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What should we do in the Context of Land Use Change Occurring Frequently in China?

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Abstract

China's effort to mitigate soil organic carbon (SOC) loss caused by rapid land use changes over the last two decades faces great challenges. Generally, land use change projects in China have been performed without considering the mechanisms involved in the link between land use change and SOC dynamic. Such situation will likely increase the climatic and environmental risks brought by land use changes. In this paper, we illustrate why most studies over the past several decades in China have been unable to provide significant guiding information for what kind of land use can be adopted to benefit the climate and ecological environments. In addition, we recommend the combination of soil organic matter fractionation with radiocarbon assessment, which researchers are working on to better predict the dynamic trends of SOC under land use change and present several proposals in regard to how to sequester more carbon in soils after land use change.

Keywords: Land use change; Radiocarbons; Fractionation of soil organic matter; Soil carbon sequestration

Introduction

Land use change and SOC dynamics

Globally, soils store more than twice the amounts of carbon present in atmospheric CO2 . SOC stock is determined by the balance of net carbon inputs to the soil (e.g. organic matter) and net carbon losses from the soil (e.g. CO2 , dissolved organic carbon, and the loss through erosion). Land use change is identified as the main driving for the balance between carbon inputs and losses in soil [1,2]. Therefore, changes in land use and land management are important causes of SOC store variation; such variation could lead to a marked climate change because altering in climate patterns is associated with atmospheric CO2 concentration [3]. Approximately 545 Gt of carbon have been released in the atmosphere by land use change and the use of fossil fuels, which resulted in an increase in the atmospheric CO2 concentration from the range of 275 ppm to 281 ppm in 1750 to 390 ppm in 2011 and 400 ppm in 2013 [4].

the coping strategies adopted at household level to bridge the gap on food deficit and (v) to assess the nutritional status of children and the elderly in Kisii County. The data used was mainly rainfall and temperature data from meteorological stations and sample data gathered from selected groups. The study population comprised of children between 6 months and 59 months, household heads, elderly people and agricultural officers. Purposive sampling was used to select agricultural officers while multistage sampling was used to select respondents at household level. Primary data was collected by use of a pre-tested questionnaire. The Measurement of Upper Arm Circumference (MUAC) tape was used to collect nutritional status of children while Body Mass Index (BMI) data was obtained from elderly people. Mann Kendall statistic was used to determine whether the trend of rainfall and temperature observed is significant while Chisquare test was used to determine whether the coping strategies observed varied significantly at household level. From the analysis, rainfall has not shown any significant change in Kisii County while temperature trend has been significantly increasing over the years at 95% confidence level. This could explain the observed reduction in river levels. Analysis of crop production and price trends of major food crops in Kisii County showed a decreasing trend of food production leading to increase in price over the years. This meant that farmers could not produce enough to take them to the next harvesting season, making farmers to adopt different coping strategies at household level which differed significantly according to Chi-Square test. Malnutrition status of both elderly people above 59 years and children between 6-59 months were similar with 23% of both children/elderly being severely malnourished.

This study has only looked at climatic factors such as rainfall and temperature. Other aspects such as depth of underground water, pH level of soil and the effects of land fragmentation also need to be looked at. This study is important to both farmers in choosing the right crop to plant, and policy makers and planners in formulating the best mitigation and intervention strategies for Kisii County food insecurity problem. This will further contribute to national efforts towards achievement of vision 2030.

Keywords:
Climate variability; Food security; Climate change adaptation; Malnutrition

Introduction

The Horn of Africa region has been attracting the attention of many researchers and donors as well due to the food crisis that led to famine conditions and severe food shortage in most parts of Somali, Ethiopia and eastern parts of Kenya during 2011 and 2012 boreal summer [1-6]. While many parts of the world also faced different weather challenges during 2011 and 2012; for instance, July-September Thailand floods in 2011 [7], March-August Texas USA drought [8], high temperatures over western Europe [9], February 2012 European cold spell [10] and the record winter drought of 2011–12 in the Iberian Peninsula [11] among others, the Horn of Africa situation was exacerbated mostly by non-climatic factors such as high global food prices, political instability, chronic poverty, and poor infrastructure among others. Nonetheless, climatic stresses associated with back-to-back failures in both the boreal winter and the boreal spring of 2007, 2008, 2009, 2011 and 2012 played a critical role [3].

Having recognized that climate variability and change is a major driving factor in most economic activities in the region, most governments such as the Kenyan government [12] integrates climate information in her policies. Climate change is quite noticeable, and it is intensifying at an alarming rate in terms of temperature increase and rainfall irregularity in Kenya [13]. For instance, [14]
analyzing precipitation and temperature over the Greater Horn of Africa during the 20th and 21st century based on a sample of Coupled Model Intercomparison Project version 3 (CMIP3) models output found that the equatorial eastern Africa region (including the entire Greater Horn of Africa (GHA)) have been experiencing a significant increase in temperature beginning in the early 1980s, in both A1B and A2 scenarios. They further showed that minimum temperatures were projected to increase by more than 2°C above the Long-Term Mean (LTM) by the mid of the 21st century. This was further corroborated by Otieno and Anyah [15] who showed that temperatures were projected to increase at a rate of 0.3/0.40 C/decade under RCP4.5/8.5 scenarios in both equatorial GHA region leading to an approximate temperature increase of 2/2.50 C by the middle of twenty first century.

Apart from the weather effect, food insecurity and famine can be caused by a number of factors such as low harvest, post-harvest losses, under nutrition [16,17], increase in food prices and population increase. While global population is set to grow to approximately 9 billion people by 2050 from the present 7 billion, which would require increased volume of food production, it is estimated that by 2080 the agricultural output in developing countries would decrease by 20% due
to climate change [16,18]. In Africa; for instance, about 250 million people are likely to face food insecurity due to crop failure, loss of livestock and lack of water as result of climate change by 2020. It is also estimated that by 2040 drought is likely to reduce the area under cultivation of maize, millet or sorghum by 40-80% in sub-Saharan Africa [19,20].

In Kenya more than 500,000 farmers of tea have experienced erratic rainfall, greater frost and high temperatures that have threatened their livelihood [21,22], forcing most of them to device ways of coping with the shortages. In Bungoma County; for example, residents have devised many ways of reducing the impact of food insecurity by reducing the number of meals taken per day, working for cash or food, borrowing
money to buy food, sell assets and some resorted to borrowing from sellers which makes them poorer [23].

Post-harvest food losses, the measurable quantitative and qualitative food loss in the post-harvest system [24], have also been a major factor contributing to the net harvest. Controlling post-harvest food loss is a key component in ensuring food security. Losses in post-harvest stage can occur due to various factors such as storage, handling, pests and weather conditions. In sub-Saharan Africa post-harvest losses are approximately at 40% of the total harvested cereals [24]. Once crops have been harvested, the unusual rains can dampen the crop yields and result in mould growth, a common phenomenon in developing countries due to reliance on weather (sun) for drying farm produce. If unfavorable weather conditions prevent the crops from drying, the post-harvest losses become high and at times mycotoxin producing moulds such as Aspersillus flavus may produce aflatoxin which can lead to health-related problems if consumed [25]. Nonetheless, in Kenya post-harvest loss is approximated to be at 50% mainly due to weather impact [24].

The aim of this study is to test the capacity of a novel technique for solar pasteurisation in order to assess its suitability for safely processing water for drinking purposes in developing countries. The device is to be used in environments where it is critical to pasteurise the water by reaching sufficient temperatures. Depending on what temperatures are reached and for how long, this would then provide safe drinking water [6]. In addition, conclusive results will allow for the pasteurisation device to be combined with a Passive Solar- Thermal Pumping system, currently being developed at University College London (UCL). This low-cost technology can be used for purifying drinking water, cooking or alternatively as a fuel-saving device, used to heat up water as an alternative to mainstream expensive, unreliable and unsustainable options.

the cause of food insecurity in the County. For instance, Kumba and Francis [26] analyzed the influence of agricultural land use on household food security situation in Kisii central. From their study, natural grass or napier grass had a significant influence on household food security while crops and fruits were not [27] looking at the effect
of land fragmentation index, quantity of planting fertilizer and the type of seed used found out that all these factors influence technical efficiency in food production [28]. Also, looking at the implication of land use/cover changes on food production and insecurity in Kisii County found out that the reduction of forest land due to rising demand for more agricultural land and settlement had impacted negatively on soil fertility leading to a decline in food production. While these studies have looked at the aspect of land use/cover change and type of
agricultural land use, they didn't consider the aspects of climate and its effects on food insecurity in Kisii County. Characterizing precipitation and temperature and further assessment of climate variability/change is a fundamental step in providing a baseline for understanding the effects of climate variables on food insecurity in Kenya, especially in Kisii County. This will be important for future climate change impact

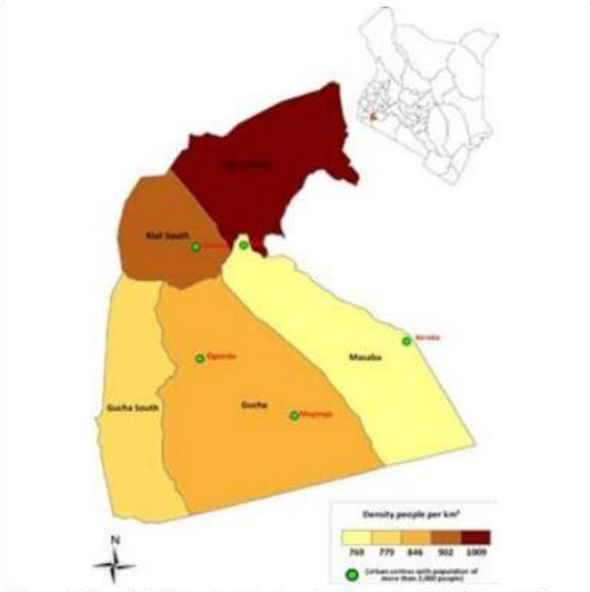

Figure 1: Map of Kisii County Showing Constituencies in Kisii County Kenya. The coloring shows the population density per constituency. (*Map adopted from softkenya.com*).

assessment and for the management of food situation in Kisii County. The County with a population density ranging from 759 -1009 per square kilometer (Figure 1) and being one of the bread basket regions in Kenya is of utmost interest. Hence in this interrogates (i) the trend of precipitation and temperature in Kisii County for the past 30 yrs, (ii) the effect of the changes in temperature and precipitation on food production in Kisii County, (iii) The perception of farmers on climate and weather information (iv) coping strategies adopted at different household level in Kisii County and (v) nutritional status of the elderly above 59 years and children between 6 to 59 months.

In the next section the different data types used and their acquisition method and a discussion of the overall methodological approach is outlined. Section 3 provides a discussion of the overall results. A summary of the overall findings and the main conclusions drawn from the study are provided in section 4.

Data and Methodology

Data

Data used in this study were categorized into two; secondary and primary data. Secondary data which consisted of rainfall and temperature data for the past 30 years (1983-2013) was obtained from Kenya meteorological stations in Kisii County and agricultural production details were obtained from sub-county agricultural offices of Marani and Bomachoge chache. Primary data consisting of Body Mass Index (BMI), nutritional status and trend in river levels were collected through pretested questionnaires. The study population consisted of household heads, children between 6-59 months, Adults over 60 years, County and sub-county agricultural officers involved in food production in Kisii County. The children below 60 months and adults over 60 years were chosen since they are more likely to suffer malnutrition [29].

Sample size and sampling technique: A Purposive sampling

	MUAC Tape in cm	MUAC Tape color	Nutritional status
Elderly People above 59 yrs	<12.5	Red	Severe/acute Malnutrition
	<12.5	Orange/yellow	Moderate Malnutrition
	>13.5	Green	Normal/well Nourished.
Children between 6-59 months	**BMI**	**MUAC Tape color**	**Nutritional status**
	<18.5	--	Malnourished
	18.5-25.5	--	Normal
	>25.5	--	Over nourished/obese

Table 1: Table showing indicator of nutritional status of the elderly and children between 6-59 months.

Variables		No. of respondents
Sex	Male	78
	Female	284
Age	18-27	22
	28-37	53
	38-47	105
	48-57	88
	Over 57	94
Education level	Primary	19
	Secondary	217
	College	41

Table 2: Table showing demographic information of respondents.

method was used to select agricultural officers at the County and sub County level. This method allows a researcher to use cases that have the required information [30,31]. At the household level, multistage cluster sampling was used [32]. This method gives a researcher room to divide the study area into various levels. In this case, the study area was divided into two sub-counties, two divisions, four locations and eight sub-locations due to the demography of the region (Figure 1) and the spatial climatic pattern. The number of household respondents was determined according to Godden [33] formula. For children between 6 months and 59 months, the MUAC tape (non-stretching measuring tape used to measure the upper arm circumference; [34]) was used to collect data on nutritional status. The arm circumference is measured in centimeters and the nutritional status classified as shown in Table 1.

Interview schedule/Questionnaire: Questionnaire was designed to gather information about peoples understanding and feeling of climate variability/change and food security. The study used structured, well-thought-out questions designed to get particular information from a respondent. The questionnaires were pre-tested for validity and reliability before the actual data collection. The questionnaire was also used to collect personal and specific information from respondents.

Methodology

Computation of Body Mass Index (BMI): BMI was computed by dividing the body weight in kilogram (kg) and height in meters squared (m^2). Height was measured using a perpendicular bar graduated in centimeters while weight was measured in kilograms by use of a weight scale. The computed BMI's were then categorized into three groups, severe malnutrition, moderate malnutrition and normal as shown in Table 1. Malnutrition in elderly people can be significant if a respondent has a BMI index of less than 18.5. The percentage of the weight of respondents was also calculated and categorized into three groups; underweight, normal and overweight was calculated and gauged against 18.5-25-30 scale. Below 18.5 indicates Underweight, 18.5-24.9 indicates Normal; 25-29.9 indicates overweight while 30.0 and above indicates obese [35,36].

Statistical test: The trend of both temperature and rainfall data from 1983 to 2015 was computed. The data was then subjected to a Mann Kendall test to test the trend since it takes into account the seasonality of the data. The Pearson product moment formula was then used to examine the relationship between climate variability and food production trend in the two sub-counties of Kisii County. Chi-square (χ^2) test was used to determine whether observed variation in coping strategies at household levels were statistically significant at 95% confidence level. Computed p-value less than 0.5% would indicate that the difference is significant.

Results

Socio–demographic information of the respondents

It was better to find out the background information of the respondents, in terms of their gender, age and education attained in order to be able to extract and analyze and judge their response objectively.

Gender distribution of the respondents:

Table 2 gives a summary of the gender of the respondents interviewed. From the table, most respondents were female at 78.5%. Traditionally men are out of the homes to go and work for the family or are employed in towns. This corroborates with Wamue and Njoroge [37] and Giuliano [38] findings that most African men are out of their homesteads either to fend for their families or in their men caucus. This means that women do much of the agricultural production and other informal activities. The computed chi square value was 117.22 at 1 degree of freedom which shows a significant difference between the number of female and male respondents. The respondents were further grouped into age sets as shown in Table 2. Most farmers were between age brackets of 38-47. This might be because at that age most of them have family responsibility and have to fend for their families either through farm activities or manual jobs. This corroborates the finding of Echebiri and Mbanasor [39] that the active members of the society who can supply labor to agricultural farms are usually in their 30 and 40 years therefore food security programmes should target this group of people.

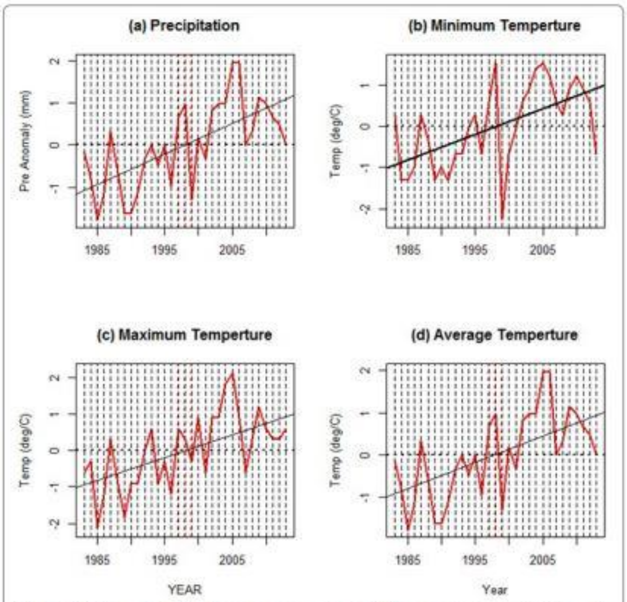

Figure 2: Figure showing temperature and rainfall anomalies over Kisii County since 1983. The standardized anomalies were calculated from the mean of the entire period.

In terms of education, majority of the farmers at 67% had secondary education level, while 22% only attained primary education level and a paltry 11% acquired college education (Table 2). Most of these farmers could not acquire white color jobs and were already having families. This explains why majority went into farming [40,41].

Precipitation and temperature trends in Kisii County

Rainfall and temperature (minimum, maximum and average) from Kisii meterological station were plotted to examine their interannual variability and subjected to Mann Kendall test for significance. Figure 2A shows rainfall variation and trend for Kisii weather station from 1983 to 2013. From the figure, the highest positive rainfall anomalies were recorded in 1987, 1997, 2005 and 2006 while the year 1985, 1989 and 2000 saw a deep in rainfall amount. The highest amount of rainfall recorded in 1987 can be attributed to the local factors such as the presence of lake Victoria around Kisii county, that enhances convectional. rainfall in the surrounding areas [42], while the lowest amount of rainfall recorded in 1984, can be attributed to drought conditions that was experienced in many parts of Africa in 1983 to 1984 [43]. Notably, the year 1997 experienced positive El Niño Southern Oscillation (ENSO – warming over Pacific Ocean) event while the year 2000 experienced negative ENSO event [44]. The computed p value of Mann Kendall test of 0.119 was greater than the critical value which showed that there has not been significant change in rainfall amount over the years. We compared our findings with the data from Kisii coffee substation which similarly showed that there has not been a significant change in rainfall amount in Kisii County according to the computed p value of 0.0522. However, the amount of rainfall recorded indicated a decreasing trend over the years, with the highest amount of 2420.1 mm recorded in 1994 and the lowest of 1710.6 mm recorded in 1984. The highest amount of rainfall that was recorded in 1994 can be associated with Indian Ocean Dipole Mode [45,46] while the lowest amount that was recorded in 1984 can be attributed to the La Niña conditions that were evolving that year [47]. On average, there has not been any significant change in rainfall amount over Kisii County for the period 1983-2013 as evinced by the p-value of 0.59 computed from Mann Kendall test, though the average trend is upward (Figure 2A). This agrees with the findings of Indeje and Semazzi [44] that some parts of Kenya have no defined patterns of rainfall indices due to rainfall variability mainly caused by local factors as opposed to large scale factors.

Consistent temperature data was only available from Kisii Karlo meteorological station. Figure 2B shows standardized anomalies of the mean annual minimum temperature from 1983 to 2013. The anomalies of minimum temperatures are on the rise over the region. From Figure 2A, the year 1998 and 2005 recorded the highest minimum temperature anomaly while the year 1999 recorded the lowest minimum temperature anomaly. Though the year 2005 experienced El Niño conditions, it later evolved into a La Niña which led to drought conditions at the end of the year. This coupled with land cover degradation might have contributed to the high minimum temperature anomaly recorded in 2005 [43].

Variables		No. of respondents
Change	Yes	305
	No	57
Direction of Change	Decrease	256
	Increase	106
Extent of decrease	Large extent	201
	Little extent	55
Rainfall reliability	Yes	69
	No	293
Quantity of food harvest	Enough	31
	Not Enough	331

Table 3: Table showing how the local community perceives change in river regime, reliability of rainfall, and satisfaction with quantity of food harvest in Kisii County.

The year 1999 was a post El Niño year that saw high amount of rainfall received in 1988 extending to January-February-March-May season [44]. This could have led to lower minimum temperature anomaly in the hottest months of January and February. In addition, the year 1999 evolved into La Niña condition which might have led to cold ocean currents blowing over land further cooling the land. Similarly, maximum temperatures are also increasing over Kisii County (Figure 2C). The highest maximum temperature anomaly was also recorded in 2005 while the lowest maximum temperature anomaly was recorded in 1985. Similar to the minimum temperature anomaly, the highest temperature recorded in 2005 can be attributed to ENSO evolution and land cover degradation. The year 1985 could not be linked to any large scale climatic forcing event. However, we suspect that the lowest average maximum temperature recorded that year could have been as a result of influx of cold Congo air mass [42] and the vegetation cover [48].

On average, temperatures have been on the rise in Kisii County (Figure 2D). The computed Mann Kendall p value of 0.001 ($p<0.05$), shows that temperatures are increasing over the region at a significant rate. This can be attributed to a range of factors which include global warming [49-51], and land use/cover change [48,52] among others..

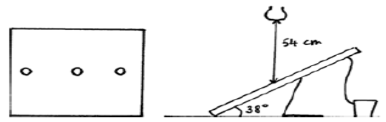

Figure 5 Schematic diagram of plan and side views of experiment 1, 2 and 4 set-up.

The device was placed between a back support and a front metal piece preventing it from sliding and providing a point of reference for the device to be placed it in the same position for each experiment.

A set of three lamps was constructed and set up at a vertical distance of 54 cm above the pasteuriser, as represented in Figures 5 and 6. These three lamps were set in line, at a distance of 20 cm from each other.

Figure 6 Pasteuriser set-up.

The central lamp was a Philips 240 Volts, 500 Watts, whereas the two lamps at each extremity of the set were Philips heat lamps of 250 Volts, 250 Watts. These lamps were installed to imitate the sun's luminosity and heat, representing outdoor conditions in which the pasteuriser would be used.

Aluminium foil paper was installed on the side facing the device, from the lamps down to the bottom of the pasteuriser in order to maximise luminosity and irradiance on the unit (Figure 7).

Figure 7 Experiment 1 set-up.

In order to understand the temperatures reached inside the pasteurising unit, a thermometer was placed inside the top of the device. In this report, the measurements for this thermometer are referred to as the temperature in the pasteuriser.

Response on hydro-meteorological questions

Changes in river regimes: We asked the respondents whether they had noticed any changes in river levels over the years and summarized their responses as shown in Table 3. 84% of the respondents agreed that river levels and wetlands have changed while 16% did not. The computed chi square value was 169.87 at 1-degree freedom ($p<0.05$), an indication of the majority of the respondent agreed that the river regimes had changed significantly. Whereas there is no discernible trend in precipitation, temperature trends are rising significantly. Therefore, changes in river volumes and wetlands can be attributed to increased evapotranspiration. Further, when asked in which direction was the river and wetlands were changing, 70.7% of the respondents indicated that the river levels and wetlands have decreased over time while 29% indicated that they have increased (Table 3). The computed chi square value was 62.2 at 1-degree freedom which indicated a significant decrease in river levels and wetlands. This observation is in line with Indeje et al. [41] who indicated that Kisii wetlands were under threat as a result of intensified agricultural activities. Further when asked to which extent were the decrease in river volumes, 78.5% of the respondents indicated that they had decreased to a large extent while 21.5% pointed that they had decreased to a small extent (Table 3). The computed chi square value was 83.3 at 1 degree of freedom ($P<0.05$) which is statistically significant. This further corroborates Mironga's [41] observation that most wetlands were seriously under threat.

Rainfall reliability: Respondents were asked to indicate whether the onset of rainfall has been reliable in Kisii County in the last three years. From Table 3, majority of the respondents at 81% indicated that rains have failed when expected while 19% indicated that it has never failed. The computed chi square value was 138.6 at 1 degree of freedom ($P<0.05$) an indication that a statistically significant majority have lost hope in planting before the onset of rains and resorted to waiting until they see the first drop to plant.

Food production trends in Kisii County

Maize and beans in Marani sub-county: Figure 3A shows maize and beans production trend from 2009 to 2015 in Marani sub-County. From the figures the lowest harvest for maize was in 2014 while the highest was in 2013. On the hand, the highest production of beans was in 2013 while the lowest was in 2012. Good harvest in 2013 for both maize and beans could be attributed to the normal conditions that occurred that year though the rainfall anomalies were on a downward trend. However, poor performance of maize in 2014 can be attributed to below normal precipitation that year (Figure 2). However, poor harvest of beans in 2012 can be attributed to climatic stresses associated with back-to-back failures in both the boreal winter and the boreal spring of 2011 and 2012 [1-3,5,53,54].

Bananas and sweet potatoes in Marani sub-county: Figure 3B shows production of bananas between 2009 and 2015. The lowest production was in 2009 while the highest was in 2011. From the annual precipitation amount received in those years, 2009 amount of rainfall was below the Long Term Mean (LTM) while 2011 annual amount of rainfall received was above the LTM. This can explain the disparity in the yields considering that bananas take about one and half year to mature. 2011 being one of the worst years in Kenya, seemingly this did not affect banana production maybe due to the previous year rainfall performance (Figure 2A). However, the lowest harvest of sweet potatoes in Marani sub county was in 2013 while the highest was in 2015 (Figure 3C). From Figure 2A, the year 2013 experienced a dropin precipitation which can be attributed to the severe drought in 2012

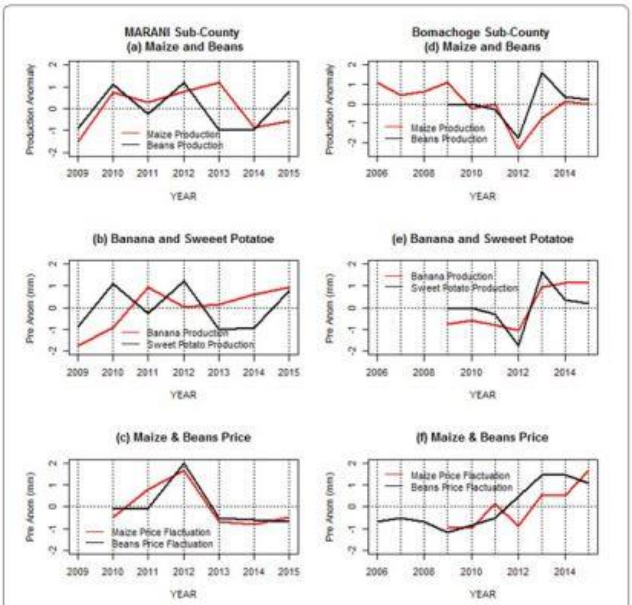

Figure 3: Figure showing variation in various crop production and price fluctuation of Maize and Beans in Marani (left panel) and Bomachoge (right panel) sub counties of Kisii County.

which extended to 2013 [1-3,53]. Despite being normal at the beginning of the year, the year 2015 evolved into an El Niño conditions at the end of the year. This can explain the performance in potato production in those years..

Experiment 2

Maize and beans price in Marani sub-county: Figure 3C shows the trend of maize and beans' prices between 2010 and 2015 in Marani Sub County. From the figure, the lowest price decrease of both maize and beans were recorded in 2015 while the highest price increase was recorded in 2012. We attributed the highest price increase for both maize and beans to back-to-back drought in 2011 and 2012 which led to low harvest. This led to high demand of the little available food stock, hence higher prices. On the other hand, the year 2015 was an El Niño years which means there was plenty of food easing pressure on the demand of maize and beans lead to reduction of prices of Maize and beans.

Maize and beans harvest in Bomachoge Chache sub-county: Figure 3D shows maize and beans harvest anomalies in Bomachoge Chache from 2006 to 2015. From the figure the highest decrease in harvest of maize and beans respectively was recorded in 2012. Similarly, this can be attributed to climatic stresses associated with back-to-back failures in both the boreal winter and the boreal spring of 2011 and 2012 [1-3,5,53,54]. The highest maize production of 103,500 bags was realized in 2006 and 2009. The highest increase in Beans harvest was recorded in 2013. The harvest in 2006 might be associated with the 2005 El Niño condition that extended to 2006, merging with the long rain season. The year 2009 was a La Niña year which can also be evinced with the decrease in annual average rainfall amount recorded in 2009. Explaining the high yield in beans in 2013 would need further investigation, though the year 2013 was normal (Figure 2A). Notably, maize yield in Bomachoge is on downward trend while Beans yield is on an upward trend. This could be due to the fact that rainfall amount in Bomachoge area is on a downward trend which affect the yield of maize while Beans take shorter duration depending on type and require less nutrients as they can fix their own.

Bananas and sweet potatoes in Bomachoge Chache sub-county: Figure 3E shows bananas production between 2009 and 2015. The highest decrease in both Bananas and sweet potatoes yield was recorded in 2012. This can similarly be attributed to back-to-back drought conditions in 2011 and 2012 [1,2,54]. High banana yield was recorded in 2014 and 2015. This can be attributed to positive rainfall anomalies that started in 2013 leading to positive ENSO event at the end of 2015. On the other hand, the highest increase in the yield of sweet potato was recorded in 2014 and 2015. The highest yield can similarly be attributed to the positive ENSO conditions that were evolving. Nonetheless, Banana yield has not been affected so much despite rise in temperature. Similar findings have been attributed to tea by Ochieng et al. [22] who found out that climate variability and change affects agricultural production, but effects differ across crops. While temperature has a negative effect on crop and maize revenues, it had a positive one on tea, while rainfall on the other hand has a negative effect on tea.

Figure 8 Experiment 2 set-up.

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Maize and beans price Trends in Bomachoge Chache: The highest increase in price of maize per 90 kg bag was recorded in 2013 and 2014 while the lowest price per 90 kg bag was recorded in 2009. However, the highest increase in beans price was in 2015 while the highest drop was recorded in 2009 and 2010. Notably, both prices of maize and beans have been rising steadily since 2009 despite the fact that beans yield have been increasing (Figure 3D). It is more understandable that the price of maize has been increasing, and this can be attributed to the decline in maize yield over the years. However, we found out that beans prices were increasing due to high demand as an alternative to maize since most people replace maize with other alternatives such as rice.

Perception of Kisii county farmers on food security and weather prediction

Quantity of food harvested in the last 12 months: The numbers of residents interviewed in Kisii County were asked whether they harvested enough food in the last 12 months of the year 2015. Table 3 shows how those interviewed responded. Only 8.6 of the respondents indicated that they harvested enough to take them to another season while a whopping 91.4% of the respondents stated that their harvest was not enough to take them through to another season. This is supported by the computed chi square value of 248.6 (P<0.05) which indicated that a significant majority of the respondents were facing food crisis in Kisii County in the year 2015. Similar findings had been indicated by the African women Studies Center [55] which stated that Kisii County is a food insecure region due to increasing urban development and high population density per square km.

Food security coping strategies: Respondents were asked on how they were bridging the gap on food deficit. From the investigation, most of the residents at 89.5% bought food from markets, which are imported from other surrounding areas and neighboring countries. 8.5% turned to their relatives for assistance while 2% depend on relief food (Table 4). Since most of the respondents said that they buy food from the nearby markets, they were asked on the source of the funds that they use to buy food items. Majority of the respondents at 24.8% sold some of their farm produce to get money for other food items while some of the respondents at 23.3% resorted to selling their properties (Table 4) which put them more in a poverty cycle. Similar findings had also been noticed in Bungoma County [23].

Planting habits: Table 5 shows the planting habits of the residents

Variables		No. of respondents
Coping strategy	Buying from nearby Markets	322
	Beg from relatives	31
	Relief food	7
Source of Funding	Selling property	75
	From employed children	53
	Cash crops	80
	Offering labor	50
	Borrow money to buy food	29
	Others	35

Table 4: Table showing how residents of Kisii County cope with food insufficiency and their source of income to bridge the gap

Variables		No. of respondents
Listen to weather forecast	Yes	59
	No	303
Heed weather forecast	Yes	9
	No	50
Planting Habit	Wait for rainfall	340
	Plant and wait for rainfall	17
	Irrigate	5
Adaptation strategies	Cultivating different Crops	140
	Soil and water conservation measures	185
	Changing planting dates according to the arrival of rainfall	40

Table 5: How residents respond to weather forecast, their perception to climate variability and their planting habit.

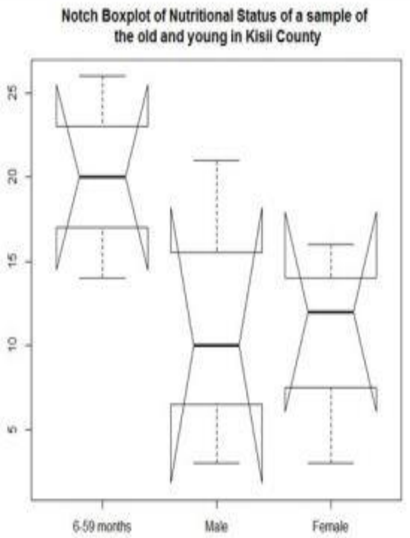

Figure 4: Distribution of the nutritional status of a sample of the residents of Kisii County.

who were interviewed. Majority of the respondents at 94% said that they wait for rainfall before planting. This probably could be due to the uncertainty in the onset of rains which corroborates the reason for the perception on rainfall reliability in Kisii County (Table 3). However, 17% of the respondents stated that they plant and wait for rainfall while 5% planted and irrigate. The computed chi square value was 45.45 at 2 degrees of freedom (p<0.05), which indicated that a significant number of Kisii residents wait for the onset of rainfall to plant.

Climate variability adaptation strategies: When asked on how they adopt to climate variability, and the majority of the residents at 51.1% preferred soil and water conservation measures followed by cultivation of different crops at 33.1% (Table 5). Those who preferred changing planting dates were at 11% while those who preferred planting different crops were at 5.5%. Similar findings have also been reported in Ethiopia where farmers in Haraghe adapted soil and water conservation measures to curb the effects of climate variability [56] and in Ghana among smallholder farmers [57]. The computed chi square value was significant at 191.38 at 3 degrees of freedom (p<0.05).

Weather forecast response: Residents were asked whether they listen to weather forecast and how they responded to the forecast. We found out that 84% of the residents never listen to weather forecasts while only 16% of the residents listened to weather forecasts (Table 5). The computed chi square value of 164.4 at 1-degree freedom (p<0.05) is an indication that majority of Kisii County residents do not care about weather forecast. On whether those who listen to weather forecast take heed of the forecast, similarly majority of the respondents at 85% never took heed of weather forecasts compared to only 15% who considered the forecast. From the computed chi square value of 28.50 at 1-degree freedom ($p < 0.05$), it is obvious that a statistically significant number of farmers in Kisii County do not listen to or if they listen to weather forecast they do not take the forecast into consideration in their agricultural activities (Table 5). This was attributed to lack of faith and understanding of weather forecast.

Nutritional status

Elderly members of the household were assessed in terms of their nutritional status using BMI as shown in Figure 4 and Table 1. Men were more nourished at 32.30% than women at 24.6%. In addition, men were more obese at 15% than women at 4.61%. This can be attributed to the fact that rural women in Africa ingest less fat due to lower household income and engage in more physical activities [58]. The nutritional status of children between 6-59 months was also assessed using MUAC tape measure as shown in Table 1. From the analysis, 23.3% of children between the ages of 6-59 months in Kisii County suffer severe malnutrition while 43.3% of the children are moderately malnourished and 33.4% are well nourished. The computed chi square value was 3.6 at 2 degrees of freedom and ($p<0.5$), an indication of significant variation in nutritional status of children less than 60 months who come from food insecure households.

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Discussion

The main objective of this study was to find out how climate variability contributes towards food insecurity/security in Kisii County. Kisii County has two sub counties; Marani and Bomachoge Chache sub counties. The study interrogated how annual precipitation and temperature (minimum and Maximum) have been changing for the past 30 years in Kisii County and how that has affected food production in the County. From the analysis, rainfall in Marani sub County has been on an upward trend over the years while rainfall in Bomachoge Chache sub County has been on a downward trend. However, Mann Kendall test do no depict any statistical significance in the trends. On the contrary, both minimum and maximum temperatures over the county are on an upward trend as well as the average annual temperature trend. The average annual temperature trend is statistically significant. This means that with increased atmospheric temperature, the water holding capacity of the atmosphere increases; hence, increased demand for more atmospheric moisture. What follows is enhanced evapotranspiration both from water bodies, wetlands and from the surface. This might explain the observed significant reduction in river regimes.

Following these climatic changes, it was noticeable that this has affected food crop production more so maize and sweet potatoes in both sub counties. For instance, the modest positive rainfall trend in Marani sub County was also reflected in the trend of Maize and Beans production where both also showed a slight positive trend, though insignificant. Similarly, a deep in rainfall in Bomachoge Chache sub County saw a decrease in maize yield over the years. However, the yield of Beans was on an upward trend in. This could be due to the fact that maize is a heavy consumer of nutrients and require more fertilize and moisture. However, Beans can thrive with little nutrients since it can fix its own and can take shorter duration to mature depending on the type. In addition, beans require less rainfall and stable temperatures.

More noticeable is the trend of sweet potatoes. Sweet potatoes trend is downward over the years in Kisii County. This is a clear pointer that sweet potatoes cannot do well in limited soil moisture conditions. Nonetheless, banana production is not affected even during drought periods. More surprisingly is that banana yield is on an upward trend over the years investigated. This could be attributed to the fact that banana takes about one and half year to mature, therefore, drought in one year can be compensated for before the plant matures. In addition, banana roots can go a little deeper into the soil therefore they can still reach water levels in the early days of drying as compared to potatoes.

The observed variability in rainfall which also affected the yields also affected the prices of the various products due to forces of demand and supply. For instance, it could be observed that both prices of maize and beans were on a downward trend in Marani sub County and on an upward trend in Bomachoge Chache sub County. The prices were more exacerbated by ENSO events especially during La Niña years. For example, the highest increase in price of maize in Marani Sub County was recorded in 2012 while the highest deep in price was recorded in 2015. Similarly, the highest increase in price of beans per 90 kg bag was also recorded in 2012 while the lowest price was similarly recorded in 2015. Noticeably, the year 2012 was one of the driest years in the recent past in Kenya and the year 2015 experienced positive ENSO events towards the end of the year.

To understand whether the residents of Kisii County were aware that most of the changes they are witnessing in agricultural production were as a result of the changing climatic conditions, a sample of the populations were interviewed to get their opinion on rainfall reliability, weather forecast and their planting habits. It was distinctively clear that a majority of the respondents at 81% had no faith in rainfall onset period and had switched to a mode of “wait and see”. This could also explain their perception on weather forecast. In fact, only a handful of the residents bothered to listen to weather forecast. Of the 16% who listen to weather forecast ~ 59 persons, only 9 persons ~ 15% considered the forecast in their agricultural activities. This is a clear indication on how farmers in Kisii County have no or little faith in weather and climate information issued to them. This tradition is replicated throughout Kenya due to the fact that majority of the population do not understand weather and climate information in a format in which it is released to the public. Most weather forecast are issued in probabilistic terms such as “chance of”, "likelihood", which is not understandable to a common man [59,60]. Nevertheless, residents of Kisii County have resorted to a number of ways of adapting to weather and climate stresses such as soil and water conservation measures, planting different variety of crops and changing planting dates according to rainfall onset dates.

From the trend of annual yield of farm produce, it is obvious that agricultural production has declined over the years. A number of residents interviewed confirmed this when they were asking whether they had harvested enough to last them to the next season in the year 2015. A paltry 8.6% of the respondents were satisfied with their harvest. This meant that a majority of the population could not have enough meals in a day leading to malnutrition, more so the elderly and children who cannot fend for themselves. For instance, from the BMI of the elderly assessed, approximately 23% were malnourished while from the MUAC tape measure, 23.3% of children between the ages of 6-59 months in Kisii County were severely malnourished. This situation has forced most of the resident of Kisii County to devise ways to bridge the gap of food deficit. While some have money to buy additional food stuff from the market, others have resorted to selling their properties which makes them poorer and dependent on their relatives and on relief food/ food aids.

In fragile food economies, like in most African countries, repetitive climatic stresses such as drought and flood events can lower resilience, disrupt development, and require large infusions of emergency assistance. This study focused on the effect of climatic factors on food security in Kisii County.

Conclusion

It is obvious that majority of the population in Kisii County do not understand what weather and climate forecasts mean in the format in which it is issued. Therefore, civic education is necessary to educate the public on weather and climate information and how to incorporate such information in their agricultural decisions. Further, it is recommended that establishment of alternative source of water such as artificial dams and boreholes are necessary to provide water during prolonged drought period. To cushion farmers against prolonged drought, deep rooted crops such as bananas should always be part of the crops in the farm. While we have only focused on rainfall and temperature, there. are other aspects that also need to be looked at such as soil moisture depth, and alternative crops that can withstand prevailing climate conditions. Better understanding and accurate prediction of rainfall totals and other factors that affect food production in the country is of importance in planning, development and management of agricultural activities in order to attain food security and move towards achieving vision 2030 in Kenya.

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