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Assessing the Value of Climate Forecast Information for Pastoralists: Evidence from Southern Ethiopia and Northern Kenya

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Summary. — Climatic variability exerts tremendous influence on the livelihoods and well-being of pastoralists in the Horn of Africa. Recent advances in climate forecasting technologies have raised the intriguing prospect of reasonably accurate forecasts of coming seasons' rainfall patterns. We explore the value of such external climate forecast information to pastoralists in southern Ethiopia and northern Kenya using data collected using both open-ended, qualitative methods to identify and understand indigenous climate forecasting methods and quantitative data collected using survey instruments. On balance, climate forecast information does not seem a limiting factor at present in pastoralist communities in the Horn of Africa.

Key words — early warning systems, livestock, risk, uncertainty, weather

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1. INTRODUCTION

Agricultural systems are notoriously responsive to climate fluctuations, creating real potential for skillful climate forecasts to improve resource management and the welfare of rural populations. Because climate shocks can have especially devastating effects among the rural poor, special attention is being given to understanding what potential, if any, exists for using climate forecasting to mitigate downside risk and to create new opportunities for reducing poverty and vulnerability, and much effort is currently being directed toward improving the skill and dissemination of climate forecasts (Hammer *et al.*, 2001; Phillips, Makaudze, & Unganai, forthcoming; Roncoli, Ingram, & Kirshen, forthcoming; Roncoli, Kirshen, Ingram, & Flitcroft, forthcoming). [1]

Climatic variability is especially pronounced and important in the dryland regions that encompass roughly two-thirds of the African continent, an area home to roughly 50 million or so Africans, a population typically far poorer than those in higher rainfall areas (Galvin, Boone, Smith, & Lynn, 2001). The past decade's droughts and floods in the Horn of Africa (HA) that buffeted the region's pastoralists [2] have combined with recent advances in climate modeling to pique donor and government interest in climate forecasting and forecast delivery channels. Considerable resources have therefore been directed toward building up climate forecasting and dissemination capacity in the region, with the Drought Monitoring Centre (DMC) in Nairobi at the hub of most such efforts (Curry, 2001b). [3] The return on these investments depends in part on an oft-unstated assumption that climate forecast information will prove valuable to the vulnerable populations it is meant to help not only indirectly, as an input into early warning systems at national and regional levels, but also directly, as a basis for improving individuals' choice under uncertainty.

Yet there has been no research of which we are aware on the value of climate forecast information, especially at the level of individual users, and certainly not among pastoralists, perhaps the population of greatest humanitarian interest for emerging climate forecast technologies. This paper aims to help fill that important void by documenting pastoralists' access to, confidence in and use of external and indigenous climate forecasts [4] in a large study region in the arid and semi-arid lands (ASAL) of southern Ethiopia and northern Kenya (Figure 1) before, during and after the 2001 long rains season. The remainder of this paper is organized as follows. Section 2 presents basic principles of information theory. Section 3 briefly describes the study region and data. Section 4 then uses these data to address the key principles identified in Section 2. Section 5 concludes with a brief summary of our findings and implications for future research and contemporary policy.

2. THE BASICS OF INFORMATION THEORY [5]

Information is valuable in helping people cope with uncertainty. To be somewhat more precise, if an individual must make resource allocation (e.g., consumption, employment) choices at time t in the face of uncertain future events or states of nature (e.g., weather), e_{t+1}, that affect the relative productivity of different alternatives available to her, then information, I_t, in the form of a message has non-negative value due to its potential to resolve temporal uncertainty and improve resource management. People commonly confuse the estimated losses associated with adverse climate shocks—a bad draw on e_t—with the value of climate forecast information, I_t. This can lead to serious overestimation of the value of information. The exact value of the exogenous information [6] depends on three necessary conditions:

(a) I_t and e_t are correlated (i.e., the message contains information), with the value of the message increasing in the information contained therein (hence the importance of forecast skill);
(b) An individual receiving I_t changes her subjective probability distribution on e_t, following Bayes' theorem, with a signal that causes a greater change worth at least as much as information that causes less or no change (underscoring the importance of confidence in forecast information received);
(c) her preferences and constraints are such that her optimal decisions will vary depending on her subjective probability distribution on e_t, with the value of information equal to the change in expected discounted welfare stream resulting from optimal decisions made with the new information in hand. Note that what matters is whether *decisions*

subject to uncertainty change, not whether *outcomes* are different, since the latter depend on the *ex post* realization of the state of nature.

These foundational principles of information theory identify several crucial questions one needs to address to assess the value of climate forecast information for any population of intended beneficiaries, HA pastoralists included.

—*First*, *what is the skill of climate forecasts*? This question lies outside the scope of the present work, although we are able to address pastoralists' capacity to understand probabilistic climate forecasts and therefore their comprehension of the concept of imperfect information (i.e., I_t is imperfectly correlated with e_t). [7]

—*Second*, *what sort of prior beliefs do prospective users hold with respect to climate patterns*? In the present context, the issue is the availability of and confidence in indigenous climate forecasts. If individuals have a base level of reliable information already and place great confidence in their resulting priors, new information is necessarily less valuable, all else held constant.

—*Third*, *who receives external forecasts*? Information necessarily has no value to those who do not receive it.

—*Fourth*, *what confidence do recipients have in external forecasts*? If forecast recipients have no confidence in the new information, they will not update their prior beliefs in response to this information, which therefore has no value.

—*Fifth*, *is the external forecast different from the pre-existing, indigenous forecast*? Recipients will update their beliefs only in so far as the new information differs from the prior subjective distribution.

—*Sixth*, *how does receipt of and confidence in external forecasts affect users' subjective probability distributions over climate*? If forecast recipients are slow to update their prior beliefs in response to new (external forecast) information, then it may take many forecasts to change beliefs and thus, potentially, behavior. As a consequence, information has little value.

—*Seventh*, *how do pastoralists' posterior beliefs over uncertain climate affect their decisions and with what consequences for their welfare*? This depends fundamentally on pastoralists' material and nonmaterial preferences (e.g., with respect to risk, the timing of consumption, and conformity to or deviation from community norms), incentives (e.g., prices, range productivity, risk of livestock loss to raiders, predators, injury or disease) and constraints on their choices (e.g., *ex ante* herd size, available cash, agroecological potential of soils and water, and accessibility to nonpastoral livelihood options).

Section 4 is structured to explore these seven core questions in turn. But before turning to the data and analysis, let us sum up the core point to take away from information theory: the value of information depends on three conditions: novelty, confidence, and ability and willingness to act on updated beliefs. In Section 4 we demonstrate that modern climate forecast information seems to satisfy only the first two of these necessary conditions in the population we study.

3. THE SETTING AND THE DATA

Average rainfall in the study region shown in Figure 1 ranges from 200–750 mm/year with coefficients of variation ranging from 44% to 65%. In the last decade alone, the region experienced three significant droughts—in 1992–93, 1996–97, and 1999/2000—and serious flooding in 1997–98. These climate shocks led to great suffering and unexpected wealth losses due to massive herd die-offs among some of the world's poorest populations. Opportunities for remunerative diversification out of extensive grazing are limited (Little, Mahmoud, & Coppock, 2001b), as rainfall is insufficient in most locations to support crop agriculture most years, and basic physical infrastructure (e.g., all-season roads, electricity, telephone) to support commerce and manufacturing is largely absent. As a consequence, pastoralists' livelihoods and behavior are especially responsive to climate fluctuations (Behnke, Scoones, & Kerven, 1991; Ellis & Swift, 1988; Sandford, 1983; Washington & Downing, 1999). Herders employ elaborate livestock management strategies based on regular, opportunistic migration in search of sufficient forage and water, herd splitting, rapid destocking, complex gift and loan systems, and raiding of other clans' and ethnic groups' herds. This responsiveness to climate fluctuations seems, on the surface, to create great opportunities for humanitarian use of climate forecasting technologies among pastoralists.

Microvariability in climate often dominates in drylands, however, weakening the broad-scale teleconnections on which most contemporary

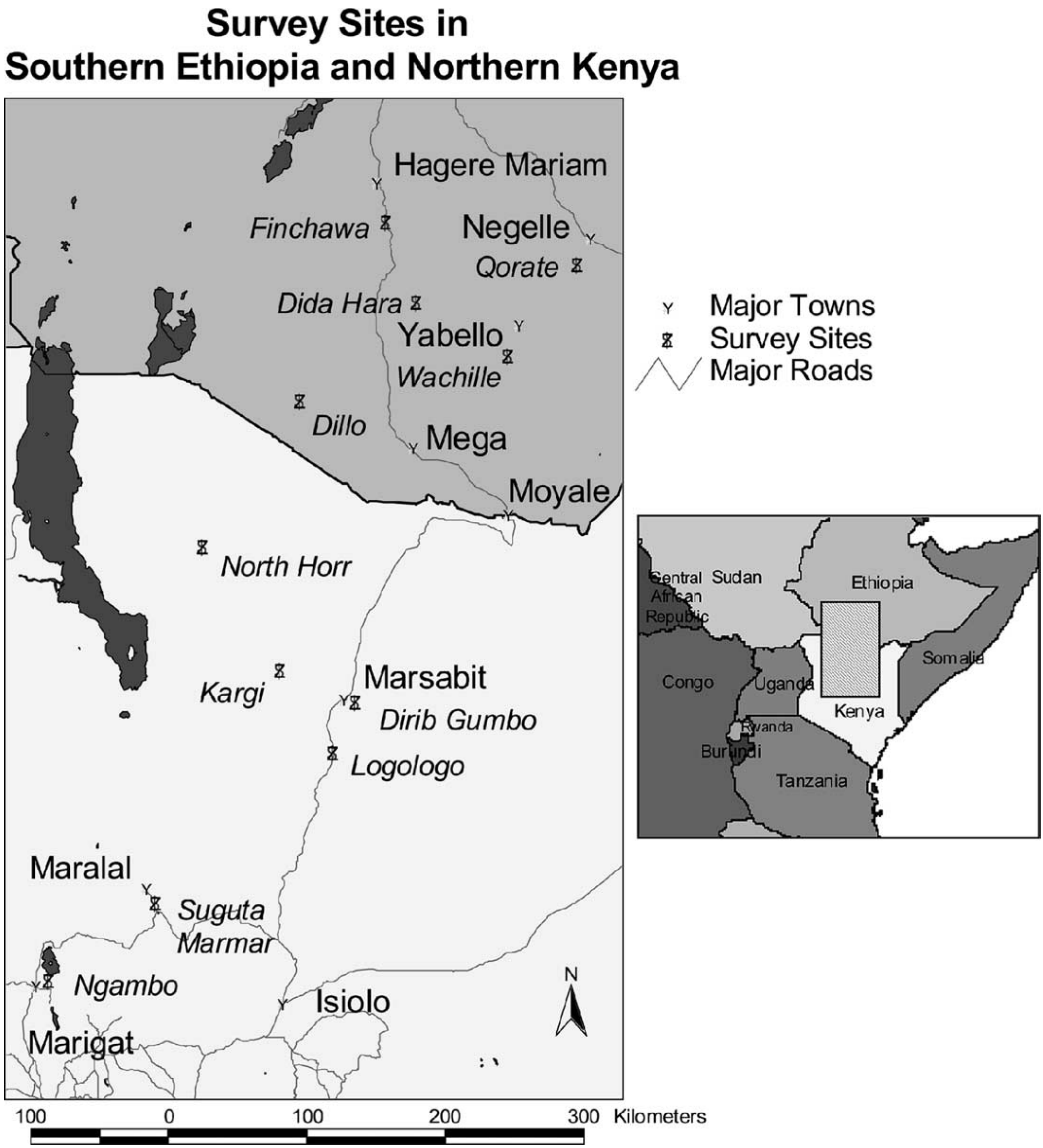

Figure 1. *Map of study sites in southern Ethiopia and northern Kenya.*

climate forecasting rests. Forecast skill may therefore not be as great as in higher potential areas nearby. Moreover, the spatial resolution of the forecasts remains fairly coarse, while extensive grazing systems depend heavily on spatial information necessary to manage herd migrations. Finally, the ability to forecast impact variables of direct interest to decision makers is significantly weaker than skill in forecasting climate drivers (Barrett, 1998). We therefore felt the need to establish the value of climate forecast information directly through primary research among African pastoralists.

The data used here were collected by USAID's Global Livestock Collaborative Research Support Program (GL CRSP) Pastoral Risk Management (PARIMA) project on a subcontract from the "Regional Climate Prediction and Applications for the Greater Horn of Africa" project undertaken by the International Research Institute for Climate Prediction at Columbia University in collaboration with the University of Nairobi's Department of Range Management. A two-stage survey was designed to bracket either side of the long rains of April–May 2001. The initial instrument was fielded from early March 2001 to early April 2001 and the follow-up module was implemented between mid-June 2001 and end-July 2001. An open-ended questionnaire was simultaneously fielded among key informants to establish prevailing indigenous climate forecasting methods. The 293 randomly sampled survey households are scattered across 10 different sites, six in northern Kenya (Dirib Gumbo, Kargi, Logologo, Ngambo, North Horr and Suguta Marmar) and four in southern Ethiopia (Dida Hara, Dillo, Finchawa and Wachile), spread over an area of approximately 124,000 km^2 (Figure 1). The sample spans several ethnic groups, including the Ariaal, Boran, Chamus, Gabra, Guji, Rendille, and Samburu.

Our survey followed one of the worst droughts in the Horn of Africa in many years. Over the two years prior to the long rains of 2001, less than 100 mm of rain had fallen in one of our Kenyan sites (Logologo), and only 120 mm in another (Kargi), with the others all well below average as Figure 2 demonstrates for our Kenya sites. [8] Having just suffered through a severe drought, pastoralists were perhaps especially sensitive to the upcoming season's rainfall, making this an opportune time for a survey such as ours.

4. THE VALUE OF CLIMATE FORECAST INFORMATION TO PASTORALISTS IN THE HORN OF AFRICA

The analysis in this section proceeds from the following basic behavioral and informational assumptions. Pastoralist households form prior beliefs about the upcoming season's climate based on past experiences and indigenous climate forecasts. [9] These beliefs may then be subject to revision following reception of external climate forecast information. Pastoralists then choose whether to act on their posterior (i.e., potentially updated) climate beliefs. We therefore label beliefs and actions based only on indigenous climate information and past experience as "unsupplemented" relative to those based on an information set supplemented with external forecast information.

(a) *Pastoralists' comprehension of probabilistic forecasts*

There is widespread perception that despite remaining limitations in predictive accuracy and spatio-temporal resolution, climate forecasting technology has nonetheless advanced faster than have forecast delivery mechanisms that reach and are trusted by targeted users (Goddard *et al.*, 2001; IRI, 2001). One widespread concern stems from the issuance of probabilistic forecasts (Nicholls, 1999). Do end-users, especially uneducated ones, understand the uncertainty conveyed in a probabilistic forecast? If not, one might reasonably worry that decision makers can react to forecast information in ways that are *ex ante*

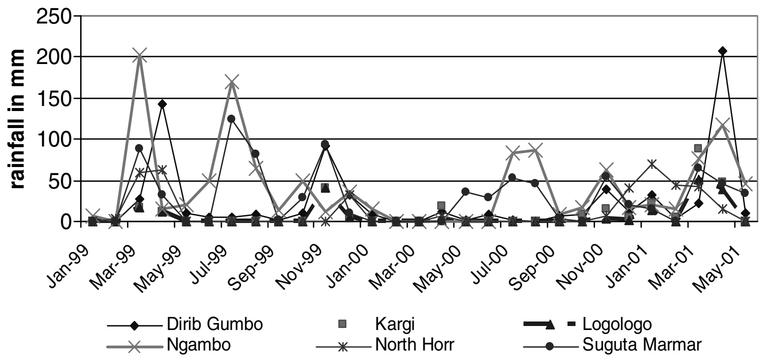

Figure 2. *January 1999–May 2001 rainfall in Kenya study sites.*

optimal but *ex post* inappropriate and consequently lose confidence in forecasts. If one can establish that on their own pastoralists express probabilistic uncertainty over climate outcomes, however, one might reasonably believe that they indeed understand the concept of forecast uncertainty and would therefore be less likely to conflate the randomness of the climate realization with forecast accuracy. Comprehensibility does not seem a big issue.

In order to get at this question, just prior to the onset of the long rains of 2001 we elicited pastoralists' probabilistic assessment of the upcoming seasonal rainfall volume in a way that made their replies directly comparable to the external forecasts released by the DMC. [10] We gave each respondent 12 stones and asked them to allocate them across three different piles on the ground, one for "above normal," one for "normal," and one for "below normal," according to their expectations regarding the rainfall for the upcoming season. The DMC had issued and the Ethiopian and Kenyan national meteorological services had widely disseminated an equivalent trinomial forecast a few weeks earlier, enabling us to compare individuals' climate expectations against the official forecast released by the region's climate experts.

One striking result of this exercise is that pastoralists, the vast majority of whom have not completed primary school—indeed, in Ethiopia, the vast majority have never attended any school and are illiterate—clearly comprehend and can communicate a probabilistic forecast, even if they would not employ such terminology. Only 10.2% of respondents put all 12 stones into any one category. Almost half of our respondents did not even put a majority of the 12 stones in any one category.

The mean probabilistic rainfall volume forecasts show considerable variation in expectations across sites that are reasonably proximate in climate forecasting terms (Table 1). For example, the DMC issued a single forecast for an area encompassing all the Kenya sites and a different, single forecast for an area to the north that encompassed all the Ethiopia sites. On average, our Kenyan respondents were considerably more optimistic about seasonal rainfall than was the DMC forecast, likely reflecting unusually good January–February (*furmat*) rains that caused respondents to expect continued above-average rainfall in the coming season. By contrast, our Ethiopian respondents were slightly more pessimistic, on average, than the DMC consensus forecast as to the rainfall prospects of the upcoming season. As it turned out, when we revisited these same households after the rains had finished, a large majority believed that rainfall had been below normal for their location during the forecast period (Table 2), due mainly to the rains ending early (Table 3). [11] As it turned out, recorded seasonal rainfall volumes were indeed consistently at or somewhat below long-term seasonal means, although recorded annual rainfall was above average for the year. Pastoralists perceptions of rainfall performance seem reasonably accurate, suggesting that their appraisals merit respect when they express confi-

Table 1. *Mean probabilistic expectations of rainfall volume for the 2001 long rains season*[a]

	Above normal (%)	Normal (%)	Below normal (%)
All sites	36	42	22
All Kenya sites	42	37	21
DG	25	39	36
KA	35	35	30
LL	15	61	24
NG	52	34	14
NH	63	25	12
SM	62	28	10
DMC Forecast: Kenya sites (Region IV)	25	40	35
All Ethiopia sites	27	48	25
DH	28	50	22
DI	15	29	56
FI	21	73	6
WA	45	44	11
DMC Forecast: Ethiopia sites (Region V)	35	40	25

[a] The codes used for sites in this and subsequent tables are as follows: Ethiopia sites: DH = Dida Hara, DI = Dillo, FI = Finchawa, WA = Wachille. Kenya sites: DG = Dirib Gumbo, KA = Kargi, LL = Logologo, NG = Ngambo, NH = North Horr, SM = Suguta Marmar.

Table 2. *Pastoralists' opinions on the realized rainfall volume of the long rains 2001*

	In your area (%)	In other areas (%)
Above normal	11	23
Normal	18	50
Below normal	69	25

Table 3. *Respondents' opinions on the realized timing of the long rains 2001*

	Started (%)	Ended (%)
Early	29	56
Late	15	8
On time	56	34

dence in forecasts *ex ante* and evaluate forecasts as having proved reasonably accurate *ex post*.

The finding that pastoralists form and communicate their own probabilistic forecasts should help assuage concerns that probabilistic climate forecasts inherently pose an obstacle to dissemination of retention among poor target populations. We will return to these data in Section 4 when we consider how receipt of and confidence in external forecasts changes pastoralists' beliefs about climate. First, however, we need to examine the primary source of climate forecast information used to form prior climate beliefs: indigenous climate forecasting methods.

(b) *Pastoralists' use of indigenous climate forecasting methods*

Pastoralists have long used indigenous forecasting methods to predict seasonal climate events. But many traditional forecasting methods are perceived as becoming less reliable with increasing climate variability, raising the question of whether external, meteorology-based climate forecasts might better help pastoralists conserve livestock wealth and contribute to sustainable use of natural resources (Roncoli *et al.*, forthcoming). In some quarters, it is therefore assumed that there exists considerable latent demand for science-based, external forecasts. As this subsection demonstrates, it is not clear that such inferences are well-founded in the case of the pastoralists we study.

Pastoralists employ an extraordinary variety of indigenous climate forecasting methods in our 10 sites. Some use observations of clouds, wind or lightning that likely have their origins in traditional understandings of what contemporary researchers might recognize as atmospheric science. Others watch the behavior of livestock, wildlife or local flora. Still others read the intestines of slaughtered animals, watch the stars or the moon, or interpret dreams or the patterns in which pairs of shoes fall when repeatedly thrown. Most indigenous methods are targeted toward particular features of the upcoming season's climate—e.g., when the rains will start, where they will fall, when they will end, etc.—the effects of these climate patterns on impact variables of interest to pastoralists—e.g., herd growth or loss, grain availability, conflict over key resources—and often at finer spatio-temporal resolution than offered by modern climate forecasts. Figure 3 presents a histogram of frequency of use of different traditional forecasting methods in our Kenya sites.

As has been emphasized elsewhere in the developing world, although traditional climate forecasting methods may be poorly

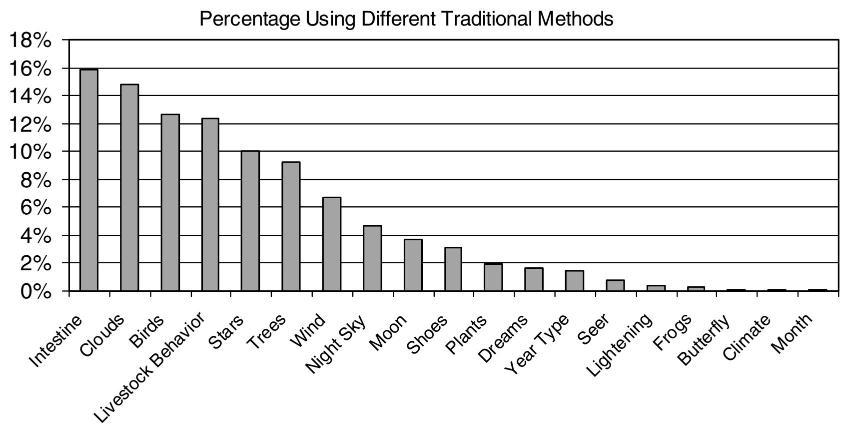

Figure 3. *Use of different traditional methods in Kenya. Each household could identify up to 10 distinct methods from which it used forecasts. This graphic represents the percentage of total indigenous forecast use data points (776 in the case of Kenya) accounted for by different methods.*

understood, they may nonetheless be based on intrinsically scientific foundations that account for moderate observed forecast skill (Orlove, Chiang, & Cane, 2000; Roncoli *et al.*, forthcoming; The Economist, 2001). As the chemist–philosopher Michael Polanyi emphasized in his articulation of the concept of "tacit knowledge," people often arrive at the correct answer, if sometimes by inappropriate, imprecise or even incorrect means because they know and can implement knowledge and skills that cannot be readily explained (Polanyi, 1966). Based on the extensive information provided by our sample communities, there seems to be considerable tacit knowledge and much room for exploration of the scientific foundations of ethno-meteorology among east African pastoralists.

Indigenous forecasts are widely heard by east African pastoralists. Before the onset of the 2001 long rains, more than 90% of our respondents had heard some sort of indigenous forecast for the coming season—about the onset of the rain, the amount of rainfall expected locally, the amount of rainfall expected in other areas, or the duration of the rains. More than 98% reported having heard forecasts for prior seasons.

They not only heard indigenous climate forecasts, they also expressed considerable confidence in them (Table 4). Ninety-four percent expressed at least some confidence in traditional forecasts of rains' start date, 84% have at least some confidence in indigenous forecasts of rainfall volume, and a majority have at least some confidence in forecasts of both rains' end dates and rainfall amounts in other areas. Some indigenous methods (reading of clouds, stars and animal intestines) inspire far more widespread confidence than other indigenous methods, while all enjoy high confidence of at least some pastoralists. It is not so much that there is a *single* indigenous forecasting method that is perceived as especially skillful, but rather that the *suite* of traditional methods seem to offer sufficient complementarity as to elicit confidence from the overwhelming majority of the region's pastoralists.

Pastoralists' *ex post* perceptions of the accuracy of forecasts they heard for the 2001 long rains reinforces their declarations of confidence in indigenous methods. Among the respondents, 97–98% felt that traditional forecasts were at least somewhat accurate and half or more deemed them very accurate in forecasting the long rains' start date and the amount expected to fall in their area. This strikes us as an extraordinarily high rate of perceived skill, whether or not it is objectively verifiable.

The evidence on indigenous climate forecasting in the region points to multiple reasons (other than tradition) why external forecasts seem not to be taking hold rapidly. First, the forecast of greatest interest to pastoralists concerns the onset of the long rains. Eighty-six percent of our respondents reported hearing such a forecast prior to the 2001 long rains and this is the climate forecast variable pastoralists consistently ranked first in terms of desirability. The timing of rains matters more to pastoralists than does the aggregate volume of rain over a season because migration patterns depend on when grass and water are available in different sites, not on the average availability over a period. As yet, there are no computer-generated long-lead forecasts of rainfall timing in this region. Second, as has already been pointed out, external forecasts are made at very low spatial resolution—typically $2 \times 2°$ or approximately 200 km grid spacing (Goddard *et al.*, 2001)—while indigenous forecasts tend to be very local in focus. Third, indigenous forecasts are communicated in local languages and typically by "experts" known and trusted by pas-

Table 4. *Distribution of level of confidence in climate forecasts by type*[a]

	Start date		End date		Rainfall volume in own location		Rainfall volume in other locations	
	Indig. (%)	Ext. (%)	Indig. (%)	Ext. (%)	Indig. (%)	Ext. (%)	Indig. (%)	Ext. (%)
Never heard	2	52	26	58	9	52	21	55
No confidence	4	10	16	12	6	12	17	9
Some confidence	60	26	43	20	46	24	39	20
High confidence	34	6	14	3	38	5	20	8

[a] Start date = forecast of onset of long rains, end date = forecast of end or duration of long rains, Indig. = indigenous forecasts, Ext. = external forecasts.

toralists. While it may well be true that the performance of particular indigenous methods has declined over recent years—we know of no evidence one way or the other on this point—the suite of traditional methods found in our study region seems to fare quite well still, in terms of widespread ongoing use, high levels of pastoralist *ex ante* confidence and *ex post* perception of forecast accuracy. The challenge for external forecasters is to demonstrate they can contribute new, valuable information to pastoralists who have access to a suite of need-driven indigenous forecasting methods.

(c) *Awareness of and access to external or meteorology-based climate forecasts*

A minority of respondents have ever heard computer-based, external climate forecasts (Table 4). Indeed, only about one-fifth of our sample had heard a modern forecast about the onset or duration of the 2001 long rains, or of the amount of rain expected to fall in their local area and in other areas from any source. Radio is by far the most common medium through which pastoralists receive external climate forecasts. No other external forecast source (television, newspapers, other printed materials, and government or nongovernmental organization (NGO) extension agents) reaches more than 3% of the pastoralist population.

In assessing the reach of external forecasts, it is important to bear in mind the material deprivation of most pastoralists. [12] In our sample, only 5% of the Ethiopians owned a radio and only 23% of the Kenyans did. The implication is that the proportion of respondents reporting that they had heard an external forecast for the long rains of 2001 almost exactly equals the overall proportion of the sample that owns a radio, suggesting a basic material constraint on receipt of external climate forecasts.

We asked whether respondents were aware of the availability of external climate forecasts through various media and found that in seven of 10 sites, a majority either were not aware that forecasts were available on radio or they had no access to a radio. The other media for external forecast delivery—television, newspapers, other printed periodicals, government or NGOs extension agents—were even less accessible than radio, perhaps explaining the extraordinarily low reported rates of access to external climate forecasts from those sources. By contrast, absolutely every respondent in eight of our 10 sites learned about traditional climate forecasts over the same period. Accessibility plainly matters.

One needs to be cautious, however, about attributing the relatively low rate of external forecast use wholly to accessibility. There are at least two other significant issues: content and timeliness of forecasts. We asked respondents to rank order different forecast content by desirability if each type of forecast could be reliably provided with some skill. As shown in Table 6, and mentioned previously, pastoralists are mainly interested in climate information pertaining to the onset date of the rains since the timing of forage and water availability drives migration patterns. This was the first choice of more than 70% of our respondents, with 94% putting it either first or second. Such forecasts are available from indigenous providers but are not presently produced and disseminated by the meteorological agencies in the Horn of Africa. Indeed, it is not clear whether climate modelers will have the capacity to offer long-lead timing forecasts in the coming few years (Goddard *et al.*, 2001). The forecast variable of least interest to pastoralists was clearly the rainfall volume expected in areas outside respondents' vicinity, i.e., in areas to which they might migrate in search of water and pasture if the rains in their area were to prove insufficient. This likely reflects the fact that extensive grazing is an inherently flexible production system, so pastoralists do not move on the basis of forecasts. Rather, they move only after having sent advance scouts to

Table 5. *Perceived accuracy of 2001 long rains forecasts, conditional on hearing a forecast*

	Start date		End date		Rainfall volume in own location		Rainfall volume in other locations	
	Indig. (%)	Ext. (%)	Indig. (%)	Ext. (%)	Indig. (%)	Ext. (%)	Indig. (%)	Ext. (%)
Not at all	2	0	22	0	3	21	9	9
Somewhat	48	39	36	83	26	32	36	43
Very	50	61	42	17	71	47	55	48

Table 6. *Pastoralists' rank of the usefulness of different types of forecast*

Rank	Start date (%)	Volume here (%)	End date (%)	Volume elsewhere (%)
1 = most desired	71.3	24.7	2.3	1.7
2	22.5	51.3	17.0	9.2
3	4.4	20.7	51.5	17.5
4 = least desired	0.0	1.6	13.0	49.5
Not useful	1.8	1.8	16.2	22.1

establish where they might find and be able to secure access to sufficient forage and water to maintain their herds in a reasonably safe area.

The other factor affecting demand for forecast information has to do with timeliness. In order to incorporate new information and make adjustments to herd or farm management (or other) behaviors, pastoralists need sufficient advance notice. The 2001 climate forum organized by the Drought Monitoring Centre Nairobi was held in mid-February, about one month prior to the usual onset of the long rains in this region. Release and dissemination of the consensus climate forecast from that meeting by the national meteorological services therefore gave pastoralists less than one month's notice.

Based on pastoralists' declaration to us as to how many weeks in advance of the season they need to receive a forecast in order for it to be useful, the 2001 long rains forecasts appear to have arrived too late. Mean lead time that respondents indicated they needed for seasonal climate forecast information to be useful was 4.6 weeks for forecasts of rainfall volume in respondents' location. [13] This finding is consistent with similar results among farmers in Burkina Faso, where Roncoli *et al.* (forthcoming) likewise found that farmers sought forecasts one to two full months prior to the onset of the rainy season. One clear implication is that future climate outlook fora should be scheduled for late January or early February if they are to prove useful to the pastoralist community.

(d) *If aware of external forecasts, do pastoralists have confidence in them?*

In order for external climate forecasts to have value among pastoralists, herders must not only receive the forecasts, they must also have some confidence in them. Even controlling for access to forecasts, pastoralists express less confidence in external forecasts than in traditional ones (Table 4). For each type of forecast, a larger proportion of respondents have no confidence in external forecasts than in indigenous ones and a smaller share have high confidence.

The good news for the meteorological community, however, is that 70–76% of respondents expressed at least some confidence in the external forecasts they heard as to the amount of rainfall expected to fall during the upcoming long rains in 2001. This confidence is associated with the perception that external forecasts exhibit reasonable skill (Table 5). Almost half of all respondents who heard external forecasts of 2001 seasonal rainfall amounts thought *ex post* that they had been very accurate. When we asked open-ended questions as to the reasons for their confidence in modern forecasts, the replies almost always revolved around the use of modern equipment ("machines") and the educational attainment and training of the meteorological staff who generate the forecasts.

Although indigenous climate forecasts clearly dominate in this setting, there appears to be a nontrivial cohort of pastoralists who indeed are interested in hearing the external forecasts because they have access to and confidence in them. Who are these pastoralists? We explore this question via a simple probit model of a binary variable taking value one if the household head had access to and confidence in external climate forecasts, zero otherwise, regressed on the age of the household head, the square of the household head's age, the years of education completed by the household head, and a set of dummy variables taking the value one if the household (i) resides in Kenya, (ii) lives near a town or major highway, (iii) owns a radio, (iv) participated in an adult education program, or (v) owns property, either a shop or a house or both, in a nearby town.

The estimation results, reported in Table 7, clearly reveal spatial heterogeneity in the probability of access to and confidence in external forecasts. Respondents in Kenya are more likely to have access to and confidence in external forecasts, as are those who reside near

Table 7. *Results for probit model of access to and confidence in external climate forecasts (N = 247)*

	Marginal effects (Std. errors)		Coefficients (Std. errors)	
Constant	N/A		−0.848	(1.11)
Location dummies				
Kenya	0.100*	(0.051)	0.436*	(0.237)
Near town/major road	0.113**	(0.050)	0.494**	(0.235)
Male	−0.068	(0.059)	−0.269	(0.222)
Formal education	0.019*	(0.011)	0.079*	(0.045)
Adult education	0.218*	(0.141)	0.703*	(0.386)
Age	−0.007	(0.010)	−0.028	(0.043)
Age^2	0.000	(0.000)	0.000	(0.000)
Own a radio	0.114*	(0.077)	0.419*	(0.253)
Own property in town	−0.065	(0.073)	−0.306	(0.399)

* Denotes statistical significance at the 5% level.
** Denotes statistical significance at the 10% level.

a town or major highway, i.e., respondents in our Dirib Gumbo, Finchawa, Logologo, Ngambo, Sugata marmar and Wachile sites. Location of residence or work plainly matters to who receives information about meteorology-based climate forecasts, with more-favored areas getting better information. Respondents in Logologo, Ngambo and Sugata marmar also often have family members employed as wage laborers in nearby towns such as Isiolo, Marigat, Meru, Nakuru, Naivasha, Gilgil or Nyahururu. This likely helps foster information flow back to rural communities, increasing awareness of external climate forecasts. Also as expected, respondents who own a radio are more likely to have access to and confidence in meteorology-based climate forecasts.

Not surprisingly, educational attainment appears to play a significant role as well, which perhaps helps explain the frequency with which respondents cited the education of meteorological forecasters as the primary reason for their confidence in these products. But, since greater educational attainment is associated with higher and more stable cash incomes among these pastoralists, this also implies the same sort of wealth bias that one commonly finds in other technology adoption studies. Climate forecasts based on meteorological science appear to be reaching primarily a relative elite that has sedentarized and enjoys good market access and nonpastoral income within the drylands of northern Kenya and southern Ethiopia, although it is impossible to establish clearly whether these forecasts are actually used by the elites or if they serve just as a mark of modernity.

(e) *Do external forecasts differ from indigenous forecasts and do pastoralists update beliefs?*

Even if pastoralists receive and have confidence in external climate predictions, forecasts only have value if they change respondents' prior beliefs. This obviously requires that the external forecast contain new information that differs somehow from extant indigenous forecasts. This difference can be with respect to the forecast variables, a point made previously in discussing the sort of climate information pastoralists most want. The difference can also come in the form of variation in forecast values of the same variables (e.g., rainfall volume). We focus now on this latter point.

Since indigenous climate forecasting methods have evolved over long periods of time to fit site-specific patterns, it is perhaps not surprising that most pastoralists perceive these methods to be reasonably accurate. In that case, accurate meteorology-based forecasts might not differ much from the traditional forecasts if both offer unbiased estimates of upcoming climate patterns. Hammer *et al.* (2001) and Phillips *et al.* (forthcoming) report that in both 1997–98 and 1998–99, Zimbabwean farmers' seasonal climate forecasts elicited in advance of the release of official climate forecasts corresponded almost exactly with the official meteorological service forecasts. This likely partly reflects the tacit scientific knowledge—based on readings of clouds, winds, flora and fauna behavior—that intersects with the explicitly scientific methods used in the climate modeling community. External forecasts that merely reinforce prior beliefs rarely change behaviors and are thus of limited value.

Given the multitude of indigenous forecasts available in the sample communities, there would not be a clear way to establish what "the" indigenous forecast was for the long rains of 2001, especially since it would likely be incomparable to the DMC's trinomial probabilistic seasonal forecast of rainfall volumes. But, because we elicited pastoralists' subjective beliefs over rainfall, we can compare the beliefs of those who only used traditional forecasts with the DMC forecasts to see if the two differ. Table 8 presents site-specific mean differences between the forecasts reported by households that used only traditional forecasts and the DMC forecasts released through the national meteorological services. In Dirib Gumbo, the site close to Marsabit meteorological station, the mean forecast is quite close to the DMC forecast. In the other nine sites, however, there seem to be nontrivial differences—at least 10% in one of the forecast categories—between the DMC forecast and the prior beliefs of pastoralists based on their own experience and traditional forecast information. The DMC forecasts clearly do not merely mimic what is already on offer.

Not only is the DMC forecast information new, but those pastoralists who receive and express confidence in modern climate forecasts indeed appear to update their beliefs accordingly. In a companion paper that econometrically explores the highly technical question of pastoralists' updating of their subjective beliefs about seasonal rainfall, we find quite a strong response (Lybbert, Barrett, McPeak, & Luseno, 2002). Indeed, under several different specifications and estimation methods, we cannot reject the null hypothesis that pastoralists who have greater confidence in modern forecasts than indigenous ones completely update, adopting the DMC forecast as their own once one controls for other covariates, such as age, gender, location and education. Interestingly enough, pastoralists' response is especially strong when the external forecasts suggest a greater likelihood of a favorable (wetter) season than they had previously believed and in locations where they have recently observed seasonally above normal rainfall, suggesting a cognitive bias toward optimism.

Table 8. *Difference in mean long rains 2001 rainfall predictions between users of traditional forecasts only and DMC forecasts*[a]

	Above normal (%)	Normal (%)	Below normal (%)
All Kenya	19	−3	−16
DG	1	−2	1
KA	10	−7	−4
LL	−10	20	−11
NG	27	−6	−21
NH	38	−15	−23
SM	37	−10	−27
All Ethiopia	−7	7	0
DH	−7	10	−3
DI	−20	−11	31
FI	−15	34	−19
WA	12	2	−14

[a] Computed as mean forecast probability of those using only traditional forecasts less DMC forecast probability, by site.

(f) *Do pastoralists adjust behavior in response to changes in climate expectations?*

Up to this point, the evidence points to widespread confidence in and updating in response to novel, modern climate forecast information among the minority of relatively elite pastoralists who presently receive computer-based forecasts. In this respect, adoption of climate forecast information fits the well-known patterns of technology adoption more generally (Feder, Just, & Zilberman, 1985; Rogers, 1995). Were these the only considerations, modern climate forecast information would appear to have significant value to pastoralists, with those with greater education and market access benefiting first, as is typical with new technologies.

The final key piece of the climate forecast information valuation puzzle relates, however, to recipients' behavioral response. If people either cannot or will not change behavior in response to information they receive, then the information has no management value. Information may nonetheless have some (limited) direct consumption value, akin to when people pay for tarot card or palm reading to satisfy some curiosity about the future. But the interest of the climate and development community revolves around the prospective instrumental value of information as a management tool.

People need more than information to be able to respond to a predictable, impending (positive or negative) shock. They must have access to resources necessary to give them strategic alternatives among which they can choose. Furthermore, the livelihood strategy they pursue must benefit from *ex ante* action and they must have the will to make such strategic choices. Other studies have suggested that poor farmers' response to climate forecast information might be limited. Roncoli *et al.* (forthcoming) report that Burkinabe farmers' capacity to respond adequately to climate forecasts is hindered by their poor access to necessary inputs and by risk aversion. Phillips *et al.* (forthcoming) similarly report that Zimbabwean farmers generally did not act on climate forecast information signaling drier than normal conditions. In both cases, limited response appears to have been due primarily to limited capacity to act, for example due to unavailability of appropriate seed.

Very few pastoralists in our sample did anything differently based on the climate forecast information they received. As Table 9 indicates, only about one-quarter of our respondents changed their behavior on the basis of the forecast start dates for the 2001 long rains. Forecast rainfall timing generates greater response than volume forecasts do, underscoring our earlier points about the greater desirability of indigenous forecasts' information content, as compared to modern, computer-generated forecasts. Less than 10% of those who received external forecasts of rainfall volumes in their own locations adjusted behavior in response. Further, most responses were with respect to cultivation practices rather than herd management strategies. Almost all the responses we got to open-ended questions asking what people did differently during the long rains of 2001 on the basis of climate forecast information referred to decisions as to whether to plant, when to sow, seed choice, etc.

In the first (pre-rains) round, we had asked people to recall what actions, if any, they took the last time they had expected above normal or below normal rains. Those who cultivate crops indicated that they had adjusted cultivation choices in response to climate forecasts, but our respondents reported no appreciable behavioral change in herd or household finance management. The primary reported response to expectations of above- or below-average came in the form of prayers and other ceremonial activities.

These results may seem puzzling since pastoralists' livelihoods depend so heavily on climatic patterns. We believe the absence of a strong behavioral response to climate forecast information may be best explained by three distinct factors: the flexibility inherent to pastoralism, lack of options available to the poorest pastoralists in our study region, and pastoralists' cognitive disposition toward forecast information. We address these now in turn.

Pastoralism is an inherently flexible livelihood that responds to realized spatio-temporal variability in production conditions. Choices over when and where to move the herd are perhaps the key management decisions a pastoralist makes (Dyson-Hudson, 1980; Little *et al.*, 2001b; McCabe, 1983; McPeak & Barrett, 2001). But they do not move on the basis of forecasts; rather, they usually send scouts to establish range conditions and safety before making the trek. Pastoralists react to climate events, but not *ex ante* because they can react *ex post*, although this sometimes entails mistakes, particularly in the form of waiting too long to move the herd.

Marketing behavior likewise is unlikely to be directly affected by climate forecast information because rainfall shocks have countervailing effects on pastoralists' incentives to sell (or purchase) animals because rainfall shocks affect both the flow of income pastoralists enjoy—primarily from milk—and the stock of assets they own, with the former (latter) effect encouraging (discouraging) sales when rainfall is low (McPeak, 2002). As a consequence, on average, observed pastoralist marketing behavior appears invariant with respect to rainfall patterns (Lybbert, Barrett, Desta, & Coppock, 2001; McPeak & Barrett, 2001).

More fundamentally, the linkage between rainfall and risk is less strong among pastoralists than one might be led to believe by conventional wisdom. Stated differently, the experience of "drought" as an adverse outcome

Table 9. *Percentage who received a 2001 long rains forecast who changed any behaviors*

	Start date	End date	Rainfall volume in own location	Rainfall volume in other locations
Traditional	26	3	15	2
External	24	0	9	13

and rainfall deficit as a biophysical event may be distinct things, as ethnographers have suggested for some time (Little, 1992). Pastoralists' declared risk assessment with respect to drought is, if anything, inversely correlated with mean rainfall as it is not semi-nomadic pastoralists who worry about drought so much as sedentarized agropastoralists clustered around towns because the former employ a livelihood strategy defined by its flexibility to respond to climatic perturbations (Smith, Barrett, & Box, 2001). As a consequence, asset risk appears to be largely household specific rather than highly covariate based on community-level experiences such as rainfall (Lybbert *et al.*, 2001).

The weaker-than-expected relationship between rainfall and pastoral risk appears at community level as well. Figure 4 plots the percentage change in rainfall between July 1999 and December 2000, relative to long-term seasonal averages in each of our sites, against percentage change in median household herd size over March–December 2000, the tail end of the recent, severe drought that struck the Horn of Africa. There is an obvious, positive correlation between the two variables, as reflected in the positive and statistically significant univariate regression coefficient estimate (10.63, not shown), but with considerable variation around the central tendency (the regression $r^2 = 0.024$). Even in a severe drought, median herd sizes grew in one site (Kargi) that suffered sharp falls in rainfall relative to seasonal averages. Kargi's Rendille pastoralists were able to move and thereby to avoid the dangers associated with seasonally low rainfall. By contrast, sharp drops in median herd size were suffered in sites that suffered only modest reductions in seasonal rainfall (Ngambo) or that even enjoyed increased rainfall (Suguta Marmar and Finchawa) but where pastoralists' mobility was limited.

Even if pastoralists were willing to move on the basis of forecast rather than realized rainfall, poorer pastoralists often lack the means to adjust behaviors to suit emerging conditions. Recent work in southern Ethiopia suggests the existence of a minimum critical herd size of 6–10 cattle necessary for herders to be mobile, with approximately one-quarter of Ethiopian Boran pastoralists falling below this threshold (Lybbert *et al.*, 2001). This subpopulation likely lacks the capacity to migrate on the basis of climate forecasts even if they wanted to do so.

The obstacles to adaptive management in response to climate forecast information can be cognitive as well as material. Status quo bias may lead to routinization of behaviors that impedes optimal *ex ante* adaptation. Moreover, in some cultures forecast information may be understood differently than is implied in conventional information theory, more as early notice of an outcome than as an input to assist human agency, as users in industrial and post-industrial societies more commonly view fore-

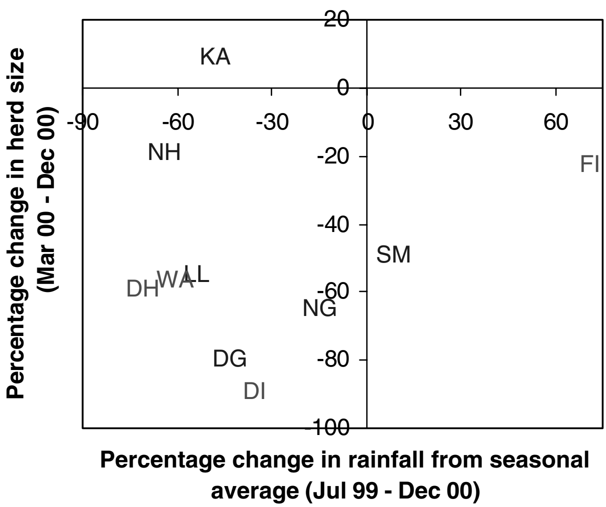

Figure 4. *Percent change in rainfall vs. percent change in median herd size.*

casts. This inference is consistent with the use of messages from dreams and, especially, by the tendency of traditional forecast methods to generate predictions about the outcome of seasons in addition to the upcoming environmental conditions. This would be consistent with the hypothesis that forecast information is treated more as early notice of what is to befall recipients rather than to equip them to take control of their circumstances and to manage their resources so as to attain the best possible outcome.

The upshot of these findings is that traditional pastoralists seem to make little instrumental use of climate forecasting information even when they have confidence in it. Most likely, this is because they have adopted a livelihood strategy built around flexibility in production, primarily through migration in response to spatio-temporal variation in range conditions. Those who choose highly flexible production systems have less need for long-lead information; they adapt to the gradual resolution of temporal uncertainty (Chavas, Kristjanson, & Matlon, 1991; Fafchamps, 1993). Moreover, climate realization and livestock loss and productivity, the variables of concern to pastoralists, may be only weakly related. Certainly a one-season realization has little to do with herd size change or even productivity.

By contrast, crop and low- or zero-grazing livestock production systems do not build in the same sort of adjustment mechanisms found in pastoralism. Agropastoral cultivators and those who practice sedentarized livestock production have to choose crop and herd management strategies carefully based on expected climatic conditions. Variation in environmental conditions has an enormous effect on productivity with very little opportunity for *ex post* corrective adjustments in these systems (Sherlund, Barrett, & Adesina, 2002). Since crop cultivation is growing rapidly among stockless and displaced pastoralists who have become sedentarized around towns where cropping is ecologically feasible (Little *et al.*, 2001a; Smith *et al.*, 2001), climate forecasting may be of greatest potential benefit to these poorest subpopulations in those limited areas of the rangelands where cropping is ecologically feasible. But, since access to and confidence in external climate forecasts strongly depends on educational attainment, which is commonly lacking among displaced pastoralists, this potential does not seem to be realized yet in our survey region.

In the longer term, it may be that the emergence of reliable and accessible seasonal forecasts at appropriate spatial scale may help foster some shift from more flexible pastoralist production systems to potentially higher expected return sedentarized production systems in semi-arid areas where sufficient water can be tapped to support such strategies. But in the arid areas and in the near term, there really do not exist viable alternatives to the highly flexible system of semi-nomadic grazing on which contemporary pastoralists still depend, and in which the value of computer-generated climate forecast information appears quite low.

5. CONCLUDING REMARKS

The evidence presented in the preceding sections offers several hopeful points for champions of improved climate forecasting as a tool to assist vulnerable pastoralists. First, we find that pastoralists readily understand and can themselves communicate probabilistic seasonal climate forecasts. Worries as to the comprehensibility of probabilistic forecasts seem misplaced.

Second, those who hear external forecasts are roughly the same proportion of the population as those who own radios and access to and confidence in external forecasts is strongly and positively associated with market access and education. Therefore, as market access and education increase and communications technologies increasingly infiltrate pastoral communities, one might reasonably expect steady growth in access to and use of scientific climate forecasts.

Third, the overwhelming majority of those who report receiving modern forecasts find them at least somewhat useful, have at least some confidence in them, and update their subjective beliefs in response to the forecast information they receive. This suggests that building confidence in forecasting—whether through further investments in improving forecast skill or in developing new communication packages and dissemination methods—is less a priority right now than is promoting the economic advancement that will both endogenously stimulate demand for computer-generated forecasts and empower pastoralists to respond to forecasts through *ex ante* optimal adjustments in resource allocation.

Rather, the pressing issues are the sorts of information provided by modern climate forecasting and pastoralists' capacity and willingness to act on beliefs about climate. The data indicate that pastoralists are most interested in the onset date and the total amount of rainfall expected in the area of residence. But seasonal forecasts are currently available only at extremely coarse spatio-temporal scale (aggregates of seasons and thousands of km^2) and the information contained therein is oriented more toward crop cultivation than to pastoral production systems. These usually include crop weather reviews for coffee, maize, sugar, tea, horticulture, tobacco, wheat, and pertinent agricultural information such as onset date of rains in the highland areas and recommended planting dates. Forecast information for dairy and ranching production systems and for tourism are also produced (Curry, 2001a; Hammer *et al.*, 2001). These reports are likewise of little value to pastoralists. Given the inherent flexibility of pastoralism as a livelihood based largely on *ex post* response to observed spatio-temporal variability in forage, water and security conditions, however, there seems little prospect for pastoralists making extensive use of seasonal climate forecast information anyway.

Ultimately, our results reinforce the conclusions offered by others (Broad, 2000; Glantz, 1996; Mahmoud & Little, 2000) that those who are interested in helping mitigate climate-related risk among vulnerable populations, such as the Ethiopian and Kenyan pastoralists we study, must be careful not to focus excessively on improving forecast skill or dissemination. These do not seem to be binding constraints at present, even if external forecasts are accessed by only a sharp minority of pastoralist respondents. Rather, greater attention needs to be given to what infrastructural and institutional advances are necessary to facilitate the use of climate forecast information within the livelihood strategies prevailing in these fragile systems.

More fundamentally, the ultimate usefulness of climate forecasts for pastoralists—as distinct from national and regional authorities, for example, in programing food aid distribution—needs some rethinking. The information most likely of value to peoples who generally migrate in response to emerging opportunities and pressures would be real time, spatially explicit weather and forage condition reporting (e.g., through finer resolution maps of recent rainfall and current range conditions), not long-lead forecasts. East African pastoralists appear to place negligible value at present on modern climate forecast information.

NOTES

1. As used in this paper, climate forecasts, also sometimes called seasonal forecasts, relate to periods of one month or more, issued in advance of the relevant season. These are distinct, therefore, from short-term weather forecasts of meteorological conditions for the coming few days to two weeks.

2. Pastoralists depend on extensive (i.e., semi-nomadic or transhumant) livestock systems highly responsive to climate-induced spatio-temporal variability in forage and water availability and disease patterns. Agropastoralists couple extensive grazing with crop cultivation and are therefore more sedentarized than pure pastoralists.

3. As we were preparing this manuscript, a new, monthly USAID-supported *Greater Horn of Africa Early Warning Bulletin* made its debut in May 2002, prominently featuring seasonal climate forecast information and underscoring the increasing prominence of this technology in relief and development planning in the region. For more information, contact ghabulletin@fews.net.

4. By "external," "science-based," "computer-generated" or "modern" forecasts we mean those produced and disseminated by meteorological services using modern scientific methods. By "indigenous," "traditional" or "local" forecasts we mean those generated within communities through any of a variety of means, some of which are traditional, others of which appear to evolve and emerge in response to changing circumstances.

5. A much richer, more technical treatment can be found in Hirshleifer and Riley (1992).

6. We focus on the case of exogenous information (so-called passive learning), which is not affected by recipients' behavior. Where individuals' behavior affects the production of information (i.e., when information flow is endogenous, or so-called active learning), then agents must choose an optimal experimental design, introducing a bit more complexity that we eschew here since it is irrelevant to the present setting.

7. Goddard *et al.* (2001) offer a good review of the current state of knowledge, forecast methods and associated skill.

8. Rainfall data come from local meteorological stations, missions, police stations, and other sources. Most are in the sites, while the most distant are for Logologo, for which we use data from Laisamis, about 25 km away, and Dirib Gumbo, for which we use data from the Marsabit meteorological station, less than 10 km away. Because the 1999 rainfall data for Kargi were missing, we also use Laisamis data for that year for Kargi.

9. As we will show, almost all pastoralists receive indigenous climate forecast information and the vast majority express confidence in these indigenous forecasts.

10. The DMC forecasts are generated from a regional climate forum that convenes scientists using different modeling methods, some based on statistical relationships between historical sea–surface temperature and terrestrial precipitation data, other derived from numerical models based on physical oceanic–atmospheric relationships. The seasonal forecasts of relevance here were released following the Seventh Climate Outlook Forum held February 14–16, 2001, in Morogoro, Tanzania.

11. Our respondents also believed that rainfall volumes had been about normal elsewhere in the rangelands. Whether this reflects microvariability or "grass is greener on the other side" bias we cannot tell.

12. In spite of this statement, we caution against inferring from the modest material endowments of pastoralists that pastoralism is not a viable livelihood. Abundant evidence shows that the resource deprivations most closely associated with human suffering are often quite different among east African pastoralists than standard asset, expenditure or income accounting approaches to poverty measurement would suggest (Anderson & Broch-Due, 1999; Little, Smith, Cellarius, Coppock, & Barrett, 2001a; McPeak & Barrett, 2001; Nathan, Fratkin, & Roth, 1996).

13. The one notable outlier in these data is Ngambo, where dependence on dryland and irrigated agriculture is higher than in other sites. Because Ngambo agropastoralists must have their fields ready to plant as soon as the rains start and because they have strong competing demands for labor in the late dry season due to herding, it is critical that they begin (manual and mechanized) field preparation more than one month before the rains start. Little (1992) found that one of the most important determinants of a successful harvest both on dryland and irrigated plots was the time of planting after the rains started, which is a reflection of field preparation.

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