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Engaging smallholder farmers with seasonal climate forecasts for sustainable crop production in semi-arid areas of Zimbabwe

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Small holder farmers in the semi-arid areas have not been able to utilize seasonal climate forecasts in making crop management decisions due to limited exposure as well as failure to interpret it. Three participatory meetings were held with farmers in Lower Gweru and Lupane Districts of Zimbabwe soon after the release of the 2008/2009 and 2009/2010 seasonal climate forecast in September of each season. This was done to solicit for farmers' prediction of the coming rainy season and come up with field test crop management practices. Farmers have their sets of indicators that they rely on to forecast seasonal rainfall which are based on generations of past experience that include environmental, biological, and traditional beliefs. There is however, need to investigate how their indicators compare with the scientific forecast in making farming decisions. Farmers claimed that the rains were starting later and finishing earlier whilst analysis of the rainfall record showed that starting rains have been later by 5 to 10 days in the last five years. There was an increase in the number of dry spells in the rainy season in the last five years compared to the period 1980 to 2008. Adding recommended amounts of fertilizers resulted in yield increases of 40% compared to adding half the recommended amounts. Growing long season varieties resulted in higher yields (22%) than growing short season varieties in the 2009/2010 wetter season while growing of shorter season variety had yield advantage (36%) over the long season variety in the 2009/2010 which was relatively dry. Frequent weeding resulted in about 8% increase in maize yields compared to weeding once in a season. The study demonstrates that knowledge of the coming season assists smallholder farmers in coming up with adaptive strategies for climate variability and change.

Key words: Seasonal climate forecast, agriculture, smallholder farmers, adaptation, semi-arid areas.

INTRODUCTION

The severity, duration and frequency of droughts especially in Sub Saharian Africas' semi-arid areas is expected to increase due to climate change (Lasage et al., 2008). Climate variability and change directly affects

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agricultural production, as agriculture is inherently sensitive to climatic conditions and is one of the most vulnerable sectors to the risks and impacts of global climate change (Parry et al., 1999). Among the most vulnerable groups to the effects of climate variability and change are the small holder farmers who live in semi-arid dry communal areas and have the least ability to adapt to climate variability and change (IPCC, 2001, 2007). This makes smallholder farmers living in these marginal areas food insecure especially now with changing climate expecting to increase the frequency of droughts (Kalanda-Joshua et al., 2011). This implies that farmers have to take a number of crucial crop management decisions and land and water management decisions before and during the growing season, based on climate information (Sivakumar, 2006). It is therefore important for farmers to integrate the issues of climate variability into resource use and development decisions for a more informed choice of policies, practices and technologies that may reduce agriculture's long term vulnerability to climate variability and change (Sivakumar, 2006).

The introduction of seasonal climate forecast into management decisions can reduce the vulnerability of agriculture to droughts (Patt and Gwata, 2002) and reduce negative impacts. It is widely accepted that climate prediction information should be introduced into the planning process as an input into the design of adaptation/mitigation plans (Zievogel and Zermoglio, 2009; Sivakumar, 2006), and this should be embedded into existing strategies of individuals and communities including their use of indigenous knowledge systems in weather forecast (Prowse and Scott, 2008; Bharara and Seeland, 1994). For seasonal climate forecasts (SCF) to have an impact on decision making, they have to be reliable, timely, and appropriate in context and readily accessible (Challinor, 2008; McCrea et al., 2005). A study carried out by McCrea et al. (2005) shows that adoption and use of seasonal climate forecasts by farmers depends on the level of understanding of the forecast, the format of presentation of the forecast and the attitude of farmers towards the usefulness of the forecast as an indicator of future rainfall.

Seasonal climate forecasts have been used before to assist farmers in making appropriate crop management decisions (Patt and Gwata 2002; Carberry et al., 2002; Meinke and Hochman, 2000) including crop choice, choice of cultivar, fertiliser use, area planted to a given crop, timing and tillage type. Farmers who attended participatory training workshops on forecasts are significantly more likely to use the forecasts than those who learn of the forecasts through non-participatory channels (Ziervogel and Calder, 2003).

Some studies in Zimbabwe (Patt et al., 2005) and Brazil (Ziervogel and Calder, 2003), demonstrate that farmers who used seasonal climate forecast significantly improved their yields compared to their counterparts who did not use it.

There are several case studies where farmers have been engaged with improved management of risks under variable climate, but there has not been any quantitative evidence. Most studies report on how farmers who have undergone training on the use of SCF understand better on how to respond to SCF compared to their counterparts who did not undergo the training (Patt et al., 2005). Challinor (2008) argues that the most effective way to conduct pro-poor adaptation research may well be to take (from the onset) a holistic view that is informed by engagement and partnership with potential benefactors. Such projects should integrate indigenous knowledge systems and traditions of the benefactors (Nyong et al., 2007; Nyong and Kanaroglou, 1999).

Rainfall characteristics such as onset, ending, dry spells, rainfall intensity and rainfall amounts are showing signs of change in Zimbabwe. The smallholder farmers in Zimbabwe depend on rainfed agriculture which is vulnerable to low, erratic and variable rainfall. Decisions on crop management strategies are very important in such semi-arid areas and are potentially improved by seasonal climate forecast. The objectives of the study were to (i) compare and document farmers' perceptions of changing climatic conditions with measured weather data, (ii) compare climate predictions obtained from the scientific seasonal forecast with the indigenous seasonal prediction and (iii) come up with management options that respond to the seasonal predictions and compare the different options in field experiments.

RESEARCH METHODS

Study areas

The research was carried out in the 2008/2009 and 2009/2010 farming seasons in Lower Gweru and Lupane Districts in South-western Zimbabwe (Figure 1) which lie in Natural Region IV. In Lower Gweru, district, Nyama and Mudubiwa wards were chosen while in Lupane, Daluka nad Menyezwa wards were chosen. The sites were chosen on the basis that they are both in the semi-arid regions of the country dorminated by smallholder farmers. The natural regions are a classification of the agricultural potential of the country, from natural region I, which represents the high altitude wet areas to natural region V which receives low and erratic rainfall averaging 550 mm per annum (Vincent and Thomas, 1960). These two districts are located in the semi-arid areas which cover 75% of the country. These districts have an annual rainfall of less than 700 mm per year and a growing season of 90 to 150 days. Droughts occurs once in every three to five years in these districts. Rainfall is erratic and ill distributed in time and space resulting in frequent crop failures that occur three out of five years. In drier parts of Southern Africa, the coefficient of variation in annual rainfall is between 20 and 40%, while the variation in yield is from less than 15 to 60% with high implications on food security (Lumsden and Schulze, 2007). Land use in the districts is typical of communal lands with dryland crop production in the rainy season and animal rearing. Farmers are dependent on rainfed crop production. The commonly grown crops are maize, groundnuts, sorghum, pearlmillets and groundnuts.

To attest farmers' claim that climate is changing, historical rainfall data from 1980 to 2008 was obtained from Thornhill airbase in

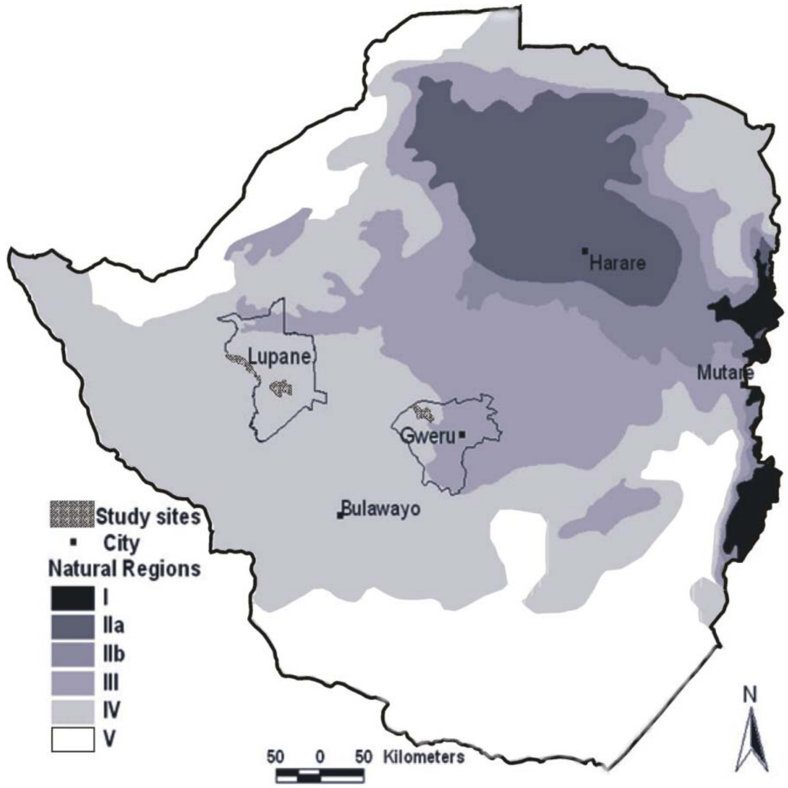

Figure 1. Map of Zimbabwe showing natural regions and locations of the study sites.

Gweru which is 20 km from Lower Gweru while that for Lupane was obtained from Lupani meteorological office. This data was used to determine starting dates, ending date and maximum length of dry spells within rainy seasons.

The seasonal climate forecasts of the study areas were obtained from the Zimbabwean Met department through the Southern African Regional Climate Outlook Forum (SARCOF) which coordinates the production of the SCF. The seasonal climate forecast is a product of pre-season forums that bring together climate experts involved in seasonal forecast development relevant to Southern African Development community (SADC) to develop the best forecast for the region through a consensus. The product that comes out of the SARCOFs is regional in nature covering the whole of the SADC. After the SARCOF, the national meteorological services, for example the Zimbabwean Meteorological Department downscales the regional product to their country-specific rainfall forecasts.

Participatory research with farmers

Three participatory workshops were held with farmers in each of the two districts to get an understanding of the farmers' perceptions of changing climate conditions, to document the indicators they use to come up with their forecast indigenous seasonal climate forecast (ISCF) and also to evaluate field experimental results based on decisions from their indigenous knowledge forecasts. The participating farmers came from two districts (Lower Gweru and Lupane), two wards per district and three villages per ward. Five farmers from each village were selected randomly making a total of 60 farmers who participated in the research. For their respective villages, farmers were asked to come up with prediction for the 2008/2009 and 2009/2010 seasons forecast using their local indicators –and their perceptions of changing climate conditions before they went into plenary to come up with a consensus of the seasonal climate forecast for the district. The indigenous seasonal climate forecast was compared with the seasonal climate forecast issued by the Department of Meteorological Services.

Farmers were then asked what management options they would take, given the seasonal climate forecast. In a participatory manner and together with the farmers, field experiments were designed with the aim of testing how farmers' variety selection, tillage method, and fertilizer type and amount decisions, based on the seasonal climate forecast, affect crop yields. Two experiments were planted out in each district for the two consecutive seasons. The 2008/2009 experiment had a split-split plot treatment structure arranged in a Randomised Complete Block Design (RCBD). Tillage was the main plot factor while variety was the sub-plot factor and fertilizer sub-sub plot factor.

The 2009/2010 experiment had a 2 x 2 x 2 x 2 factorial treatment structure arranged in a RCBD. For each treatment there were two tillage systems, two varieties, two fertilizer levels and two weeding times. The treatments were replicated three times.

RESULTS AND DISCUSSION

Farmers' perceptions of climate change

Farmers indicated that climate has been changing in the previous five years, in that rains start earlier, rains end latter and the maximum number of dry spells has

Table 1. Rainfall starting dates, ending dates and maximum length of dry spells in the last 5 years and between 1980 and 2008 in Lower Gweru and Lupane Districts.

District	Lower Gweru			Lupane		
(Median dates)	Rainfall onset	Rainfall ending dates	Maximum length of dry spells within rainy season	Rainfall onset	Rainfall ending dates	Maximum length of dry spells within rainy season
1980-2008	Nov 14	Feb 22	16	Nov 12	Feb 9	18
Last 5 years	Nov 5	Mar 1	20	Nov 22	Mar 25	20

For dry spells: maximum length of dry spells (Dec 1 to Mar 31).

Table 2. Shows the indicators that farmers use to predict the rainfall season.

Wet year	Drought year
(i) *Rhus Lancea* and *Lannea discolor* trees produces lots of fruits	(i) *Rhus Lancea* trees produces few fruits
(ii) *Azanza garkeana* do not fruit well	(ii) *Lannea discolor* produces fruits but aborts them
(iii) Heat wave experienced	(iii) Before the rains
(iv) Early haziness soon after winter	(iv) Extended winter period
(v) North easterly winds	(v) North easterly winds dominant
(vi) Frogs turning brownish	(vi) White frogs appear in trees
(vii) Water birds making a lot of noise	(vii) Lots of thunderstorm without rains
(viii) Butterflies seen hovering in the air from north to south starting in October	(viii) Early rains starting from early October

increased. Comparison of the meteorological records with farmers' assessment of climate change showed a large disparity, with few of the stated changes being evident in the long term record. For example, farmers claimed that the rains were starting later and finishing earlier. Analysis of the rainfall record showed that starting rains (20 mm in 2 days) have been later by 5 to 10 days in the last five years compared to the 1980-2008 period at Lupane site but, for Lower Gweru District, it actually started earlier, by 9 days (Table 1). There was no evidence at any one site that the rain season was finishing earlier. Data on dry spells shows that there was an increase in the number of dry spells in the rainy season in both districts. This suggests that farmers might have poor memories of the rainfall variability over the longer term, and given their almost non-existent measurement of rainfall thereby highlighting the need to cross-check (with measured data) farmer derived information about perceived climate change. A similar result was obtained by Moyo et al. (2013) who observed that climatic data show no evidence that corroborates the farmers' perceptions.

Comparison of scientific and indigenous forecasts with measured and long term rainfall records

Farmers use a variety of indigenous knowledge systems in predicting weather. Table 2 shows the various indicators used to predict whether the coming season is dry or wet in the two districts. The indicators that the farmers are using are similar to those that have been recorded by other researchers elsewhere in the country, Zambia and Malawi (Kalanda-Joshua et al., 2011; Chagonda et al., 2010; Mubaya, 2010).

The scientific seasonal forecast for Lower Gweru was Normal to Above Normal for the period October, November and December (OND) while normal rains were predicted for the period January, February and March (JFM) in the 2008/2009 season (Table 3). The forecast for Lupane was Normal to below normal for the period OND while normal to below normal rains were expected for the period JFM in the 2009/2010 season. In the 2009/2010 season, the forecasts were below normal to normal in the two districts for both periods OND and JFM.

There was impressive consistency between farmer predictions on seasonal rainfall using indigenous knowledge of environmental indicators and the actual rainfall totals. The indigenous knowledge system predicted a wetter 2008/2009 and drier 2009/2010 season while actual rainfall total was 944 mm for 2008/2009 and 562 mm for 2009/2010 season respectively. The SCF in 2009/2010 predicted normal to below normal rainfall, while farmers at Lower Gweru and Lupane also forecast a poor rainfall season using local indicators but actual rainfall totals were 505 and 617 mm at Lower Gweru and Lupane respectively for the two seasons. It is likely that the deviation of the observed and predicted rainfall could be on one hand due to the fact

Table 3. Comparison of scientific and indigenous forecasts with measured and long term rainfall records.

Variables	2008/2009		2009/2010	
	OND	JFM	OND	JFM
L Gweru	Above Normal	Normal	Below Normal to Normal	Below Normal to Normal
Lupane	Normal to Below Normal	Normal to Below Norma	Below Normal to Normal	Below Normal to Normal
Farmer				
Prediction for both Lower Gweru and Lupane	Wet		Dry	
Actual rainfall	784 mm (Lower Gweru) 1105mm (Lupane)		505 mm (L Gweru) 617 mm (Lupane)	
Long term rainfall range	Lower Gweru 650 – 800 mm Lupane 450 – 650 mm			

Table 4. Treatments for the trials in the two districts during the 2008/2009 and 2009/2010 seasons.

Variables	2008/2009	2009/2010
Tillage	CP Ridge	CP Ridge
Cultivar	SC403, SC513, OPV	SC403, SC513
Fertility	0, 4.2 tons manure,31 kg/ha N, 66 kg/ha N	31 kg/ha N, 66 kg/haN
Weeding	non	1 weeding 2 weeding

CP- conventional ploughing, SC403 Very early maturing maize variety (110-120 days), SC513 early to medium maturing maize variety (120-130 days). OPV: medium to long season variety (125- 140 days).

that the scientific forecasts could not be downscaled enough to capture variation over a small area which could be too coarse to address local farmers' needs (Mahoo and Mpeta, 2010).

Scientific seasonal forecasts generally have greater accuracy for drier seasons that are associated with El Nino events in Southern Africa (van Heerden et al., 2002; Nicholson and Selato, 2000; Lindesay et al., 1986). The 2009/2010 season was El Nino and it was better predicted than the 2008/2009 season by the scientific climate forecast and therefore influenced the prediction of normal to below normal rainfall over Zimbabwe. However, the 2009/2010 season was predicted dry by the indigenous knowledge forecast and the observed rains were below the normal range which is consistent with the scientific forecast's normal to below normal rains.

Response to seasonal climate forecasts

Table 4 shows the management options that farmers in the two districts settled in order to respond to the 2008/2009 and 2009/2010 seasonal climate forecasts. Some of the treatments are different in the two years since the forecasts were different hence different management practices were proposed by the farmers in response to the forecasts therefore inter-seasons results cannot be compared.

The 2008/2009 season was predicted to be above normal in the first half and normal to below normal in the second half of the season. Farmers decided to have fertility treatments so as to try different levels of nitrogen fertilizers and manure. The reasons for the inclusion of the manure treatment was twofold; 1) to demonstrate the usefulness of the material as a fertilizer for crop production, and 2) to demonstrate that it can be a cheaper alternative source of plant nutrients that can cut down the fertilizer cost. Farmers recognized that soil water management to retain most of the rainfall was very important so as to maximize water use efficiency they therefore decided to have tied ridges (Table 4). Since the season was predicted to be normal to above normal in

Table 5. OND and JFM rainfall for the 2008/209, 2009/2010 and historical records (1950-2005) for Lupane and Lower Gweru respectively.

Variables	2008/2009	2009/2010	Long term	2008/2009	2009/2010	Long term	Long term totals
	OND	OND	OND	JFM	JFM	JFM	
Lupane	331	231	208-258	453	351	333-385	450-650
Lower Gweru	445	222	201-300	403	280	301-401	650-800

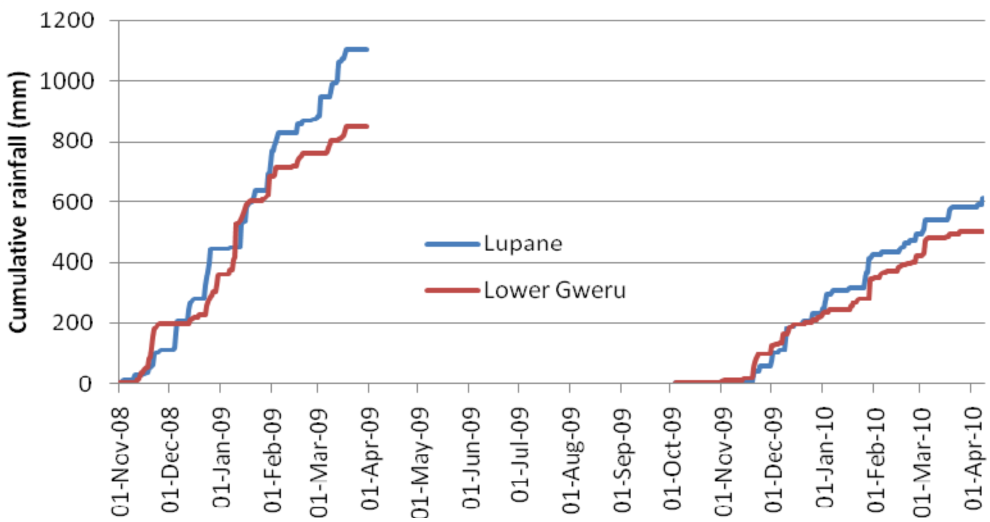

Figure 2. Cumulative rainfall in Lupane and Lower Gweru District.

the first half and normal to below normal in the second half of the season, a short season variety was expected to do well hence "SC403" was chosen and compared with a long to medium season variety. An open pollinated variety was chosen because farmers had poor access to hybrid seed, and because they wanted to compare its performance with the hybrids in a season that was not that good.

The 2009/2010 season was predicted to be below normal to normal in both OND and JFM. Farmers came up with varying strategies that ranges from growing of short season cultivars, small grains, water harvesting techniques, planting with the first rains, deep ploughing, stagger planting, application of lower than recommended fertilizers, thorough weed management among others. Low fertilizer levels were chosen since low rains were expected while weeding was very important to reduce moisture competition between crops and weeds. They maintained short season varieties (SC403) that mature early and compared it with a medium season variety (SC513). Tied ridging to capture *in-situ* rainfall was also recommended during this season.

Farmers came up with different management practices for the two years that were contrasting in climate. For instance the use of a short season variety irregardless of forecast outcome, would ensure that they at least are assured of some harvest. This shows that they are risk averse and would want to minimize losses. Sivakumar (2006) observed that farmers have to take a number of crucial crop management decisions and land and water management decisions before and during the growing season, based on climate information. Hansen (2005) and Huda et al. (1991) demonstrate that the ability to understand, monitor and predict weather provides an opportunity to evaluate alternate management strategies for decision-making that takes advantage of good years whilst minimizing losses during unfavorable years.

Field experimentation

Recorded rainfall

Figure 2 shows the cumulative rainfall for the two study sites. The rainfall totals for 2008/2009 were 1105 and 784 mm for Lupane and Lower Gweru respectively. The OND and JFM rainfall totals were above the long term range for both Lupane and Lower Gweru during the 2008/2009 season while they were within the long term range during the 2009/2010 season in Lower Gweru only (Table 5). In 2009/2010 total rainfall was 617 and 503 mm respectively for Lupane and Lower Gweru Districts.

Table 6. Effect of fertiliser levels on maize yields during the 2008/9 and 2009/10 seasons in Zimbabwe.

Treatment	2008/2009			2009/2010		
	Daluka	Nyama	Mudubiwa	Daluka	Nyama	Mudubiwa
67 kg/ha N	4.06[a*]	1.60[a]	3.82[a]	1.446[a]	1.900[a]	0.331[a]
31 kg/ha N	3.34[ab]	0.873[b]	2.78[b]	0.975[b]	1.242[b]	0.164[b]
Manure	2.760[b]	0.641[bc]	1.50[c]			
Zero N	2.140[b]	0.414[c]	1.13[c]			
*LSD	0.898	0.319	0.595	0.297	0.390	0.101

*Number with the same letter are not significantly different, LSD: Least Significant Difference.

Table 7. Effect of weeding times on maize yields during the 2009/2010 season in Zimbabwe.

Treatment	Daluka	Nyama	Mudubiwa
	2009/2010	2009/2010	2009/2010
Weed 1	1.033[a]	1.567[a]	0.193[a]
Weed 2	1.388[b]	1.583[a]	0.252[b]
LSD	0.297	0.390	0.101

*Number with the same letter are not significantly different.

Table 8. Effect of varieties on maize yields during the 2008/2009 and 2009/2010 seasons in Zimbabwe.

Treatment	2008/2009			2009/2010		
	Daluka	Nyama	Mudubiwa	Daluka	Nyama	Mudubiwa
SC403	3.4[a]	0.905[a]	2.54[a]	1.23[a]	1.858[a]	0.253[a]
SC510	2.73[a]	0.880[a]	2.16[a]	1.2[a]	1.283[b]	0.242[a]
OPV	3.1[a]	0.861[a]	2.22[a]			
LSD	0.660	0.276	0.515	0.297	0.390	0.101

*Number with the same letter are not significantly different.

Experimental results

Adding recommended amounts of nitrogen (67 kgN/ha) gave significantly higher yields than adding low fertilizers levels, manure and no nitrogen at all in the sites except during the favorable 2008/2009 season when between 800 and 1100 mm of rainfall was received in Daluka ward (Table 6). No significant differences in yield were recorded between adding recommended amounts of nitrogen and adding low amounts of nitrogen (31 kgN/ha) during this season. 2008/2009 was a wetter year and we would have expected yield differences between adding 67 and 31 kgN/ha of nitrogen. Adding 67 kgN/ha of fertilizers gave significantly higher yields than adding 31 kgN/ha of nitrogen at all the three sites during the 2009/2010 season.

Weeding two times gave significantly higher yields than weeding once at Daluka and Mudubiwa while there were no significant differences at Nyama (Table 7). It has been observed that weed competition results in crop yield losses hence weed control improves maize yield grain (Abouziena et al., 2008; Dalley et al., 2006). There were no yield differences attributed to variety in both seasons and at all the three sites (Tables 7 and 8) during the 2008/2009 season and the 2009/2010 season accept at Nyama where the short season variety (SC403) outperformed the medium season variety (SC513).

The treatments that were recommended by farmers for adapting for below average season did not perform better than those that were meant for an above average season. For example, the recommended fertilizers levels resulted in better yields than low fertilizer levels that are meant for below average rainfall predicted in 2008/2009 season but ended up having higher than expected rainfall amounts. Studies elsewhere have demonstrated that there are no yield gains emanating from adding high amounts of fertilizers in drier seasons and differences are only obtained in wetter seasons (Mburu et al., 2011).

However, the short season varieties that are meant for below average season outperformed the long season varieties possibly because of the short length of the growing season. The suggested tied ridges and ripping that are meant to increase soil moisture under drier conditions did not give yield differences because the tied ridges were destroyed by heavy downpours during the early part of the seasons.

Conclusions

Farmers can only forecast a wet or dry season from their indicators while the scientific SCF indicate whether is normal, below normal or above normal for two periods of the rainy season, OND and JFM. Results from this study demonstrate that, in the absence of the scientific SCF, farmers can use ISCF which has proved to be consistent with each other in the two years. It is also important that SSCF and ISCF be integrated thereby imbedding adaptation strategies in communities' existing knowledge of climate variability and indigenous prediction systems which is being recommended by Huq and Reid (2007).

The study demonstrates that seasonal climate forecast is an ideal entry point for bringing meteorological officials, researchers and extension agents together in working with the farmers in coming up with crop management practices that respond to the seasonal climate forecast thereby increasing their crop yields. From discussions held with the farmers and the nature of experiments proposed by the farmers, in response to the 2008/2009 and 2009/2010 forecasts (both modern and indigenous knowledge), it was evident that farming decisions are influenced by the seasonal climate forecast which include decisions on the following: choice of crop and variety, tillage systems to use, planting date, fertilizer amounts to use and when and how to weed.

Conflict of Interest

The authors have not declared any conflict of interest.

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