Assessment of arable farmers' understanding of scientific weather forecasts in Ngamiland East, Botswana

Amogelang Mabophiwa,[1] Oliver Moses,[2] and Keotshepile Kashe[3]

Abstract

Scientific weather forecasts provide early warning information that is essential for arable farmers to adapt to climate variability and change. However, the use of forecasts by farmers is limited by their lack of understanding of forecasts. This study assesses arable farmers' understanding of the various aspects of seasonal weather forecasts in Ngamiland East, Botswana, to identify those aspects which they do not understand. The study also suggests improvements that can be made on the forecasts to make it easier for farmers to understand them and be able to use them for their benefit. It also assesses arable farmers' strategies of adaptation to climate variability and change. The study utilised face to face interviews to collect qualitative data using semi-structured questionnaires. From the results, 28% of the farmers reported that they did not use the forecasts in their decisions making about planting, mainly because they did not understand them. The challenge for nearly a quarter (22.5%) of those who did not use the forecasts was the spatial scale aspect of the forecasts. More than one third of the farmers (35%) suggested that to improve the forecasts, the forecasts should be downscaled to their local area scale. Based on these findings, it is essential to improve the forecasts to make them easier to understand so that even farmers with low educational levels can also use them.

Keywords: Arable farmers, climate change, Ngamiland East, rainfed agriculture, seasonal weather forecasts

[1]Faculty of Social Science, University of Botswana, Gaborone
[2]Research Scholar, Okavango Research Institute, University of Botswana, Maun. Email: omoses@ub.ac.bw
[3] Research Scholar, Okavango Research Institute, University of Botswana, Maun.

Introduction

Most parts of the African continent, particularly Sub-Saharan Africa (SSA), are highly dependent on rainfed agriculture (Juana, Kahaka, and Okurut, 2013; Ayanladea, Radeny, John, and Mortonc, 2017). Just like in most countries in SSA, arable farmers in Botswana rely on rain-fed agriculture, which is affected by declining rainfall and increasing temperatures due to climate change (Batisani and Yarnal, 2010; Moses, 2017). SSA's climatic trends shift on seasonal and annual bases due to climate variability as manifested by changes in rainfall onset, duration, cessation, seasonal totals, dry spells, recurrent droughts and floods (Shongwe et al. 2009; Simelton et al., 2013; Jiri, Mafongoya, Mubaya, and Mafongoya, 2016). Water is the most crop yield limiting factor in most of SSA due to erratic rainfall (Guilpart et al., 2017). Shifts in rainfall patterns exacerbate the already low crop yields and threaten food security. There is need for farmers to adapt to climate variability and change in order to reduce their vulnerability to such climatic changes and maximise opportunities when favourable rains are anticipated (Grothmann and Patt, 2005; Ash and Matyas, 2012; Sanga, Moshi, and Hella, 2013; Roudier et al., 2014). Adaptation strategies include the use of weather forecasts as early warning information and planting suitable crop varieties according to their water requirements during the growth cycle (Smit & Skinner, 2002; Creswell andClark, 2009; Hammer, Neville and Christopher, 2013).

Weather forecasts used as early warning information can be generated by scientists using scientific methods and by local traditional farmers using indigenous knowledge to generate traditional weather forecasts. Traditional weather forecasts are not the focus of this study; the focus is on scientific weather forecasts. Information on traditional weather forecasts can be found in a number of studies such as Zuma-Netshiukhwi, Stigter, and Walker (2013); Kolawole, Wolski, Ngwenya, and Mmopelwa (2014) and Jiri et al. (2016). Scientific weather forecasts include daily weather forecasts (short to medium range weather forecasts) and seasonal weather forecasts (also known as long-range weather forecasts or short-range climate forecasts). Daily weather forecasts have a range that does not usually exceed ten days because of the chaotic nature of the atmosphere (Stern and Easterling, 1999). They are generated using Numerical Weather Prediction (NWP) models. Seasonal weather forecasts on the other hand are generated based on the interaction of the atmosphere with a slow, varying but predictable driver of climate variability, which is the El Niño Southern Oscillation (ENSO; Harrison et al., 2007). Seasonal weather forecasts indicate departures from a 30-year mean climate for the coming season; i.e., they indicate whether the expected rainfall or temperatures will be normal, below normal or above normal. They have a lead time of a couple to several months ahead of the coming season. They give users an overall regional picture of how the season will unfold without spatial or temporal details, and generally cover a period of three months. Due to their long lead time, they are crucial in providing early warning information which can be used by arable farmers in their decisions on the selection of crops to be planted well before the planting season starts, according to their water requirements during the growth cycle (Harrison et al., 2007). In this study, attention is devoted to seasonal weather forecasts than to daily weather forecasts as they have a relatively longer lead time and forecast range, hence are more useful for planning purposes. It is to be noted that although daily weather forecasts have a relatively shorter range (10 days or less), they complement seasonal weather forecasts in terms of giving more forecast details such as rainfall onset and dry spells.

Despite seasonal weather forecasts being crucial in providing early warning information for adaptation purposes, there are several generic factors that affect their utilisation by arable farmers in various parts of the world, particularly in Africa. These factors include failure to provide accurate forecasts, which compromises their credibility (Bryan, Temesgen, Gbetibouo, & Ringler, 2009; Frimpong, 2013 cited in Jiri et al., 2016). Lack of understanding (which can also be caused by language barrier) and accessibility of the forecasts also affects uptake of the forecasts (Patt and Gwata, 2002). Patt and Gwata (2002) also indicated that some farmers do not use the forecasts because they are not downscaled to their local area scale. Some farmers are not aware that such forecasts exist, while others do not know their usefulness (Feleke, 2015). Poor dissemination of the forecasts, which includes late delivery or failure of the forecasts to reach farmers, also limits their utilisation (Zinyengere et al., 2011; Adejuwon and Neil, 2012). Other factors include weak institutions and reliance on traditional forecasts (Makebea, Moses and Kaisara, 2012; Kolawole et al., 2014). Makebea et al. (2012) and Kolawole et al. (2014) indicate that the generic factors that affect utilization of the forecasts such as lack of understanding of the forecasts as already mentioned, are also applicable in Botswana, particularly in Ngamiland which was their study area. However, these studies did not identify the aspects of the forecasts which limited understanding and use of the forecasts by arable farmers.

The present study therefore assesses the various aspects of seasonal weather forecasts to identify those that are not understood by arable farmers, hence affecting the use of the forecasts in Ngamiland East, Botswana. The various aspects of the forecasts that are assessed include forecast graphics, forecast text which consists of technical jargon, giving a general idea of how the season will be over a region without spatial or temporal details. This study also determines how the forecasts could be improved for easier understanding and use. It also assesses how arable farmers adapt to climate variability and change. This study is crucial since its findings would be useful in that it suggests improvement to seasonal weather forecasts, which in turn would improve their utilisation by arable farmers.

Materials and methods

The study area

The study area is Ngamiland East, Botswana. It is represented by Maun, Shorobe and Toteng (Figure 1), with populations of 55784, 1031 and 556 respectively (Central Statistics Office, 2011). People living in Ngamiland East are engaged in various livelihood activities such as arable farming. The representative sites were selected based on the large number of arable farmers who rely on rainfed agriculture, which is a sector that is sensitive to climate variability and change.

The climate of the study area is generally semi-arid, with high inter- and intra-seasonal variability in rainfall. Mean annual rainfall is about 500 mm (Bhalotra, 1984, 1987; Moses, 2017). Most of it occurs between October and March (planting is done within this period), but sporadic rainfall can be observed in April. In the study area, rainfall is triggered mainly by synoptic scale weather systems such as surface lows, inter-tropical convergence zone (ITCZ), westerly and easterly waves. Westerly and easterly waves have more influence at 500hPa geopotential height than at 850hPa (Tyson, 1984). The highest mean monthly maximum temperatures range from 32 to 35°C while mean monthly minimum temperatures can be as low as about 10°C (Bhalotra, 1984, 1987; Moses, 2017).

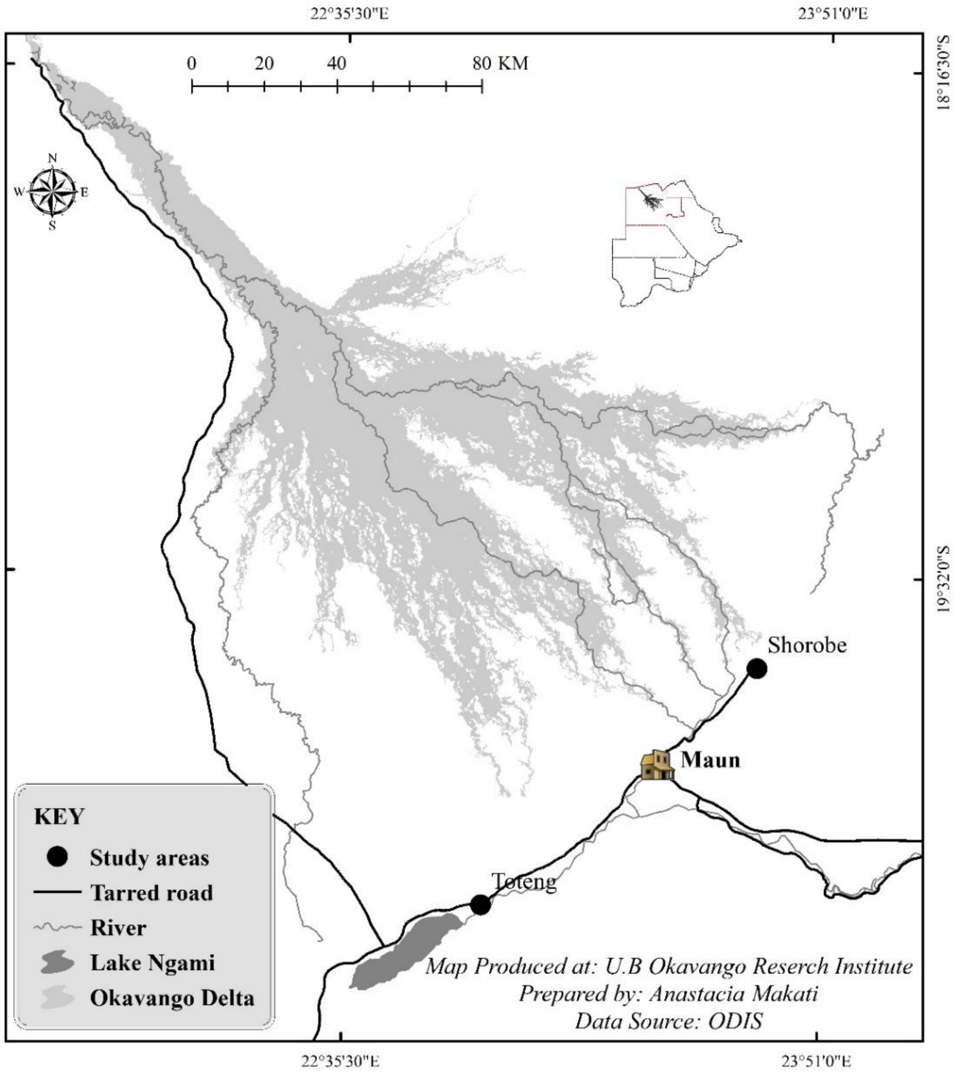

Figure 1: Map of the Okavango Delta showing study sites representing the study area

Data collection

The study used snowball sampling technique since it was difficult to find farmers in one place. This is because the study was conducted off the planting season between June and July 2017. Arable farmers were contacted by telephone for face to face interview appointments. Only those who were active in arable farming were interviewed, and they referred us to other farmers they knew within the locality. Farmers' telephone numbers were obtained from agricultural extension officers.

Face to face interviews were carried out to collect qualitative data using semi-structured questionnaires. The questionnaires had three sections. The first section was on the farmers' characteristics, which captured data such as the farmers' age, gender, livelihood activities, number of years of involvement in arable farming and level of education (primary, secondary, tertiary and no formal education). The second section was on climate variability and change. This section collected data on the farmers' awareness of the changes in the climate in terms of rainfall and temperature and on the ways by which they adapted (they were to select their answers from planting early, planting late, reducing the planting capacity, not planting at all, planting suitable crop varieties and other (specified by the farmer)).

Regarding the farmers awareness of climate variability and change, they were asked to answer by saying yes or no. The third section was on seasonal weather forecasts. The data captured in this section included farmers' understanding and utilisation of the forecasts in their planting decision making or reasons for not utilising them. Where farmers indicated that they did not use the forecasts because they did not understand them, they were asked to indicate the specific aspects of the forecasts which they did not understand. The farmers were also asked to suggest how the forecasts could be improved for easier understanding. The data captured in the third section of the questionnaire also included ways by which the farmers accessed the forecasts.

Data analysis

The collected data were analysed using Statistical Package for Social Scientists (SPSS) having been firstly coded. Descriptive statistics such as frequency, percentages, pie and bar chats were generated to summarise the data. The descriptive statistics were then analysed and interpreted.

Results and discussion

Farmers' characteristics

Forty arable farmers (20 males and 20 females) participated in the study. Their demographics are presented in Table 1. It can be seen from the table that the youngest farmer was 30 while the oldest was over 80 years old. Most of them were in the age brackets 40-49 and 50-59 years (27.5% each), followed by those who were 60-69 years old (20%). As expected, young people (39 years or less) are less interested in farming as their percentage is only 12.5%. Those who were 70 years old or more also constituted only 12.5%, perhaps the reason being that people of that age are not strong enough to plough. Almost half of the respondents (45%) only had primary education with some not even going beyond standard 4, while 17.5% had no formal education. With most of the respondents' educational level ranging from no formal education to primary education (62.5% in total), there is a challenge when it comes to understanding seasonal weather forecasts. Similar results were obtained by Makebea et al. (2012), who also indicated that knowing farmers educational level is crucial in determining the degree to which they utilise weather forecasts. There is therefore a need to improve the forecasts to make them easier to understand and be used by most farmers, even those with low educational level. It can also be seen from Table 1 that other livelihood activities of arable farmers included pastoral farming (30%), formal employment (12.5%) and *Ipelegeng* (drought relief program) (10%). The arable farmers' lengths of farming experience are given in Table 2. From the table, the majority of them had been involved in arable farming for 10-15 and 20-30 years (25% each and 50% in total), while 17.5% had been practicing arable farming for over 30 years.

Table 1: Demographics of arable farmers

		Frequency (n=40)	**Percentage** (%)
Gender	Male	20	50
	Female	20	50
Age (years)	30-39	5	12.5
	40-49	11	27.5
	50-59	11	27.5
	60-69	8	20
	70-79	3	7.5
	>80	2	5
Education	Primary	18	45
	Junior	6	15
	Senior	5	12.5
	Tertiary	1	2.5
	Adult education	3	7.5
	No formal education	7	17.5
Livelihood activities	Crop production	40	100
	Pastoral farming	12	30
	Ipelegeng	4	10
	Formal employment	5	12.5

Table 2: Arable farmers' years of involvement in farming

Number of years in farming	Frequency (n=40)	Percentage (%)
<5	5	12.5
5-10	4	10.0
10-15	10	25.0
15-20	4	10.0
20-30	10	25.0
>30	7	17.5
Total	40	100.0

Awareness of and adaptation to climate variability and change

Arable farmers' awareness of climate variability and change is shown in Figure 2. Most of the farmers (95%) were aware of the changes in the climate. The respondents indicated that they noticed a decrease in rainfall over the years and an increase in temperatures with the winter season no longer being as cold as it used to be. They linked the tropical cyclone Dineo that occurred in February 2017 (Moses and Ramotonto, 2018) to climate change. Only a few (5%) of the farmers indicated that they did not notice any changes in the climate over the years. As indicated in literature, there is need for more research to improve our understanding on the factors that hinder farmers from recognizing changes in the climate (Shisanya and Khayesi, 2007; Roco, Engler, Bravo-Ureta, and Jara-Rojas, 2014).

Strategies of adaptation to climate variability and change by arable farmers are presented in Figure 3. The figure shows that the majority (60%) of them adapted by planting suitable crop varieties which can withstand harsh weather conditions. The least used adaptation strategy was increasing planting capacity (12.5%). Other adaptation strategies included planting early (27.5%), planting late (22.5%) and reducing planting capacity (20%). Planting early was preferred over planting late as it enabled the farmers to capitalise on the anticipated rainfall. When rainfall was expected to be favourable (normal or above normal), farmers planted crops such as maize. Otherwise if rainfall was expected to be unfavorable, they planted crops such as sorghum and millet which do not need a lot of water. Even though the study focused on farmers who depend on rainfed agriculture, it is worth noting that some farmers in Ngamiland East resort to what is locally known as *molapo* farming along the Okavango River bank as a strategy for dealing with low and erratic rainfall (VanderPost, 2009; Molefe, Cassidy, Chimbari, and Magole, 2013).

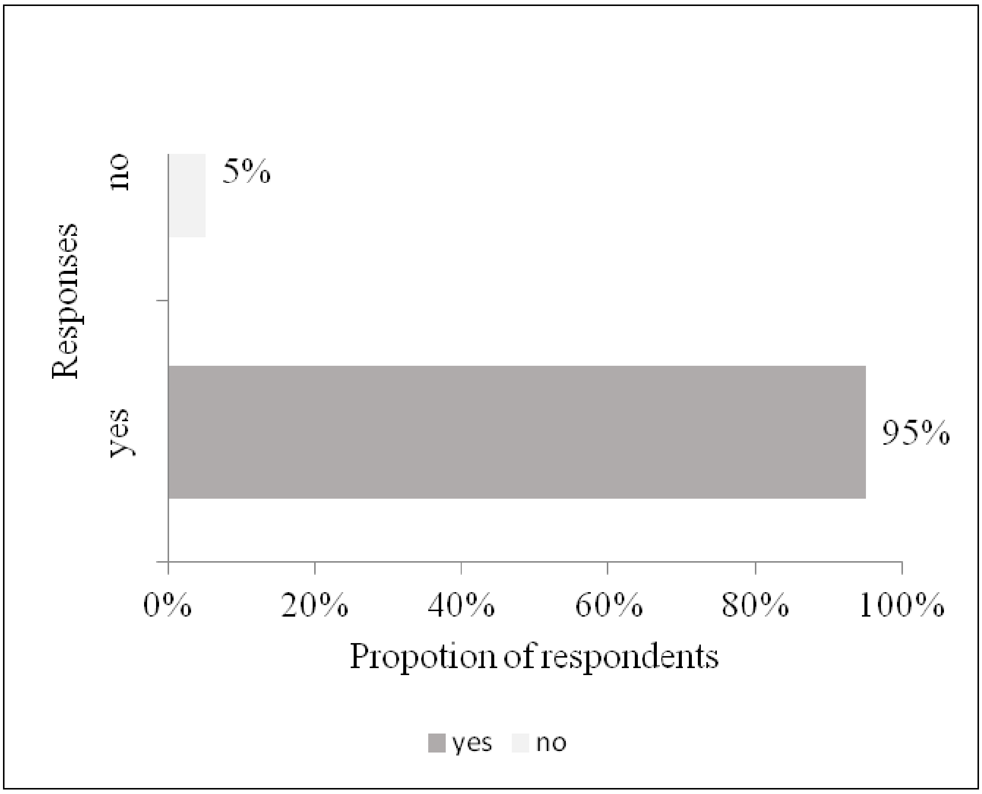

Figure 2: Arable farmers' awareness on climate variability and change

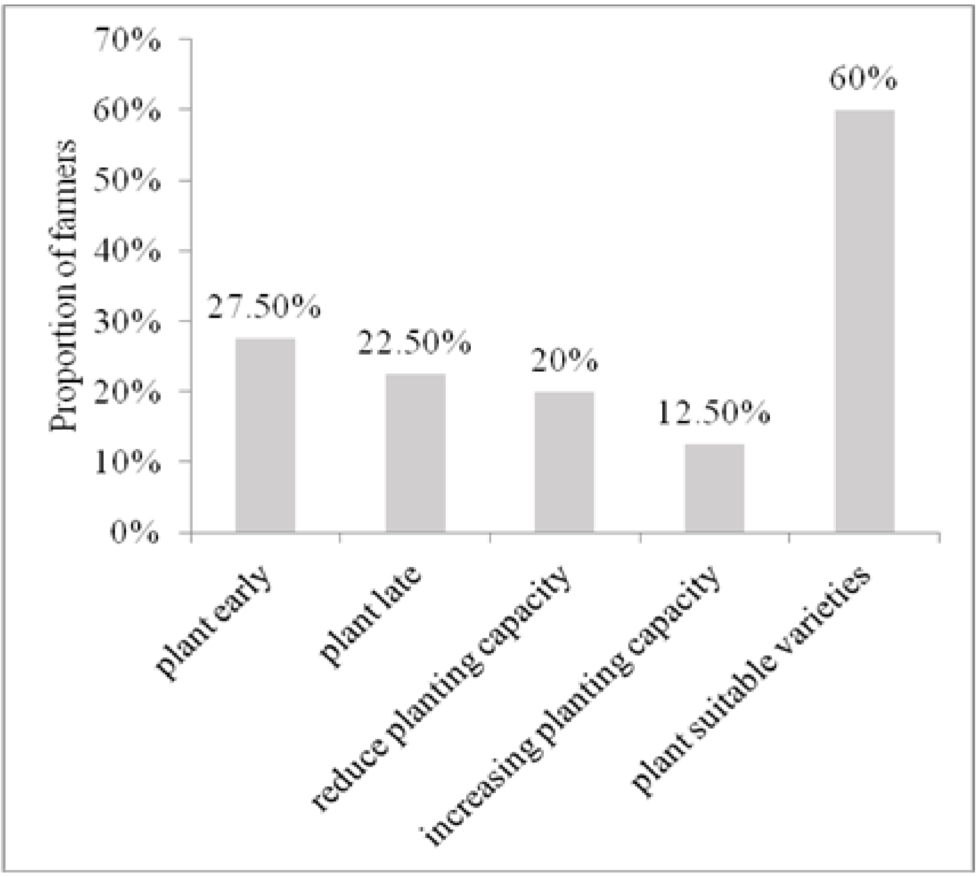

Figure 3: Arable farmers' adaptation strategies to climate variability and change

Understanding and utilisation of seasonal weather forecasts

The results on the utilisation of seasonal weather forecasts by arable farmers in their planting decision making is shown in Figure 4. The figure shows that 72% of the farmers used the forecasts. According to the farmers, the forecasts helped them to make informed decisions on when to plant and which crop varieties they could plant which would withstand the expected climatic conditions. Still from Figure 4, 28% of the farmers did not use the forecasts in their planting decision making. Their reasons for not using the forecasts are given in Figure 5. From the figure, the most common reason (40%) was that they did not understand the forecasts. The other reasons were that the forecasts were unreliable (33%), they did not contain all the information that they needed (20%), and that they did not have access to the forecasts (7%).

Since the farmers' most common reason for not using the forecasts was that they did not understand them, their understanding of the various aspects of the forecasts was assessed to identify those which they did not understand. Those aspects of the forecasts are indicated in Figure 6. From the figure, almost a quarter of the respondents (22.5%) had challenges with the spatial scale aspect of the forecasts, i.e., they did not know how to deduce forecasts for their local areas from the forecasts of the whole region or district. The figure also shows that 7.5% of the farmers did not understand forecast graphics, 5% did not understand forecast terminology (technical jargon) and the same percentage of the farmers had challenges with the temporal scale of the forecasts, i.e., they did not know how to construe forecasts for specific months from the summarized forecasts for a three months period. A study carried out in Pandamatenga (Chobe District, Botswana) commercial farms, also found out that farmers had challenges with the temporal and spatial scale aspects of the forecasts (Fitt, 2012).

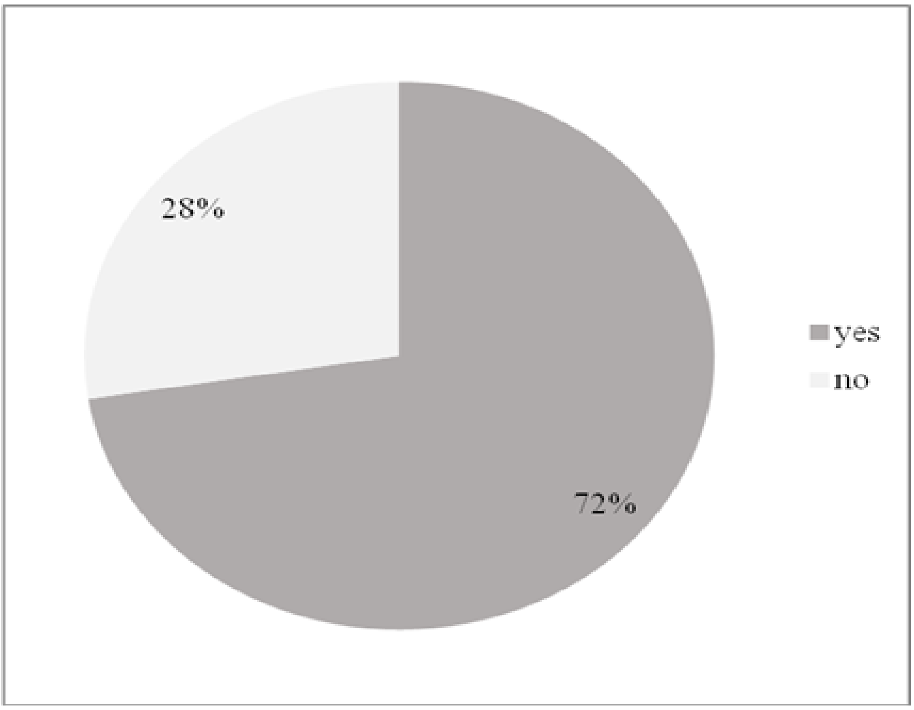

Figure 4: Seasonal weather forecasts utilization by arable farmers in planting decision making

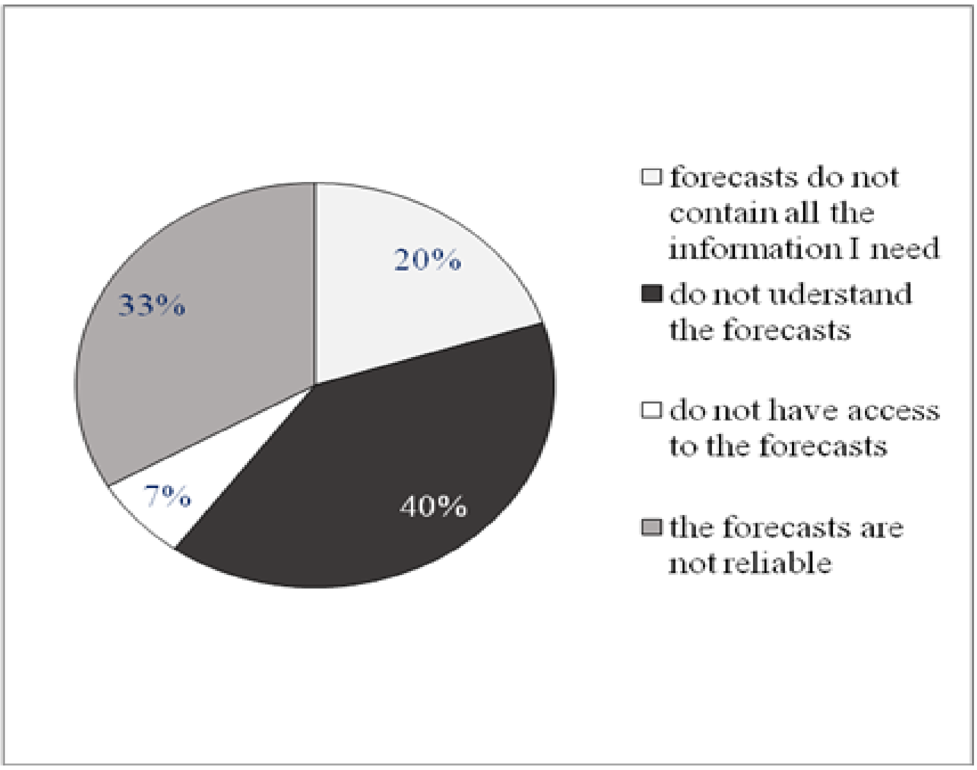

Figure 5: Reasons for not using seasonal weather forecasts by arable farmers

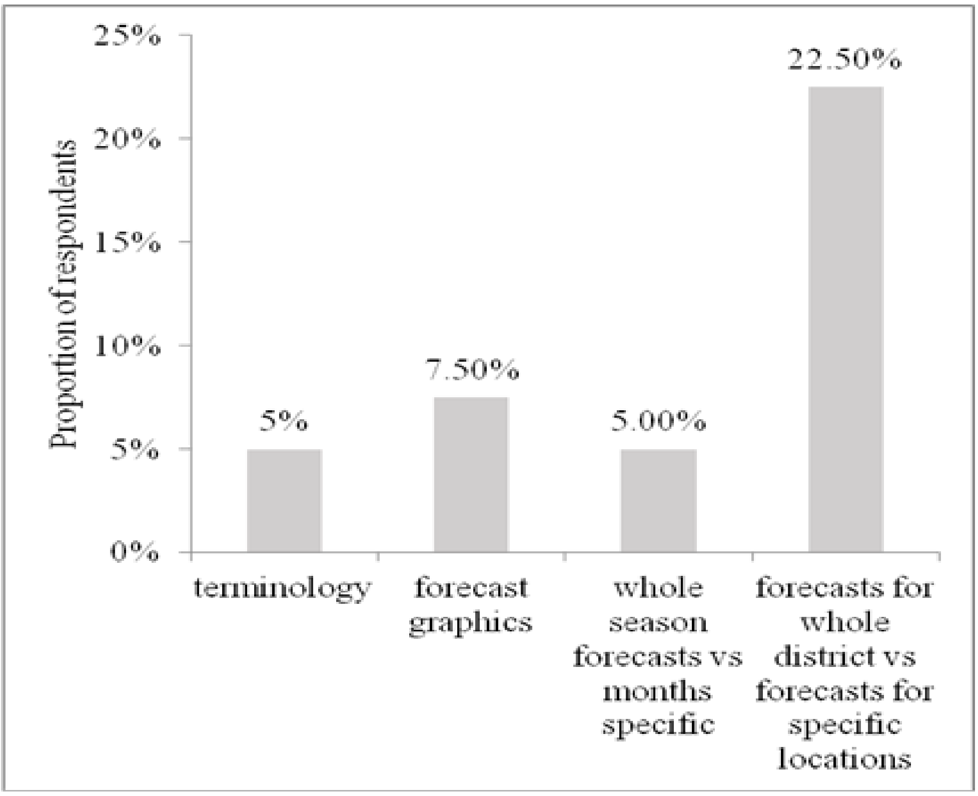

Figure 6: Arable farmers' understanding of the various aspects of seasonal weather forecasts

Accessibility of seasonal weather forecasts to farmers

Arable farmers indicated that they accessed seasonal weather forecasts in several ways (Figure 7). The figure shows that most of them (90%) accessed the forecasts through radio. These results are in concert with Makebea et al. (2012). Agricultural extension officers also played a significant role (67.5%) in disseminating the forecasts to the farmers. Other ways through which the farmers accessed the forecasts included television (42.2%), friends and family (18%) and newspapers (5%). Even though visiting the nearest meteorological office is one of the ways of accessing weather forecasts, none of the respondents indicated that they used this option.

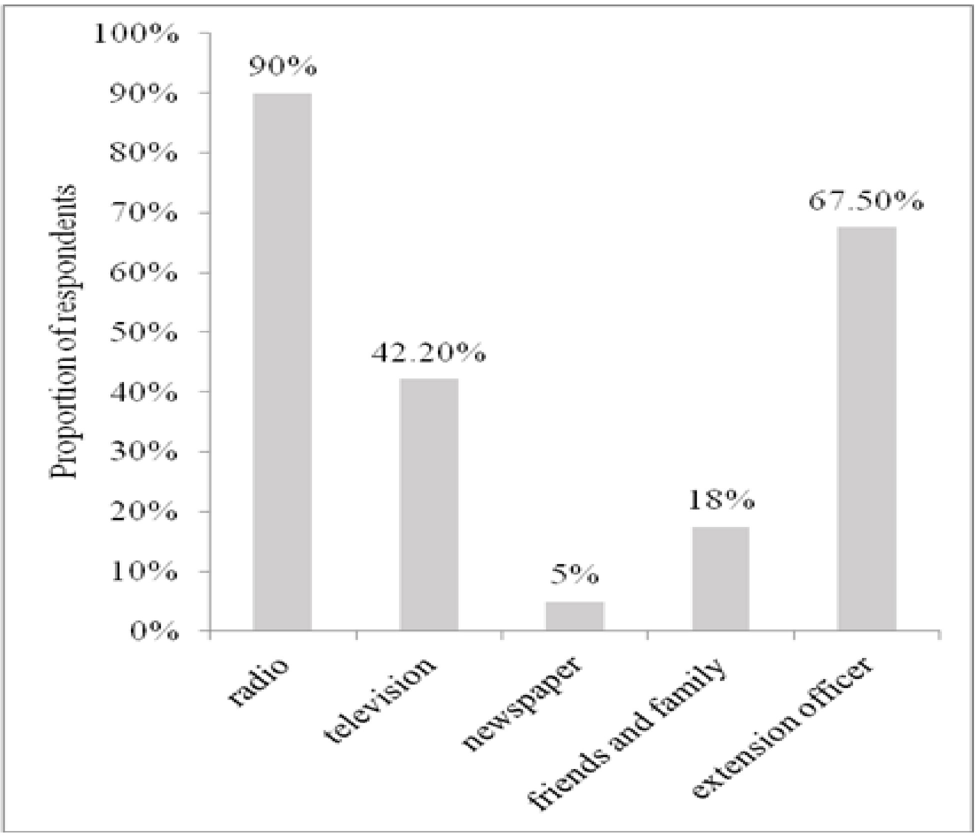

Figure 7: Arable farmers' ways of accessing seasonal weather forecasts

Suggested improvements to seasonal weather forecasts

Improvements to seasonal weather forecasts that were suggested by the farmers which could make the forecasts easier to understand and use are presented in Figure 8. The figure shows that 35% suggested that the forecasts should be downscaled to their local area scale. A study carried out by Feleke (2015) on farmers' weather forecasting needs for climate change and adaptation in the Central Rift Valley of Ethiopia also got similar results. The study indicated that the capacity to adapt was affected by lack of forecasts that were downscaled to local area scale. In addition to downscaled forecasts, it can also be seen from Figure 8 that 7.5% of the farmers suggested that the forecasts should be rebroadcasted on the radio and television several times so that those who might have missed earlier broadcasts may have another opportunity to hear or watch them. It also shows that 5% of the farmers suggested that the forecasts should be disseminated to farmers' clubs or associations, and that the leaders of such associations, agricultural extension officers and their field assistants should be trained for effective dissemination and use of the forecasts. Additionally, the figure shows that 17.5% of the farmers felt that the forecasts were satisfactory hence there was no need to improve them.

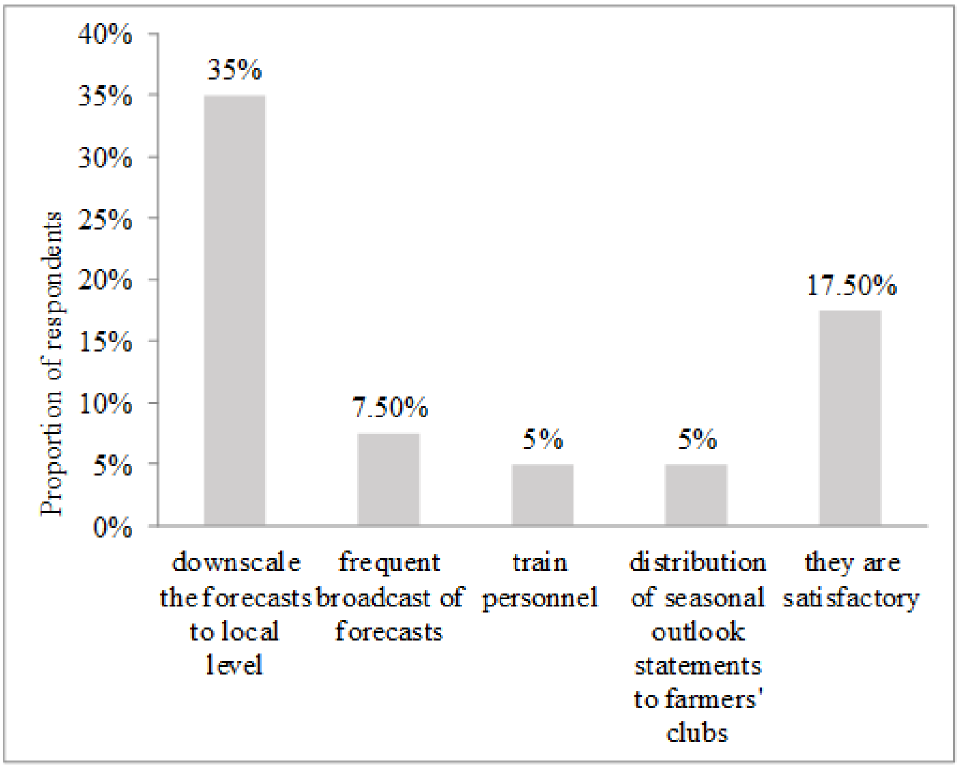

Figure 8: Improvements to seasonal weather forecasts as suggested by arable farmers

Conclusion

Almost all the farmers (95%) indicated that they noticed changes in the climate over the years. They adapted to the changes in the climate mainly (60% of the respondents) by planting suitable crop varieties which can withstand harsh weather conditions. To make planting decision making, about three quarters of the farmers (72%) indicated that they used weather forecasts which they accessed mainly through the radio. However, 28% of them did not use the forecasts in their planting decision making, the most common reason being that they did not understand the forecasts. Almost a quarter (22.5%) of those who did not use the forecasts indicated that they had challenges with the spatial scale aspect of the forecasts, i.e., they did not know how to deduce forecasts for their local areas from the forecasts of the whole region or district. Most of the farmers' educational level ranged from no formal education to primary education (62.5% in total), which made it difficult for them to understand the forecasts. It is therefore necessary to improve the forecasts to make them easier to understand so that they can be used even by farmers with low educational level. More than one third (35%) of the farmers suggested that the forecasts should be downscaled to their local area scale as an improvement. The results are comparable with those of Feleke (2015), who conducted a study on farmers' weather forecasting needs for climate change and adaptation in the Central Rift Valley of Ethiopia. In addition to forecast improvement recommendation, this study also recommends that young people (39 years or less) should be encouraged to practice arable farming as it was found out that only a few of them (12.5%) practiced it. Furthermore, it is also recommended that farmers should visit the nearest meteorological offices to obtain weather forecasts. The advantage of visiting meteorological offices for weather forecasts is that they can get further clarification of the forecasts from the experts. This study found out that none of the respondents indicated that they visited the nearest meteorological office to obtain weather forecasts.

References

Adejuwon, J., and Neil, L. (2014). *Climate change and adaptation*. London: Earthscan.

Ash, K. D., and Matyas, C. J. (2012). The influences of ENSO and the subtropical Indian Ocean Dipole on tropical cyclone trajectories in the southwestern Indian Ocean. *International Journal of Climatology* 32(1), 41-56.

Ayanladea, A., Radeny, M., John, F. and Mortonc, M. J. (2017). Comparing smallholder farmers' perception of climate change with meteorological data: A case study from southwestern Nigeria. *Weather and Climate Extremes* 15, 24–33.

Batisani, N. and Yarnal, B. (2010). Rainfall variability and trends in semi-arid Botswana: Implications for climate change adaptation policy. *Applied Geography* 30(4), 483–489.

Bhalotra, Y. P. R. (1984). *Climate of Botswana Part I: Climatic Controls*. Gaborone: Department of Meteorological Services.

Bhalotra, Y. P. R. (1987). *Climate of Botswana Part II: Elements of limate*. Gaborone: Department of Meteorological Services.

Bryan, E., Deressa, T. T., Gbetibouo, G. A., and Ringler, C. (2009). Adaptation to climate change in Ethiopia and South Africa: Options and constraints. *Environmental Science and Policy* 12(4), 413-426.

Central Statistics Office (2011). 2011 *Population and housing census preliminary results brief*. Gaborone: Census Office.

Creswell, J. W. and Clark, P. V. (2009). *Designing and conducting mixed methods research*. California: SAGE Publications.

Feleke, H. G. (2015). Assessing weather forecasting needs of smallholder farmers for climate change adaptation in the Central Rift Valley of Ethiopia. *Journal of Earth Science and Climatic Change* 6(10), DOI:10.4172/2157-7617.100031.

Fitt, M. (2012). *Assessment of use and value of weather and climate information for commercial arable farmers in Botswana*. Cape Town: University of Cape Town.

Grothmann, T. and Patt, A. (2005). Adaptive capacity and human cognition : The process of individual adaptation to climate change.*Global Environmental Change* 15(3), 199–213.

Guilpart, N., Grassini, P., van Wart, J., Yang, H., van Ittersum, M. K., van Bussel, L. G., ... and Cassman, K. G. (2017). Rooting for food security in Sub-Saharan Africa. *Environmental Research Letters* 12(11), 114036.

Hammer, G. L., Neville, N. and Christopher, M. (2013). *Applications of seasonal climate* *forecasting in agricultural and natural ecosystems*. New York: Springer Science and Business Media.

Harrison, M., Kanga, A., Magrin, G. O., Hugo, G., Tarakidzwa, I., Mullen, C., … and Meinke, H. (2007). Use of seasonal forecasts and climate prediction in operational agriculture. *CAgM Report*, 102.

Jiri, O., Mafongoya, P. L., Mubaya, C. and Mafongoya, O. (2016). Seasonal climate prediction and adaptation using indigenous knowledge systems in agriculture systems in southern Africa: A review. *Journal of Agricultural Science* 8(5), 156-172.

Juana, J. S., Kahaka, Z. and Okurut, F. N. (2013). Farmers' perceptions and adaptations to climate change in Sub-Sahara Africa: A synthesis of empirical studies and implications for public policy in African agriculture. *Journal of Agricultural Science* 5(4), 121–135.

Kolawole, O. D., Wolski, P., Ngwenya, B., and Mmopelwa, G. (2014). Ethno-meteorology and scientific weather forecasting: Small farmers and scientists' perspectives on climate variability in the Okavango Delta, Botswana. *Climate Risk Management* 4, 43-58.

Makebea, M., Moses, A. and Kaisara, M. (2012). Uptake of early warning scientific weather information by local farmers in some selected villages of Ngamiland, Botswana (undergraduate project). Okavango Research Institute, University of Botswana.

Molefe, C., Cassidy, L., Chimbari, M. and Magole, L. (2013) Influence of flooding variation on molapo farming field size in the Okavango Delta, Botswana. *International Journal of Agricultural Research and Review* 2, 27-37.

Moses, O. (2017). Heat wave characteristics in the context of climate change over the past 50 years in Botswana. *Botswana Notes and Records* 49, 13–25.

Moses, O. and Ramotonto, S. (2018). Assessing forecasting models on prediction of the tropical cyclone Dineo and the associated rainfall over Botswana. *Journal of Weather and Climate Extremes* 21, 102-109.

Pachauri, R. K., Allen, M. R., Barros, V. R., Broome, J., Cramer, W., Christ, R., ... and Dubash, N. K. (2014). *Climate change 2014: Synthesis report*. Contribution of Working Groups I, II and III to the fifth assessment report of the Intergovernmental Panel on Climate Change (p. 151). IPCC.

Patt, A. G. and Gwata, C. (2002). Effective seasonal climate forecast applications: Examining constraints for subsistence farmers in Zimbabwe. *Global Environmental Change* 12, 185–195.

Roco, L., Engler, A., Bravo-Ureta, B. E. and Jara-Rojas, R. (2014) Farmers' perception of climate change in mediterranean Chile. *Regional Environmental Change* 15, 867–879.

Roudier, P., Muller, B., D'Aquino, P., Roncoli, C., Soumaré, M. A., Batté, L. and Sultan, B. (2014). The role of climate forecasts in smallholder agriculture: Lessons from participatory research in two communities in Senegal. *Climate Risk Management* 2, 42–55.

Sanga, G. J., Moshi, A. B. and Hella, J. P. (2013). Small scale farmers' adaptation toclimate change effects in Pangani River basin and Pemba: Challenges and opportunities. *International Journal of Modern Social Sciences* 2(23), 169–194.

Shisanya, C. A. and Khayesi, M. (2007). How is climate change perceived in relation to other socioeconomic and environmental threats in Nairobi, Kenya? *Climate Change* 85, 271–284.

Shongwe, M. E., Van Oldenborgh, G. J., Van Den Hurk, B. J. J. M., De Boer, B., Coelho, C. A. S. and Van Aalst, M. K. (2009). Projected changes in mean and extreme precipitation in Africa under global warming Part I: Southern Africa. *Journal of Climate* 22(13), 3819-3837.

Simelton, E., Quinn, C. H., Batisani, N., Dougill, A. J., Dyer, J. C., Fraser, E. D., and Stringer, L. C. (2013). Is rainfall really changing? Farmers' perceptions, meteorological data, and policy implications. *Climate and Development* 5(2), 123-138.

Smit, B., and Skinner, M. W. (2002). Adaptation options in agriculture to climate change: A typology. *Mitigation and Adaptation Strategies for Global Change* 7(1), 85-114.

Stern, C. P. and Easterling, E. W. (1999). *Making climate forecasts matter*. Washington DC: National Academy Press.

Tyson, P. D. (1984). The atmospheric modulation of extended wet and dry spells over South Africa 1958-1978. *Journal of Climatology* 4, 621-635.

VanderPost, C. (2009). Molapo farming in the Okavango Delta. fact sheet 7/2009. Maun: Harry Oppenheimer Okavango Research Centre, University of Botswana.

Zinyengere, N., Mhizha, T., Mashonjowa, E., Chipindu, B., Geerts, S. and Raes, D. (2011). Using seasonal climate forecasts to improve maize production decision support in Zimbabwe. *Agricultural and Forest Meteorology*: 151(12), 1792–1799.

Zuma-Netshiukhwi, G., Stigter, K. and Walker, S. (2013). Use of traditional weather/climate knowledge by farmers in the south-western Free State of South Africa: Agrometeorological learning by scientists. *Atmosphere* 4, 383-410.