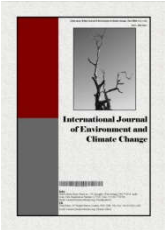

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Effect of Institutional and Farmer Based Climate Change Adaptation Measures on Crop Production in Mavuria Ward, Mbeere South Sub-county, Embu County, Kenya

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Authors' contributions

This work was carried out in collaboration among all authors. Authors SKN, GKG, JN and JRN designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Africa is under pressure from climate stresses and is highly vulnerable to the impacts of climate change. In Kenya, agriculture is the backbone of the economy making it an important contributor to food security of rural households. Currently crop productivity is being affected by continued climate variations and decline in soil fertility. Adaptation to climate change requires to be given high and urgent priority for sustainable crop production. A study was conducted in Mavuria ward, Mbeere South Sub-County, Embu County to evaluate the effects of climate change adaptation on crop production. The study used both descriptive and experimental research designs. The primary data on adaptation measures was collected from farmers and institutions using questionnaires. In the data analysis, descriptive statistics were used to organize the climate data and that of the respondents into frequencies. Further, a Pearson correlation test was done to determine the

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relationship between farmer and institutional based mechanisms on adaptation to climate change at α=0.05. The main adaptation mechanisms identified were soil fertility improvement, soil and water conservation, early planting, pest and disease control, provision of certified seeds, and awareness creation. In view of these findings, the study recommends continuous implementation of these measures that can help strengthen farmers and institutional adaptation mechanisms towards climate change for improved crop production.

Keywords: Climate change; crop production; farmers; institutions; adaptation measures.

1. INTRODUCTION

Climate change has been established as disastrous and would cause catastrophic damage to food availability in Kenya [1,2,3,4,5] by causing climate-induced changes in yields, shifts in land use patterns, and shifts in cropping patterns [6]. Agriculture is particularly important to the rural communities as they rely on animal and crop production for their livelihoods. Crop productivity is affected by continued climatic variations, hence minimizing economic benefits for many farmers. Inadequate soil nutrients greatly reduce agricultural productivity exposing farmers to food insecurity. Farmers need to employ adaptation mechanisms to counter the effects of climate change and declining soil quality. Institutions play a key role in research which goes along in educating farmers on various adaptation mechanisms towards food security. A rising rate of heating has predominantly taken residence over the last 25 years, and 11 of the 12 warmest years on best have happened in the previous 12 years [7]. Rising temperatures, rainfall variability, and new climatic regimes pose threats to biodiversity and human livelihoods alike [8]. African continent is currently undergoing pressure from climatic anxieties and is greatly susceptible to effects of climatic variation [9]. Several African regions are documented as possessing climatic conditions that are amongst the most dynamic in the world on periodic and decade time scales.

Agricultural production greatly depends on rain to satisfy the crop water requirements. Due to rainfall variations agricultural production will be harshly affected in several nations in Africa, especially for subsistence farmers in sub-Saharan Africa. Under climatic variation, much agricultural land will be rendered unproductive, with smaller crop raising periods and lesser yields. Rising temperatures has continued to cause shifts in crop growing seasons which affects food security and changes in the distribution of disease vectors [10,11]. Temperature increases will potentially increase rates of extinction for many habitats and species (up to 30 per cent with a 2°C rise in temperature). An increase in extreme occurrences will have impacts on lives and health as well as related environmental and economic effects [12]. Changes in rainfall, drought and heat waves negatively affect crop production by exerting multiple stresses on the soil, water and atmospheric environments that affects species distributions and vegetation cover. Climate change affects agriculture in a number of ways, including through changes in average temperatures, rainfall, and climate extremes (e.g. heat waves); changes in pests and diseases; changes in atmospheric carbon dioxide and ground-level ozone concentrations; changes in the nutritional quality of some foods; and changes in sea level [13].

In an effort to counter the rising food insecurity caused by climate change, Kenya together with global and regional climate change partners have ratified various climate change adaptation mechanisms [11,14,15]. Adequate adaptation options to climate change that ensure avoidance of vulnerabilities, risks, and impacts are essential for climate associated mitigation [15]. Such measures are the most feasible and indeed essential safeguard to livelihoods of the affected communities [16]. In particular, there exists the need to integrate the planned adaptation, top-down adaptation [17], autonomous (endogenous), and bottom-up adaptation approaches [18]. Although developing nations face challenges in including climate change demands into government policies there is need for farmers to adjust to climatic variation for sustainable crop production. Information is scarce about the most operative methods in which organisations can enable local adaptation to climate change. In most cases, policy formulation is done with very limited participation of relevant stakeholders making it partial and inadequate [19]. Effects of climate change vary greatly at the local level, and its impacts on different local vulnerability is also highly variable and therefore, only those policy-making

processes that facilitate and enhance endogenous adaptation practices will promote effective adaptation [20,17,21]. To aid effective and workable adjustment actions, departments and administrations, as well as organisations and NGOs, must factor in integrating climatic dynamics during budgeting and planning at all stages of choice making [22].

To date, climate change is an emerging environmental challenge and has been considered through increased variability and uncertainty of precipitation [23]. The livelihood of the farmers in Mavuria ward depends mostly on agriculture for which reason this area is identified as highly vulnerable to climate change. Adaptation planning at the local level is important to address the granularity of climate change impacts, which may vary within national boundaries, and to enable farmers and communities to be in charge of their own choices and futures under climate change. In Africa rural farmers have been practicing a range of agricultural techniques as coping strategies and tactics to enable sustainable food production and deal with extreme events. Adaptation strategies in agriculture are based on a combination of specific actions like switching from one crop variety to another or systemic changes like diversifying livelihoods against risks or an institutional reform to create incentives for a better resource management. It is necessary to understand these coping mechanisms so as to inform policy and decision makers at all levels in the exploration of ways and means of adding value on some of these coping mechanisms to transform them into adaptation [15].

Gathering and sharing of local knowledge, better understanding of climate change patterns and the adaptive capacity of local population is a necessary starting point for investigating climate change adaptation mechanisms. Although some research work has estimated the likely magnitude of climate change impacts on crop productivity, these assessments have largely been at global, regional and national levels. Climate change and soil fertility decline in Mavuria Ward has resulted to several non-governmental and community-based organizations promoting varied adaptation measures for use by farming households in agricultural production. However, it is not fully known whether the coping mechanisms utilized in Mavuria Ward are effective in addressing crop productivity. This study aimed at determining the effects of institutional and farmers based climate change adaptation measures on crop production in Mavuria Ward, Mbeere South Sub county, Embu County.

2. METHODOLOGY

2.1 Study Area

The study was carried out in Mavuria Ward, Mbeere South Sub County, Embu County, Kenya. The Ward has four locations namely Mavuria, Gichiche, Kithunthiri and Kianjiru. Embu County is located approximately between latitude 0° 8’ and 0° 50’ South and longitude 37° 3’ and 37°9’ East. It borders Kirinyaga County to the West, Kitui County to the East, Machakos County to the South, Murang’a County to the South West, Tharaka Nithi County to the North and Meru to the North West (Fig. 1). The county is divided into four constituencies, namely; Runyenjes, Manyatta, Mbeere South and Mbeere North covering a total area of 2,818 sq. km.

2.2 Research Design, Population, Sample Size and Sampling Procedure

The study adapted a case study research strategy that places more emphasis on the full analysis of a limited number of events or conditions and their interrelations. The case study deals with the processes that take place and their interrelationship. The research involved assessment of the effectiveness of institutional and farmer based adaptation measures. The population of the study area was estimated to be 7,637 households by 1999 Kenya census data. A representative sample was determined as in Krejcie [24] and from a household population of 7,637, a sample of 364 respondents was obtained. A stratified proportionate random sampling technique was used to select respondents.

The number of farmers in each location (stratum) was determined and the sample for each location proportionately obtained. In each stratum, systematic random sampling was used to get a representative sample. The respondents were guided through the questionnaire and those who did not understand English, an interpreter assisted in administering the questionnaires. A key informant from each relevant institution from Mavuria Ward was interviewed to give expert opinion on the climate change adaptation measures that they were applying. The targeted institutions were Kenya Red Cross Society, Faith based organisations, Non-Governmental

Organisations and Community Based Organisations operating within Mavuria Ward.

2.3 Data Collection and Analysis

This involved collection of primary data from the local farmers and selected institutions through questionnaire administration. A semi-structured questionnaire was administered to farmers and institutions existing in the study area to solicit information on the measures applied by institutions in adapting to climate change and their effectiveness and identify whether they were short or long term. A total of 364 respondents were interviewed using the questionnaire. The data collected was analysed using SPSS version 25 software. Pearson correlation test was done to determine the strength of the relationship between farmer and institutional based mechanisms on climate change adaptation at$\alpha \leq 0.05$. The methods were grouped in terms of similar themes and analysed using descriptive statistics in form of percentages and the results were presented in form of tables and graphs.

3. RESULTS AND DISCUSSION

3.1 Farm Size in the Study Area

Of the farmers sampled 48.9% had 0-2 acres of land, 33.0% had 3-4 acres of land, 15.6% had 5-6 acres of land, and 3.3% and 0.3% had 7-8 and 9-10 acres respectively (Fig. 2). There is a high chance of competition between crops in the smaller acreage lands making the yields to reduce due to increased demand for nutrients and space [25].

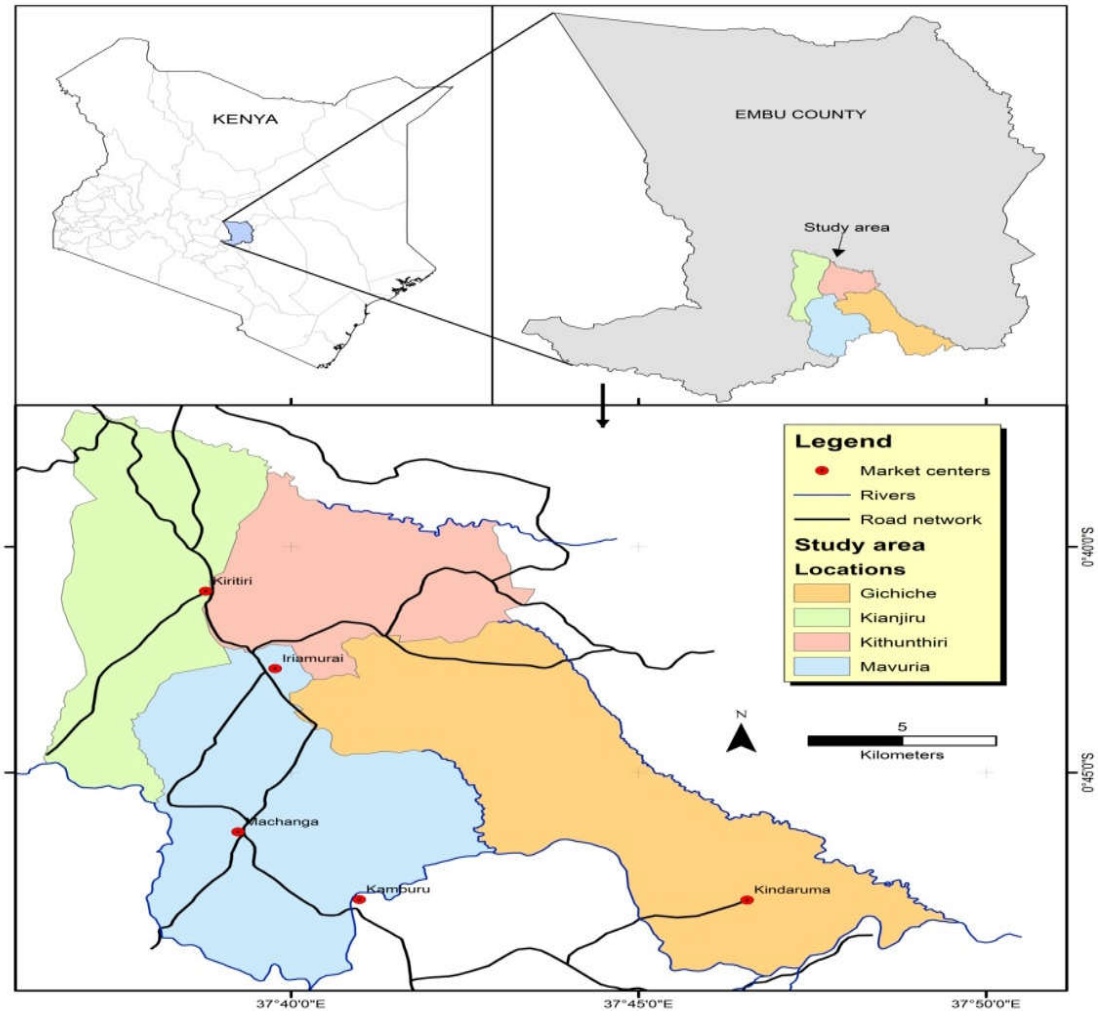

Fig. 1. Map of study area, Mavuria ward [26]

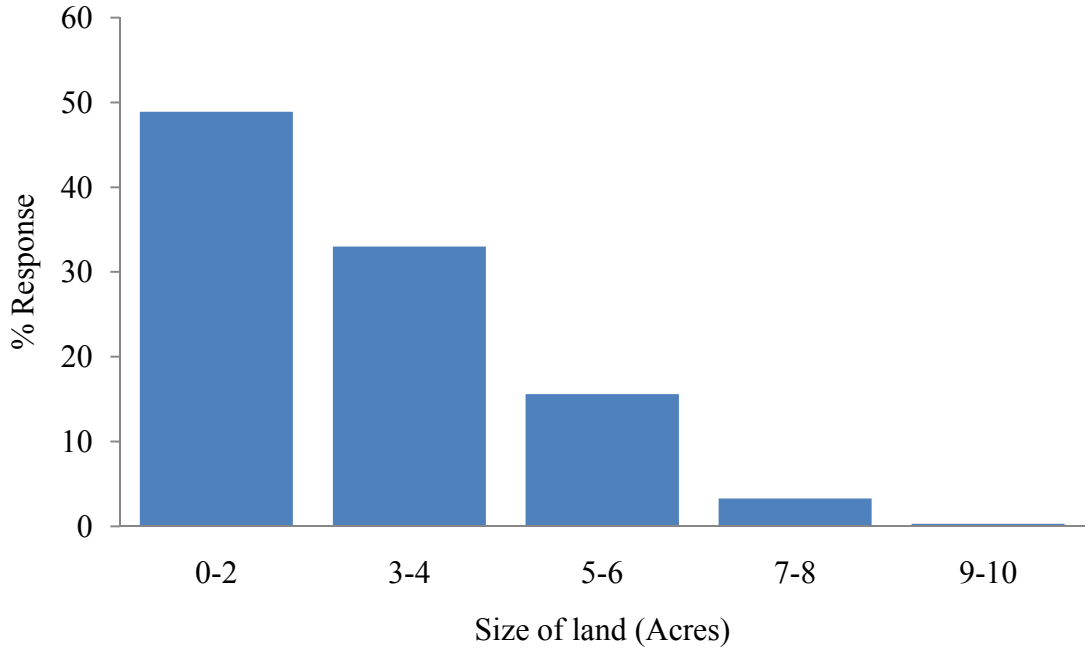

Fig. 2. Response rate on farm size per category in Mavuria ward

3.2 Major Crops Grown in the Study Area

Out of the 364 farmers' sampled, 97% farmers stated that they grow maize. Other crops grown are cowpeas, beans, green grams, sorghum, millet, pigeon peas, cassava, sweet potatoes, and ground nuts and dolicos lab lab in descending order. The four major crops grown in Mavuria Ward were maize, cowpeas, beans and green grams (Fig. 3).

Agricultural potential in the County varies by agro-ecological zone (AEZ), depending on the thermal and altitudinal conditions, from the hot and dry semi-arid lower zones in the Tana River Basin in Mbeere North and South, to the windward side of Mount Kenya that is cold and wet; Embu highlands such as Runyenjes and Manyatta. Embu County is categorized into 8 agro ecological zones (AEZs) [27]. Lower Midland 5 (LM5) is hot and dry semi-arid, including areas of Mbeere North and Mbeere South is common for drought-resistant crops such as millet, sorghum, green grams, and indigenous livestock keeping [27]. The major food crops grown are; maize, sorghum, millet, beans, cow peas and pigeon peas while cash crops include; green grams, chick peas, cotton and mangoes [27]. Crop production data over the years in terms of 90 kg bags per season was acquired from the State Department of Agriculture office Mbeere South Sub county (Tables 1-2).

3.3 Effects of Climate Variability on Crop Production

The influence of climate parameters was analyzed for the four major crop yields produced in the region. The four major crops identified by the farmers were maize, beans, cowpeas and green grams. The relationship between rainfall, temperatures, and the major crops over the study period is indicated in Table 3. The results show a continuous decline in production from 2008 to 2014. A Pearson correlation test conducted to establish how climate variables affect different crop production in Mavuria ward resulted to a correlation coefficient 'r' of rainfall with maize yield of 0.443, 0.719 with beans, 0.556 with Cowpeas and 0.394 with green grams (Table 4). Further, the relationship of rainfall with the yield of all the crops was positive but in none of the cases was the relationship significant. When the relationship of the yield of the different crops with temperature was determined with a Pearson correlation test, it was not possible to get the correlation coefficient. This is because the temperature was more or less constant (mean of 22°C for every year) and this lack of variance made it impossible to carry out the test.

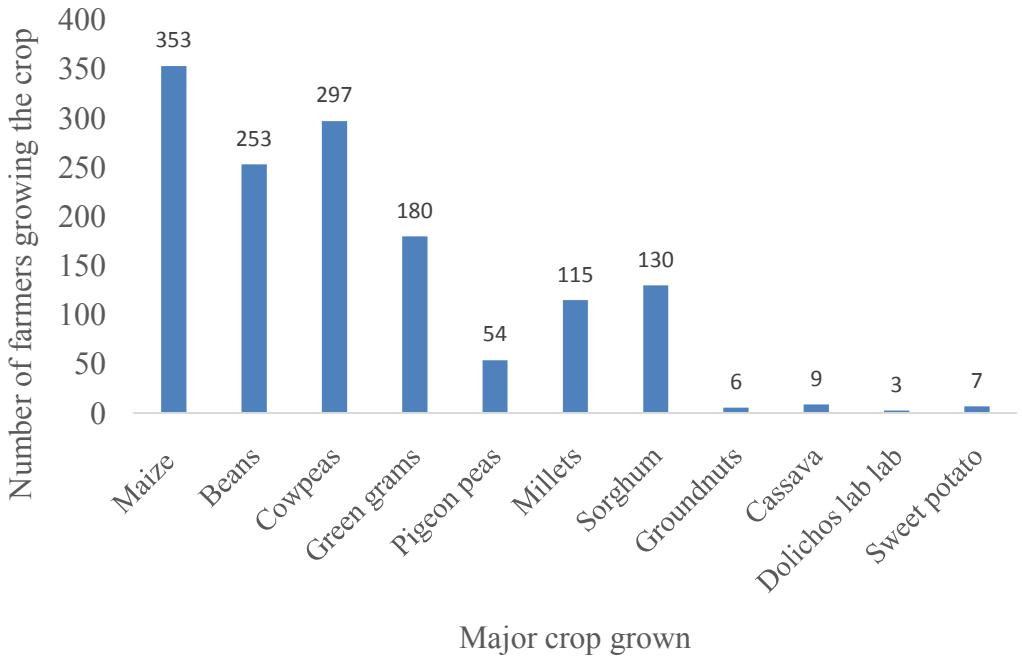

Fig. 3. Number of farmers per crop grown in Mavuria ward

Table 1. Crop yields in Mavuria ward for year 2008 to 2014

Season and crop	Year							Potential yield/Yr (90 kg bag/ ha)
	2008	2009	2010	2011	2012	2013	2014	
1st Season*								
Maize	2.5*	3	12	2	2	10	2	25
Sorghum	4	2	8	3	3	8	3	25
Millet	3	2	8	3	3	8	3	20
Beans	2	3	6	3	2	5	1	20
Cowpeas	4	2	8	3	3	8	3	22
Green grams	3	2	8	4	3	8	3	15
Pigeon peas	5	2	8	4	3	8	3	30
2nd Season*								
Maize	0.3	12	4	6	8	1	2	25
Sorghum	2	8	4	6	6	2	3	25
Millet	2	8	4	6	6	2	3	20
Beans	0.4	6	2	3	4	0.5	1	20
Cowpeas	0.7	7	3	5	6	2	2	22
Green grams	2.8	8	3	5	6	2	2	15
Pigeon peas	4	7	3	6	6	2	2	30

*Source: State Department of Agriculture Mbeere South Sub County, 2015; 1st Season-Mar –July (Long rains) 2nd Season-October-January (Short rains). *Shows yield obtained by farmers*

Table 2. Production of the major four crops per annum

Crop	2008	2009	2010	2011	2012	2013	2014	Potential Yield (90 kg bag/ha)
Maize	2.8	15	16	8	10	11	4	25
Beans	2.4	3	8	6	6	5.5	2	20
Cowpeas	4.7	9	11	8	9	10	5	22
Green Grams	5.8	10	11	9	9	10	5	15

Table 3. Comparison of effect of rainfall and temperature to production of major crops grown in Mavuria ward from 2008 to 2014

Year	Rainfall	Temperatures	Maize	Beans	Cowpeas	Green Grams
2008	51.9	21.7	2.8*	2.4	4.7	5.8
2009	54.8	22.5	15	3	9	10
2010	74.1	22	16	8	11	11
2011	58.6	21.7	8	6	8	9
2012	71.3	21.9	10	6	9	9
2013	60.6	22.1	11	5.5	10	10
2014	62.8	21.9	4	2	5	5

**Crops production is in 90 kg bags*

In comparison to studies by Downing [28], in Kenya, high temperatures would have a helpful influence in highland areas which are cooler but a negative effect in low areas of land and especially in the arid and semi-arid zones which are naturally warmer. This implies that food production would increase with rising temperature and rainfall, but in the semi-arid areas, yields would decline as a result of low rainfall. However, in their study, Fischer [29] suggested that the impact of climate change on food production in Kenya would be positive but results would vary by area. Climate change is impacting ecosystems through changes in mean conditions and in climate variability, coupled with other associated changes such as increased ocean acidification and atmospheric carbon dioxide concentrations [30]. Hence long-term effects of climate change on crop production are larger than short-term effects, therefore requiring farmers to adapt effectively and build their resilience. Poudel [31] reported that changing climate have a significant impact on crop yields.

In their studies Monteith [32] and Morison [33] indicates that water requirements for plant growth surges with temperature, suggesting a positive rather than negative interaction. On the other hand, high temperature results to drying of soils causing little water available for crop, this decreases yield and negatively impacts on quality. Dry soils are highly susceptible to erosion, causing emergence of new pests and diseases, sun scorch damage and biodiversity loss including tree loss [34]. Therefore, as temperature and rainfall rise, the heat and water stress is increased, thus decreasing crop yields over time. This calls for strong mitigation and adaptation strategies in order to deal with the threats posed by climate change.

Climate change is big challenge facing African nations, due to their geographic exposure (the geographical location of most African countries on the lower latitudes), low income, greater reliance on climate-sensitive sectors such as agriculture and weak capacity to adapt to the changing climate [35]. The effects have been experienced in all sectors such as health, agriculture, livestock, environment, hydropower generation and tourism [14]. Kenya is unfavourably affected by climatic variability and change because of her dependency on rain fed agriculture, with variability in rainfall and temperature directly affecting crop and livestock yields. Agriculture is the backbone of the Kenyan economy with an estimated GDP share of 26 percent in 2012 [36], and thus remains an important contributor to employment and food security of rural populations. Climate variability and change have adversely affected this sector. This situation is expected to worsen in the future if the latest 6th report findings of IPCC are anything to rely on [10].

3.4 Effects of Institutional Based Climate Change Adaptation Measures on Crop Production in Mavuria Ward

From the study, the respondents gave a list of adaptation measures against climate change that have been impacted to them by various institutions. These adaptation measures were tallied and presented as shown in the Table 5. Natural resource-dependent poor farmers bear an uneven burden of adverse effects of climate change. Home-grown organisations have moulded how rural farmers reacted to environmental challenges in the past. They promote mechanisms that will translate the impact of future external interventions to facilitate adaptation to climate change. Since adaptation to climate change is local, it is important to understand better the role of local institutions in shaping adaptation and improving capacities of the most susceptible social groups. This study focused on three types of local institutions relevant to influencing climate change and soil

Table 4. Correlation of yields by climate factors

Crop		Climate factor	
		Rainfall	Temperature
Maize	Pearson Correlation	0.443	-
	Sig. (2-tailed)	0.320	-
	N	7	7
Beans	Pearson Correlation	0.719	-
	Sig. (2-tailed)	0.068	-
	N	7	7
Cowpeas	Pearson Correlation	0.556	-
	Sig. (2-tailed)	0.195	-
	N	7	7
Green Grams	Pearson Correlation	0.394	-
	Sig. (2-tailed)	0.382	-
	N	7	7

Table 5. Adaptation methods by institutions

Adaptation method	Frequency	Percentage
Provision of certified seeds	78	21.4
Provision of farm inputs and implements	117	32.1
Training and awareness creation	94	25.8
Link to the markets	17	4.7
Early warning systems	27	7.4
Financial assistance	10	2.7
Others*[like provision of food aid, partial payment of school fees, employment]	21	5.8
Total	364	100.0

Table 6. Farmers Response to changes of climate parameters and crop yield

Climate Parameter	Frequency	Percentage
Change in the rainfall pattern and distribution	364	100
Temperature was also observed to have changed by	80	22.22
Climate related changes (flood occurrence and low dam water levels)	40	11.11

fertility adaptation measures on crop production in Mavuria Ward. These included; civic, public, and private in their formal and informal forms. These shape the farmer's livelihoods impact of climate hazards through a range of essential functions they perform in rural settings as established from the study.

The main interventions included; provision of certified seeds (21.4%), provision of farm inputs (32.1%), training, and awareness creation (25.8%), linking farmers to the market (4.7%), early warning systems (7.4%), financial assistance (2.7%) and others (5.8%). These measures offer an enabling environment for implementation of the practices and technologies that the farmers reported to have acquired. These adaptation measures focused on the wide range of actions that raised the adaptive capacity of agricultural systems. The study considered the set of institutional and farmers based measures that have particular potential to raise adaptive capacity among farmers in Mavuria ward.

Adaptation planning at the local level is important to address climate change impacts, which may vary within national boundaries, and to enable farmers and communities to be in charge of their own choices and futures under climate change. The outcome of the key informant questionnaire was organized as per the objectives of research study. The key informant questionnaires were administered to ten institutions in the study area which were Kenya Agricultural and Livestock Research Organization (KALRO), State department of Agriculture Mbeere South Sub County, Catholic Diocese of Embu, Climate PAL in Mbeere in Embu County, Kenya Forest

Service Embu, Meteorological Department Embu, Tana and Athi Rivers Development Authority Embu, Kamurugu Agricultural Development Initiatives Mbeere South Sub County and National Environment Management Authority Embu County. All the institutions indicated that they have noticed changes in climate.

The changes of climate parameters were notably precipitation and temperature. The changes comprised change in the rainfall pattern, distribution, temperature flood occurrence and low dam water levels (Table 6). The identified major impacts of climate change on crops were low crop yield and total crop failure at 77.78% and 22.22% respectively. All the institutions indicated that the climate change phenomena have had impacts on the farmers' livelihoods in the area of study and that all are providing assistance to the populations though in different forms.

The assistance provided to the farmers were numerous and had different levels of effectiveness. They were provision of drought tolerant crop seed, tree planting, training on water/soil conservation, climate change awareness and linking to carbon trade organizations to the farmers. Others included awareness creation of other agricultural practices e.g. irrigation, change cropping system, water harvesting and agribusiness ventures. Further, organic farming, financial assistance and weather forecast assistance were also included. The institutions additionally ranked the listed climate change adaptation measures impacts on food security in the study area. Majority of institutions (44.44%) indicated that the climate change coping mechanisms applied were effective. Also managing conditions, stress, hazard, risk or opportunity, adjusting to changing condition and adequate weather predictability were listed as effective against food insecurity. Others measures were cropping, water management and farming options for cropping.

3.5 Effects of Farmers Based Climate Change Adaptation Measures on Crop Production in Mavuria Ward

The farmers in Mavuria listed several adaptation measures for climate change and soil fertility that they use. The responses of various measures were summarized into six major types (Table 7). Land degradation is a global negative environmental process that causes the decline in the productivity of land resources' capacity to perform their functions and use of both physical and biological soil and water conservation technologies and agronomic interventions would have paramount importance in improving soil quality for better agricultural production and productivity [37]. The main adaptation strategies undertaken by farmers were categorized into six clusters which included; early planting (19.0%), use of soil and water conservation methods (22.5%), application of fertilizers and manure (16.5%), changes in crops and cropping patterns (20.3%), pests and disease control (17.0%) and others (4.7%). The results obtained in this study showed that 76.57% of sampled farmers had effectively adapted to climate change, which was a possibility of having good outcomes such as food security, poverty reduction, increase in crop yield, infrastructure development (irrigation, water harvesting) among others.

These results corroborate with the findings of Boko [38] who noted that strategies of adaptation already observed in Africa include diversification of livelihood activities, adjustments in farming operations and selling of labour. According to Benedicta [39] the main adaptation strategies of farmers includes change in crop types, planting short season varieties, changing planting dates and crop diversification. According to Sekaleli [40] some of the farmers' 'adaptation strategies includes water harvesting technologies, conservation tillage, use of keyhole and trench gardens, agro-forestry and application of traditional medicine to control pests and diseases.

Table 7. Farmers based adaptation measures

Adaptation measure	Frequency	Percentage
Early planting	69	19.0
Use of soil and water conservation methods	82	22.5
Application of fertilizers and manure	60	16.5
Changes in crops and cropping systems	74	20.3
Pest and disease control	62	17.0
Others	17	4.7
Total	364	100.0

With regard to the farm size, the findings of this study revealed that farm size positively and significantly influence the choice of adaptation measures such as increase irrigation, use of drought resistant crops and planting time (early or late). This implies that farmers with large farm size are more likely to choose irrigation, use drought resistant crop and planting time as adaptation measures to climate change than farmers with small farm size. In other words, having a large farm size increases the probability of using irrigation, use of drought resistant crops and adoption of planting time as an adaptation measure.

However, this study observed that farmers were aware of long-term climate phenomena (perceptions), but the main factors found to have positive influence of their perceptions included farming experience and access to information on climate change. Due to limited adaptive capacity to climate change majority of farmers were observed to be more vulnerable to climate change as evidenced by the production loss due to extreme weather events in the study area.

4. CONCLUSION

The study established that the available institutional based climate change and soil fertility adaptation measures on crop production in Mavuria ward that were effective included provision of certified seeds, farm inputs and implements, training and awareness, early warning systems and financial assistance to farmers. On the other hand, effective farmers based climate change and soil fertility adaptation measures on crop production that were identified included early planting, use of soil and water conservation measures, application of manure and fertilizers and pest and disease control. Various institutions were found to play a key role in the study area. These institutions included Government departments, Parastatal, non-Governmental organizations and community-based organizations which are important in giving the farmers tools and incentives and knowledge/skills. They indicated that they had noticed changes in climate. The prominent changes of climate parameters were notably precipitation and temperature. They identified major impacts of climate change on crops as low crop yield and total crop failure at 77.78% and 22.22% respectively.

The institutions alluded that the climate change phenomena have had impacts on the people livelihoods in the area of study and were providing assistance to the populations in different forms. The assistance provided to the farmers were numerous and had different levels of effectiveness. They were provision of drought tolerant crop seed, tree planting, training on water/soil conservation, climate change awareness and linking to carbon trade organizations to the farmers. Farmers' response showed that they received great support from the institutions in terms of adaptations. They ranked these adaptation practices in order of significance and most of them revolved around fertility improvement, soil and water conservation, good crop husbandry and improved agro-inputs. Others included access to credit, marketing and farm diversification.

5. RECOMMENDATION

Local institutions need to be strengthened at the grass root to enable farmers to effectively adapt to climate change variability. This is because they are key to knowledge and experience sharing through coordinated exchange programs, as they continuously support farmers at early stages of technology, assist in marketing and offer credit. Government need to come up with policies which should cushion the farmers from the negative impacts of climate change. They should give incentives to farmers to effectively adapt to climate and promote the best practices.

CONSENT

As per international standard or university standard, respondents' written consent has been collected and preserved by the author(s).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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