THE ROLE OF WEATHER INFORMATION IN SMALLHOLDER AGRICULTURE: THE CASE OF SUGARCANE FARMERS IN KENYA

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ABSTRACT

Weather forecasts have shown potential for improving resilience of African agriculture to climate shocks in the recent past. This is aimed at ensuring food security, to eradicate extreme hunger and poverty. Climatic characteristics that impact this productivity should therefore be investigated to negate effects that contribute negatively to a stable socio-economic environment. However, there is limited documentation on how much farmers utilize weather information in their crop choice and crop management practices to make informed decisions. This study investigated the role of weather information (rainfall and temperature) on sugarcane productivity and choice of related crops using a 37 year weather and yield data collected for sugarcane growing Counties from data archives at Sugar Research Institute. The data was then analyzed using mean correlation and regression analysis through statistical tools to establish cause effect relationship between rainfall and temperature characteristics on sugarcane yield to inform management recommendations for the study area. These results showed that rainfall distribution was significantly correlated with sugarcane yield ($r = 0.70$; $P = 0.001$).Temperature variations was equally significantly correlated ($r = -0.36$; $P = 0.027$) with sugarcane yield and this was attributed to deficiency in soil moisture during its maximum growth season. The study concluded that rainfall distribution through the growth season of sugarcane impacted its productivity hence; adaptation strategies such as timeliness of planting season, choice of maturity period and harvesting period would enhance sugarcane productivity and choice of relevant crops for intercropping, boarder crop management and crop rotation in an intensified cropping system. This study recommended the use of supplemental irrigation, appropriate management practices that ensure soil moisture conservation, planting of early maturing varieties and timely harvesting as action practices for enhanced food security. These results validate prior evidence that climate forecasts may be able to help Sugarcane farmers in Kenya to adapt to climate variability, especially helping them capitalize on weather information to select relevant food crops for improved livelihoods. Realization of potential advantages appears associated with a context where there is greater varietal choice and options for intensive agriculture.

KEY WORDS: Rainfall, temperature, productivity, intensive agriculture

1. INTRODUCTION

In recent time climate change has become a topical issue because of its largely detrimental impacts on natural and human systems. The most frequently cited activities or operations likely to be affected by climate variability and change are agriculture, forestry, hydrology and fisheries. Agriculture forestry and hydrology usually top the agenda of the most affected areas by the issue of climate change and variability (FAO, 2010) because of its implication on livelihood.

Agriculture contributes heavily (over 50%) of the gross domestic product (GDP). Moreover, agriculture is the main source of livelihood in most developing countries yet, it is vulnerable to changes in climatic variables such as rainfall, temperature and radiation (Mendelsohn *et al.*, 2008).This is because despite technological advances made, climate and weather play a vital role in agricultural production (Villanueva and Hiraldo, 2011). Furthermore, production of agricultural product process such as food fibre, beverages energy, fishery and poultry will be greatly affected by climate change based on their response to extreme weather conditions. Suitability of land for different types of crop and pasture will also be affected by the increasing changes in weather variability.

1.1 CLIMATE OF KENYA

The climate of Kenya is highly variable due to the combined influence of altitude and the two monsoon systems. Movements of air masses between the two high pressure belts in the southern and northern hemispheres within the Inter-tropical Convergence Zone (ITCZ) produce rainy and dry seasons around the year. From December to March, Kenya is generally under the northeast monsoon, when the movement of dry air is from the north direction. From March to June, the Eastern wind dominates, bringing moist air from the Indian Ocean which results in heavy rains within the area. Between June and September the southeast monsoon is prevalent, and much of the country is influenced by air subsidence which inhibits rainfall and causes low temperatures. From September to November, the wind direction is again from the East, bringing moisture from end of October to early December, referred to as "short rains" season. Moreover, the high variation in the topography of sugarcane growing Counties (4,000m above sea level (a.s.l) in the west and to below sea level in the East and water bodies exhibits a diversified climate on all parameters that affect evapotranspiration (temperature, wind, humidity and radiation). This climate varies from mostly cool, to always warm/hot depending on the location. This variability leads to different water requirements for sugar production in different agro ecological zones.

1.2 RAINFALL AND TEMPERATURE

Increased variability in climate and weather in Kenya, contributes to increased drought, aridibility and ground water depletion during the dry months of January to February, and August. This eventually affects agricultural productivity as well as occurrence of pests and diseases (Adamgbe and Ujoh, 2013). Changes in temperature, rainfall, ultra violet (UV) radiation, and carbon dioxide (CO2) levels also have a major impact on agricultural production. Other climatic effects on agriculture are the shifts in seasonal climatic patterns and increase in frequency and intensity of weather extremes. It has also been noted that crop productivity can significantly be influenced by variability in rainfall and temperatures (Rowhani, Lobell *et al.*, 2011). Therefore, countries in sub-Saharan Africa like Kenya are at a greater risk because of predominantly being on rural economies and low levels of agricultural diversification (IFAD, 2010). Furthermore, most of them depend on rainfed agriculture and lack capacity in terms of political, social, technological and financial base to adapt to effects of climate change (Eriksen *et al.*, 2008). Current climatic trends, predictions and analysis have shown that the most vulnerable groups to increased climate risks are small scale farmers in the tropical and subtropical areas (Change, 2007). This explains the reason why there has been decrease in production of main crops such as maize, sugarcane, wheat and rice while population continues to increase. Because of these we are likely to experience the risk of hunger, food insecurity and reliance on aid from developed counties.

In order to address these challenges there is need to be able to increase agricultural productivity. Sugarcane being the 3rd leading cash crop to tea and horticulture in Kenya requires best management practices to enhance its productivity. Moreover, sugarcane cropping systems thrive in intensified agriculture through intercropping, crop rotation and boarder crop management which avails food to small holder farmers and they await maturity of sugarcane. It is this economic contribution of sugarcane to Kenya that increases its importance in Africa and in the world (Lindell and Kroon, 2011).

It is important to note that rainfall and temperature play a major role in determination of crop yields in a tropical environment because the two determine the supply of water to plants and uptake of nutrients. Furthermore growth and production of crops can be limited by rainfall, as the crop is usually sensitive to moisture deficit. Additionally, rainfall determines most growing season among the developing countries such as Kenya where agriculture is usually rainfed (Mulianga *et al.*, 2013). Usually every farmer is keen to know the amount of rainfall to expect as it determines the success and failure of their crops.

In the sugarcane growing areas of Kenya, there is a high variability in temperature and rainfall. From year to year and County to County, the rainfall in these areas has been characterized by evident variability (KESREF, 2010). In the recent years there has also been unpredictable delay of onset effective rainy season without delays in cessation. This has made it difficult for farmers who rely on the recommended planting seasons (Amolo *et al.*, 2010), usually causing them to plant with uncertainty any period they receive rainfall. Moreover this uncertain rainfall season is significantly variable in its duration, sometimes stretching to two or three months. Based on soil type, delay in planting implies that the crop will be stressed before its root network is fully developed to extract deep soil moisture. CROPMON weather service has come in handy, to bridge this gap by providing timely weather information to farmers for informed decision making on farm operations. The variability of weather patterns has got serious consequences to the ecosystem as it seriously diminishes the effort that is being put in place by individuals and the government to ensure food supply and food security in the area. An evaluation of cropping practices in the 2017 – 2018 revealed that early-season dryness affected planting and germination of 2017 "long-rains" crops (FAO, 2018). Weather information amidst such variable weather conditions is capable of helping sugarcane farmers on which short term legumes they could plant alongside their perennial crop for enhanced food security through an intensive agriculture system.

2. MATERIALS AND METHODS

2.1 Study Area

The study covers the western region of Kenya, in areas where sugarcane is grown (Figure 1) located between 34.8° E to 35.08° E and 0.02° N to 0.11° S. An altitude of 1000 m (in lowlands) to 1800 m (in the escarpment) characterizes the topography of the landscape, with rainfall of between 1400 mm and 1900 mm. The main crop in the zone is sugarcane, besides food crops. Different sugarcane varieties are planted in the months of April and September in accordance with the bimodal rainfall in February to May and September to December (Mulianga *et al.*, 2013; Shisanya *et al.*, 2012). It is the poor rainfall distribution with prolonged drought between November and March that provide an enabling environment to undertake this study.

The proximity to highlands and nearness to the lakeshore causes a considerable spatial variation in rainfall. The annual monthly maximum temperatures ranges from 25 to 31 ºC, while the annual monthly minimum temperatures range from 12 to 16 ºC (Onyango *et al.* 2005). Farming within the sugarcane landscape is dependent on rainfall and therefore all farming activities are influenced by climate hence crop production usually takes place during the rainy seasons.

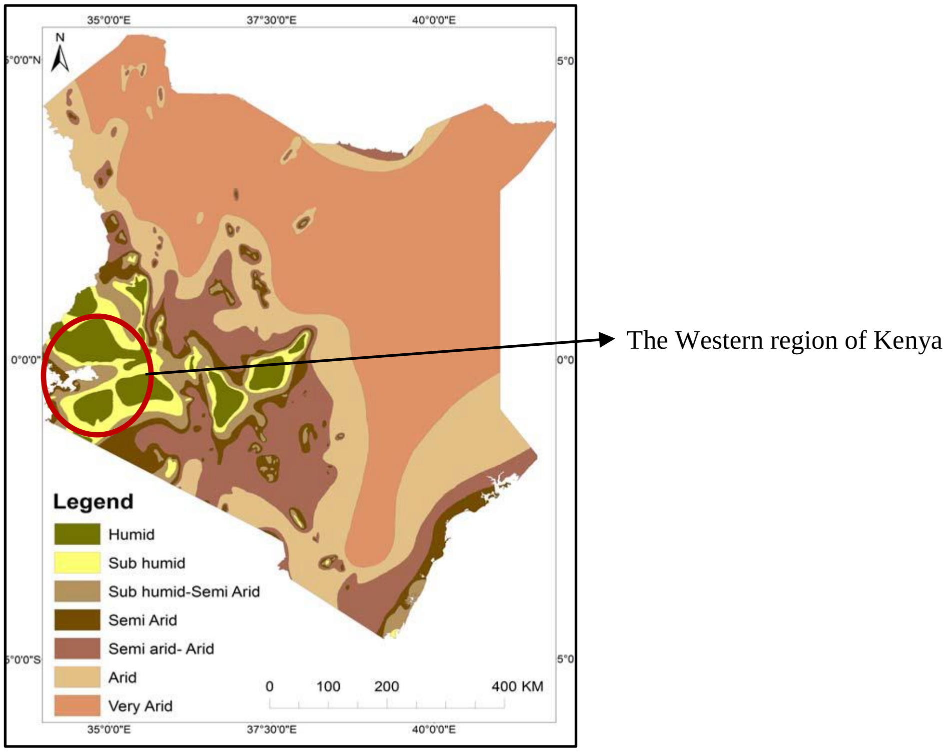

Figure 1: Location of the sugarcane land scape of Kenya (Data source: Kenya-GIS online Data, 2017).

2.2 Data and methods

2.2.1 Data

Time series rainfall, temperature and yield data were collected from the Sugar Research Institute's data archives. Average annual rainfall was obtained by summing the daily rainfall amounts and dividing by the number of days. Average annual temperature was also obtained by summing the maximum temperature and the minimum temperature and dividing by 2. Yield in tonnes of cane per hectare (tch) data was obtained from 1981–2017 which gave 37 point data points.

2.2.2 Methods

Time series plots were used to determine the trend for yield, rainfall and temperature over time. Karl Pearson's correlation analysis was then used to determine the presence and significance of relationship between yield and rainfall; and yield and temperature. Significance level was set at 95% Confidence Level (CL) and so the correlation coefficient was significant if it's associated P-value was equal or less than 0.05.

Significant correlation was further exposed to a linear regression analysis to determine the extent of the effect of rainfall and temperature on yield.

The regression model used in this study was; $Y = \beta 0 + \beta 1X1 + \beta 2X2$

Where; β0= Intercept

- β1and β2 = Regression coefficients estimates
- X1 = Average Annual Temperature
- X2 = Average Annual Rainfall
- Y = Average Annual Yield

The significance level was set at 5% and therefore the regression coefficients would be significant when the associated p-values was less than or equal to 0.05. Yield was regressed with both temperature and rainfall and also regressed with rainfall and temperature independently.

3. RESULTS AND DISCUSSION

The time series plot (Figure 2) illustrates a constant decrease in yield over time similar to the analysis undertaken on the 1976-2013 data in Mulianga et al., (2016). These findings are also similar to those of Mutonyi (2013), who attributed this decline to soil degradation and other environmental factors (Mulianga *et al.,* (2013); Shisanya *et al.,* (2010)).

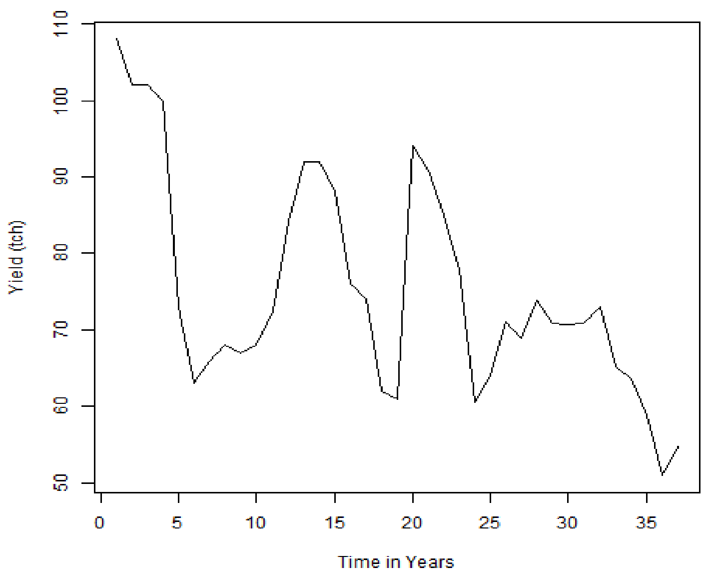

Figure 2: Yield trend from 1981 to 2017

3.1 Correlation of yield, rainfall and temperature

Results of Karl Pearson correlation test between rainfall, temperature and yield found that there was a significant negative correlation of r = - 0.36; P = 0.027 between yield and temperature at 95% confidence level. This shows that increase in temperature leads to decrease in yield due to water deficiency in the soil that limits the circulation of micro-organisms into the crop. There was also a significant correlation between yield and rainfall (r = 0.70, P=0.001) at this scale. In their study, Mulianga *et al.*, (2013) found significant correlation between rainfall and yield when yield and rainfall data were aggregated at the zonal scale (r = 0.80). Mulianga *et al.*, (2013) concluded that the significance of this correlation was due to consideration of the agro environmental conditions in the different agro ecological zones. In this study, the coefficient of determination R^2 = 0.53 in the relationship between rainfall and yield suggests that there are unexplained factors such as time lag and sunshine hours that affect yield. This argument is supported by a different study which explained that rainfall was significantly correlated with biomass over a one month time lag (Shisanya *et al.*, 2010). Moreover, FAO, (2018) realized that there was delay in planting in the 2017-2018 sowing season due to delayed rainfall. Their evaluation of NDVI (normalized difference vegetation index) during the rainy season revealed that NDVI increased with the crop area. This implied that farmers were uncertain about the expected rains hence they quickly planted their crops at the onset of rainfall. We infer that access to weather information would have prepared the farmers, to timely plan for the planting season. Moreover, different legumes thrive varied in different amounts of rainfall and different spoils (Mulianga et al., 2015). Weather information is therefore key in deciding which type of legumes to plant with expected amounts of rainfall to minimize yield losses. Table 1 shows the correlation coefficients and their associated significance on yield in this study.

Table 1: Correlation coefficients for rainfall and temperature with yield at annual scale

	Yield (tch)	*Average Temperature*	Average Rainfall
Yield (tch)	1.000		
Average Temperature Significance	-0.3562** 0.0273	1.000	
Average Rainfall Significance	0.7015 0.0011	-0.2572 0.0981	1.000

An investigation on variations of rainfall and temperature over the period, from 1981 to 2017 showed that there was slight variation between the average rainfall and temperature (the minimum average annual temperature = 21.8^0C and maximum average annual temperature = 24.9^0C). The minimum annual average rainfall in the period was 2.7mm and maximum annual average rainfall was 2.7mm and maximum annual average rainfall was 5.5mm. Figures 3 and 4 show the time series plots for the years 1981 to 2017.

A linear regression model was then fit to determine the effect of rainfall and temperature on yield over the period. It was found out that annual average temperature had a significant effect on yield at 95% CL, P= 0.04, R^2=0.54 with a regression coefficient of -7.768. The regression model is given as;

*Yield (tch) = 245.75+1.978*Rainfall – 7.768*Temperature.*

Rainfall had a significant effect on yield at 95% CL, P=0.03, R^2=0.53 and a regression coefficient of 1.978. We infer that the long dry months in the region (November to March) affect productivity of sugarcane negatively. This study recommends supplemental irrigation to meet the crop water requirement during the critical stage of its growth to enhance food security. Furthermore, results of this study present a threat to food security during the 21st century if farmers continue to over rely on rainfed agriculture without timely weather information to improve their cropping practices.

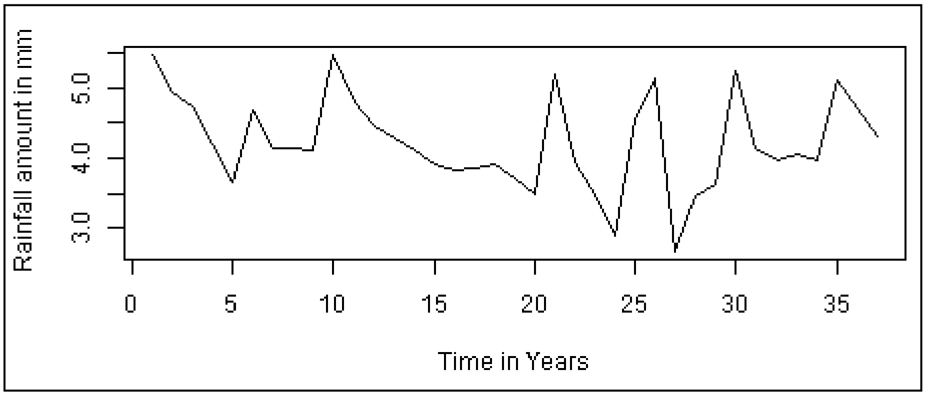

Figure 3: Plots of average annual rainfall from 1981-2017

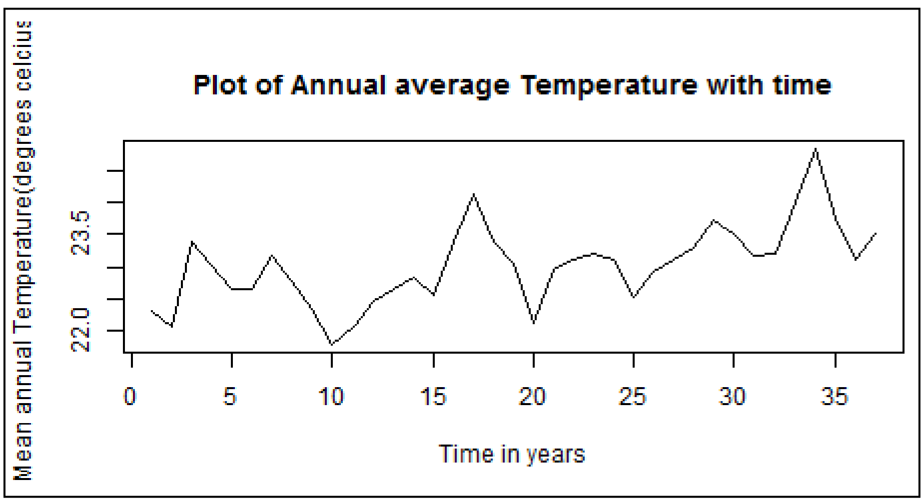

Figure 4: Time series plots of average annual temperature from 1981-2017

Results of this study show the reliance of agricultural production on rainfall and temperature. It implies farmers commence farming at onset of rains (FAO, 2018) but have little to do when the dry spell follows such a rainy season. The negative impact of temperature on the crop present the effect of lack of prior information on weather that would lead to 95% yield loss. We infer that given the erratic distribution and amounts of rainfall realized over the 37 year of study, weather information is vital in choice of the appropriate variety, appropriate legumes for either; intercrops, border management, or crop rotation within the sugarcane landscape, that would lead to an intensive agriculture system among small holder farmers in Kenya.

4. CONCLUSION AND RECCOMENDATION

The study has shown that there was a significant correlation between rainfall and yield at the seasonal scale. Moreover, there was great variability in annual average rainfall and yield. We concluded that weather information is very important for farmers to plan their cropping practices for enhanced productivity. Moreover, when rainfall is normalized at the seasonal level, the effect of time lag and its impact on biomass is minimized. This is evident in the study data and also in the findings of FAO, (2018). Further, temperature has an inverse effect on yield, thus crops in the ripening stage should not be exposed to the dry season unless with supplemental irrigation. Moreover, based on weather information, suitable legumes should be selected as intercrops, boarder management and crop rotation to support an intensive agricultural system for improved livelihoods.

This study recommends supplemental irrigation to meet the water requirement of sugarcane during its critical stage of growth. Further, improved sugarcane varieties that require less consumptive use of moisture and have shorter growing period should be made available to farmers to counter the impact of temperature for enhanced productivity. It is therefore important to avail weather information to guide farmers on timely farming operations so that the crop is planted with sufficient moisture, fertilizer is applied under sufficient moisture and that the crop is mature for harvesting during the dry season. The high significance in the yield versus rainfall at the zonal scale presents the need to explore and educate farmers on good agricultural practices that will ensure moisture availability which is crucial for sustainable sugarcane production.

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