local livelihoods and social networks (Finan & Nelson 2002, Lemos et al. 2002, Roncoli et al. 2002a, Luseno et al. 2003).

Another long-standing question is whether traditional forecast indicators are reliable and have a scientific basis. The dearth of long-term data series for local indicators, such as fruiting of wild tree species or behavior of birds or insects, has hampered efforts to assess their scientific validity. In a few cases, natural causality has been deduced or demonstrated in the case of phenomena such as the appearance of celestial bodies (Pepin 1996, Orlove et al. 2000, 2002) and the direction and intensity of winds (Kanani & Pastakia 1999 cited in Orlove et al. 2002, Waiswa et al. 2004). This question can only be successfully addressed by innovative cross-disciplinary research, such as the path-breaking study of Andean farmers' predictions conducted by Orlove et al. (2000, 2002). This study combined analyses of ethnographic, historical, agricultural, atmospheric, and astronomic data to show that traditional forecasts of seasonal climate based on the visibility of the Pleiades have a certain level of skill as well as a natural explanation.

2.3. Communicating probability

Ethnographic research on local forecasting knowledge illuminates another debated issue in climate application work, namely whether and how decision makers, and particularly those with less education and fewer resources, may understand the uncertainty of forecasts (Orlove & Tosteson 1999, Stern & Easterling 1999, O'Brien et al. 2000). Risk communication studies have shown that lay users' processing of probability is marred by cognitive biases (Nicholls 1999, Kahneman 2003, Marx et al. in press). Such biases may be stem from the communication process itself, for instance whether uncertain information is presented in the form of descriptive statistics or vivid imagery (Marx et al. in press), or it may stem from the users' own personal experience, for instance from recent events (Hammer et al. 2001, Hansen et al. 2004, McCrea et al. 2005).

The concern that probabilistic forecasts may increase farmers' vulnerability has given rise to a multiplicity of experiments conducted during ethnographic fieldwork or participatory workshops. Luseno et al. (2003) used a 'proportional piling' exercise (a common participatory research tool) to test this capacity among East African pastoralists. The latter were given 12 stones and invited to allocate them to 3 piles according to their expectations that the upcoming season would receive above, below, or near normal rainfall. The fact that most respondents placed some stones in each of the piles, rather than all in one pile, was interpreted as evidence that they had some notion of probability distribution. Likewise, researchers in Zimbabwe engaged farmers in exercises with pie charts divided into sections and mounted on spinners (Suarez & Patt 2002). Farmers went through several iterations of this game confronting increasingly complex configurations of probabilities. Participants' understanding of probability distributions and their ability to integrate forecasts into their decisions improved based on feedback from success and failure, validating findings from studies indicating that farmers can learn how to use forecasts if exposed to them for a few years (Roncoli et al. 2000a, 2005, Patt 2001, Patt & Gwata 2002, Podesta et al. 2002, Phillips & Orlove 2004, Ziervogel 2004). A problem with these simulations, however, is that they are disconnected from the context of everyday life. Some climate application studies have sought to address this shortcoming by building on illustrations drawn from local experience, such as when people look for signs that may predict the sex of an unborn child (Phillips & Orlove 2004) or when soccer fans estimate the likelihood of victory based on the absence or presence of star players (Suarez & Patt 2002). These studies have shown that most farmers are able to understand that, even when signs indicate one outcome as most likely, a different outcome may indeed occur.

In Burkina Faso, the CFAR project team faced the challenge of explaining a weak probability forecast, in which the chances that seasonal rainfall would be above, below, or near average would be almost the same. They did so by devising the example of a farmer who randomly captures a chicken from his/her chicken coop to sell at the market. Probabilities were represented by numbers of chicken of 3 different colors. In a strong probability scenario, the chicken coop would host many more chickens of one color than of the other two. In a weak probability scenario, there would be similar numbers of chickens of each color, so that the likelihood of selecting any color was about the same. A subsequent survey indicates that almost half of the participants understood that the likelihood of occurrence of different rainfall scenarios differed, although not by very much (Roncoli et al. 2005). Yet, as with the cases examined above, these hypothetical scenarios and examples do not adequately render the complexity, iterative nature, and livelihood implications of real-life agricultural decisions.

Given the difficulties of explaining terciles (which define the probability of rainfall being above, below, and near long-term average) to users, some projects experimented with other ways of representing probability. Preliminary studies show that farmers in the Southeast USA and in Argentina find probability-of-exceedance graphs, showing the likelihood that rainfall would exceed or fall below a given threshold, more useful than terciles (Breuer et al. 2000, Hansen et al. 2004). A recent study in Kenya tested a module for communicating forecasts that used such graphs (J. W. Hansen pers. comm.). The basic assumption was that farmers' understanding would be enhanced if the new information was presented in ways that built on their personal experience. Thus, participants were shown time-series graphs of past climate variation (monthly rainfall distribution) and were then led from this more concrete level to a more abstract representation of hypothetical forecasts in the form of probability of exceedance graphs (Hansen et al. 2004).

While visual representation is often believed to be a universal medium, verbal communication may be more suitable to climate application efforts in Africa, where knowledge is most often processed and transferred orally. In the course of participatory workshops in Burkina Faso, narratives, analogies, and metaphors elicited a more favorable response than visual aids and practical exercises (Roncoli et al. 2002c). The importance of linguistic aspects of climate prediction is illustrated by a recent study conducted among farmers in Uganda (Orlove & Kabugo 2005). The analysis centered on a set of 20 cases of 'signs' that predict climate and non-climate related events, showing how their meaning is far from fixed (e.g. X means Y), but constantly re-negotiated in the course of daily conversations. The study has recently moved its focus from conversation among individuals to discussion of climate forecasts within farmers' groups. Combining linguistic analysis of transcripts of group discussions, ethnographic observation of participatory processes, and follow-up interviews with group participants, this research examines how social context (e.g. hierarchies based on ethnicity, gender, and seniority) shapes the processing of climate information. The underlying premise is that, rather than being neutral technical information, climate predictions insert themselves in existing power relations and can catalyze dynamics that can be revealed through an analysis of social discourse (Orlove et al. 2006).

The probabilistic nature of climate forecasts amplifies the risk that the information may be distorted by communicators and intermediaries (Broad 2000, Podesta et al. 2002). While development agents, extension workers, farmer representatives, village leaders, etc. can play useful roles in facilitating forecast use, they may also publicize diverging interpretations that confuse users. There is ample evidence of the role of the media in translating probabilistic forecasts into deterministic statements and sensationalistic warnings (Nicholls & Kestin 1998, Pfaff et al. 1999, Broad & Agrawala 2000, Glantz 2002, Lemos et al. 2002). Field studies have also documented cases in which commercial operators have bent the interpretation of climate forecasts in ways that served their interests (Pfaff et al. 1999, Hammer et al. 2001, Broad et al. 2002, Ingram et al. 2002, Roncoli et al. 2004). In these situations, the ability to access and interpret raw information gives certain stakeholders (e.g. industrial fisheries) an edge over those with more limited skill and resources (e.g. artisanal fishermen). In some countries, investigating and documenting these cases may entail ethical dilemmas and political risks: foreign researchers may be refused research permits and their local collaborators and sources may suffer harassment.

2.4. Assessing credibility and accuracy

To minimize the possibility of misunderstandings and manipulation and to balance caution and confidence in responses to climate forecasts, decision makers must be able to assess the accuracy of the information as well as the credibility of its source. Confusing or inaccurate wording can seriously undermine farmers' ability to do this, leading to over- or under-reactions. Several researchers have stressed the need for precision about what is being predicted (for example, explicitly referring to 'rainfall' rather than to 'season' or 'yields') and for clarity about the timescale and uncertainty of the forecast (Fischhoff 1994, Hammer et al. 2001, Letson et al. 2001, Hansen 2002, Patt & Gwata 2002, Podesta et al. 2002, Ziervogel 2004). Vague terms such as 'likely' or 'normal' may be interpreted differently than intended (Nicholls & Kestin 1998, O'Brien et al. 2000, Phillips et al. 2002, Tribbia 2002, Patt & Schrag 2003, Hansen et al. 2004).

Attention to language is important, not only in communicating forecasts but also in assessing decision makers' reactions, all the more so when this assessment entails translation across languages and cultures. For example, a study conducted in 3 communities in Mali (part of a larger-scale project with over 500 respondents in 13 villages in 4 Sahelian countries), reports that most respondents rated scientific forecasts between 'satisfactory' and 'excellent' in terms of reliability, friendliness, timeliness, resolution, presentation and lead time (Tarhule & Lamb 2003). Yet it is unclear how such parameters were operationalized into survey questions and translated into comparable terms in multiple languages. In contrast, in reporting findings from their study of Argentinian farmers, Letson et al. (2001) offer to provide the Spanish version of questions and responses.

Recognizing that farmers' perceptions of accuracy of climate forecasts may fluctuate at different points in time and across spatial and social boundaries, studies have sought to elucidate the determinants and patterns of such variation. A key question is how farmers' attitudes about forecasts change in relation to the performance of forecasts over time. These efforts have largely centered on structured surveys and quantitative modeling, striving to quantify how many times forecasts must be 'right' before farmers are willing to trust them, or how many times forecasts may 'fail' before farmers lose confidence in them (Ziervogel et al. 2005, Cabrera et al. 2006a). A range of formal and informal methods has been used to identify patterns and variables that may explain different levels of trust in forecasts. Ethnographic research shows that, while farmers everywhere recognize the uncertain nature of local predictions, belief in their reliability fluctuates widely. For instance, confidence in traditional forecasts was found to be waning in Burkina Faso and Mexico (Eakin 1999, Roncoli et al. 2002a), while it remained strong in East Africa and in the Andes (Luseno et al. 2003, Valdivia et al. 2003). Even within the same region, trust in forecasts may differ across sectors of the population. Stratified sample surveys of Bolivian farmers and East African pastoralists found that formal education, off-farm income, urban residence, and access to roads were factors associated with lower confidence in local forecasts and potentially greater openness to scientific forecasts (Valdivia et al. 2001a, Luseno et al. 2003). Farmers' expectations and assessments of accuracy differ as well in relation to the source of climate information (Jones et al. 2000, Ingram et al. 2002, Jagtap et al. 2002). Nelson & Finan (2000) reported that Brazilian farmers expect greater accuracy from meteorologists than from traditional rainmakers. Yet, a study conducted among Indian peanut farmers shows that they recognize that climate prediction is not an exact science and that scientists may disagree among themselves about what forecasts mean (Gadgil et al. 2002).

The meaning of 'truth' and 'trust', both core elements in social discourse on climate forecasts, are also defined by culture and context. There may be substantial discrepancies between the ways people in rural communities and in scientific circles establish what counts as truth and what warrants trust. In some African cultures, for example, credibility is gained by speaking prudently and behaving with caution and reserve. Among the Fulbe, a pastoralist society of West Africa, asserting something one is not sure about is considered reprehensible, almost a form of 'lying' (Riesman 1992). In scientific circles, on the other hand, credibility hinges on being explicit about methods used (e.g. defining the forecast parameters), and quantifying as much as possible (e.g. in a probability distribution). Cultural values are at work in both cases. Ethnographic research shows that beliefs about the purpose of science and the role of technology in research shape experts' judgments about the soundness of evidence of global warming (Lahsen 1999). Reconciling various stakeholders' assessments of the meaning and accuracy of climate forecasts will require expanding the scope of fieldwork beyond farming communities to examine the scientific process as cultural practice.

A common limitation in assessments of farmers' understanding of probability, including some cultural model work, is the tendency of taking farmers' statements at face value, without considering how culture structures not only what people think, but also how they talk about it. For example, the future may be understood as pre-determined by divine plans, but the latter are unknowable to humans, who therefore face uncertainty. In this perspective, forecasting may be seen an expression of vanity or of lack of faith in God's mercy (Roncoli et al. 2002a). And yet, the belief that all is in divine hands does not prevent farmers from engaging in purposive action, including prayers to negotiate a more favorable fate or from enacting concrete strategies to mitigate their vulnerability to risk (Roncoli et al. 2002a). It is therefore important to examine what farmers say in the context of what they do. The next section considers how farmers' understandings of climate forecasts translate into management decisions and livelihood outcomes.

3. DECISION PROCESSES AND CONTEXTS

Decision-makers differ in their vulnerability to climate fluctuations and in their ability to use climate information. Inequalities in resource endowment and social entitlements mean that some farmers are better able to access and apply climate forecasts to their benefit than others. But contrary to what is often assumed, vulnerable farmers are not entirely precluded from adopting forecast-based adaptations. While they may be hindered by a dearth of resources, poor farmers are nonetheless able to use forecasts by making small adjustments in their productive strategies as the season unfolds. The complex, iterative nature of these strategies and of the multiple determinants of production means that they are rarely captured by formal surveys. Farmer-centered, interactive approaches enable insights into the dilemmas and the trade-offs farmers face at each stage of the decision process. In so doing, they provide a reality check on simulation modeling and decision support tools that are used to assess the outcome of alternative options. However, the configuration of these options, including the availability of climate information, is shaped by the policy and institutional arrangements fashioned by supra-local players, such as the State. Likewise, an assessment of impacts must consider stakeholders that fall beyond the community territory or the agricultural sector. In highlighting the diversity of decision makers and complexities of decision making, this section challenges decision analysis and decision support efforts that are solely focused on household-level and on-farm dynamics and calls for multi-sited, interdisciplinary research efforts.

3.1. Characterizing vulnerability

It is widely recognized that, given its multidimensional nature, climate vulnerability cannot be represented by a single variable. Vulnerability studies have used indicators or thresholds that signify livelihood security (crop yields, nutritional measures) or capacity for resilience (literacy, infrastructure, property rights, etc.) (Stephen & Downing 2001, Luers et al. 2003). Drawing on extensive experience with household livelihood assessment work, Finan & Nelson (2002) developed a multidimensional approach in order to classify 500 households in northeast Brazil according to their different levels of vulnerability to extreme climate events. The classification was based on variables such as land and livestock, income flows, technology, off-farm income, coping strategies, drought responses, knowledge and use of climate forecasts, and participation in relief and support programs. In addition, for each household, researchers calculated the value of subsistence crops produced and of cash crop sales, and constructed a 3 level matrix based on values of farm production and animal assets.

Measuring socioeconomic diversity among farming households can be a challenge in areas where means and outcomes of production are not always commoditized or easily quantified, such as in many parts of Africa (Scoones 1995). In a case study on responses to drought in Burkina Faso, sample households were stratified according to distribution of animals and other material assets (plows, donkey carts, bicycles, radios), estimating values at the average selling prices at the time of the survey (Scoones 1995). However, these measures were necessarily imprecise, because (1) ownership, especially of livestock, is often vested in relations that cross-cut individual households; and (2) asset and animal ownership is a dynamic variable characterized by frequent turnover, especially during the dry season when animals are sold or slaughtered for religious and social celebrations and marriage transactions. To address these limitations, a participatory wealth ranking exercise was conducted with local informants who used local indicators of well-being, centered on productive assets (plows, livestock, male labor) and food security, to cross-validate the stratification based on survey results.

Rather than stratifying households on the basis of quantitative variables, Valdivia et al. (2001a,b) opted for a qualitative approach, centered on a typology of livelihood portfolios. Drawing from a survey of 45 families in Bolivia, they identified 9 variables that capture crucial aspects of relative vulnerability, including stage in life cycle, levels of technological intensity, market integration, off-farm income, investments, and ability to adopt less vulnerable technologies. By applying cluster analysis, they devised a classification composed of 3 levels of livelihood diversification. Their study showed that households with greater off-farm incomes were better able to use climate forecasts, not only to reduce risk, but also to maximize opportunities. Yet, diversification could also undermine the ability to predict climate risk because more diversified farmers spent less time in the fields or in the communities and were therefore less able to observe forecasting indicators (Valdivia et al. 2003). This research spanned several years and included Andean communities in Bolivia and in Peru. This enabled researchers to conduct panel surveys during years marked by different rainfall outcomes in combination with ethnographic methods, such as focus groups, case study interviews, and network analysis.

Field-based studies also highlight the significance of non-economic dimensions of vulnerability. Among Andean farmers, the elderly and those with tenuous connections to extra-community institutions and social networks were found to be at disadvantage (Valdivia et al. 2001a,b). In Brazil, greater vulnerability was defined by low levels of education and remoteness of residence (Lemos et al. 2002). In West Africa, the CFAR project found that gender, ethnicity, and caste were key dimensions of marginality (Roncoli et al. 2002b, 2004, 2005). While quantitative methods are important in operationalizing variation among users and correlations with causal factors, they do not often reveal these more subtle aspects of vulnerability. In-depth interviewing and participant observations are instrumental in elucidating the social and ideological mechanisms that reproduce privilege and marginality in everyday practice.

3.2. Identifying opportunities and constraints

The deconstruction of the 'user' category into differently endowed and socially positioned groups, as illustrated above, dovetails with efforts to identify constraints and opportunities to applying climate forecasts to agricultural decisions. Drawing from a comparative analysis of case studies of forecast dissemination among producers of developing countries, Archer (2003) stressed the need to identify vulnerable social groups that are at risk of being 'underserved' by climate application efforts. She proposes that this be done by drawing on the methodological and theoretical advances in the fields of vulnerability science and gender analysis. Archer's own work amongst South African smallholders provides an example of this kind of disaggregated analysis, showing how significant differences among users can exist within households as well as among households. By means of a combination of statistical analysis and qualitative methods, the study indicates that gender and relationship to the household head determine differential access and ability to respond to forecasts.

Most studies on farmers' access to information have relied on formal surveys. The data show that resource-limited rural producers are less likely to receive forecasts from extension services or the media (Hudson & Vogel 2003, Phillips 2003, Thornton et al. 2004). Literacy and language barriers often exclude the rural poor, ethnic minorities, pastoralists, and women. While many studies identify the radio as the most common means of communication in rural areas, they also recognize that broadcast coverage does not always reach remote areas, where pastoralists move with their herds and the cost of batteries can be an obstacle for those with limited cash income (O'Brien et al. 2000, Phillips et al. 2001, Luseno et al. 2003, Phillips 2003, Orlove et al. 2004, Ziervogel 2004). Time constraints also prevent farmers, and especially women, from listening to radio programs. In South Africa, Archer (2003) found that forecasts disseminated through radio were more likely to reach men, while women relied more on personal interaction with extension agents. But in other parts of Africa, government extension services are being weakened by reductions in public spending mandated by structural adjustment programs or replaced by private providers, who may favor better-off farmers who can pay for the services.

Participatory approaches have enabled researchers to better understand communication patterns among farmers and to devise and test innovative dissemination strategies. For example, Valdivia et al. (2003) applied network analysis to explore the flow of climate information among different categories of Andean farmers, from local experts to intermediaries, to users (Valdivia et al. 2001b, 2003). Recognizing the centrality of farmer-to-farmer communication, the CFAR project in Burkina Faso has trained key farmers (representative of different social groups) to operate as information nodes between forecast producers and their own communities (Roncoli et al. 2002b, 2005). Taking advantage of the growing popularity of cellular phones, researchers in Uganda worked with journalists to produce interactive radio programs, during which listeners could intervene by calling in, thus overcoming one of the main limitations of dissemination by radio, namely the inability to ask questions (Phillips & Orlove 2004). In Uganda and elsewhere in Africa, the RANET project (www.ranetproject.net) has promoted an information system based on solar-powered equipment, mobile radio stations, and satellite-based internet technology as a way to reach marginal populations and to directly involve communities in programming. But in many parts of Africa, the Internet continues to 'by-pass' poor farmers and may not be a realistic option in the near future (Besemer et al. 2003). Participatory farmer workshops, which introduce scientific forecasts by building on farmers' own knowledge and experience, have proven to be more effective in facilitating understanding and use of forecasts than outreach efforts through government extension and mass media (Phillips & Orlove 2004, Patt et al. 2005, Roncoli et al. 2005). However, none of these studies elucidates the cognitive processes whereby these approaches translate into greater comprehension and confidence.

Evidence from Latin America and southern Africa, where seasonal precipitation forecasts have greater skill and dissemination is more institutionalized, indicates that even when farmers receive, understand, and trust climate forecasts, their willingness and ability to apply them to production decisions remain low (O'Brien et al. 2000, Letson et al. 2001, Phillips et al. 2001, Valdivia et al. 2001a, Lemos et al. 2002, Ziervogel & Calder 2003, Boone et al. 2004). This has often been attributed to low levels of awareness and understanding of the information by farmers. But non-adoption may also result from a failure by scientists and policy-makers to appreciate the complexities and constraints that characterize the decision environment in which farmers operate (Podesta et al. 2002). Fieldwork among producers of developing countries has shown that this environment is often characterized by severe material and institutional constraints, such as lack of land, labor, seed, inputs, credit, animal traction, tenure security, market access, and information (Eakin 2000, O'Brien et al. 2000, Vogel 2000, Phillips et al. 2001, Valdivia et al. 2001a, Ingram et al. 2002). Resources that enable rapid, flexible responses to climate variability, such as labor-saving technology and farm credit, are key factors in household resilience and productive viability. For example, farmers who have plows or tractors can plant earlier, thereby getting a head start on a farming season that promises to be drier than normal. They can also expand their planted acreages to take advantage of good rains or make up for lower productivity in case of poor rains. Farmers with large households or the means to mobilize extra-household labor are better able to practice water conservation techniques or build bunds and ridges to control water flow in their fields. Those who have access to multiple and diverse landholdings may choose to plant field types with lesser or greater water retention capacity, according to whether more or less rain is predicted. Forecasts may induce farmers to choose different crops or crop varieties (e.g. drought resistant or high yielding cultivars), but these choices require money and connections to procure seed. Farmers may regulate fertilizer application to prevent crop scorching in case of drought or to maximize yields if it rains well, or adjust use of chemical inputs to control weeds and pests that may proliferate in different climatic conditions. But these strategies entail additional cash and labor outlays. Affluent farmers are generally more able to mobilize these resources and can, therefore, take better advantage of climate information.

This situation appears to support the hypothesis that, while poor farmers may stand to benefit from forecasts the most, they may be prevented from realizing such benefits by lack of means to enact appropriate and timely responses (Blench 1999). This assumption has led some researchers to propose that climate application efforts should target larger, intensive, market-oriented producers, who are more likely to use and benefit from climate forecasts than marginal subsistence farmers (Amissah-Arthur 2003). Yet, other researchers have found that lack of resources does not entirely preclude the adoption of climate forecasts (Ingram et al. 2002, Phillips 2003, Phillips & Orlove 2004, Ziervogel 2004, Patt et al. 2005, Roncoli et al. 2005). Several case studies illustrate that poor farmers can also make use of forecasts, mostly by making small experimental adjustments in management strategies (Eakin 2000, Hammer et al. 2001, Phillips et al. 2001, Hansen 2002, Ingram et al. 2002, Patt et al. 2005, Ziervogel et al. 2005). Based on a survey of about 500 farmers in Zimbabwe, Patt et al. (2005) found no significant correlation of forecast use with wealth status, educational levels, and demographic characteristics. In coastal Peru, less educated lower-income residents exhibited higher response levels, because they needed to bolster their poor quality dwellings against the possibility of flood damage (Orlove et al. 2004). By combining participatory methods with quantitative surveys and agent-based modeling, a study among farmers in Lesotho showed that, while wealthy households realized greater yield gains, climate forecasts benefited poor farmers the most by reducing the likelihood of food shortage (Ziervogel et al. 2005).

3.3 Understanding farmers' decisions

Examples of potential positive effects of forecast application to agriculture, such as those reported for Argentina, Zimbabwe, and India (Hansen 2002), are generating considerable optimism. But demonstrating a direct linkage between changes in crop yields and specific management practices that are assumed to result from climate forecasts remains a challenge, as production decisions and outcomes are determined by many environmental, agronomic and economic factors other than climate (Patt et al. 2005, Ziervogel et al. 2005). The study by Patt et al. (2005) in Zimbabwe breaks new ground by empirically testing the hypothesis that climate forecasts induce management decisions that lead to actual increases in yield. The authors found evidence that farmers who attended participatory workshops and used forecasts obtained small increases in production. Yet, they could not establish a clear connection between those farmers' cropping choices and subsequent yield gains and they did not unravel the reasoning process that translates farmers' interpretation of the forecast into adaptive decisions.

Understanding this reasoning process is crucial, because even successful agricultural adaptations entail additional costs, risks and trade-offs (Roncoli et al. 2001). A forecast for poor rainfall, for example, may induce farmers to choose crops and varieties that withstand drought but are less productive or less marketable, or to plant in lowland areas that become flooded if it rains more than predicted. Farmers' choices are shaped by livelihood needs and goals (e.g. a health crisis or desire for education) and cultural values (e.g. preferences for certain staple foods). Decisions may also be informed by farmers' tacit knowledge, based on years of experience and interaction with their environment, which farmers may not be consciously aware of, thus rendering them unable to articulate such knowledge in response to research questions (Luseno et al. 2003). These complexities cannot be easily captured by the formal methods that characterize most agricultural research. Intensive interaction with farmers and in-depth data collection techniques are essential to illuminate the iterative nature of farmers' decision-making processes and the interplay of influences that shape them (Hansen et al. 2004). For example, in Burkina Faso the CFAR project relied on ethnographic interviews with key informants to develop a decision tree model (Gladwin 1989) for different types of farming systems and rainfall scenarios (Roncoli et al. 2000b). The approach enabled researchers to identify key points in the decision process where management practices might be modified to adapt to predicted climate scenarios, as well as the dilemmas farmers face in making such adaptive decisions.

An increasing awareness of the constraints and challenges that characterize farmers' decisions has prompted an interest in combining agronomic modeling with participatory approaches (Nelson et al. 2002, Podesta et al. 2002). Simulation models and decision-support tools can also facilitate learning by farmers as well as scientists by enabling them to explore different options and the potential risks and gains associated with them (Tsuji et al. 1998, Jones et al. 1999, Hammer et al. 2001, Meinke et al. 2001, Hansen 2002, Boone et al. 2004, Ritchie 2004). The South East Climate Consortium (SECC) in the southern USA has demonstrated that stakeholders' involvement, through workshops, participatory appraisals, and feedback mechanisms, is crucial to the development of demand-driven, climate-based decision-support tools for producers and intermediaries (Breuer et al. 2000, Jagtap et al. 2002, Cabrera et al. 2006a,b). Some have also suggested that models may be more useful in stimulating dialogue than in directing decisions, particularly when the design of interactions is informed by social learning approaches, rather than spearheaded by scientists (Hammer et al. 2001). Meinke et al. (2001, 2006, this issue), on the other hand, caution that intensive scientist–producer interaction may not always be feasible or sustainable in areas where literacy levels are low, such as in Africa.

Interactive exercises and workshops have also provided a context for simulating how farmers incorporate new information and lessons from experience into their management decisions. Hansen et al. (2004) engaged farmers in Argentina in a set of farm decision simulations. Farmers were given maps of land holdings and detailed information about cropping history, prices, etc. and asked to decide what crops they would grow. The same task was repeated first without the forecast and then with the forecast, which was presented in 2 different formats to test their relative effectiveness. In Lesotho, Ziervogel (2004) used role-plays illustrating how farmers would advise neighbors on crop and livestock management strategies to adopt in response to forecasts for either above or below normal rainfall; 3 rounds (representing 3 consecutive seasons) were repeated to capture how decisions were influenced by what happened the previous year. She also applied a matrix to examine consequences of a 'false' forecast for both below and above average rainfall scenarios for better-off and resource-poor farmers. This method also elucidates how variation in asset endowment among households determine different forecast-based adaptations and in livelihood impacts.

Some studies are moving beyond the single focus on agricultural production that characterizes research on forecast-based decision-making to consider how climate-related decisions articulate with other types of risks. In Lesotho, Ziervogel & Calder (2003) centered their analysis on an integrated model of sustainable household livelihood (Scoones 1998, Solesbury 2003). This model considered the totality of environmental resources (natural assets); financial, material, and infrastructural resources (economic assets); human energy, knowledge and skills (human assets); and social networks and institutional linkages (social assets). Using ethnographic case studies of farm households and hypothetical scenarios of climate variability, the study showed how forecast responses reflect and affect a household's endowment of various types of assets.

What is still missing from most climate application studies is an analysis that links these differences in household vulnerability and endowment to the framework of conditions and pressures that stem from the market and the state (e.g. how colonial rule or national politics exacerbated regional imbalances or stratification among ethnic groups).

3.4. Broadening the scope of analysis

While most climate application research has focused on farm-level and household-level decisions, some studies have sought to explore the broader institutional and policy context that shapes livelihood risks and resource entitlements. Echoing lessons from a large body of work on vulnerability and adaptation to climate uncertainty, pilot studies of climate forecast application have recognized that farmers' ability to use climate forecasts to enhance livelihood security and income opportunities hinges on the existence of an enabling decision environment (Pielke et al. 2000). Such an environment is structured by mechanisms that regulate access to land and natural resources, transport and market infrastructure, input and credit availability, agricultural extension, and other rural services (Pfaff et al. 1999, Broad 2000, Eakin 2000, O'Brien et al. 2000, Meinke et al. 2001, Finan & Nelson 2002, Ingram et al. 2002, Phillips et al. 2002, Podesta et al. 2002, Luseno et al. 2003).

In Lesotho, actor–network analysis was used to show how stakeholders' position and exchanges within an institutional and political network affected the types of information they are exposed to. Workshops at national and sub-national levels elicited participants' views about forecast utility, potential uses and impacts of forecasts, and participants' relation to other stakeholders (Ziervogel & Downing 2004). Focus groups and semi-structured interviews were also conducted with institutional stakeholders at various levels. A coding system characterized stakeholders in terms of workshop participation, being in the public or private sector, scale of activity, and roles in forecast use and dissemination. Stakeholder networks were then mapped out to identify institutional blockages in information flow. This spatial representation pointed to the relation of institutional actors to the state as the key factor. The analysis stops short of elucidating the power relations, political agendas, and conflicting interests that underpin institutional choices relative to climate predictions (a limitation the authors do recognize). But the methodology pioneered in this study can provide a powerful tool to advance this type of exploration.

The work by Lemos et al. (2002) and Finan & Nelson (2002) in northeast Brazil (1 study published separately by 2 sets of authors) offers a more contextualized institutional analysis that takes into account the complex interplay of conflicts and alliances among political actors at multiple scales. The researchers interviewed over 50 stakeholders at local, intermediate, and national levels, including political leaders, bank managers, rural extension agents, labor unions, NGOs, and the media. The institutional assessment was complemented by ethnographic fieldwork, and content analysis of media and government documents. By reconstructing the sequence of decisions that accompany the issuing of a forecast, the arrival of a drought, and the mobilization of drought relief programs, the study showed how political agendas influence the way climate information is distributed and utilized. The findings indicated that climate predictions play a double role in policy making. In some instances, decision makers use scientific information to legitimize politically expedient decisions. In other cases scientific findings contribute to public interests by setting limits to political favoritism (Lemos 2003).

Broad et al. (2002) provide a systematic framework for integrating political economy and stakeholder analysis, based on their study of industrial and artisanal fisheries in Peru. Drawing on ethnographic and archival research, they constructed a matrix depicting goals and decisions for a diverse range of stakeholders, including industrial and artisanal fishers, administrators, labor, banks, media and foreign interests, and environmentalists. The analysis showed how outreach strategies (e.g. whether to provide the forecast only to intermediaries or to the general public) imply a prioritization among stakeholders' interests. In different policy contexts (e.g. more or less restrictive regulations) and information environments (e.g. existence of one or multiple forecasts), such strategies affect stakeholders' goals (e.g. sustainability or national economy) in different ways. When these goals are in conflict and access to information is skewed, a win-win situation is not always possible. This is particularly the case when there is competitive use of common resources. The authors concluded that forecast application strategies must be informed by a disaggregate definition of societal impact, considering whose welfare counts as a benefit among groups, including future generations.

To capture impacts on direct and indirect (sometimes 'invisible') stakeholders, the scope of analysis needs to be extended beyond the 'local' and the 'present'. It needs to encompass effects on social groups that do not reside locally (e.g. pastoralists or migrants) and on those that do not farm, but have political clout (e.g. urban consumers). Phillips et al. (2002) combined national statistics on land use with survey data on 450 rural households in Zimbabwe to project the aggregate effects of farmers' planting decisions on consumer prices. For example, a forecast for drought conditions may induce farmers to reduce acreages planted, thus aggravating food shortages and price hikes at the national level. Hammer et al. (2001) also considered the implications that variations in crop calendars and forecast skill among regions of the world may have for international trade. They concluded that the ability to benefit from forecasts is likely to depend on where producers and consumers are located with respect to such variation.

Spatial analysis techniques, such as those proposed by Amissah-Arthur (2003) in her work in Kenya, can aid such investigations by illuminating the relation between regional patterns of market integration and land use on the one hand and the potential for using and benefiting from forecasts on the other hand. Geographic information systems and remote sensing can help elucidate how forecast responses may interact with intra- and inter-seasonal variation in resource availability and access. They can also facilitate assessments of landscape impacts of farmers' adaptations, such as the expansion of cultivation in wetlands, rangelands, or marginal areas. Participatory methods can enhance these efforts by ground-truthing imagery and incorporating farmers' perspectives. At the same time, spatial techniques can serve as tools in eliciting local knowledge and cultural perceptions. Realizing these synergies will require a close integration of social and biophysical sciences to be at the core of climate application research.

4. CONCLUSIONS

Sustained interaction with farmers is essential for gaining insight into how they understand and respond to climate information. Ethnographic and participatory methods throw light on the ways farmers perceive climate and its manifestations, its uncertainties and predictability, and the credibility and accuracy associated with climate information. They also enable us to better understand how farmers assess their vulnerability to climate risk, the obstacles and options they face, and the livelihood outcomes of the choices they make. However, to realize this potential, ethnographic and participatory approaches need to overcome their limitations. Ethnographic methods should not be reduced to descriptive compilations of typologies and indicators, and participatory methods need to go beyond the uncritical deployment of rural rapid appraisal tools.

Language is a rich arena for explorations of people's understandings of the past and the future, and the changes they experience (Hill 2003). A consideration of the historical influences that shape local notions of time and nature can infuse ethnography with an appreciation of the pluralistic and dynamic character of culture. Linguistic analyses of how key terminologies and their use shift over time and in different contexts can provide entry points into this process (Orlove et al. 2006). Language is the medium whereby people negotiate common understandings and solutions to the challenges they face (Easton 2004). Attention to the sociolinguistics of group interaction can enrich participatory approaches by throwing light on the cultural meanings and power differentials that structure public discourse. Climate application research offers a unique opportunity for investigating the relationship between uncertainty of information and dynamics of participation (Peterson et al. 2006).

A fundamental critique of farmer-centered approaches concerns the tendency to consider farmers as a homogeneous class. But disaggregating farmers into simple dichotomies, such as wealthy or poor, commercially- or subsistence-oriented, is equally inadequate. Many studies show that even resource-poor producers vary in terms of their exposure and sensitivity to climate shocks and in their ability to use decision support tools to bolster their resilience. Ethnographic research can elicit meaningful indicators whereby local people assess their own vulnerability and the inequalities that characterize their communities. Participatory methods can also be used to determine the range of response options and to rank them in terms of availability and preference. These qualitative parameters can then be used to stratify quantitative surveys and to structure modeling of available options and potential outcomes. Illustrations of such methodological pluralism can be found among studies of community-based carbon sequestration (Tschakert 2004) as well as in recent forecast application research (Ziervogel et al. 2005).

Field research shows that farmers are able to experiment on their own, to combine different types of knowledge, and to adapt technologies to their own circumstances. Yet this capacity should not be romanticized at the expense of a realistic assessment of the challenges resource-poor farmers face in coping with climate variability and change. Adaptive strategies may entail hidden costs, not measurable in terms of yields and income, or evenly distributed among household members. Higher yields or profits may be attained at the expense of health and nutrition or by foregoing opportunities for education, leisure, and social life. Impacts may not always be visible in the short term and may not stop at the farm gate or compound door. Studies of vulnerability to global environmental change provide valuable insights into this complex web of direct and indirect effects www.gecafs.org/publications/index.html. Lessons have been distilled into menus of structured and interactive tools and matrices for matching research issues with suitable methods. Such frameworks also highlight the analytical value of narratives, such as case-study accounts of how and why some households or groups become more vulnerable and others more resilient.

Climate application research has significantly benefited from the methodological advances reviewed in this article. The main challenge that remains to be addressed is the need to transcend the 'technology adoption' paradigm that still informs many of its research questions (Agrawala & Broad 2002). Such shift entails a reformulation of goals, from facilitating the 'uptake' of climate forecasts, to understanding how climate information can interact with other resources and capabilities to empower rural producers to make decisions and enact strategies that reduce their vulnerability to climate risk. Such a perspective requires not only a composite methodology but also cross-scale (Stephen & Downing 2001) and multi-sited (Appadurai 1995, Marcus 1995) research design. The analytical scope must be broadened to encompass local communities and their multiple action spaces (Painter et al. 1994) as well as the higher spheres of decision-making, where policy and science are shaped (Agrawala et al. 2001). For example, the Climate Outlook Fora offer a unique opportunity to examine the intellectual and political negotiations whereby science products are transformed into media messages and policy guidelines (for a review see Basher et al. 2001). Regional and global forecasting institutions, such as the African Center for Meteorological Applications to Development (ACMAD), based in Niamey, Niger, and the International Research Institute for Climate and Society (IRI) at Columbia University, have embraced the mission of transforming climate science into an instrument of development. Key questions are how various institutional actors interpret such a mandate, how decisions are made with respect to the relevant parameters, tools, sectors, and regions, and how these decisions are to be prioritized. The interplay of different values and decision criteria (e.g. forecast skill, societal need, economic potential, or institutional capacity) may reflect diverging intellectual and political agendas. Understanding and reconciling these contradictions may help narrow the gap between supply and demand of climate products (Broad 2002). Climate application initiatives, such as NOAA's Regional Integrated Science Assessment (RISA) programs, emphasize a user-driven agenda. But the dynamics of stakeholder participation and partnership in climate application work has not been critically examined. Ethnographic and participatory approaches have substantially advanced climate prediction research by enabling bottom-up learning. There are also opportunities to apply them in the investigation of decisions and discourses surrounding climate forecasting at regional and global levels (see e.g. Broad & Orlove in press).

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