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Ethno-meteorology and scientific weather forecasting: Small farmers and scientists' perspectives on climate variability in the Okavango Delta, Botswana

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ABSTRACT

Recent trends in abrupt weather changes continue to pose a challenge to agricultural production most especially in sub-Saharan Africa. The paper specifically addresses the questions on how local farmers read and predict the weather; and how they can collaborate with weather scientists in devising adaptation strategies for climate variability (CV) in the Okavango Delta of Botswana. Recent trends in agriculture-related weather variables available from country's climate services, as well as in freely available satellite rainfall products were analysed. The utility of a seasonal hydrological forecasting system for the study area in the context of supporting farmer's information needs were assessed. Through a multi-stage sampling procedure, a total of 592 households heads in 8 rural communities in the Okavango Delta were selected and interviewed using open and close-ended interview schedules. Also, 19 scientists were purposively selected and interviewed using questionnaires. Key informant interviews, focus group and knowledge validation workshops were used to generate qualitative information from both farmers and scientists. Descriptive and inferential statistics were used in summarising the data. Analysis of satellite rainfall products indicated that there was a consistent increase in total annual rainfall throughout the region in the last 10 years, accompanied by an increase in number of rain days, and reduction of duration of dry spells. However, there is a progressive increase in the region's temperatures leading to increase in potential evaporation. Findings from social surveys show that farmers' age, education level, number of years engaged in farming, sources of weather information, knowledge of weather forecasting and decision on farming practices either had a significant relationship or correlation with their perceptions about the nature of both local [ethno-meteorological] and scientific weather knowledge. Nonetheless, there was a significant difference in the mean scores of farmers in relation to their perceptions and those of the climate scientists about the nature of both local and Western knowledge. As farmers are adept at judging seasonal patterns through long-standing ethno-meteorology, one major CV adaptation measure is their ability to anticipate changes in future weather conditions, which enables them to adjust their farming calendars and make decisions on crop type selection in any given season.

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Introduction

Traditional African cultures comprise an institution of "rainmakers" – people who would not as much invoke the rains, but anticipate them based on ethno-meteorology (see for instance, Gewald, 2002; Huffman, 2009). The forecasting was based on skillful art of observing the natural environment as expressed in the timing or flowering of plants, hatching of insects, arrival of migratory birds, etc., which enables farmers to make adjustments in farming calendar and crop selection types in any given season. This indigenous knowledge[1] was often passed down from one generation to the other. Thus smallholder farmers value their ability to accurately observe and anticipate local conditions in various ways that serve their needs better than outside forecasts (see Onyango, 2009; Ouma, 2009). Elsewhere, it is acknowledged that local knowledge, at the least, plays a complementary role in generating climate information and understanding climate variability (see Ifejika Speranza et al., 2010; Orlove et al., 2010). The ability to anticipate changes at seasonal and shorter time scales and to adjust the farming practice accordingly, is a key element in creating resilience of indigenous farmers to the vagaries of weather conditions, thus serving as the basis for improving food security. This is particularly important in the context of climate variability (CV) and change which now constitute a serious threat to agricultural productivity and food security in sub-Saharan Africa. It is increasingly recognised that the adoption of seasonal forecast is an important element of climate change adaptation strategy, particularly in arid and semi-arid southern African countries (Hansen et al., 2011).

Scholars have documented different ways in which local communities historically adapted to CV in Botswana (Prah, 1978; Hitchcock, 1978; Cooke, 1978; Dube and Sekhwela, 2008; Landau, 1993). However, modernisation has eroded the knowledge system of community people to the extent that these local custodians are stigmatised as '. . . backward charlatans' (Onyango, 2009). Apart from the labeling and stigmatisation experienced by small farmers, abrupt changes in weather patterns, which also interrupt natural indicators used in ethno-meteorology,[2] continue to overwhelm the smallholders in their present circumstance. For instance, the Nganyi clan in western Kenya, which is noted for its expertise in weather reading and rain-making, has admitted that the present global warming associated with climate change has become a daunting challenge facing them in their agricultural activities (Ouma, 2009). More than ever before, smallholders are now consistently vulnerable, making them more socio-economically miserable. Regardless of the present influx of scientific weather forecast, it appears smallholder farmers are already enmeshed in the complexities of CV and climate change.

Contemporary, periodic seasonal forecasts are issued by government departments dealing with meteorology. Unlike short term forecasts (5–10 days ahead), seasonal forecasts (3–6 months ahead) based on ensemble runs of global and regional climate models as well as analyses of synoptic conditions performed by skilled meteorologists in most cases do not provide handy and timely information relevant to farmers' needs. For example, the forecast released regularly by Southern African Regional Climate Outlook Forum, provides information in the form of probabilities of terciles with often minimal differences between them (e.g. 35% chance of below normal, 35% chance of normal and 30% chance of above normal rains). Such forecast language and concepts involved may not be understood by smallholder farmers. Also, there is little understanding about the extent to which these forecasts actually reach smallholder farmers, and to what extent these are appropriated and used by them to prepare for the expected inclement weather conditions. Additionally, the magnitude of the upcoming change in weather conditions is not usually communicated to farmers.

Consequently, failure of farm harvests with its associated poor returns on investment has led farmers to continue to diversify their means of livelihoods by appropriating (whether rightly or wrongly) other ecosystems services. Although a few long-term data exists, there is evidence that temperatures have been increasing in the past thirty years in Botswana in line with global and regional trends. As far as rainfall is concerned, the changing pattern is less obvious. There was a considerable reduction of rainfall observed between the 1970s and 1990s throughout the country, with a considerable drought during 1984–1986 (Bhalotra, 1987). There is also an understanding that droughts in Botswana are associated with *El Nino* episodes, but the relationship is not straight forward (Nicholson et al., 2001). However, the rains have been progressively improving since around year 2000, leading to the occurrence of floods that might have been considered disastrous in 2010. Such a precipitation history implies that rainfall is not only inherently variable (and thus from agricultural point of view, unreliable) on a year-to-year basis, but also that there is a strong variability at multi-decadal time scales. This multi-decadal variability has been detected in statistical analyses of rainfall and river flow time series (McCarthy et al., 2000; Mazvimavi and Wolski, 2006) and corroborated by 60–120 year cycles found through stalagmite and tree ring paleoclimatic analyses by Tyson and his colleagues (Tyson et al., 2002). More recently, Jury (2010) analysed the relationship between Okavango River discharges and sea surface temperature variability, and found a weak, but statistically significant relationship between North Atlantic Oscillation (NAO) index and summer (January–April) Okavango discharges manifesting itself at time-scales longer than 30 years. The modes of climate variability such as NAO, manifested at decadal and longer time scales, have a strong potential to modify influence of the well known sea-surface temperature anomalies (like *El Nino* or *La Nina*) on rainfall (see, for instance, Power et al., 1999). The multi-decadal variability in rainfall, due to its characteristic time scale longer than 20–30 years, is firstly often confused with effects of climate change, but more importantly it is

[1] In this context, indigenous or local knowledge, weather forecasting knowledge and ethno-meteorology are, on the one hand, used interchangeably in this paper. On the other hand, meteorology and scientific weather forecasting connote the same thing. Weather scientists and meteorologists also mean the same thing.

[2] Ethno-meteorology is an indigenous way of forecasting and interpreting local weather conditions in a given locality or remote community.

reminiscent of such effects (Hulme and Kelly, 1993). Thus it offers an opportunity to study social adaptation mechanisms and strategies, adequacy of established policy, institutional frameworks, etc. in order to enhance a better understanding of the current scenario in the Delta. Thus the original research from which this paper is derived was sponsored by the SysTem for Analysis, Research & Training (START) and the US National Science Foundation (NSF) in 2011. It primarily aimed at creating a platform for local farmers and weather scientists (meteorologists) to interact and engage in 'transforming exchanges' activities with a view to enabling them cross-fertilise ideas on weather knowledge production and adaptation strategies against CV in the Okavango Delta of Botswana.

In this paper, we consider weather forecasting in the context of adaptation to the prevailing CV, and current and future climate change, under the presumption that building resilience to current conditions will improve resilience to change. The research therefore addresses, amongst others, the questions of how local farmers in the Okavango Delta of Botswana read and predict the weather; how they access scientific information on seasonal weather forecast; how the smallholders and weather scientists perceive the nature of both local and scientific weather forecasting; whether or not science should be complementary or supplementary to indigenous seasonal weather forecast; and how the smallholders can work together with weather scientists in order to devise adaptation or coping measures against CV.

Methodology

Study area

The Okavango Delta is a globally renowned Ramsar[3] site. It is characterised by permanent watercourses, seasonal floodplains and islands, and a range of wildlife and vegetation species. The Okavango River in Ngamiland District is part of a larger northern drainage system that includes the Chobe and Linyati river basins. The Okavango Delta system thus provides perennial water sources that support riparian and non-riparian livelihood activities (see Fig. 1). The Ngamiland District is divided into two administrative entities, namely Ngami and Okavango sub-districts.

The provisional population figure of Ngamiland (both East and West) in the 2011 population census result is 137,593 people with an annual growth rate of 1.9% (CSO, 2011). The district is characterised by a multi-ethnic setting with a diversity of cultures and ethnic groups who pursue various livelihoods and use resources differently. Some of the ethnic groups include Batawana, BaYei, HaMbukushu, BaSarwa, BaXhereku, BaSubiya and BaKgalagadi. While majority (75%) of the farming activities in this area rely on rain-fed agriculture, about 25 per cent of farming activities are based on the use of inaundated flood plains (i.e. flood recession farming) locally known as *Molapo* farming (VanderPost, 2009). Molapo farming is found in the flood plains and at the western and south eastern fringes of the Delta, mainly Gumare/Tubu and in the Shorobe-Matlapaneng/Maun area (see Fig. 1).

Sample size and data collection

Using a multi-stage sampling procedure (encomapssing series of stages culminating in a simple random sampling), a total number of 592 households heads were selected from and interviewed in eight rural communities from August 2011 to February 2012 (Table 1). Specially trained field assistants (3) who already acquired Bachelor's degrees and the Okavango Research Institute's Social Sciences technicians (2) were employed in collecting the data. These field enumerators were complemented by at least one community assistant in each of the villages studied. A fair representation of the Okavango Delta was ensured by sampling three communities from the distal area (Semboyo, Habu and Tsau); two from the mid-Delta area (Jao and Etsha 6); and three from the upper panhandle area (Ngarange, Tsodilo and Chukumuchu). The respondents were interviewed using a pre-tested close and open ended interview schedule. Key informant approach was used to elicit qualitative data from farmers in our preliminary survey. Also, 18 purposively selected weather scientists[4] were interviewed using a pre-tested close and open ended questionnaire. We also used a knowledge validation workshop (comprising 36 participants who were farmers, village chiefs, community elders and social scientists and meteorologists) to further elicit information and create a knowledge sharing forum between stakeholders.

Additionally, meteorological and hydrological data for the analysed period in the study area and its surroundings were compiled for juxtaposition with farmers' perceptions, and as a basis for assessing the relationship between yields and climatic conditions. Since the rain gauge network is very sparse in the study area, satellite products such as Tropical Rainfall Measuring Mission product 3B42 (TRMM 3B42 and RainFall Estimates 2.0 (RFE 2.0) were used. Inundation extents in the Okavango Delta were derived from archival Moderate-Resolution Imaging Spectroradiometer (MODIS) satellite imagery. Seasonal weather forecasts from various sources (UCT CSAG and SADC) were compiled. Hydrological forecasts (flood extent, water levels) were done based on seasonal forecasts and available hydrological models.

[3] The Convention on Wetlands, which held at Ramsar, Iran in 1971, is also known as the "Ramsar Convention". It is an intergovernmental treaty that outlines the commitments of member countries to maintain the ecological character as well as plan the sustainable use of their wetlands especially those designated as Wetlands of International Importance in their territories.

[4] There are a few number of weather scientists/meteorologists in Botswana. Those available amongst them at the time of the study were therefore selected for the interview.

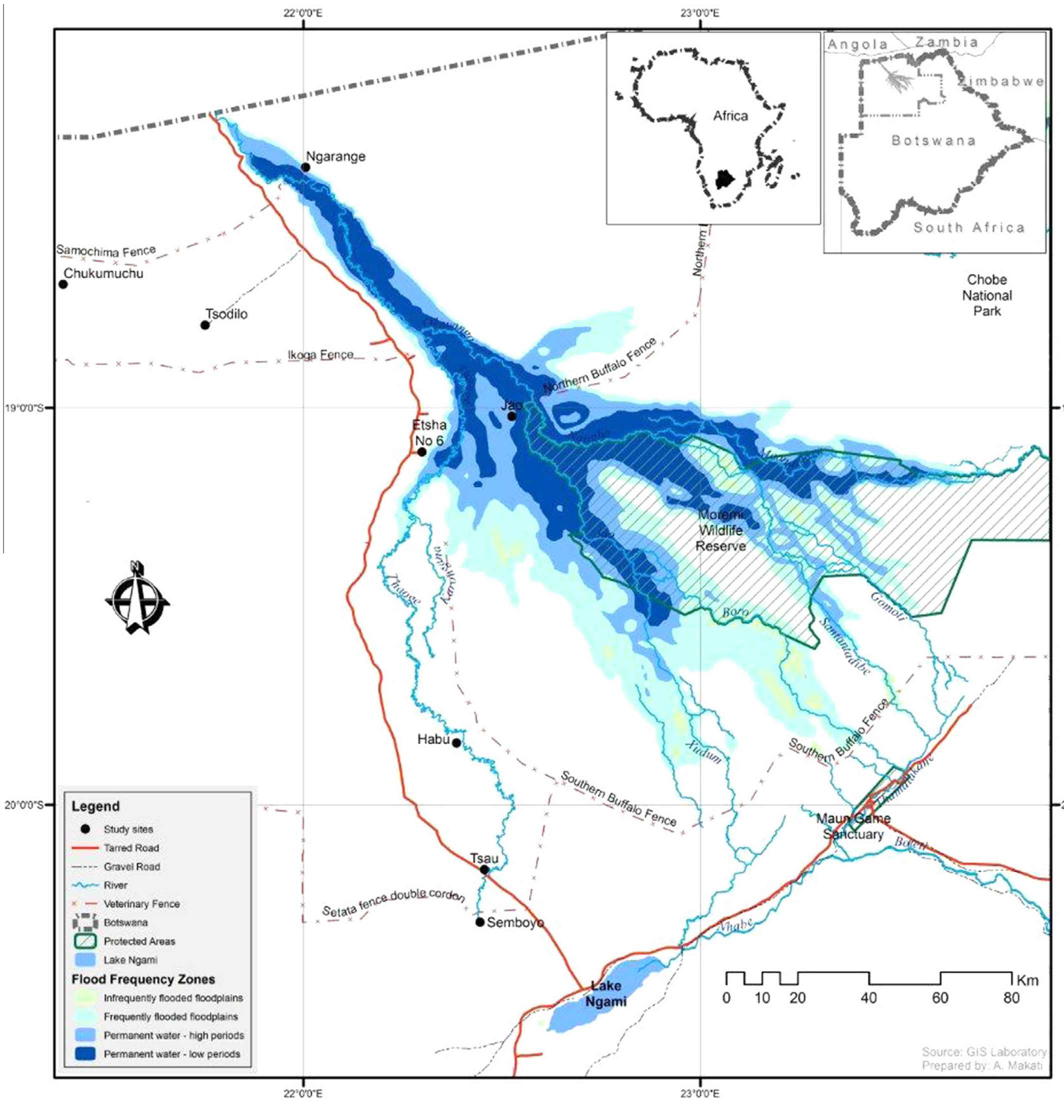

Fig. 1. A map showing the distribution of riparian communities and water channels in the Okavango Delta as well as the communities studied.

Table 1
Villages and total number of households sampled for the survey. Source: field survey, 2011–2012; (CSO, 2011).

S/N	Village	Total number of households (HHs)	25–30% of households (HHs)
1.	*Semboyo*	118	30
2.	*Habu*	161	40
3.	*Tsau*	494	124
4.	*Etsha 6*	821	221
5.	*Jao*	63	19
6.	*Ngarange*	332	95
7.	*Tsodilo*	78	23
8.	*Chukumuchu*	128	40
Total		2195	592

Hydrological forecasting in the Okavango Delta

The Okavango River derives its water flow from the Cuito and Kubango Rivers originating from the upland plains of Angola. The amount of water from these sources determines the volumes and extent of floods in any given season in the Okavango Delta floodplains. Situated in a semi-arid environment where rainfall is indeed scarce, farmers in the area mainly rely on these seasonal floods to actualise their traditional practice of flood recession agriculture (see VanderPost, 2009). Given that the weather events in Angola largely determine the social-ecological and livelihoods activities of riparian communities in the Delta, it is therefore pertinent in this research to explore the hydrological trends in the area vis a vis the prevailing CV and how these correspond with farmers' observations and farming activities. In our preliminary investigations and key informant interviews, some farmers in Ngarange community at the upper panhandle of the Delta (Fig. 1) had indicated the flow of rivers in the Delta could be used to make weather predictions. They observed that *a year of rains and bountiful harvest is preceded by a one-directional free flow of rivers. However, an agricultural season of limited rainfall is imminent in a year when rivers appear to flow in a spiral-like manner*. The logic behind this observation is that a high volume of water as depicted by 'free flow of rivers' suggests that the upland plains of Angola has received plenty of rainfalls, which also may probably have positive effects on the weather patterns of northern Botswana. Naturally, the Okavango Rivers gradually dry up when they receive little or no water, thus suggesting the spiral movement or flow as seemingly observed by the community people.

That said, hydrological forecasting is not routinely carried out in the Okavango River basin and in the Okavango Delta. Considering the seasonal flood dynamics, whereby the flood wave takes several weeks to travel down the main Okavango River and another 2–3 months down the Okavango Delta, only forecasts with lead time of 3–6 months can provide information of value exceeding that obtained from a hydrological monitoring system. We investigated here the usefulness of a seasonal forecasting system, in which we linked the ensemble weather forecast routinely run at Climate System Analysis Group within Global Forecasting Centre for Southern Africa (GFCSA) with a hydrological model of the Okavango catchment. The analyses however have preliminary character, as the system is still being developed and improved. Thus we present only general, initial analyses. The skill of the hydrological forecast (i.e. how well the forecast discharges and water levels correspond to the actual ones) is affected by a number of factors: uncertainty of the accuracy of the climate model; uncertainty of the forecast drivers of local climate (in the case of seasonal forecast, it is sea surface temperature, sea ice, aerosol concentrations, etc.); and internal uncertainty of the hydrological model.

In order to assess the usefulness of this forecasting system, we have analysed a time series of hindcasts (i.e. simulations of the past conditions) obtained from this system, specifically looking at representation of interannual hydrological variability. In this way, we have looked at an inherent uncertainty of the forecasting system that is not related to how well we assess future drivers, but rather it is dependent on the uncertainties of the climate and hydrological models. The hindcast represents here "the perfect" forecast. In other words, the actual seasonal forecasts can never be better than the hindcasts.

The climate forecast is based on a 10-member initial condition ensemble of runs of HadAM3P model. The three-months lead time forecast based on persisted observed sea surface temperatures (SSTs) is released monthly. The hydrological model is a version of the semi-conceptual Pitman model used earlier in the context of climate change impact studies (Hughes et al., 2011). The model simulates Okavango River catchment upstream from the inlet to the Okavango Delta, and is run on a monthly basis with inputs of rainfall and potential evapo-transpiration provided for 22 sub-catchments ranging in size from 1000 to 10,000 km^2.

A major limitation in the development of the hydrological forecasting system for the Okavango is the virtual lack of ground rainfall data from Angola after the late 1960s. Additionally, our earlier work reveals that satellite rainfall products RFE 2.0 and TRMM3B42 provide biased rainfall estimates and that these errors affect assimilation of data into the forecast and their use in statistical downscaling procedures (Wolski et al., 2012). In view of the above and in order to link outputs of the Global Climate Model (GCM) with the hydrological model (and instead of rigorous downscaling procedures), we have used histogram matching unbiasing technique, applied to GCM data, regridded to finer resolution and averaged within each sub-catchment.

The median of the ensemble hindcast simulations represents the timing of the seasonal cycle of Okavango River flows well, matching the annual trough in November and the peak in April/May (see Fig. 2). Nonetheless, the interannual variability is not well captured, with low correlation between observed and simulated total annual flows and lower variance in simulated than in the observed flows (see Fig. 3). There are two periods when deviations of ensemble median from observations seemed to be systematic: 1993–1997, when below average flows were observed (in fact flows in this period were amongst

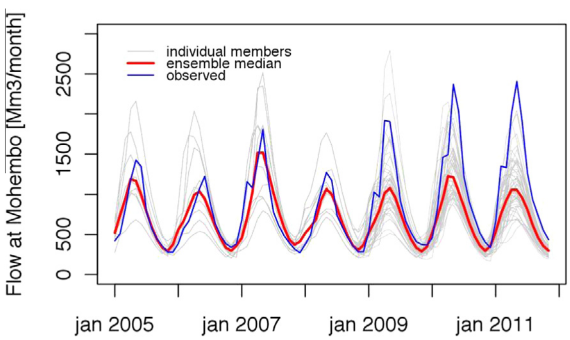

Fig. 2. Monthly flows in the Okavango River at Mohembo, observed and simulated based on hindcasts of HadAM3P model.

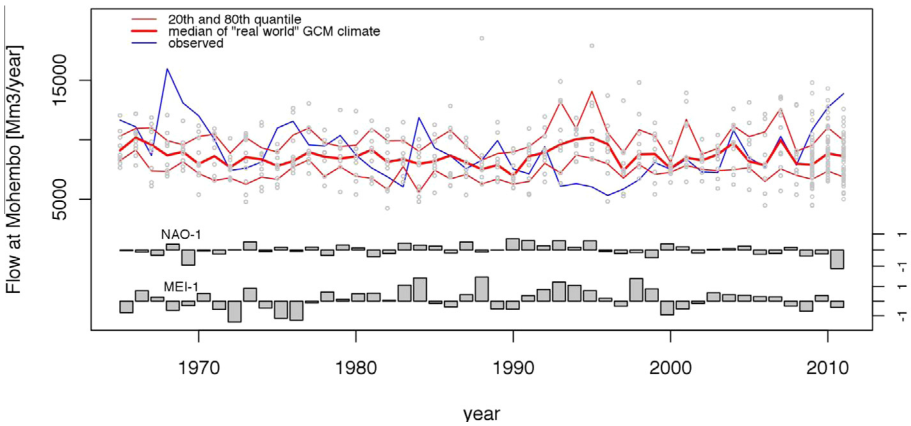

Fig. 3. Annual flows of the Okavango River at Mohembo, observed and simulated based on hindcasts of HadAM3P model, values of two indices of global climate variability (NAO – North Atlantic Oscillation, and MEI – Multivariate ENSO Index).

the lowest on record), but when ensemble simulations are consistently above average; and 2009–2011, when hindcast simulations were consistently below the high recorded flows. The underestimation of flows by ensemble simulations is also present in individual above-average years of 1975, 1979 and 1984. Additionally, during the period of 1999–2008 when flow levels were moderate, the pattern of interannual variability was remarkably well represented by the ensemble median.

We have explored possible relationships between climatic drivers (synoptic conditions in the region and indices of modes of global climate variability such as North Atlantic Oscillation, Pacific Decadal Oscillation and ENSO) and the accuracy of the hindcast, but no definite conclusions could be reached. There are some differences in these drivers for the various pluriannual periods differing forecasting system's performance, but these differences do not have a strong diagnostic power. In other words, one cannot, unfortunately, determine conditions for which forecasting system would underestimate, overestimate, or correctly represent actual conditions.

Given the context of this paper, the major conclusions from this exercise are that: current, state-of-the-art seasonal hydrological forecasting system for the Okavango basin, unfortunately, does not produce accurate forecasts all the time; there are sequences of years when the forecasting system performs well, but there are also sequences of years when performance is not adequate from the point of view of flood protection and planning of agricultural activities (such as *molapo* farming); the forecasting system failed to predict the high flood conditions, particularly in the years 2009–2011; and the system is complex and it is rather difficult to communicate its outcomes and meaning to the general public.

Results and discussions of social survey

Demographic attributes of farmers and weather scientists

The analyses and discussions in Sections 'Demographic attributes of farmers and weather scientists, How local farmers negotiate[6] scientific weather information and Farmer's [local] knowledge of weather forecasting and climate change adaptation strategies' intend to invoke the social ecological framework/perspective and situate the interviewees, especially the farmers, in that context. Thus social ecological model explains the nature of interactions between human beings and their environment, which engender certain processes and conditions that influence human development within the environment in which people live (Bronfenbrenner, 1994). The framework views individuals as enmeshed in socio-cultural relationships within social institutions of families, social networks, communities, etc. that potentially influence, directly or indirectly, individual's propensity or ability to act in certain ways (Bronfenbrenner, 2009). Thus variables such as sex, age, education, household size, etc. play key roles in people's inter-relationships and roles within a given community. Data analysis shows that majority of the farmers (n = 592) were females (64%). About 56% of the scientists interviewed were men (n = 10) (Tables 2 and 3). While the average age of the farmers was 51 years (with a standard deviation [SD] of 18.7), the weather scientists had an average age of 46 years (with a standard deviation of 8.9). Nonetheless, a fairly significant proportion of the farmers (~25%) were older than 65 years. The analysis suggests that most farmers are still within the active age of farming. While 43.8% of the farmers did not attend any formal or non-formal education system, only 3.2% had post-secondary education. Some 18.4% obtained secondary school certificate while only 5.1% never finished secondary education. Only 5.4% of the farmers attended adult literacy class. Most of the scientists (~67%) had bachelors and postgraduate degrees. Those of them who did not acquire more than secondary education may have received in-service training in the course of their career development (see Table 3). Generally, most farmers in the study area did not acquire requisite [formal] education. The most common language spoken by farmers is Setswana. Nonetheless, there are variants of other specific local dialects associated with certain groups such as the BaHerero and the BaSarwa (San) who are found in settlements like Chukumuchu and Tsodilo,

Table 2
Distribution of farmers by demographic attributes. Source: Field survey, 2011–2012.

Variable	Frequency	%	n = 592
Sex			
Male	213	36	
Female	379	64	
Total	592	100	
Age			
Below 26 years	25	4.3	
Between 26 and 45 years	245	41.3	M = 51.06
46–65 years	175	29.6	
Above 65 years	147	24.8	SD = 18.7
Total	592	100	
Education level			
I had no formal or non-formal education	259	43.8	
I attended adult literacy class	32	5.4	
I attended pry standard school but never finished it	72	12.2	
I had primary standard 7 certificate	71	12	
I attended secondary education but never finished it	30	5.1	
I had Secondary School Certificate	109	18.4	
I had post-secondary education	19	3.2	
Total	592	100	
Household size			
Only one person	39	6.6	
Between 2 and 5 members	246	41.5	M = 6.28
Between 6 and 9 members	179	30.3	SD = 4.0
Above 9 members	128	21.6	
Total	592	100	

Table 3
Distribution of weather scientists by demographic and socio-economic attributes. Source: Field survey, 2011–2012.

Variable	Frequency	%	n = 18
Sex			
Male	10	55.6	
Female	8	44.4	
Total	18	100	
Age			
Below 26 years	–	–	
Between 26 and 45 years	9	50.0	M = 46.1
46–65 years	9	50.0	SD = 8.9
Above 65 years	–	–	
Total	18	100	
Education level			
I had Secondary school certificate	4	22.2	
I had Post-secondary education	2	11.1	
I had Bachelor's degree	6	33.3	
I had Postgraduate diploma certificate	2	11.1	
I had Postgraduate degree	4	22.2	
Total	18	100	
Income earned per month (BWP)			
Between 5001 and 7500	4	22.2	
Between 7501 and 10,000	3	16.7	
Between 10,001 and 12,500	5	27.8	
Between 12,501 and 15,000	1	5.6	M = 10686.00
Between 15,001 and 17,500	2	11.1	SD = 2483.40
Between 17,501 and 20,000	1	5.6	
Between 20,001 and 22,500	1	5.6	
Above 22,501	1	5.6	
Total	18	100	

respectively (Fig. 1). As a result of their inability to read and write, a significant proportion of the farmers may have been disadvantaged in negotiating their ways in the process of technology adoption and information uptake. Their average household size was about 6 persons (with a standard deviation of 4.0). This may have had positive implications on readily available of farm labour (Table 2). The average income for the farmers was BWP620.02 per month[5] (with a standard deviation of BWP1,

[5] 1 US$ exchanges for BWP 9.02 at the time of writing this paper.

Table 4
Distribution of farmers by how they negotiate knowledge of scientific weather forecasting. Source: field survey, 2011–2012.

Variable	Frequency	%	n = 592
Personal contact with Metereological service agent in the last 6 months			
None	592	100.0	
Total	592	100.0	
Medium of contact with weather information[a]			
Only through the television	20	3.4	
Only through the radio	247	41.7	
Through both radio and TV	70	11.8	
Through radio, TV and other means	12	2	
Occasional personal contact with Met. Service agents	2	0.3	
Through friends, colleagues and neighbours	33	5.6	
I do not receive any weather information	202	34.2	
Others – Agric. Extension officers	28	4.7	
Reasons why farmers did not adopt scientific weather information[a]			
Some or most scientific weather information are too complex to understand	36	6.1	
Some or most of the forecasts are erroneous or do not tally with actual reality	29	4.9	
Weather forecast information are not properly conveyed by the Met. Service in the language we understand	14	2.4	
Media (e.g. TV, radio, newspapers, etc.) through which weather information are conveyed are not available to us	96	16.2	
We do not have access to any weather forecast information; weather forecasting agents do not have contacts with our community	202	34.2	
Lack of promptness in receiving weather information and other reasons	253	42.7	
Sources of local weather information for making farming decision[a]			
I obtain weather information from local Ngaka/Dingaka[b] alone	36	6.1	
I obtain weather information from friends, colleagues and neighbours	33	5.6	
I obtain information from elderly people in my neighbourhood	333	56.3	
Apart from obtaining information from Ngaka/Dingaka,[b] friends and neighbours, I also obtain information independently	157	26.5	
Others	39	6.6	

[a] Multiple responses.
[b] *Ngaka* (singular) or *Dingaka* (plural) in Setswana means doctor(s).

098.4) and that of the scientists was BWP12, 147.00 per month (with a standard deviation of BWP2, 483.4) (Table 3). The large value of SD for farmers' monthly income may have been influenced by the large variation between the minimum and maximum values of farmers' earnings in the area, where majority of them had very low monthly income. While 72.8% of the farmers earned less than BWP500.00 per month, only a few of them (0.2%) earned more than BWP9000.00 per month.

How local farmers negotiate[6] scientific weather information

Human agency and capability have direct relationship with an individual's ability to make careful choices between several alternatives and be able to prioritise them (Sen, 1999). A local farmer's ability to make informed decisions is therefore largely governed by his or her personal and unique experiences acquired over the years. The distribution of farmers by how they negotiate knowledge of scientific weather forecasting is shown in Table 4. Analysis indicates that there is a communication gap between farmers and development agencies in the Okavango Delta; all the farmers had not had any personal contact with the Meteorological Service Department (DMA)/agents in the last 6 months. In Botswana, the officers of the DMA have the statutory role of engaging directly with community people during which meetings are organised for the purpose of providing weather information for community members. This is in addition to conveying weather messages through the mass media. The media through which farmers accessed weather information were diverse. However, a significant proportion of the interviewees got information from the radio (42%) or a combination of both radio and television (~12%). Social networks such friends, colleagues and neighbours (~6%) and other channels such as the Agricultural Extension officers (also known as agricultural demonstrators) (~5%) constituted other means through which farmers obtained weather information. More importantly, some 34.2% of the farmers claimed they did not receive weather information at all. Specifically, lack of access to weather information (34.2%) and, social amenities and mass media such as the television, radio and newspaper (16.2%); the complexity of weather information (6.1%); erroneous forecasts which do not tally with actual reality (~5%); poor delivery of weather information by the DMS (2.4%); and lack of promptness in receiving weather information, and other reasons (~43%), influenced farmers not to uptake weather information.

In essence, well over 76% of the farmers did not adopt scientific weather information. Majority of them therefore utilised local or indigenous weather information for making farming decisions. For instance, 56.3% of the respondents claimed they obtained information from elderly people within their neighbourhood. Those who obtained information independently in

[6] The concept of 'negotiation' used in this context connotes agreement/disagreement by farmers to use scientific weather information as conveyed by the Department of Meteorological Service (DMA).

Table 5
Farmer's knowledge of weather forecasting (n = 592). Source: field survey, 2011–2012.

Statement*	Strongly agree	Agree	Undecided	Disagree	Strongly disagree
Based on personal experience, I can predict whether there will be enough rains or not in a farming year	194 (32.8)**	230 (38.9)	26 (4.4)	74 (12.5)	68 (11.4)
Through mere smells, I can discern whether it is going to rain or not at a particular time	119 (20.1)	171 (28.9)	35 (5.9)	143 (24.2)	124 (20.9)
Through the chirpings of some birds and sounds from certain insects, I can predict whether it is going to rain or not	243 (41.0)	240 (40.5)	19 (3.2)	47 (7.9)	43 (7.3)
I make necessary decisions to overcome any weather problem as required and deemed fit	109 (18.4)	252 (42.6)	59 (9.9)	108 (18.2)	64 (10.8)
Through certain plants, I can predict whether it will rain or not	227 (38.3)	216 (36.5)	29 (4.9)	65 (11.0)	55 (9.3)
Our forefathers from whom we acquired farming experience have had long standing and proven experience of weather forecast from which I have benefited	447 (75.5)	107 (18.1)	20 (3.4)	12 (2.0)	6 (1.0)
I can, through the gathering of clouds in certain direction in the sky, predict whether it will rain or not	247 (41.7)	218 (36.8)	17 (2.9)	61 (10.3)	22 (3.7)
I can predict the abundance or otherwise of rains based on the pattern of early rains in a farming year.	203 (34.3)	170 (28.7)	39 (6.6)	118 (20.0)	62 (10.5)
Through certain symbols/signs, I am able to discern whether there will be excess or scarce rains in a given farming year	157 (26.5)	278 (47.0)	42 (7.1)	60 (10.1)	55 (9.3)
Through star constellation, I can predict whether it will rain or not	76 (12.8)	98 (16.6)	75 (12.7)	83 (14.0)	260 (43.9)
From personal experience, I am able to predict the extreme of temperatures in a given farming year	124 (20.9)	193 (32.6)	48 (8.1)	112 (18.9)	115 (19.4)
Using trend observation [sequence of yearly weather events], I can determine what the climate would be in a particular farming season	108 (18.2)	248 (41.9)	57 (9.6)	94 (15.9)	85 (14.4)

* Multiple responses.
** Percentages are in parenthesis ().

addition to consultations with *Ngaka*/*Dingaka*,[7] friends and neighbours comprised 27% of the interviewees. Only 6% of the farmers obtained weather information from friends, colleagues and neighbours. The analysis shows that farmers largely rely on communal social networks in accessing indigenous weather information. While most farmers exhibited certain degree of autonomy by largely using local knowledge in their farming decisions, when to commence planting, for instance, is sometimes influenced by other factors which are not weather-related. Among many communities in Botswana, it is a norm to plant at the beginning of the rainy reason, with the hope that it will rain during the course of the season. There are many cases where the rains stopped, thus resulting in crop failures. The decision to plant or not is also influenced by government's desire to achieve specific goals for certain sectors in the economy. For example, government may want to increase the contribution of the agricultural sector to gross domestic product (GDP) (UNDP, 2012; Omari, 2010; Seleka, 2005) and hence encourage farmers to always take advantage of the first rains without any foreknowledge of the seasonal forecasts.

Farmer's [local] knowledge of weather forecasting and climate change adaptation strategies

Given the existing gap and lack of effective information exchange between farmers and weather scientists, ethnometeorological knowledge may have played a significant role in smallholders' ability to devise CV adaptation measures in remote communities of the Delta. The distribution of farmers by their [local] knowledge of weather forecasting is therefore presented in Table 5. Well over 70% of the respondents used personal experience to predict whether there will be enough rains or not in a farming year. A substantial percentage of the farmers (49%) claimed to discern whether it is going to rain or not at a given time by merely smelling the environment. Eighty-two percent of them based their prediction of the rains by listening to the chirpings of some birds and sounds from certain insects. Most farmers (~75%) claimed to predict the rains through the behaviour of certain plants. A great majority (~94%) of them opined that their forefathers had long standing and proven experience of weather forecasting from which they benefitted. While about 79% of the respondents used observation of cloud gatherings and their location in the sky to make predictions of the possibility of precipitation, 63% could predict the rainfall abundance or scarcity in a year based on the pattern of early rains in a given farming season. The use of certain symbols/signs such as wildebeests and birds' movement (74%), and star constellation (~30%) are also prominent in predicting the rains a given farming year'. While about 54% of the farmers used personal experience to predict extreme temperatures, about 60.2% used trend observation (i.e. sequence of yearly weather events) to discern climate events in a particular farming season.

The inference from these analyses suggests that through many years of careful observation of phenomena around them, farmers use diverse symbolic natural objects and items to predict the weather. To buttress this claim, preliminary investigations in villages such as Etsha 6, Jao, Semboyo, Chukumuchu, Tsodilo and Ngarange show that community people and

[7] Ngaka (singular) or Dingaka (plural) mean(s) [a] traditional doctor(s) in Setswana. These are people who are socialized into the profession mainly by virtue of being born into the family of traditional healers (i.e. ascribed status). Nonetheless, some people who are not in that lineage willingly choose to train as a traditional doctor.

farmers have diverse approaches to weather prediction. These include certain indicators/signals from some particular trees; clouds gathering and their direction; star constellations; certain birds'; and movement/appearance. For instance, in Semboyo community (where a significant proportion of the population has indigenous weather knowledge), one of the elders said:

> 'There is a certain shrub (called Moretlhwa known in English as Brandy bush/Raisin bush [*Grewia flava*]), which bears fruits twice in a year (we call this Moretlhwa wa ntlha). If the tree bears fruits from November to early December in a given year before the advent of the rains [first rainfall], this portends that there would be a low rainfall in that year. However, if the tree bears fruits around February/March (we call this Moretlhwa Wa bobedi), it shows that there will be plenty or more rainfall in that year. But in a situation where the tree bears no fruits at all, this portends a serious danger; a drought is inevitable in that given year. Also, there is a tree [locally referred to as Motopi (*Boscia albitrunca*); the flowering or fruiting of this tree prior to the rains is an indication that the year will experience abundant rainfalls.'

Adapting to changes in weather patterns, which are more noticeable in rainfall scarcity and extreme temperatures, therefore, involves the identification and planting of certain crops, which naturally have the capability to withstand drought conditions. For instance…farmers plant certain traditional crops because of their life spans and maturity period. Our people do this in response to the peculiarity of the environment. Of interest is that people act on the basis of the advice provided by the chief (Kgosi) who apparently must have received certain spiritual instructions in line with the nature of the approaching season. For instance, sorghum (Mabele-Mapindi) which takes longer to mature is planted during rainy years. However, another variety of sorghum (Mabele-Pende) is planted during the seasons of little rainfall. Also, Ngwai, which is a variety of beans, is planted during years of little rainfall while *Dinawa* (another variety of beans) is planted when the rains are abundant…(A group of elders in Ngarange community, Botswana.)

Determining the level of farmers' knowledge in local weather forecasting

We used the 12 Likert items/statements in Table 5 to determine the level of ethno-meteorological knowledge of the farmers. The Likert items/statements, most of which favored the use of local knowledge in weather forecasting were rated on a 5-point Likert scale, where 1 was the minimum point and 5 was the maximum point for each statement. From the 12 items, the possible maximum score for a respondent is 60 points while the minimum is 12 points (Carifio and Perla, 2007; Glass et al., 1972). Ranked on a scale of 1–5, the possible maximum average score for each farmer for all the 12 statements is therefore 60/12, which is 5 points. Thus, the grand mean score computed for all the farmers was 3.58 with a standard deviation of ±0.81. To determine the range in which low scores fall on the scale, the standard deviation value was subtracted from the grand mean score. Conversely, the standard deviation value was added to the grand mean score in order to determine the range for high scores on the scale. Farmers were then categorised into a range of low (1.00–2.77), moderate (2.78–4.38) and high (4.39–5.00) level of knowledge in indigenous weather forecasting. The distribution of farmers by their level of weather forecasting knowledge in the Okavango Delta of Botswana is presented in Table 6. Analysis shows that 17% of the farmers had low level of weather forecasting knowledge. While 66.2% of the farmers were considered as having modest weather forecasting knowledge, 17.1% however had a very high level of knowledge in ethno-meteorology. The analysis shows that a significant number of the farmers (83.3%) had a considerable expertise in local weather forecasting.

Farmers' perceptions about the nature of local and scientific weather knowledge

In attempting to determine the congruence between scientific weather forecasting and ethno-meteorology, we endeavoured to analyse farmers and weather scientists' perceptions about the efficacy of the two forms of knowledge. First, we examined how farmers felt about the nature of both local and Western knowledge in weather forecasting and how effective they thought the two bodies of knowledge are in predicting weather conditions. How farmers perceive these bodies of knowledge will affect their propensity to uptake and use weather information for their benefits.

The distribution of farmers by their perception about the nature of local and scientific weather knowledge is presented in Table 7. While some of the statements used as the units of analysis favour both knowledge systems, some from another perspectives, disfavour the two forms of knowledge. Nonetheless, most of the eleven (11) items or statements are more sympathetic towards the efficacy of local knowledge. These items/statements were constructed based on our earlier interactions with local farmers and the literatures (see for instance, Ifejika Speranza et al., 2010; Orlove et al., 2010). They were rated on a 5-point Likert scale of 1–5. The maximum points possible for a farmer is 55 while the minimum is 11. The computed grand average for the farmers was 3.86 with a standard deviation of ±0.58. The farmers' relatively high value meant

Table 6
Farmers' distribution showing their level of weather forecasting knowledge. Source: field survey, 2011.2012.

Farmers knowledge level	Frequency	%
1.00–2.77 (Low)	99	16.7
2.78–4.38 (Moderate)	392	66.2
4.39–5.00 (High)	101	17.1
Total	592	100.0

Table 7
Distribution of farmers by their perceptions about the nature of local and scientific weather knowledge ($n = 592$). Source: field survey, 2011–2012.

Statement*	Strongly agree	Agree	Undecided	Disagree	Strongly disagree
Scientific weather forecast cannot be relied upon as it does fail most of the time	116 (19.6)**	149 (25.2)	40 (6.8)	150 (25.3)	137 (23.2)
Unlike local knowledge, which is simple to understand in weather prediction, the same cannot be said of scientific knowledge	219 (37.0)	145 (24.5)	34 (5.7)	123 (20.8)	71 (12.0)
Both local and scientific knowledge in weather forecasting are over the years produced through observation, experimentation and validation	157 (26.5)	338 (57.1)	45 (7.6)	30 (5.1)	22 (3.7)
Unlike scientific knowledge in weather reading, which follows certain procedures in its production process, local knowledge is unregulated and haphazard or unorganised	199 (33.6)	275 (46.5)	44 (7.4)	44 (7.4)	30 (5.1)
Unlike scientific approach to weather forecasting, local knowledge in weather prediction does not require the use of sophisticated tools or equipment to do the job	292 (49.3)	262 (44.3)	17 (2.9)	7 (1.2)	14 (2.4)
Unlike western science, formal education or training is not needed to acquire skills in local weather forecasting	279 (47.1)	209 (35.3)	21 (3.5)	57 (9.6)	26 (4.4)
Unlike western approach to weather forecasting, wielding local knowledge in weather prediction does require little or no financial investments	330 (55.7)	202 (34.1)	16 (2.7)	23 (3.9)	21 (3.6)
Scientific weather forecasting and local predictions are mutually exclusive; they are two different things altogether	189 (31.9)	163 (27.5)	44 (7.4)	140 (23.6)	56 (9.5)
Local approaches to weather prediction is always accurate and as such are the best in making the right decisions in farming activities	147 (24.8)	187 (31.6)	45 (7.6)	116 (19.6)	97 (16.4)
Whereas scientific weather forecasting is purely secular, local knowledge in weather reading entails a great measure of spirituality	374 (63.2)	179 (30.2)	19 (3.2)	10 (1.7)	10 (1.7)
Scientific approach to weather forecasting should only be complimentary or supplementary to local approach in making farming decisions	137 (23.1)	202 (34.1)	40 (6.8)	112 (18.9)	101 (17.1)

* Multiple responses.
** Percentages are in parenthesis ().

that they naturally would favour their own knowledge systems, holding all other factors constant. In terms of reliability of weather information, some 45% of the farmers affirmed that '[s]cientific weather forecast cannot be relied upon as it does fail most of the time', a total of 49% thought otherwise. Nonetheless, our preliminary investigations with some key informants indicate that local people naturally have more inclinations towards ethno-meteorology than mainstream meteorology because of their personal experiences over the years. This claim buttresses Onyango and Ouma's viewpoints (see Onyango, 2009; Ouma, 2009) and the summary of the hydrological forecasting in Section 'Hydrological forecasting in the Okavango Delta', which outlined that meteorological/scientific predictions may not necessarily be as accurate as expected due to certain intervening variables. Regarding the complexity or otherwise of information, about 62% of farmers believed that local knowledge is simple to understand in weather prediction as against the complex nature of scientific knowledge. A significant proportion (~84%) of the farmers affirmed that both local and scientific knowledge in weather forecasting are produced through observation, experimentation and validation. Interestingly, this claim somewhat points attention to the possibility that there is a meeting point between both forms of knowledge. Referring to the methodologies of knowledge production, 80.1% of the respondents believed that the production of scientific knowledge in weather reading is procedural in nature as against the local knowledge, which is informally produced and devoid of any regimentation and regulations (Kolawole, 2012). In relation to the mode of knowledge production, an overwhelming majority (~94%) of the respondents opined that '...local knowledge in weather prediction does not require the use of any sophisticated tools or equipment' (such as satellite technology and computer models) unlike in scientific weather forecasting. Also, majority (82.4%) of the farmers were of the opinion that 'formal education or training is not needed to acquire skills in local weather forecasting'. About 90% affirmed that the use of 'local knowledge in weather prediction requires little or no financial investments' unlike in scientific weather forecasting. On the commonality or variance in the two forms of knowledge, 59.4% of the farmers opined that 'scientific weather forecasting and local predictions are mutually exclusive; they are two different things altogether'. Also, majority (56.4%) of the farmers believed in the accuracy of ethno-meteorology. This may have had a strong influence on the degree to which they relied on the use of this body of knowledge in making farm decisions. On substantive ground, a large majority of the farmers (93.4%) admitted that 'local knowledge in weather reading entails a great measure of spirituality' unlike scientific weather forecasting, which is purely secular in nature. While science is acknowledged to be open and offering easy access to those who have the skills to apply it for practical use, local knowledge in weather forecasting is somewhat closed in most cases and only members have insights on what it entails.

In our preliminary investigations, however, farmers were of the opinion that that there was need to find a suitable platform where they [the farmers] could work with weather scientists so as to enable them devise effective adaptation measures against the changes now experienced in weather patterns.

Table 8
Distribution of weather scientists by their perceptions on the nature of local and scientific weather knowledge (n = 18). Source: field survey, 2011–2012.

Statement*	Strongly agree	Agree	Undecided	Disagree	Strongly disagree
Scientific weather forecast cannot be relied upon as it does fail most of the time	–	–	–	8 (44.4)	9 (50)**
Unlike local knowledge, which is simple to understand in weather prediction, the same cannot be said of scientific knowledge	1 (5.6)	5 (27.8)	2 (11.1)	6 (33.3)	4 (22.2)
Both local and scientific knowledge in weather forecasting are over the years produced through observation, experimentation and validation	3 (16.7)	5 (27.8)	3 (16.7)	4 (22.2)	2 (11.1)
Unlike scientific knowledge in weather reading, which follows certain procedures in its production process, local knowledge is unregulated and haphazard or unorganised	3 (16.7)	5 (27.8)	5 (27.8)	4 (22.2)	1 (5.6)
Unlike scientific approach to weather forecasting, local knowledge in weather prediction does not require the use of sophisticated tools or equipment to do the job	8 (44.4)	7 (38.9)	3 (16.7)	–	–
Unlike western science, formal education or training is not needed to acquire skills in local weather forecasting	4 (22.2)	6 (33.3)	2 (11.1)	5 (27.8)	1 (5.6)
Unlike western approach to weather forecasting, wielding local knowledge in weather prediction does require little or no financial investments	4 (22.2)	5 (27.8)	3 (16.7)	4 (22.2)	2 (11.1)
Scientific weather forecast and local predictions are mutually exclusive; they are two different things altogether	–	2 (11.1)	1 (5.6)	10 (55.6)	5 (27.8)
Local approaches to weather prediction is always accurate and as such are the best in making the right decisions in farming activities	–	2 (11.1)	2 (11.1)	9 (50)	5 (27.8)
Whereas scientific weather forecasting is purely secular, local knowledge in weather reading entails a great measure of spirituality	3 (16.7)	3 (16.7)	6 (33.3)	3 (16.7)	2 (11.1)

* Multiple responses.
** Percentages are in parenthesis ().

Weather scientists' perceptions on the nature of local (ethno-meteorological) and scientific weather knowledge

In this section, we examined the viewpoints of weather scientists about the nature and effectiveness of both local and Western knowledge in weather forecasting. Thus the distribution of weather scientists by their perceptions about the nature of the two forms of knowledge is shown in Table 8 below. As indicated earlier in Sections 'Determining the level of farmers' knowledge in local weather forecasting and Farmers' perceptions about the nature of local and scientific weather knowledge', while some of the Likert items/statements used as the units of analysis favour both knowledge systems, some are constructed to disfavour the two forms of knowledge. However, most of the items rated on a 5-point Likert scale of 1–5 are more sympathetic towards the efficacy of local knowledge. The grand average score computed for weather scientists is 1.96 with a standard deviation of ±0.56. Almost all (94.4%) of the scientists did not agree that '[s]cientific weather forecast cannot be relied upon as it does fail most of the time'. While some 33.4% agreed that scientific knowledge is difficult to understand in making weather prediction, about 55.5% did not think so. A significant 44.5% of the weather scientists affirmed that '[b]oth local and scientific knowledge in weather forecasting are over the years produced through observation, experimentation and validation'. This viewpoint aligns with the opinion of 83.6% of farmers who agreed on the issue. That 44.5% of the scientists had a similar viewpoint on the commonality of both knowledge systems is noteworthy. While about 45% of them believed that scientific knowledge production in weather forecasting is procedural and methodical as against the unregulated and unorganised procedures in ethno-meteorological knowledge production, only about 28% of them disagreed with the viewpoint. Like most of the farmers did, a significant proportion of the weather scientists (83.3%) acknowledged that '. . .local knowledge in weather prediction does not require the use of any sophisticated tools or equipment' (such as satellite technology and computer models) as against what applies in scientific weather knowledge. About 56% of them agreed that formal education or training is not needed in acquiring local weather forecasting skills unlike in western science. Half (50%) of the scientists agreed that the use of 'local knowledge in weather prediction does require little or no financial investments' as against the financial requirements that scientific weather knowledge entails. A significant 83.4% of them agreed that '[s]cientific weather forecast and local predictions are. . .two different things altogether'. This buttresses the viewpoint of 59.4% of the farmers who agreed on the same issue. Nonetheless, about 78% of the scientists did not agree with the view that '[l]ocal approaches to weather prediction is always accurate and as such are the best in making the right decisions in farming activities'. While a significant proportion (33.3%) of the weather scientists did not have an opinion as to whether or not '. . .local knowledge in weather reading entails a great measure of spirituality', 33.4% supported the notion and about 28% of them disagreed with the viewpoint. However, weather scientists who participated in our interactive knowledge validating workshop session agreed among others that:

(i) There is need to constitute a joint evaluation committee (comprising stakeholders such as the community people, farmers and scientists) to assess local and scientific forecasts in relation to their effectiveness and use amongst farmers.
(ii) Both farmers and scientists need to work together with a view to coming up with a common working tool; they would need to agree on local indicators (predictors), which in their present forms, vary in interpretations from one locality to the other.
(iii) There is need to organize contact workshops, public lectures and through the mass media in order to create the right platforms for weather knowledge sharing between weather scientists, local farmers and communities – it is important for stakeholders to interact together.
(iv) Provision of advisory service is an imperative – both local farmers and weather scientists would need to cross-fertilize ideas on weather forecasting knowledge through scheduled meetings.
(v) As a starting point, documenting local weather knowledge in both Setswana and English is vital.
(vi) Setting up of experimental stations, where scientists and farmers could work together to either filter, validate or foster both knowledge systems, particularly local weather knowledge – it is considered worthwhile to design a local experimental nodal points for this purpose in order to avoid any ambiguity.

How farmers and scientists produce weather knowledge

Aimed at identifying the commonalities in the procedures used in producing both scientific knowledge in weather forecasting and ethno-meteorology, this sub-section analyses both farmers and scientists on how they derive their insights in making weather predictions. A significant proportion (∼61%) of the farmers claimed that they engaged in local observations and experimentation to produce weather knowledge and also '...rely on many years of experience with our immediate environment to generate weather knowledge'. Whereas about 13% of them claimed that they relied solely on local procedure in weather forecasting, 7.4% were of the opinion that they did not even care whether weather information/knowledge exists or not. The inference is that most farmers constantly interact with the natural phenomena around them to generate weather knowledge.

While majority (∼89%) of the scientists opined that they relied solely on scientific procedures in generating weather knowledge, only a paltry percentage (∼11%) of them indicated that they worked with local farmers, artisans and native philosophers in the process of producing weather knowledge. If this last claim were true, the finding still shows that weather scientists had limited interactions with farmers in weather knowledge production in the study area. However, the interactive knowledge validating workshop organised for stakeholders during the course of the research allowed farmers and weather scientists to engage in discussions and cross-fertilisation of ideas.

Prompted to give their opinions on the problems associated with climate variability in Botswana and particularly in the study area during the stakeholders' interactive workshop, the weather scientists provided a number of clues. These include degradation of the environment due to loss of vegetation as a result of low precipitation; drought and flooding events especially in areas, which in the past, rarely experienced the phenomenon (flooding); disappearance of flora and fauna due to long dry spells, shift in rainfall patterns in time and space, which invariably affects farming activities and farm outputs; and more incidences of veld fires. Others include extremes of temperatures leading to either heat stress for people and animals or low temperature causing human and animal diseases; outbreak of water-borne diseases such as malaria in flood prone areas, etc. Nonetheless, it was admitted by some of the scientists that climate change is a phenomenon that is still not fully understood by them.

Relationships between farmers' attributes and their perception of the nature of local and Western knowledge in weather forecasting

As earlier indicated in Section 'Farmers' perceptions about the nature of local and scientific weather knowledge', farmers' viewpoints were obtained in relation to how they perceived the nature and effectiveness of both ethno-meteorology and scientific weather forecasting. Each farmer was then assigned a score derived from his or her average point from the 11 statements. For instance, a farmer who scored 55 points is assigned an average score of 5 points (i.e. 55/11). Age (X_1) was measured in relation to how old the farmer was at the time of the interview (e.g. a 40-year old farmer was assigned 40 points). Education level (X_2) was measured on the basis of the level the individual attained. For instance, an individual who did not have any form of education was assigned 0 point; a farmer who went to adult literacy class was assigned 1point; a person who attended primary standard school and did not finish it was assigned 2 points; a respondent who had primary standard 7 certificate was assigned 3 points; a farmer who attended secondary school but did not finish it was scored 4 points; etc. (Table 2). The variable named 'years engaged in farming' (X_3) was measured in terms of the number of years the individual had carried out farming activities. Monthly income (X_4) was measured based on the amount of earnings of each household per month. Household size (X_5) was measured in terms of the number of people living and eating under the same roof, comprising those who totally depended on the household head or those who contributed to the household socio-economic well-being. Indigenous source(s) of weather information (X_6) was measured in terms of the number of channels through which an individual received ethno-meteorological messages. Knowledge of weather forecasting (X_7) was measured by placing 12 Likert items/statements addressing indigenous weather knowledge on a 5-point Likert scale. The average for each farmer was then computed (see earlier explanations on the measurement of perceptions,

Table 9
Pearson correlation and multiple regression analyses showing the relationship between farmers' attributes and their perception about the nature of local and Western knowledge in weather forecasting. Source: field survey, 2011–2012.

Variable	'r' Value	Co-efficient of determination (r^2)	b	T-value
Age	0.209**	0.043	0.050	2.321**
Education level	−0.109*	0.012	0.133	1.548*
Number of years engaged in farming	0.105**	0.011	0.069	0.372
Household monthly income	−0.011	0.000	0.000	−1.578
Household size	−0.011	0.000	0.043	0.680
Source(s) of indigenous weather information	0.177**	0.031	0.720	2.333**
Knowledge of weather forecasting	0.392**	0.154	0.167	6.114***
Farmer's decision on farming practices	−0.464**	0.215	−0.337	−8.594***

$R^2 = 0.303$, $R = 0.550$, adjusted $R^2 = 0.288$.
*** Test statistic significant at $P \leqslant 0.01$ level.
** Test statistic significant at $P \leqslant 0.05$ level.
* Test statistic significant at $P \leqslant 0.10$ level.

Y). The decision on farming practices[8] (X_8) was also measured through a 7-item/statement question addressing a farmer's viewpoint as to whether or not s/he used ethno-meteorological knowledge in making decisions before carrying out farming operations. The statements were placed on a 5-point Likert scale and the average (representing the score) for each farmer was then computed. We hypothesised that there is a significant relationship between farmers' demographic/socio-economic attributes and their perceptions of the nature of both local and scientific weather forecasting. In summary, a farmer's perceptions (Y) will depend on all other explanatory variables (Xs) in the regression model presented below:

$$Y = a + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6X_6 + b_7X_7 + b_8X_8$$

where: Y = a farmer's perceptions on the nature of local and scientific knowledge, a = intercept constant, b = regression co-efficient, X_1 = age, X_2 = level of education, X_3 = years engaged in farming, X_4 = household monthly income, X_5 = household size, X_6 = source(s) of indigenous weather information, X_7 = knowledge of weather forecasting, X_8 = farmer's decision on farming practices.

Pearson product-moment correlation and multiple regression analyses showing the relationships existing between explanatory variables, Xs (i.e. demographic, socio-economic and psychosocial characteristics of farmers) and their perceptions on the nature of both local and scientific knowledge in weather forecasting (Y) are presented in Table 9. Analysis showed that at $p \leqslant 0.01$ level of significance, there is a positive and significant correlation between a farmer's age ($r = 0.209$) and his/her perceptions of local and scientific weather knowledge. As many of the farmers had favourable perceptions about their knowledge systems (see Table 7 above), this might imply that the older the farmer is, the more likely is he or she to prefer the use of local knowledge in forecasting and interpreting weather scenarios with the ultimate goal of adapting to CV. The reason is that his or her experience plays a major role in local knowledge production and farming activities. This is further buttressed by the positive and significant correlation existing between the number of years in which the farmer has engaged in farming activities ($r = 0.105$; $p \leqslant 0.01$) and his or her perceptions of the nature of both knowledge systems. At $p \leqslant 0.05$ confidence level, a significant but negative correlation exists between a farmer's level of education ($r = -0.109$) and his or her perceptions of the nature of both local and scientific knowledge in weather forecasting. This implies that the more educated the farmer becomes; the more likely is he or she to prefer the use of scientific weather knowledge in farming decisions. Also sources of indigenous weather information ($r = 0.177$; $p \leqslant 0.01$) and [local] knowledge of weather forecasting ($r = 0.392$; $p \leqslant 0.01$) both had positive and significant correlation with a farmers' perceptions of the nature of the two knowledge systems. This implies that the more accessible the local knowledge information is, the more the farmer would prefer its use. And the more knowledgeable the farmer becomes in terms of the acquisition of wealth of local knowledge in weather forecasting, the more favourable the farmer's perceptions are about indigenous weather knowledge. Overall, a farmer's decision on farming practices ($r = -0.464$; $p \leqslant 0.01$) had a strong but negative correlation with his or her perceptions of the nature of scientific weather knowledge. The implication is that his or her decision is at variance with scientific weather information, possibly because of the unavailability of weather information from the relevant agencies or farmers' lack of infrastructures to receive the messages (see Table 4).

The co-efficient of determination (r^2) explains the magnitude of relationship of each of the explanatory variables (Xs) on farmers' perceptions about the nature of weather knowledge (Y). For instance, knowledge of weather forecasting by the farmer explains or predicts 15.4% of the variations in Y. Also, some 21.5% of the variations in Y are explained or predicted by the farmer's decision on farming practices. Age of the farmer and his or her education level only explained or predicted 4.3 and 1.2% of the variations in variable Y (which is the farmer's perception of the nature of both knowledge systems), respectively.

The results of the regression analysis show that at $p \leqslant 0.05$ level of significance, age ($t = 2.321$) and sources of indigenous weather information ($t = 2.333$) had positive and significant relationship with a farmer's perception about the nature of local and Western knowledge in weather forecasting. Whereas, knowledge of weather forecasting possessed by the farmer

[8] Farming practices or operations include land clearing, ploughing, harrowing, planting, harvesting, etc. Farmers' decisions on when to commence these operations in any farming season (e.g. planting) are subject to the prevailing weather conditions.

($t = 6.114$) had a positive and significant relationship with his or her perception of the nature of local and Western knowledge at 99 per cent confidence level ($p \leqslant 0.01$), a negative but significant relationship existed between his or her decision on farming practices ($t = -8.594$) and how he or she perceived the nature of both local and Western knowledge in weather forecasting. While on the one hand, perceptions do influence actions, on the other hand, actions could as well influence perceptions such as in Pierre Bourdieu's habitus in which an individual within a given rural social system has been socialised into a particular way of life – where society has been deposited in the individual '...in the form of lasting dispositions, or trained capacities and structured propensities to think, feel and act in determinant ways, which then guide them' (Wacquant, 2005). Indeed an individual's habitus explains how s/he perceives and reads meanings to the physical, natural and socio-cultural phenomena around him or her in relation to its dependency on history and human memory (Bourdieu, 1977). This is easily discerned in individuals' 'learned habits, bodily skills, styles, tastes, and other non-discursive knowledges that might be said to "go without saying" for a specific group...' and which appear to operate below the level of 'rational ideology' (Mauss, 1934). At $p \leqslant 0.10$ level of significance, education level had a positive and significant relationship with the farmer's perception on the nature of knowledge in weather forecasting in the Okavango Delta of Botswana.

More importantly, the R^2 value of 0.303 implies that 30.3% of the variations in Y (farmer's perception of the nature of both local and Western knowledge in weather forecasting) are explained by all the significant variables in the multiple linear regression equation. Nonetheless, an R value of 0.550 shows that 55% of the changes or variations in the dependent variable Y are explained by all the variables computed in the regression model.

Conclusions

The paper presented the analysis on the perceptions of both farmers and weather scientists on the nature of local and scientific weather knowledge as they affect farming decisions in an era of changing climatic conditions. While none of the farmers claimed that they had contact with the DMS agents in the last 6 months before the survey, majority of those who had access to weather information did so through the radio. More importantly, most of the respondents indicated they did not have access to weather information; their communities did not have contact with weather forecasting agents. And majority of the farmers mainly obtained weather information from elderly people within their neighborhood and through native diviners/doctors (Dingaka). Local farmers' lack of contact with scientific weather information may have been buttressed by the admission of half (50%) of the scientists population that they never had contact with farmers in the last six months before the survey. Generally, local farmers relied on many years of experience with their immediate environment to generate weather knowledge. About 90% of them were of the opinion that the production of local knowledge in weather forecasting needed no capital investment; neither did it need any sophisticated equipment to do so. Also, majority (57.2%) of the farmers felt scientific weather forecasting should complement local approach in weather reading. Most of the scientists expressed the same opinion as well. A comparison of the perceptions of the two groups (small farmers and scientists) was carried out. While the average score for the farmers in relation to their perception on the nature of local and scientific knowledge was 3.86 with a standard deviation of ±0.58, that of the weather scientists was 1.96 with a standard deviation of ±0.56. The relatively wide variation in the scores of the two groups of respondents (i.e. a variance of 1.90) implies that there was a significant difference in their perception about the nature of both local and Western knowledge.

Age, education level, number of years engaged in farming, sources of weather information, knowledge of weather forecasting and farmer's decision on farming practices had significant correlation and relationship with the respondents' perception on the nature of both local and scientific weather information. While it is acknowledged that the identified factors are crucial for policies and decision-making in information dissemination, more attention needs to be paid to the yearning of farmers to work closely with scientists in the production of weather forecasting knowledge. Of interest, however, are the comments obtained during stakeholders' workshop where all (farmers, scientists, community elders and others) unanimously agreed that there was need to put in place necessary platforms through which all of them could work together in order to adequately address the challenges posed by climate change and variability.

Arising from the findings in this paper are some pertinent issues, which might find relevance in policy processes addressing CV and smallholder agriculture. First, qualitative and culturally transmitted knowledge about weather scenarios (as generated by local knowledge), bolstered by further research, and quantitative and specific knowledge about the alterations and consequences of CV (as generated by scientific knowledge) need to be integrated for better decision making. Farmers and scientists need to agree on local indicators (weather predictors), which in their present forms, vary in interpretations from one locality to the other. Integration of these two knowledge systems will also correct the seemingly wrong perceptions of some stakeholders (e.g. policy-makers, politicians, academics/scientists, etc.) that local knowledge is not well positioned to handle complex contemporary problems of an ever changing environment. Second, contact workshops, public lectures and the mass media are strategies for creating the right platforms for weather knowledge sharing between weather scientists, local farmers and communities. If done systematically, advisory service could also provide both local farmers and weather scientists the opportunity to cross-fertilise ideas on weather forecasting knowledge through appropriate platforms (e.g. scheduled meetings). Third, documentation of local weather knowledge in local dialects and English is vital for adequate and effective information sharing. Fourth, filtering, validating or fostering both knowledge systems, particularly ethno-meteorological knowledge, could be achieved through the establishment of local experimental centres in designated communities where ethno-meteorology thrives.

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