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Seasonal precipitation forecasts: Agro-ecological knowledge among rural Kalahari communities

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Increasing climate variability in the semi-arid Kalahari environment calls for better and timely seasonal precipitation forecasts to enable decisions at farm level and avoid disruption of livelihoods dependent on the natural resource base. This study revealed the growing importance of precipitation forecasts among agro-pastoral communities, particularly the amount, timing, duration and distribution of rainfall. Whilst a number of traditional indicators like stars, flowering of certain tree species and clouds were used, their reliability is gradually waning off in the face of increased climatic variability. Subsequently meteorology-based seasonal forecasts are preferred and accessed by most households. A lead-time of 1 to 2 months before commencement of the rainy season would enable agro-pastoralists to adequately prepare and take advantage of anticipated moisture surplus or avert production shortfalls if moisture deficits are predicted. Thus, combinations of some of the traditional methods and timely, easily understood meteorology-based forecasts would enable better accuracy of predictions and allow Kalahari agro-pastoralists to buffer their livelihoods against the adverse effects of climate variability and ensure sustainable rural development.

Key words: Agro-pastoralists, Botswana, climate variability, indicators, meteorology, traditional.

INTRODUCTION

Despite the technological advancements made in climatic forecasts over the years (Dilley, 2000; Meinke and Stone, 2005), there still remains great uncertainty. Climate variability is an inherent characteristic of the world's climate system and thus cannot simply be wished away. Climatic forecasting is particularly important to the agricultural sector in southern Africa, from which the region draws the bulk of its food supply. Rural agro-pastoral communities of the Kalahari, who are heavily dependent on their environment for subsistence, have inhabited and managed the often harsh and highly dynamic ecological systems for centuries and have, at times as a matter of necessity, developed multiple adaptive livelihoods. With annual rainfall ranging from below 20 mm along the western coastal areas of Namibia to over 3000 mm in some highland areas of Malawi (Nicholson et al., 1988), such extremes as droughts and floods and the disruption of livelihoods associated with them, are well known to these communities. For example, USAID/OFDA (1996) estimated that over 100 disastrous droughts, floods, related epidemics and pest infestations had affected 70 million people in southern Africa over the past thirty years. Despite efforts to minimize risk, communities' resilience is gradually being eroded with subsequent extreme events, which are generally expected to increase in frequency in future (Batisani and Yarnal, 2009). Considering the limitations in precision and timeliness of weather forecasts in southern Africa (Unganai and Kogan, 1998), communities are stressed even further and have to revert back to the traditional agro-ecological knowledge base they have relied on over the years to predict climatic conditions.

Traditional knowledge has often been on the receiving end of many a debate, with Scott (1988) attributing this to scientists' skepticism of its value unless it has been recast in scientific terms, and may dismiss it as superstition and irrationalism. Nonetheless, the recognition of agro-ecological knowledge of communities is increasingly gaining recognition (UNEP, 1998; Mauro and Hardison, 2000; Ingram et al., 2002; Reed et al.,

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2007). Using Botswana as a case study, an effort was made therefore to determine how rural agro-pastoral communities of the Kalahari have predicted seasonal precipitation patterns over the years, the reliability of such indicators in the face of increasing rainfall variability as well as the perceptions towards scientific climate forecasts. This could lead to greater understanding of the value of traditional agro-ecological knowledge, which could be enhanced and used concurrently with scientific knowledge in what Thomas and Twyman (2004) termed hybrid knowledge - thereby enabling better rainfall predictions, farm management decisions and secure livelihoods for Kalahari's rural communities.

MATERIALS AND METHODS

Study areas

Botswana is land-locked, and lies at the centre of southern Africa, between latitudes 18 and 27°S and longitudes 20 and 29°E and covering approximately 582,000 km^2. The landscape is flat to gently rolling. Agro-pastoral communities in Kgalagadi North and Bobonong Sub-districts were the targeted study group. The location of Bobonong in eastern Botswana is characterized by mainly agro-pastoral communities, while Kgalagadi North in south-western Botswana edges towards the margin of agro-pastoralism with some people not cultivating crops at all. Kgalagadi North study site is more towards the Kgalagadi (Kalahari) Desert than the Bobonong site. This widened scope facilitated a comprehensive study of the agro-ecological knowledge base with regard to seasonal precipitation forecasts in Botswana. Kgalagadi North is characterized by a highly variable and erratic rainfall regime, with an average of about 350 mm annually (Bhalotra, 1985). Rainfall follows a uni-modal pattern, with most of the rain received between October and April. Evapo-transpiration rates are high, with maximum summer temperatures (October to April) average of 41°C in January and February and a mean minimum for August of -8°C in the dry winter months (May to August).The soils of the area are infertile arenosols (FAO, 1991). The vegetation type is southern Kalahari bush savanna (Skarpe, 1986). Bobonong experiences temperatures above 33ºC in summer, which decline to about 4ºC in winter. Long-term rainfall averages 350 mm per annum and occurs mostly in October to April. The main soil type is eutric regosols and in some areas petric calcisols/chromic luvisols (FAO, 1991). The vegetation consists of mopane woodlands and Acacia tree/shrub savanna (Weare and Yalala, 1971). Subsistence agriculture is the main source of livelihood of the communities in both study areas. Pastoral farming is dominated by traditional production systems within communal grazing areas termed 'cattleposts' or meraka. The main livestock kept are cattle, goats, sheep and donkeys. Subsistence crop cultivation is practiced but to a lesser extent.

Data collection

Before commencing with the study, a pilot survey was undertaken. All the enumerators had tertiary education and some experience in the field as well as being fluent in Setswana, the local national language spoken by the respondents in the targeted study areas. Multiple tools were employed - conventional survey method, anthropological tools such as participant observation and participatory tool involving Focus Group Discussions (FGDs).

The first approach involved a survey conducted for a week in each study area during the 2009/2010 season. Detailed standard questionnaires with open-ended, multiple response and dichotomous questions, were administered to a representative sample of the respective communities. Within each purposively selected sub-district, a multi-stage sampling procedure was employed - at first to identify the villages and then the agro-pastoralists within the respective villages. The agro-pastoral households[1] were selected at random with the assistance of the extension officers from the Ministry of Agriculture. In the Bobonong sub-district, 50 subsistence farmers were interviewed from Lepokole and surrounding communal areas of Sekgopswe, Mmamanaka and Mmaditshwene. Kgalagadi North sub-district had 40 households interviewed in Hukuntsi, Lehututu and Tshane villages. The sample size took into consideration the statistical minimum requirement of 30, possibility of non-response and unavailability of identified respondents during the ploughing and planting period as well as resource constraints. The survey collected information primarily on livestock ownership, fodder production, crops planted, draught power, access to climatic information, extension, technology, markets and credit as well as traditional precipitation indicators currently in use and their level of reliability.

In addition, a second approach of data triangulation through FDGs and key informant interviews using a predefined checklist (community heads, farmers' association representatives and agricultural extension officers) was done to get a holistic understanding of challenges and opportunities emanating from seasonal precipitation forecasts. Selection of key informants took into consideration the age, gender, literacy and social standing of the participants, as Case et al. (2005) argues that these factors influence variations in traditional knowledge in communities.

Ranking of important crops and livestock species was done according to their perceived importance by the farmers. The use of the matrix scoring exercise was employed (Mukherjee, 1994). For livestock species, attributes deemed important in ranking included numbers kept, ease of acquisition, ease of marketing, prices fetched from sales, hardiness and utility of such animals. Crop preference scores were done based on attributes including drought tolerance, pest and disease resistance, yields, cultural acceptance, labour requirements (especially weeding and bird-scaring), prices fetched from sales and post-harvest 'shelf life'. Reliability ranking of traditional indicators was done on 4 levels (1-very reliable, 2-sometimes reliable, 3-not reliable and 4-no longer used). Simple and familiar objects such as stones and sticks were used in assigning scores. Relevant secondary sources augmented primary data (for example, agricultural census reports).

Collected data were subjected to the Statistical Package for the Social Sciences (SPSS). Frequencies were calculated using descriptive statistics for respondent demographics, socio-economic characteristics and related variables and summarized in tabular form.

RESULTS AND DISCUSSION

Agro-pastoral activities

In Botswana, agriculture is the backbone of rural economies, despite its unprecedented decline in contribution to the country's Gross Domestic Product (GDP) over the years, from 40% during independence in 1966, to 2.5% in 2003 and recently at 1.8 % in 2009 (MFDP, 2009). The reasons forwarded for these declines are several, but the primary ones being the growth of the

[1]Following Niehof (2004), a household herein refers to a family-based co-residential unit that takes care of resource management and the primary needs of its members.

mining and tourism sectors (WHO, 2007) and to some extent the stagnation of the agricultural sector itself as well as recurrent droughts (MFDP, 2009). The two major forms of agricultural production practiced are arable farming and pastoralism. MoA (1993) estimates that about 80% of the rural families still depend on rain-fed cultivation, while livestock (particularly cattle) constitute the bulk of the gross agricultural product.

In Bobonong study area, households were engaged in both crop cultivation and rearing livestock, all done for subsistence with occasional sales. The most common crops grown were maize (*Zea mays*), millet (*Pennisetum* spp.) and sorghum (*Sorghum* spp.). Others included groundnuts, beans, melons and sweet reed. Looking at the livestock ownership dynamics, the most common were poultry (68%), goats (64%), donkeys (60%) followed by cattle (50%) and lastly sheep (16%). None reared pigs or horses. By contrast, Kgalagadi North Sub-district had more households owning cattle (84.2%), goats (81.6%), poultry (60.5%), donkeys (52.6), horses (39.5%) and sheep (15.9%). Horses are used by herdsmen mainly when looking after other livestock, especially suited to navigate the Kalahari's extensive and predator-filled terrain. Cattle are especially important as they affect the culture, politics, economy and the ecology of rural Botswana and its inhabitants (Keijsper, 1993) and this was confirmed further in this study as most households perceived households with less (<25) or no cattle to be 'poor'. The common crops cultivated and ranked as important in the farmers' view were maize, melons and beans and to a lesser extent sorghum. The broadcasting method of planting was employed by the majority of households in both study areas.

Generally fodder production is unpopular in many parts of the country, and the study areas were no exception. A mere 16 and 13.2% of the farmers produced their own fodder in Bobonong and Kgalagadi North respectively, the bulk of which was from standing crop residues (*Zea mays* stover) and *Dolichos lablab* in Bobonong. This is an expected outcome primarily because of the erratic and inadequate rainfall regime in these semi-arid environments. If rainfall is not enough to support arable crops, it follows that the same would apply to fodder production - given the limited irrigation options in the study areas even in 'good' years.

According to MoA (1991), one of the most limiting factors in arable farming in the country is farm power. During ploughing and planting season, households used different forms of farm power. Traditionally Batswana (citizens of Botswana) used oxen as draught power (Vierich and Sheppard, 1980) but the donkey has increasingly become the preferred draught animal because of its 'hardiness' in withstanding dry spells and extended droughts and partly due to its classification culturally as a non-food source. In addition to being an important mode of transport for rural farmers (example, transporting water and harvests to markets), donkeys are also readily available in all districts of Botswana (Aganga et al., 1999). In Bobonong the majority (98%) of the farmers used animal drawn ploughs, exclusively donkeys, 58% of which were the farmers' own. The other 2% hired tractors. The reasons advanced for using animal drawn ploughs included lack of other less expensive alternatives (72%), non-compaction of soil (2%) and the fact that the farmers' fields were not destumped (40%), and thus inaccessible to tractors. There was also a shortage of tractors and thus longer waiting time, attributed to the government's newly-introduced (2009) Integrated Support Programme for Arable Agriculture Development (ISPAAD) which aims to improve household and national food security through provision of draught power and fertilizers, tractors, logistical support and seeds.

By contrast, 29% of Kgalagadi North farmers used tractors because they are faster (15.6%). Although use of tractors has dramatically increased due to grants extended to farmers countrywide, MoA (1991) argues that animal draught power is still more economical. Tractors are generally expensive to purchase, operate and maintain and thus animal draught power remains important to rural farmers. It is worth noting that 18.4% of the households sampled in Kgalagadi North did not practice crop production at all, perhaps because of the risk associated with the enterprise due to low soil fertility (Chanda et al., 2003) as well as low and highly variable spatial distribution of rainfall in the area. Kgosikoma (2006) similarly reported CVs of 48 and 40% for the adjacent Hukuntsi and Kang villages respectively[2].

Meteorological forecasts farmers require

Because of the limited amount and uneven distribution of rainfall in time and geographic scope, rainfall represents the most limiting factor for agricultural and livestock production in Botswana (Chipanshi et al., 2003; Batisani and Yarnal, 2009; Mogotsi, 2010). Thus, it is hardly surprising that most households in the study areas showed a keen interest in precipitation forecasts and 86.1% had access to meteorological forecasts. In Bobonong area, the primary source of climatic data was radio broadcasts (68%) and other sources included government agricultural extension officers (27.3%), community Kgotla meetings (18.2%) and television broadcasts (11.2%). Most households had access to seasonal forecasts (44%) and daily forecasts (26%), though 54% did not have regular access to this information.

In Kgalagadi Sub-district, radio broadcasts were still the main source of climatic forecasts (55.3%), followed by television broadcasts (21.1%) and extension officers at 10.5%. Of all households with access to this information, 42.1 and 39.5% received daily and seasonal forecasts

[2] CVs of 33% mark the critical value where non-equilibrium dynamics emerge (Ellis, 1995).

respectively. Only 34.2% of households regularly accessed climatic data either because they were engaged in other activities and thus missed broadcasts or were simply not interested. Other sources of climatic information used by fewer people included going to district meteorological stations, using traditional methods, communication with area political leaders, school-going kids and friends.

The Department of Meteorological Services (DMS) broadcasts expected daily temperatures (minimum and maximum) throughout the year, as well as rainfall amounts during the wet season (September to April). Even before the commencement of the rainy season, DMS releases their predictions indicating whether to expect normal, below or above normal rainfall amounts. The popular media used for dissemination are radio, television broadcasts and agricultural extension officers because of their unparalleled reach deep into remote rural areas. The increased number of meteorological stations throughout the country over the years has enabled better continuity in weather monitoring and dissemination of forecasts, although still formulated at a larger scale because of dependence on the global climatic system and its associated complex dynamics (Usman and Reason, 2004; Todd and Washington, 1998). And herein lies the fundamental aspect of scale which differentiates the two systems - traditional indicators are highly location-specific (at village level) while meteorological forecasts are at a much broader scale (at district level and beyond) and thus do not adequately capture spatial variation of rainfall.

Most agro-pastoral households surveyed identified critical information they needed from effective forecasts, namely:

(1) Will it be a drought year or not?
(2) What is the total amount of expected rainfall?
(3) When will the rains commence and end?
(4) How will the rainfall be distributed in space and time?

A combination of these parameters was most preferred rather than a single parameter. This might be due to the nature of the rainfall regime in both study areas, and in many regions of Botswana. Not only is rainfall generally low, it is also erratic and highly variable in distribution - making agriculture a risky undertaking. Crops such as maize, though preferred because of their low labour requirements (example, less weeding and no bird-scaring), are sensitive to moisture deficits. Even sorghum ready for harvest can be destroyed by late heavy rains. Thus farmers also required forecasts with a lead-time of 1 to 2 months before the actual rainy season commenced.

This would enable them to adequately prepare for ploughing and planting of fields through maintaining perimeter fencing (in most cases made of cut Acacia branches), looking for draught animals, tractors and labour, borrowing ploughs and getting free seed from the agricultural extension officers. This would mean farmers ought to have forecasts towards the end of the dry season, as early as late July and beginning of August. Ingram et al. (2002), while working with farmers in Burkina Faso also reiterated that meteorologists must balance needs for forecast accuracy with timeliness. This is certainly true because precise but late forecasts are less valuable to a farmer than a ‘crude’ but early forecast. The latter can enable a farmer to make decisions on which varieties to plant or whether to cull and sell some of the livestock, buy supplementary feed for livestock and so on.

Traditional precipitation indicators used

Most households in Kgalagadi North (63.2%) and Bobonong area (50%) professed they could predict weather conditions using traditional indicators. A number of indicators were used to make seasonal precipitation forecasts (Table 1).

Agro-pastoral communities of southern Africa have always used traditional indicators to predict weather conditions (Shumba, 1999; Ziervogel, 2001; Chang’a et al., 2010), and Botswana agro-pastoral communities are no exception. The most widely used indicators in the study areas were astronomical (stars), atmospheric (clouds) and biological (vegetation) characteristics. Multiple indicators were used at the same time for better rainfall prediction. This agro-ecological knowledge was more pronounced among the older members of the community, indicating accumulated experience over the years. Younger members did not readily reflect this agro-ecological knowledge. Hence unless this apparent gap is filled, the knowledge could be lost as older members do not pass on their experiences to younger generations - neither orally nor through written literature. While studying farmers’ perception to drought in Tanzania, Slegers (2008) also noted that the natural environment provides a wide source of knowledge about weather conditions to those who have learned to read and interpret its signs, or who can draw from experience of previous encounters.

Reliability of traditional precipitation indicators

Though possessing a wide array of indicators, communities were less convinced of their reliability and even relevance today. Reliability ranking was done on four levels (1-very reliable, 2-sometimes reliable, 3-not reliable and 4-no longer used). In Bobonong area, most indicators were less trusted - with stars, vegetation and wind deemed still reliable by only 14, 6 and 4 % of the respondents. For example, sometimes vegetation does sprout in late August just before start of the rainy season but no rain falls until deep into October. Or clouds gather but are ‘blown away’ by wind and no rain falls – and as

Table 1. Some of the traditional indicators used in the study areas to predict seasonal precipitation.

Indicator	Characteristic of indicator used	Aspect predicted	Households	
			Bobonong (%)	**Kgalagadi North (%)**
Wind	Hot wind blowing gently from no particular direction	Rainfall	4	36.8
	Strong wind with lot of dust	No or little rain		
Stars	Big star visible	Good rains	22	10.5
Vegetation	Sprouting and flowering of most *Acacia* species	Beginning of rains	18	13.2
	Mass fruiting of *Boscia albitrunca*/*foetida* (motlopi/mopipi) and *Adansonia digitata* (mowana)	Low rainfall		
Sun	High afternoon temperatures	Rainfall	-	2
Insects	Increased presence of *Macrotermes* species, 'sebokolodi' and 'khukhwane e khibidu'	Rainfall	2	-
Clouds	Dark clouds building up in the afternoon	Intense but short duration rainfall	10	10.5
	Clouds moving from the Namibian direction (westerly)			
Thunderstorm	Hear thunder and see lightning	Intense rainfall	-	7.9
Fog/mist	Dense fog/mist early in the morning	Clear sky, no rain	2	-
Rainbow	Seeing rainbow in horizon	Rain temporarily halts	2	-
Moon	Bigger ring/circle around moon	Good rains	4	
Birds	Increased presence of *Quelia* birds and sparrows	Good rains	8	-
Livestock	Calving of cattle (Oct-Feb)	Rainy season	-	2
	Livestock not coming back to drinking water points	It has rained in neighbouring areas		7.9
Wild animals	Increased presence of elephants (*Loxodonta africana*) near water points meant for livestock	Low rainfall	9	-
Rain making ceremonies*	Praying and traditional healers consulting the Gods	Good rains	2	-

*No longer practiced.

one respondent puts it, 'clouds are not rain'.

In Kgalagadi North, even less farmers thought that their traditional indicators were still reliable. Wind, clouds and vegetation characteristics were still reliable (each 5.3%). One of the main reasons cited for the erosion of credibility and confidence in traditional indicators was the perceived increased variability of rainfall and recurrent droughts over the years. Botswana has a low rainfall regime with high variability which results in semi-arid conditions. Chipanshi and Ringrose (2001) noted that the mean annual rainfall total ranges from less than 250 mm with a coefficient of variability of 45% in the extreme southwest part of the country to over 600 mm with a coefficient of variability of 25% in the extreme northeast. Though there is no definite pattern of droughts in Botswana, drought episodes display an average periodicity of approximately 16 to 20 years (Bhalotra, 1985; MFDP, 1997). Furthermore, several researchers (Hitchcock, 1979; Batisani and Yarnal, 2009) reckon that climate variability has indeed increased over the years. This increased rainfall variability and uncertainty could have rendered traditional precipitation indicators inadequate, leaving some of the households to conclude that ‘only God knows’. This fatalistic attitude, as noted by Park (1999), is often common when people feel helpless and attribute responsibility to a higher power or authority.

Meteorological forecasts versus traditional forecasts

Because of the unreliability of indicators in the preceding discussion, it is thus not surprising that fewer households (36 and 47.4% in Bobonong and Kgalagadi North respectively) actually used traditional precipitation indicators to make ‘serious’ farm management decisions like clearing new fields, setting planting dates and selling of part of the livestock herd. This is especially important because resources, which are often limited in subsistence rain-fed agriculture (Green and Raygorodetsky, 2010), have to be mobilized only when some level of uncertainty has been removed from the farmers’ mind. That is, in addition to environmental variability, the economics have to also be considered. Speranza et al. (2009) also discovered that few agro-pastoralists in Kenya adapted their practices in response to traditional knowledge based forecasts partly due to limited resources. This thorough assessment of risk illustrates the rationality and pro-activeness of agro-pastoralists, who are often portrayed as passive victims of environmental variability.

Therefore, households who used traditional indicators concurrently combined it with meteorology-based forecasts. If given a choice between traditional methods of predicting precipitation and meteorology-based forecasts, most households chose the latter. Bobonong had 66% of such households while Kgalagadi North had 73.7%. Several reasons were advanced for choosing meteorology-based forecasts. Some of the reasons included better reliability and precision of forecasts (68.6%) from DMS since the government has modern and sophisticated technology to ‘see into the future’. Interestingly, not all who chose meteorology-based forecasts did it for their reliability, but simply because it was the only forecast they had (13.8%) since traditional methods were extinct. For the other respondents who chose traditional methods over meteorology-based forecasts, it was because of the less reliability of meteorology-based forecasts (23.7%), as well as the simplicity and familiarity (56%) of traditional methods.

This then calls for DMS to interpret the scientific forecasts to resonate with their intended local recipients and avoid using jargon-loaded language like ‘below normal’ rainfall, ‘normal to above normal’ rainfall and so on. The DMS and agricultural extension officers can also take advantage of traditional indicators familiar to local communities and form the basis for developing weather advisory. Also because of the probabilistic nature of forecasts (Meinke and Stone, 2005), users of such information should be informed of the inherent uncertainty in climatic forecasts. This is particularly important should the predicted forecasts fail to materialize when farmers have made irrevocable decisions. Hence, Dilley (2000) cautions that this may ultimately have implications on future acceptance and use of advance climatic information by communities.

Conclusions

Kalahari agro-pastoral communities are keenly interested in seasonal precipitation forecasts since their livelihoods are intricately linked to the rain-driven natural resource base. Though equipped with accumulated agro-ecological knowledge, communities are gradually losing faith in this knowledge in the face of increasing rainfall variability. Thus meteorology-based forecasts are increasingly becoming important, and should be tailored to be understood by the end user. Still, the few remaining traditional indicators in use could be explored and used together with modern meteorology-based forecasts to enable timely and relevant decision making at the farm level and thus buffer farmers from adverse shocks due to climate variability. This would contribute to making agro-pastoralists better managers in the harsh and unpredictable environment they operate under.

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