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Use of Seasonal Climate Forecast in Agricultural Decision-making among Smallholder Farmers in Semi-Arid Southeastern Kenya

Morris Maingi Mwatu
Tutorial fellow, Department of Social Sciences Education, Alupe University College, Kenya

Abstract:
Various adaptation strategies to climate variability have been used over the years with little attention given to the vital role played by seasonal climate forecast (SCF) in providing information on the expected climatic conditions to adapt to. This study sought to assess the level of use and constraints in using seasonal climate forecast in agricultural decision-making by smallholder farmers in semi-arid Voi sun-County. SCF for October-November-December (OND) 2015 was obtained from Kenya Meteorological Service (KMS) and compared to observed climatic conditions for the season. Climatic data of the study area for the period 1985-2014 was obtained from Voi Meteorological station and used to calculate the OND mean rainfall for the study area. Questionnaires were administered to 204 household heads randomly selected from two Locations and interview schedule administered to five purposively selected Key Informants. Primary data collected was analyzed using descriptive statistics and Pearson Correlation test. The study showed that 41.7% of smallholder farmers used OND 2015 SCF in agricultural decision-making. Key constraints to use of seasonal climate forecast were lack of trust in the forecasts and inadequate extension support. The household's socio-economic characteristics that were found to have a significant relationship with use of SCF were education level and reason for farming. The study concludes that although OND 2015 SCF was accurate, there was poor use of the forecast in agricultural decision-making mainly due to lack of trust on the information and low level of training on its use. The study recommends enhancement of awareness on importance of SCF information and training on its use in agricultural decision-making especially in semi-arid areas

Keywords: *agricultural decisions, seasonal climate forecast, semi-arid Kenya, smallholder*

1. Introduction

Climate plays an essential role in many human activities especially agriculture. Despite the improvement in agricultural technologies in fields such as plant breeding, soil fertility and weed science, climate remains a primary determinant of agricultural productivity due to the biophysical relationship which crops establish with dynamic atmospheric environment (Meza and Wilks, 2008). Causes of climate variability and its effects have today been well understood with the timing and degree of the variability now being a major concern (Crist, 2007). Adaptation, which entailed measures put in place to cope with the changing climatic conditions as well as taking advantages of opportunities created by such changes, is the most appropriate approach in dealing with climate variability. Climate forecast is essential in determining the most appropriate adaptation strategies to seasonal climate variability to use. Climate forecast lie in three categories: weather forecast for the next few days, seasonal climate forecast for the next few months and decadal climate forecast which projects climate conditions for many years to come (Faures *et al*., 2010). Out of these three, information on seasonal climate is the most appropriate for smallholder farmers growing annual crops. Seasonal climate forecasts provide information on expected seasonal rainfall conditions in terms of its onset, amount and cessation, vital in making on-farm decisions on adaptation strategies in semi-arid areas (Klopper *et al*., 2006).

Greater knowledge on ocean-atmosphere interactions and use of Global Circulation Models (GCMs) has led to improved seasonal climate forecasting skills useful in strategic agricultural decision-making (Baigorria *et al*., 2008). El Niño Southern Oscillation (ENSO) is the most common known driver of inter-annual climate variability around the world. This is a periodic appearance of unusually high Sea Surface Temperatures (SSTs) in the central and eastern Pacific Ocean which results into regional warming across the tropics leading to increased probability of drought and other extreme weather events in some areas and excess rainfall in others (Motha, 2007). ENSO is caused by ocean-atmosphere interactions due to eastward expansion and westward contraction of the SSTs in the western Pacific Ocean which bring about positive anomalies in the central Pacific. The SSTs and an index of surface pressure gradient is monitored and used to predict seasonal climate conditions over the tropical regions. Measurement of SSTs in the Pacific allows the simulation of likelihood of ENSO up to six months in advance with progress and strength of the El Niño being monitored through near-real-time ENSO observing systems (Faures *et al.*, 2010).

El Niño conditions usually persist for nine to 12 months or longer from June with its peak between November and February where its impacts are felt in a region's main rainy season (Lyon, 2014). A positive phase of the Indian Ocean Dipole (IOD) is sometimes triggered by El Niño events. This is a pattern of warmer-than-average conditions in the Western equatorial Indian Ocean coupled by cooler-than-average conditions in the East. This positive IOD phase usually results in wetter conditions in East Africa and drier conditions in Southeast Asia and Australia. There exists a positive correlation between IOD phase and precipitation received during OND with less significant changes in precipitation received during MAM as it demonstrates weak correlation with SSTs in the ocean basins (Matondo, 2010). As interactions between the ENSO and IOD persist, the latter can alter the impacts of the former. Regional climate forecasts provided by various national meteorological services are, therefore, the most reliable as they forecast on multiple timescales; seasonal, monthly, weekly and daily.

Adoption of seasonal climate forecast depends on the variables being forecasted, the quality and the likely benefits of the forecast and the manner in which forecasters communicate the information to end users (Ash *et al.*, 2007). Seasonal climate forecasts can greatly improve agricultural productivity if the timing and reliability of the forecasts are improved. Early provision of seasonal climate forecast with sufficient lead-time can assist in adjustment of most of the critical agricultural decisions thus contributing to efficient agricultural management practices (Apipattanavis *et al.*, 2010). Seasonal climate forecast has been used in many parts of the world in making on-farm agricultural decisions. Many studies have shown that in Australia seasonal climate forecasts have been used with great success since late 1980s (Hayman *et al.*, 2007). Similarly, seasonal climate forecasts have been used in North America with USA National Oceanic and Administration's Climate Prediction Centre (NOAA/CPC) issuing forecast to farmers on regular basis (Scheneider and Garbrecht, 2006). In the sub-Saharan Africa, large-scale commercial farmers have used seasonal climate forecast in their major agricultural decision-making with remarkable success (Oyekale, 2015).

Although it is generally true that seasonal climate forecasts have enormous benefits, many constraints prevent their optimal use due to the manner in which the forecast are produced, disseminated, interpreted and applied in various decision-making processes (Klopper *et al.*, 2006). Despite the availability of modern seasonal climate prediction software, the final product has not been widely adopted especially among the marginal groups and lacks immediate effects to end-users due to uncertainties involved as well as difficulties in downscaling and interpreting the forecasts (Garbrecht and Scheider, 2007). Usefulness of forecasts derived from climatic models is hindered by factors such as low awareness, mismatch between model forecast and users' needs as well as the complexity and probabilistic nature of the information (Power *et al.*, 2007). A study conducted on the role of climate education in agriculture among Australian farmers established that many farmers lack formal education on use of SCF with those trained having attended only a one-day course (George *et al.*, 2007). A wide institutional gap, therefore, exist between the producers and the users of seasonal climate forecasts.

Unreliability of seasonal climate forecast due to perceived inaccuracy has also been a major hindrance to the uptake of seasonal climate forecasts by many potential end-users (Meza and Wilks, 2008). A study on generation, dissemination and evaluation of seasonal climate information for targeted groups in Australia noted that seasonal climate forecasts' accuracy is a confounding obstacle to the application of the seasonal forecast information in agricultural management (George *et al.*, 2007).

Another major challenge in the adoption of seasonal climate forecasts in agricultural decision-making is the inability by the forecasts generators to demonstrate advantages of using the information. This is due to the fact that seasonal climate forecast is just information and not tangible good where trials can be done to test compatibility with the existing farm practices before application (Cabrera *et al.*, 2007). Forecasted information also tends to dictate the type of crops to be grown, which is unpopular among many farmers. In a study on levels integration of seasonal climate forecasts into farming decisions among Australian farmers, it was established that only 30 – 50% of farmers use climate forecasts despite its wide-spread dissemination (Hayman *et al.*, 2007).

Trust of seasonal climate forecasts by farmers has also been dwindling over the years due to perceived forecast errors. A study carried out in Lesotho to assess the impact of anticipated information model on the trust of seasonal climate forecast by end-users found out that forecast errors have negative impact on trust and therefore forecasters ought to inform users of the uncertainties of the forecast (Ziervogel *et al.*, 2005).

Information on seasonal climate forecasts is widely generated and disseminated in most regions of the world. In Kenya, the Kenya Meteorological Service (KMS) disseminates seasonal climate forecasts about one month before onset of March-April-May (MAM) and October-November-December (OND) rainfall seasons. Despite many years of generation and dissemination of the forecasts, it has not been established if this information translates into agricultural risk reduction, especially among smallholder farmers in low agricultural potential areas such as semi-arid Voi sub-County. This studysought to assess the extent to which SCF have been effective as an adaptation strategy among smallholder farmers in semi-arid areas. Study findings will provide a feedback to practitioners on the state of adaptive capacity particularly use of seasonal climate forecasts as an adaptation strategy to climate variability in semi-arid areas. It will also provide knowledge to smallholder farmers on the appropriateness of response strategies to SCF.

2. Methodology

2.1. Study Area

Voi sub-County is located in the semi-arid Southeastern region of Kenya. It lies within latitude 2⁰42´S and 4⁰08´S and longitude 37⁰41´E and 39⁰14´E covering an area of 3,269.1 Km^2. The sub-County's altitudinal rise range between 250 and 850 metres above sea level. The area is generally dry with an average temperature of 25^0 C and a mean annual rainfall of about 500mm. Rainfall is received in two seasons; long rains between March and May and short rains between October and December with the short rains being most useful for crop farming (RoK, 2013). Voi Meteorological station, a major synoptic station in Kenya, is located in the sub-County between the two administrative locations (Mbololo and Sagalla) chosen for this study. The study was limited to these two locations due to their proximity to Voi meteorological station, important for collecting reliable rainfall data. In addition, the two locations are predominantly occupied by smallholder farmers.

2.2. Data Collection

2.2.1. Household Survey

The study used questionnaire to collect data at household level. The target population included all smallholders farming household heads in Mbololo and Sagalla administrative Locations. A complete list of all smallholder farming households was used to develop the sample frame where a sample of 246 households was selected through random sampling. This represented five per cent of the total 4,917 households in Sagalla and Mbololo Locations according to 2009 Kenya's Census Report (RoK, 2010). However, 204 respondents participated in the study translating to a response rate of 82.93%.

2.2.2. Rainfall Data

Voi meteorological station was used to obtain rainfall data since it was reliable, with no missing and it is found close to the study area. KMS forecast for OND 2015 rainfall season was used since the study was based on the fact that OND rain seasons are the most reliable for rain-fed agriculture in semi-arid areas and has a high skill of prediction compared to March-April-May rains (Cooper *et al*., 2008). Three secondary datasets were collected and used in this study. Observed daily rainfall data for OND 2015 season was obtained from Voi meteorological station. Seasonal climate forecast information for OND 2015 was downloaded from KMS website after its release. Rainfall data for 30 years, 1985-2014, was obtained from Voi Meteorological Station and used to find the mean rainfall for OND in Voi sub-County which was to be used as the 'normal' rainfall in the interpretation of the OND 2015 seasonal climate forecast issued by KMS.

3. Results and Discussion

3.1. The 2015 October-November-December Forecast and Advisory

The Kenya Meteorological Service issued OND 2015 seasonal climate forecast for the whole country indicating the expected amount, onset date and cessation dates as well as relevant advisories for different sectors of the economy. The OND 2015 forecast for Southeast Kenya was a highly enhanced (above normal) rainfall. The forecast further indicated that the rainfall season was to be driven by El Niño conditions as well as warming of the SSTs in the Western equatorial Indian Ocean adjacent to the East Africa coastline. According to the KMS forecast, counties in the coastal region (within which the study area is found) were expected to experience onset during the 2^{nd} to 3^{rd} week of October. The forecast also stated that the study area expected cessation in the last week of December. In addition to amount, onset and cessation of the rainfall, KMS advised farming communities to maximize crop yield by applying appropriate land use management. The advisory read in part;

"Farmers (should) double their efforts to reap maximum benefit from these good conditions"
(KMS, 2015).

Farmers were further advised to work closely with Agriculture officers for relevant advisories to avoid losses which arise as a result of the highly enhanced rainfall.

Despite the onset date for the rainfall being on 7^{th} October, the area had six rainy days in the whole month with only two days receiving rainfall of over 10mm. Farmers ended up losing crops they had planted due to the prolonged within-season dry spell. They complained of having replanted thrice during the season as crops would dry up upon germination. KMS had only issued a general outlook of the OND 2015 forecast without taking cognizance of varied local topographical characteristics as well as local rainfall patterns. The wording used in the forecast issued was not very specific regarding to Southeastern Kenya. There was no clarity of language used in the forecast and this may have affected interpretation of the forecast thus affecting its use in agricultural decision-making. This is supported by a study on perception and use of seasonal climate among farmers in Southeastern Kenya which noted that unclear language in forecast dissemination may greatly hamper its uptake (Recha *et al*., 2008).

3.2. OND 2015 Observed Rainfall in Voi sub-County

Daily rainfall for OND 2015 recorded at Voi meteorological station was obtained and analyzed. Figure 1 shows daily rainfall trend for OND 2015 recorded in Voi.The onset date for OND 2015 rainy season was on 7^{th} October as shown in Figure

1. This was in agreement with the forecasted onset date for Voi sub-County which was indicated as the 2nd to 3rd week of October. The forecast on the onset date was therefore accurate. The cessation date for OND 2015 rainfall was forecasted to be in the last week of December. This was also in line with the cessation date observed at Voi which was on 27th December. The total amount of rainfall for OND 2015 rainy season received in Voi was 358.7mm according to the records at Voi meteorological station. This was more than the calculated 30 years mean of Voi of 296.1mm. When expressed as a percentage, this was 121.14%.

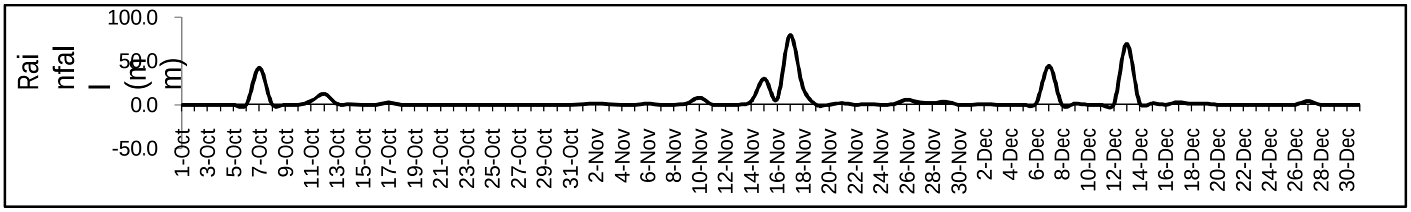

Figure 1: Daily OND 2015 recorded rainfall for Voi meteorological station

According to KMS guidelines, normal rainfall lies between 75% - 125% of the mean, above normal is rainfall over 125% of the mean while below normal is rainfall less than 75% of the mean (KMD, 1984). From these guidelines, Voi sub-County received normal, with a tendency to above normal, rainfall in OND 2015 season. Although Voi sub-County received rainfall amount close to the forecasted by KMS, the distribution was poor, an indication a great within season rainfall variability.

3.3. Smallholder Farmers' Use of SCF in Agricultural Decision-making

Majority (87.7%) of smallholder farmers received OND 2015 SCF and therefore they were aware of the climate outlook for the season. About 60.9% of the respondents indicated that they relied on radio to get the information. This was followed by learning from friends/neighbours at 22.3% and from TV with 9.5%. Only 3.4% of the respondents indicated that they got the forecast from government extension officers. Smallholder farmers who used OND 2015 SCF information in agricultural decision-making were 41.7% of the total respondents. About41.7%of the total respondents received and used OND 2015 SCF information in agricultural decision-making as shown by Table 1. Majority (61.2%) of those who used the information altered land preparation dates. Although SCF information is expected to guide farmers on the types of crops to grow in a particular season based on the expected onset, amount and cessation of the rainfall, this was not the case. Respondents who changed the type of crops planted were the least (28.2%). This suggests that there is poor uptake of SCF in agricultural decision-making aimed at adaptation to climate variability among smallholder farmers in Voi sub-County. This is in agreement with the findings of a study on use of SCF among Nebraska farmers which showed low use of the information in agricultural decision-making (PytlikZillig *et al*., 2010). Out of the 179 respondents who received SCF from KMS, only 38.6% of the respondents indicated that the OND forecast that they obtained was useful to their farming decisions.

Change	Yes		No	Total
Land preparation dates	Count Percentage	52 61.2%	33 38.8%	85 100%
Type of crops planted	Count Percentage	24 28.2%	61 71.8%	85 100%
Crop variety planted	Count Percentage	41 48.2%	44 51.8%	85 100%

Table 1: Change in farm management decisions by smallholder farmers

3.4. Constraints to Use of OND 2015 SCF in Agricultural Decision-making

A total of 179 (87.7%) out of 204 respondents interviewed indicated that they received OND 2015 seasonal climate forecast information with only 25(12.3%) respondents having not received the information. The two most cited reasons for not receiving the OND 2015 SCF information were '*I did not have the means of accessing the information*' and '*I did not know where to get the information'* both at 40%. This finding suggests that KMS, although has been able to reach 87.7 percent of the farmers in Voi sub-County, should aim for total coverage as far as information reach is concerned. A total of 94 of the respondents did not use OND 2015 SCF after accessing it. This represents 52.5% of those who accessed the forecast. Lack of trust on the SCF information was cited by the majority (51.1%) of the respondents as the reason for non-use. This was followed by lack of extension support, at 25.5%, financial challenges at 14.9% and finally inability to interpret the forecast at 8.5%. This implies that there is lack of trust in SCF by most of smallholder farmers in Voi sub-County. This finding confirms results of a research carried out in Chile on use of seasonal climate forecast agriculture whose findings showed that many farmers do not trust SCF information due to perceived inaccuracy, major hindrance to its uptake (Meza and Wilks, 2008).

Only 8.9% of the respondents who received OND 2015 SCF indicated that they were trained on interpreting and using the information. This implies that the information generated by KMS may still be unclear to most of the smallholder farmers in Voi sub-County hence not relevant in their agricultural decision-making. This is collaborated by findings from interview with the location agricultural officers who said that only a few smallholder farmers are invited to the Agriculture Development Support Programme (ADSP) meetings where SCF information is discussed. These meetings are usually organized at sub-County level and the few invited farmers are expected to train others on use of SCF information. However, no follow-up is done to ascertain the same. These findingsagree with those of George *et al.* (2007) whose study established that many farmers in Australia lack formal education on use of SCF.

Socio-economic characteristics of smallholder farmers may also, to some extent, lead to constraints in access and use of seasonal climate forecast information. Pearson Correlation was used to test use of OND 2015 SCF and the smallholder farmers' socio-economic characteristics as shown on Table 2.

Variable	Pearson Correlation Coefficient	Significance
Location	.068	.337
Gender	.115	.103
Education level	-.15*	.032
Age	.108	.124
Reason for farming	.321**	.000
Acreage	.037	.597

Table 2: Correlation between use of SCF and socio-economic characteristics
*** significant at 0.01 level*
** significant at 0.05 level*

According to Table 2, use of SCF is not significantly correlated to the location of the farmer, gender, age and acreage under farming. However, it has a weak but significant correlation with respondents' education level ($r=-0.15$, $p=0.032$, $\alpha=0.05$) and reasons for farming ($r=0.321$, $p=0.000$, $\alpha=0.01$). In this study, there is a weak negative and significant relationship between the level of education and use of SCF. This implies that respondents with higher education level are the less users of SCF information in agricultural decision-making. These findings are contrary to those of Comin and Hobija (2010) who established that there is a positive relationship between education level and adoption of technology. This could be attributed to the fact that smallholder farmers with higher education levels may have alternative sources of livelihood beyond crop farming.

On the other hand, there is a weak positive and significant relationship between use of SCF information and reason for farming. This implies that there is a higher rate of use of SCF information in agricultural decision-making among farmers who practice agriculture mainly for source of income compared to those who practice for source of food. A farmer who has invested in farming for income will be keen on seasonal climate characteristics so as to avert losses and maximize yield. These findings are in agreement with those of Oyakale (2015) and Klopper *et al.* (2006) whose study findings established that SCF information has been a vital decision-making tool among commercial farmers in sub-Saharan Africa as compared to subsistence farmers.

4. Conclusion

The study has attempted to establish response to seasonal climate forecast and constraints faced by smallholder farmers in Voi sub-County in use of the forecasts. OND 2015 seasonal climate forecast for Voi sub-County was accurate as per the KMS prediction but its use by smallholder farmers was not as expected. Out of the 41.7% of the total smallholder farmers who used the forecast 61% responded by altering land preparation dates and 48% by changing crop variety. This represents 25.4% and 20% of the total smallholder farmers respectively. Main constraints to use of seasonal climate forecast among smallholder farmers in Voi sub-County are lack of access to the forecast, training on use of the forecast and lack of trust on the forecast issued by KMS. Education level and reasons for farming also influence use of seasonal climate in agricultural decision-making.

In order to improve on the use of SCF by smallholder, local administrators and other leaders in the communities, including religious leaders, should be involved in dissemination of SCF advisory which are vital component of the forecasts. This can be achieved by training them through seminars organized by the Ministry of Agriculture in conjunction with KMS in order to make such leaders trainers of trainers in their localities. Access to seasonal climate forecast should be improved by diversification of the dissemination channels. Smallholder farmers should be trained on how to use SCF in agricultural decision-making through extension services. Smallholder farmers should also look at farming partly as a source of income so as to appreciate the role of seasonal climate forecast in agricultural decision-making in order to improve on its use.

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