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Full Length Research Paper

Climate change; Farm level definition, causes, perceived impacts and coping mechanisms in three farming systems of Tanzania

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Despite the numerous general codes of practices to adapt to climate change, many farming communities are still vulnerable partly due to lack of locally adapted measures. This research was conducted to establish socioeconomic factors influencing vulnerability and adaption to climate change in three farming systems of Tanzania. Participatory techniques were used to investigate how farmers defined climate change, perceived its impacts to agriculture and their coping mechanisms. All had knowledge that climate change is happening but the differed in the way they defined the phenomenon, perceived its impacts and the adaptation strategies they took. More than 80% of the farmers had no correct definition of climate change. 5% to 20% defined climate change in the context of rainfall variability and warming up of the earth. Less than 5% had knowledge that climate change is associated with emission of green house gases, deforestation, environmental degradation, and poor production practices. Positive and negative impacts of climate change were reported in all the farming systems. Between the farming systems, differences in coping mechanisms were noted. Coping strategies and socioeconomic characteristics were correlated. Indigenous coping strategies and the socioeconomic status should be considered when planning for climate sensitive agriculture.

Key words; Maize, cassava, sorghum, farming system, climate change, adaptation

INTRODUCTION

Although it has been a continuous process, currently climate change is more pronounced and is a concern worldwide. According to IPCC 5th Assessment Report (AR5), climate change is an irrevocable fact; it is happening and will continue over decades and centuries to come. The report confirms with at least 95% certainty that anthropogenic factors are the dominant cause for current climate change through emissions of greenhouse gases. Without mitigation action, global mean temperature would likely pass the internationally agreed limit of 2^{o} C above pre-industrial levels at some point this century may be even before 2050(Halford and Foyer, 2015a; Halford and Foyer, 2015b). Climate change is already affecting the Earth's temperature, precipitation, and hydrological cycles.

Impacts of Climate Change are now being felt in many ways(Halford and Foyer, 2015a). The first impact is on the changing hydrologic cycle, leading to more frequent and intense droughts and floods with severe effects on agricultural systems and production. The second impact is the warming up of the globe. The third impact is the increasing atmospheric CO_2. Over the next 30-50 years, CO_2 concentrations will increase to about 450 parts per million by volume (ppmv) (Halford and Foyer, 2015a; Halford and Foyer, 2015b). Africa including Tanzania will be more vulnerable to climate change due to multiple stresses (Musvoto et al., 2015).

The IPCC 2007 report provides an extensive assessment on the expected effects of climate change on agriculture in the Africa region. Due to the multiple stresses of poor infrastructure, poverty and governance It estimates that Africa will be the most vulnerable. Temperatures are likely to increase by between 1.5 - 4ºc in this century. These changes will have far-reaching consequences for the poor and marginalized groups, among which the majority depend on agriculture for their livelihood(Nicholson, 2015). Agriculture accounts for more than 40 percent of gross domestic product across the East African region. However this is being compromised by challenges related to ecosystems degradation, poor infrastructure, lack of reliable information and policy coordination (Nicholson, 2015). The weather systems are becoming more erratic and violent. Given their low capacity to adapt, poor and marginalized groups are likely to become more desperate, threatening their very survival under the changing scenarios of climate change. Under business as usual, east African Agriculture will have a bleak prospect given that crop production across the region depends overwhelmingly on rainfall(Thorn et al., 2015). 2015).

The poor countries whose economy is governed by rain fed agriculture operated by smallholder farmers in the rural areas are particularly vulnerable(Nyanga et al., 2011). The reports point out that smallholder farmer in different rural settings and farming systems perceive and define climate change differently hence take different coping strategies(Okonya et al., 2013). The perception and definition attached to climate change depend on frequency and severity of climate related natural calamities such as drought and floods (Nyanga et al., 2011; Tambo and Abdoulaye, 2013). In addition, socio economic factors like education, household size, livestock ownership, agro-ecological zone, farm size and access to credit are known to drive the perception and abilities to cope with adverse impacts of climate change (Gebrehiwot and van der Veen, 2013; Nori et al., 2008; Okonya et al., 2013). For instance reports in African countries like Ethiopia(Belachew and Zuberi, 2015; Debela et al., 2015; Skambraks, 2014), Kenya(Kalungu et al., 2013), Senegal (Dieye and Roy, 2012), Ghana(Yaro, 2013), Zambia (Nyanga et al., 2011), and Nigeria(Tambo and Abdoulaye, 2013) show different farm level perceptions to climate change and adaptation strategies.

In Tanzania climate change is linked with changes in community structure, geographical distribution and therefore livelihood of farmers (Crandall et al., 2000). The farmers are constrained by uncontrolled climatic factors like moisture, temperature, flood, drought and rainfall(Weber, 2006). The uncontrolled changes dictate the socioeconomic activities of farmers. It is from these natural controls, different farmers have one or more dominant crops which have adapted well to the existing climatic situation(Nyong et al., 2007; Weber, 2006). The dominant crop makes up the farming and livelihood system of the particular area. As a result of the uncontrolled check of climate change the farmers in different farming systems have always been developing coping mechanisms in response to the type change they experience at a particular time(Roma, 2008).

Maize, Cassava and Sorghum are food security crops in different rural settings of Tanzania. When there is surplus production, these crops are also used as cash crops by selling to urban centers and neighboring countries. Maize is mainly grown in highland agro ecosystems where it constitutes the maize based farming system. The cassava is a crop common in low land agro ecosystems along the coast of Indian Ocean and Lake Victoria where it constitutes the cassava based farming system. Sorghum is grown in the central semi arid ecosystems where the farmers are mainly semi pastoralists and sorghum is their main staple food. These differences in livelihood options make farmers view climate change differently and may be impacted differently as well.

Despite the diversity in perception(Dhanya and Ramachandran, 2015) and farm level adaptation options in different rural settings, many actors in climates resilient agriculture proposed general codes of practice to adapt to climate change. The recommended practices have often times lacked adaptability to the local physical and socioeconomic conditions. Lack of adaptability could partly be due to the climate experts who could not take into account the farmer’s local knowledge on climate change. Limited documentation of the indigenous knowledge regarding the definition and perceived impacts of climate change in relation to the specific social settings(Hou et al., 2015) can be explaining this drawback. This research therefore was conducted to establish socioeconomic factors influencing vulnerability and adaption to climate change in three farming systems of Tanzania. Specifically in the three farming systems, the study sought to understand the socio economic differences between them, how farmers defined climate change and its impacts. Also the research aimed to investigate the adapted adaptation measures and link them with the socio economic characteristics of the people. The findings are useful in planning for a locally adapted climate sensitive agriculture.

METHODOLOGY

Description of the study area

The study was carried out in selected sorghum, maize and cassava based farming systems of Bahi district of Dodoma region in Tanzania. The sorghum based farming system is characterized of semi-arid climate with erratic unimodal rainfall that ranges from 450-650 mm which begins from around December to June. Although livestock production and cultivation of drought-resistant grain and fodder crops are emphasized, less-tolerant crops like maize are also dominant. The soils in the study areas can broadly be categorized into two clusters consisting low infiltration rate, relatively high fertility clays and high infiltration rate, relatively low fertility sandy loams. The clays are either alluvial or derived from dolerite outcrops, while the sandy loams are derived primarily from granite. Furthermore the study was conducted in the maize based farming system of the Southern Highland of Tanzania in Songea rural district of Ruvuma region. The area is characterized by prolonged unimodal rainfall regime starting from November continuing to the end of April. Annual rainfall in these regions ranges from 550 mm to 3690 mm. Food crops produced in these areas include maize, beans, sunflower, potatoes, finger millet, rice and various vegetables. Moreover the study was conducted in the cassava based farming system was conducted four villages of Mkuranga District of Coast region in Tanzania. The district is topographically divided into coastal belt and the upland area. The coastal belt is characterized with sand soil with low water holding capacity, high water table and poor soil fertility. Upland area covers the whole has its greater characterized of loam sand soil suitable for cultivation. The study area obtains shorter rains (*vuli*) usually from October to December and long rains *(Masika*) from March to June. Annual precipitation varies from 800mm to 1000mm with irregular spatial and temporal distribution. The area is usually warm throughout the year, with an average temperature of 28^{o}C. Crop cultivation is the major economic activity producing cereals (maize, paddy) root crops cassava ,sweet potatoes) and leguminous while cash crops cultivated include cashew nuts, coconuts and tropical fruits like oranges, pineapples, mangoes and passions.

Sampling Design

In each farming system, four villages were randomly selected. In each village proportional random sampling was employed where by a minimum of 25 interviewees were chosen depending on village population size and level of heterogeneity. Sufficient consideration of gender groups was taken care. A total of 320 questionnaires were administered in the shown denominations (Table 1).

Table 1: Sample size in villages of the different farming systems

Farming system (FS)	Village name	Number of households	Percent
Maize based FS	Magingo	26	8.13
	Mpitimbi	25	7.81
	Mshangano	25	7.81
	Nakahuga	25	7.81
	Subtotal	**101**	**31.56**
Cassava based FS	Lukanga	37	11.56
	Kizapara	29	9.06
	Vikindu	11	3.44
	Kitomondo	32	10.00
	Subtotal	**109**	**34.06**
Sorghum based FS	Chibelela	23	7.19
	Ilindi	34	10.63
	Mkakatika	28	8.75
	Mundemu	25	7.81
	Subtotal	**110**	**34.38**
TOTAL		**320**	**100**

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Research Tools

Rapid Participatory Assessments was the first tool to be applied to get information about general Community knowledge and farm level indicators of climate change. Based on the identified indicators semi-structured and open interview were administered to a gender balanced set of respondents selected randomly although only those who had an age of above 35 years were eligible. The age criteria was meant to solicit correct comparisons of current climatic conditions with those in at least past 20 years to 2010 based on memory. The respondents included pastoralists, crop producers and agro pastoralists. Identification, analysis and documentation of the traditional indicators used for seasonal rainfall forecast in Southwestern highland were conducted, adopting similar approach to that by Kihupi et al. (2002). Focus group discussions were used in weighing and balancing the information collected through interviews with a view to produce generalizations that represent the traditional knowledge existing in the community.

Data Collection

Both secondary and primary data on temperature, rainfall, and dry spells were collected using different approaches including structured interviews, focus group discussion, documentary review and field observations. Explanatory variables collected were demographic characteristics; age, sex, marital status, education and household size of the study population. Socioeconomic characteristics such as farm size, means of communication, type of housed, farm incomes, off farm income, livestock incomes and household annual income. Farmers' perceptions to climate change, impacts and the adaptation measures adopted in each farming system were investigated. Four point scale was used to determine the perceived change in temperature and rainfall patterns. Two point scales was used to determine perceptions and both indigenous and science based adaptation measures applied and the farm level. Focused group discussion was used to investigate different indigenous methods used in weather forecasting and whether they are still applied and how do they match with scientific forecasts. Focus group discussion of up to eight people was organized and the various techniques used within the community in weather forecasting were explored and ranked in the order of reliability and the data were analyzed qualitatively.

Data Analysis

Descriptive statistics (frequencies, means) were calculated using Statistical Analysis for social sciences (SPSS) software. Analysis of variance to detect differences between farming systems were calculated. Where differences were noted, post hocs were used to separate the means causing the differences. Correlation coefficients were calculated to establish existing relations between response and explanatory variables.

RESULTS AND DISCUSSION

Demographic Characteristics and Perception on Climate Change

More than half of the respondents were males and 79% were in the working age of 20-60 years (Table 2). Majority (82%) was married. The result in Table 2 shows that majority (70%) of the respondents had completed primary education.

Table 2: Demographic characteristics of the study population

Characteristic	Group category	Frequency % (N = 320)
Sex	Male	70
	Female	30
Marital Status	Married	82.81
	Single	6.56
	Widow	6.56
	Divorced	4.06
Age	15-20 years	1.25
	21-40 years	44.06
	41-60 years	35.00
	Above 60 years	19.38
Education	No formal education	21.88
	Primary	69.69
	Secondary education	5.00
	Above secondary education	3.15

House hold dependence ratio

Over 45% of the respondents had an average household size of 5 to 6 members and half of them were dependant school age and under five children (Figure 1). Only minority (<10%) had family size less than two and greater than 13 without dependants. Composition of the household has special importance to the household's farm size and the type of technology the household can afford. Not only that but also house hold size with large number of dependants is greatly associated with poverty and environment destruction accelerating climate change. The results in Figure 4 showed that more than half of the respondents had an average household size of 4 to 7 members and between 2-4 dependants. The influence of household size on use of adaptation methods can be seen from two angles. The first assumption is that households with large family members may be forced to divert part of the labour force to off-farm activities in an attempt to earn income in order to ease the consumption pressure imposed by a large family size (Yirga and Bejitual, 2007). The other assumption is that large family size is normally associated with a higher labour endowment, which would enable a household to accomplish various agricultural tasks. For instance Croppenstedt *et al*. (2003) argue that households with a larger pool of labour should be more likely to adopt agricultural technology and use it more intensively because they have fewer labour shortages at peak times. Here it is expected that households with large family size to be more likely to adapt to climate change.

Farm size

The results in Figure 2 show that the households in the three farming systems had an average farm size of 7 acres. Analysis of variance revealed significant differences ($P \leq 0.05$) in farm sizes between farming systems (Figure 2). Of the three farming systems, sorghum based farming system had the average household farm size of close to 10 acres. The smallest average farm size (5 acres) was noted to be common among the maize based farming systems. This difference can be attributed to the pastoral land size being combined with crop land. Farm size represents wealth which can be transformed into credits or cash. Since it is regularly hypothesized that the adoption of agricultural technologies requires sufficient financial well being (Knowler and Bradshaw, 2007) then those with large farm size are expected to be early adopters of new agricultural technologies. Farm size is associated with grater wealth and it is hypothesized to increase adaptation to climate change. Studies on adoption of agricultural technologies indicate that farm size has both negative and positive effect on the adoption showing that the effect of farm size on technology adoption is inconclusive (Bradshaw et al., 2004)

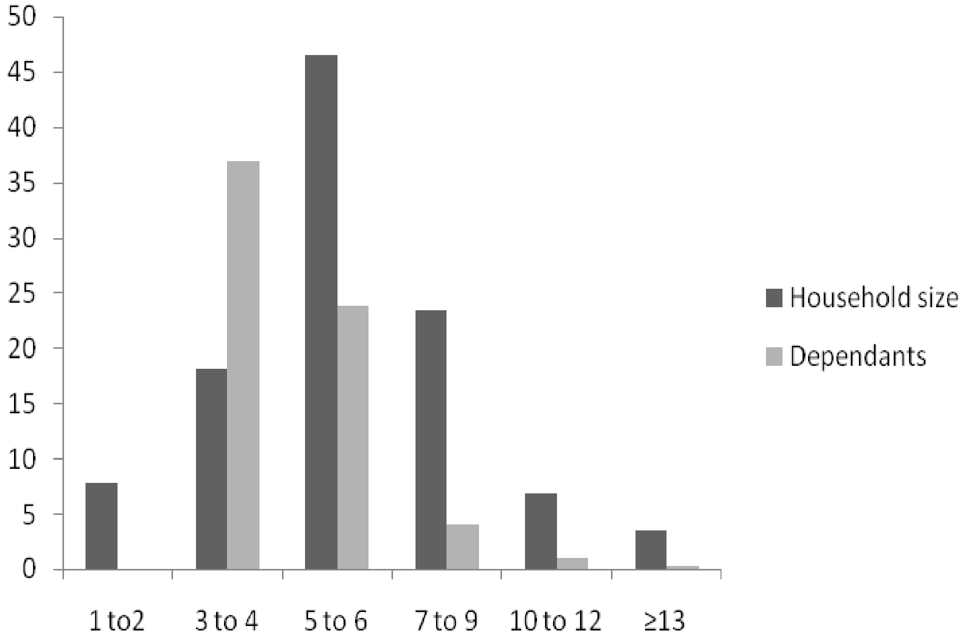

Figure 1: Household size and number of dependants

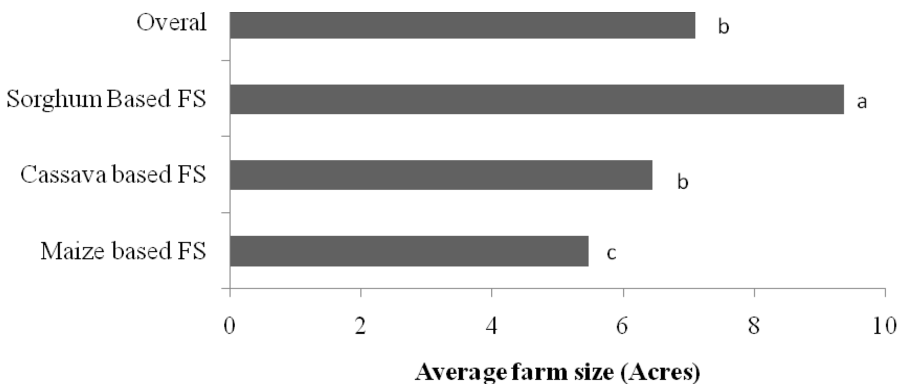

Figure 2: Household Farm size (Acres)

Bars headed by the same letters are not significantly different at 5%

Household income characteristics

Annual household income, farm (crop) income, and non farm incomes of different farming systems were significantly different (P ≤ 0.05) (Figure 3). The respondents in the maize based farming have highest (TZS 2500000) annual income exceeding the average income by 26%. It was followed by the sorghum based farming system which was lower than the former by 20%. The cassava farmers were wealthier in terms of their assents particularly uncultivated land.

The difference can be attributed to production of maize which is used as major staple food for the household as well as the whole nation and beyond. This makes maize both a food and cash crop that unlike cassava which is considered a poor man's crop and is less preferred by wider community(Fermont et al., 2010; Nassar and Ortiz, 2007). It is consumed by only few peoples along the coast of Tanzania. Household income is an important attribute in the adaptability to climate change as it shows the purchasing powers of some technologies like seeds of drought tolerant varieties. This is in line with other studies which have reported the impact of income on adoption of new technologies that there is a positive correlation (Mendola, 2007) between adoption and income levels. Other reports indicate that higher income farmers may be less risk averse, have more access to information, have a lower discount rate and longer term planning horizon(Curran and Meuter, 2005).

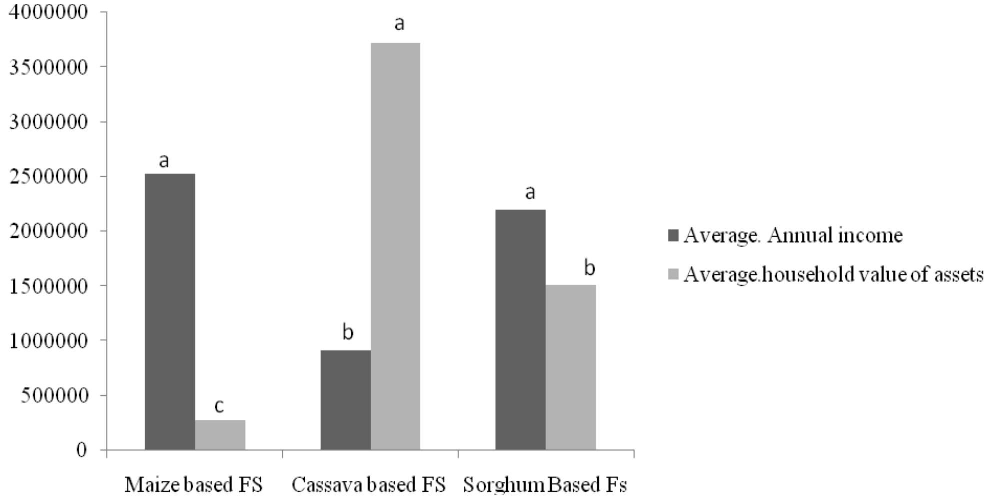

Figure 3: Household income earnings and asset value in each farming system

Bars headed by the same letters are not significantly different at 5%

Figure 4 presents significant different (P≤ 0.05) income levels from different income generating activities in the three farming communities. The results point out that crops are the most important source of income compared to livestock and off farm activities. The maize based farming community earns the highest (TZS 2,500,000/annum) followed by sorghum farmers (TZS 2000000/annum). Results in Figure 5 showed livestock has significantly the highest importance probably because apart from saving as source of income the play role as a store of value, source of traction (specially oxen) and provision of manure required for soil fertility maintenance(Moll, 2005; Mulder et al., 2010). The earnings from off farm activities in the sorghum based farming system is the highest (TZS 1500000/annum) implying they have more options to diversify source of income than the rest of the communities under this study.

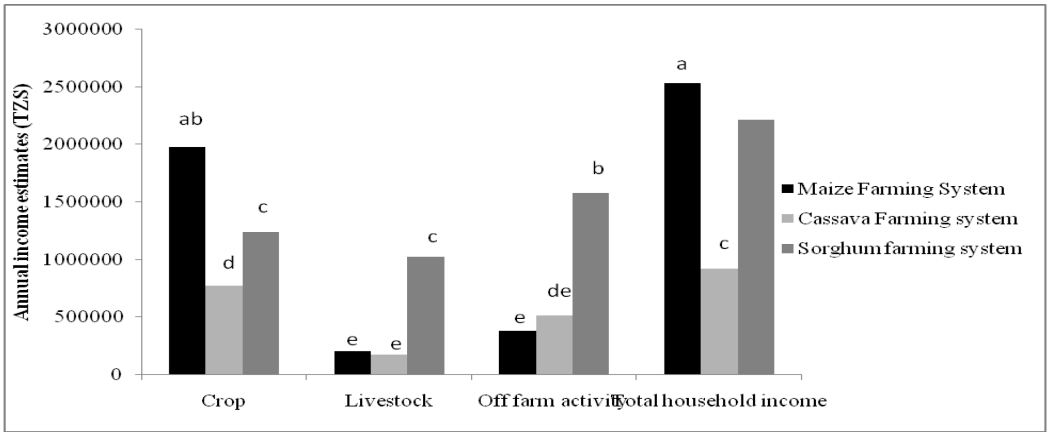

Figure 4: Income earnings from different activities in the three farming systems

Bars headed by the same letters are not significantly different at 5%

Smallholder farmer's perception on climate change

Results in Table 3 showed that climate change is defined differently (P ≤ 005) at different levels of conceptualization as also reported by West *et al*. (2007). Of the three farming systems highest (40.4%) ignorance on climate was observed among respondents in the cassava based farming systems. The overall results indicate that of those who showed understanding of climate change, majority (16.6%) perceive climate change as irregular distribution of precipitations and 15.6% perceive climate change as increase in temperature. These results are in agreement with those reported by Hassan and Nhemachena (2008) who observed that farmers perceive climate change as long-term temperatures rise, declining precipitation, pronounced changes in the timing of the rains, and frequent droughts.

Table 3: Analysis of variance for farmers' definition of Climate change and causes in three farming systems

	Farming system			
Variable	Maize (N = 101)	Cassava (N = 109)	Sorghum (N= 110)	F value
Climate variability	10.9c	9.2c	10.0c	0.06
Increasing temperature	8.9cd	16.5b	20.9b	0.02
Increasing temperature and reduced rainfall	15.8c	5.5cd	4.5d	0.01
Occurrence of new diseases	0.0f	0.9e	0.0f	0.6
Irregular rainfall distribution	20.8b	16.5b	12.7c	0.06
Frequent drought	4.0e	3.7d	5.5d	0.7
Deforestation consequence	2.0e	0.0f	0.0f	0.65
Result of industrial gas emission	1.0f	0.9e	2.7e	0.66
Result of environmental degradation	5.9e	3.7d	4.5d	0.57
Poor production practices	2.0e	2.8d	0.0f	0.58

Columns with the same letters are not significantly different at 5%

The analysis of variance indicated that there were significant differences (P ≤ 0.05) between farming systems in perceptions of what are the indicators attributed to climate change (Table 4). Statistics show that farmers in the three farming systems equally (P > 0.05) perceived erratic rainfall onset and ending, increased incidences of climate extremes and rising temperature as indicators of climate change. While close to half the famers in maize and cassava based farming system perceived increasing crop productivity as an indicator of climate change, those in sorghum farming system perceived decreasing crop production as indicator of changing climate. The results signified that climate change could have positive effects in some crop while adversely affecting other as also reported in the past (Lobell et al., 2011; Nyanga et al., 2011; Rosenzweig and Parry, 1994).

Table 4: Perceived indicators of climate change in three farming systems

	Farming system			**F value**
	Maize (N=99)	**Cassava (N = 109)**	**Sorghum (N =109)**	
Rainfall start late in the season	72.7a	80.7a	65.1b	0.61
Rainfall start earlier than usual	64.6b	61.5b	60.6b	0.59
Increased incidences of drought	32.7d	80.7a	73.4a	0.04
Increasing temperature	67.3b	79.8a	67.0a	0.67
Increasing crop productivity	45.5c	44.0c	23.9d	0.02
Decreasing crop productivity	38.8d	60.6b	61.5b	0.05
Recurrent food shortage/famine	24.7de	58.7b	58.7b	0.03
Change in types of livestock kept	22.4e	21.1d	29.4c	0.06
Decreasing number of livestock	21.4e	12.8e	28.7c	0.02
Occurrence of new animal species	26.5de	16.5e	28.7c	0.02
Occurrence of new plant species	47.5c	27.5d	40.7d	0.05
Outbreak of new diseases affecting humans	64.6b	40.4c	62.0b	0.06
Outbreak of new plant diseases	55.6c	39.4c	57.4b	0.04
Outbreak of new livestock diseases	54.1c	31.5d	54.6b	0.05

Columns with the same letters are not significantly different at 5%

Perceived crop production trend

The perceptions of the crop production trend in the maize, cassava and sorghum based farming system were significantly different (P ≤ 0.05).The Figure 5 shows that close to half of the farmers experienced decreasing crop productivity. The decrease was mainly associated to the increasing climatic stress factors particularly water stress. However the same could be due non climatic factors like declining soil fertility, pests, diseases and poor agronomic practices as directed by extension agents (Abdulai and Huffman, 2005). On the other hand it can be equally true that climate change is behind the decline in crop production indirectly by being a causative of soil degradation and emergency of new pests, weeds and diseases as also noted by other authors (Anandajayasekeram et al., 2007; Ngowi et al., 2007). Further analysis revealed that the farmers in the study area had responded to the impact of climate change and variability through various local adaptations including shifting cultivation, planting early maturing varieties, switching to drought tolerant food crops like cassava and growing cash crops like grapes, sunflower. Moreover other farmers supplemented the deficits by doing off farm activities like carpentry, brick laying and local brewing.

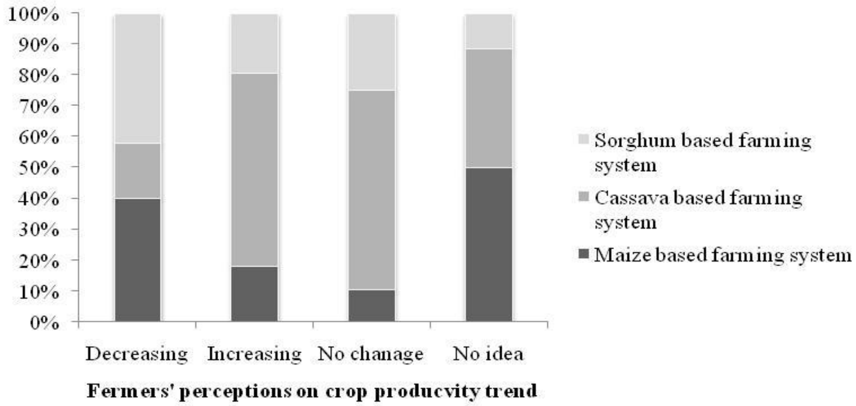

Figure 5: Farmers' perceived crop production trend in the three farming systems

Soil fertility

Results in Table 5 show that that the indicators which the smallholder farmers use to describe the soil fertility status in the three farming systems varied significantly (P ≤ 0.05). Even within the farming system, the importance with which particular indicators are used varied significantly (P ≤ 0.05). Across the three systems, crop yield was the most important indicator of soil fertility as mentioned by 56%, 45% and 59% of the farmers in maize, cassava and sorghum based farming systems respectively (Table 5). Natural vegetation such as Tegetes *minuta* and *Tripsacum laxum* including soil characteristics like colour, soil structure, humus and microbial activities were differentially (P ≤ 0.05) considered indicators f soil fertility. Low soil fertility was widely recognized by farmers in the study areas using various indicators (Table 5). Progressive decline in crop yields was attributed more with soil fertility than rainfall. Crop stunting leaf chlorosis and red soil were related to poor soil fertility although no specific nutrients would be indicated. Other notable indicators of low soil fertility included dominance of sandy particles in the field, and germination of grass *ukoka* (*Cynodon dictylon*.) This result is similar to the report by (Bwambale, 2015)

Table 5: Comparison of farmers' perceptions on soil fertility status in three farming systems

	Maize	Cassava	Sorghum	P value
Indicators of good soil fertility				
High yields	55.54cd	45.23c	58.8a	0.048
Vigorous plant growth	41.54e	34.38d	24.06c	0.002
Mbayaya (*Tegetes minuta L*)	31.76f	34.27d	33.96b	0.056
Likongole (*Tripsacum laxum*)	51.76d	44.27c	4.96e	0.000
Height of grasses	31.76	34.27d	33.96b	0.066
Presence of miombo tree	51.86d	34.38d	13.75c	0.004
Dark clay	31.54f	54.38b	34.06b	0.003
Highly friable	81.76a	54.27b	33.96b	0.001
Black soil	71.76b	34.27d	33.96b	0.001
Presence of humus	61.54c	64.38a	34.06b	0.001
Termite mounts	31.76	34.28d	33.96b	0.684
Indicators of low soil fertility				
Eroded soil	54.54b	40.91a	4.54c	0.000
Sandy soil	26.32c	25.66b	48.026a	0.048
Ukoka grass (*Cynodon dactylon*)	60a	40a	0d	0.000
Red soil	47.59b	24.82c	27.59b	0.003
Chlorosis	55ab	25b	20b	0.013
Stunted growth	46b	34ab	20b	0.023

Columns with the same letters are not significantly different at 5%

The Figure 6 shows the assessment of farmers in the farming systems on notable changes of soil fertility over time. Generally, the farmers' scores show a declining trend of soil fertility in all the farming systems. The declining soil fertility can be attributed to various factors including soil erosion due to run off, wind, and poor agronomic practices. The perceived declining soil fertility is in agreement with the surveys carried out in other agro ecosystems in Tanzania (Ajayi et al., 2011; Enfors and Gordon, 2007; Mowo et al., 2006).

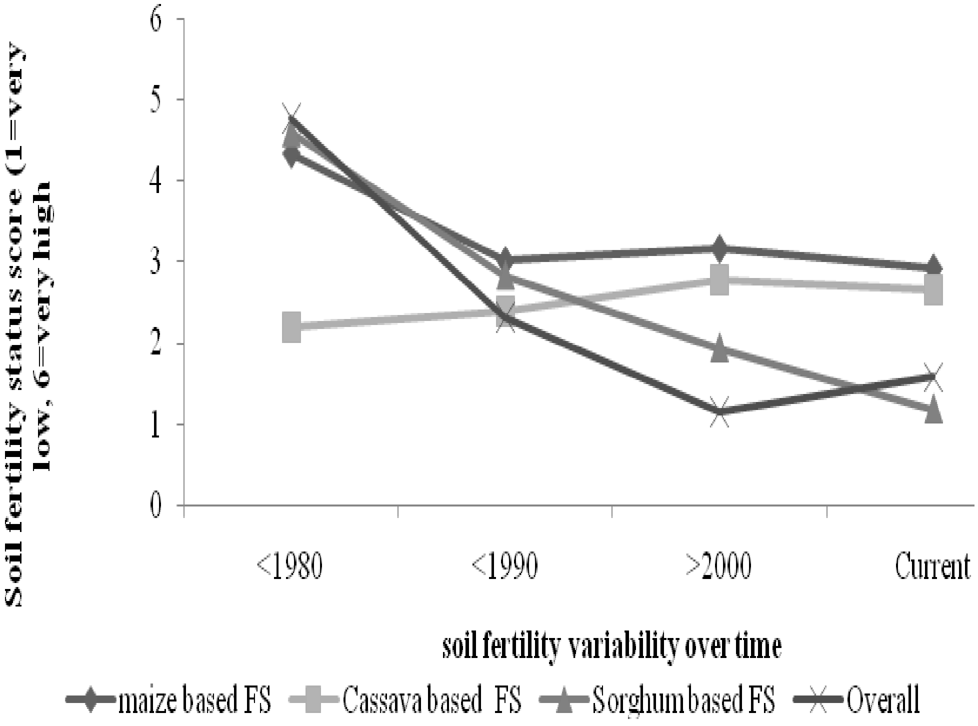

Figure 6: Farmers' perceived soil fertility changes in the farming systems (FS)

Decadal floods and drought frequencies

The result in Figure 7 shows that the frequencies of both dry spell and floods were increasing. This result can be explained as the spatial and temporal distribution of rainfall in the study area continued to worsen and there could be a time and place where there was heavy precipitation leading to floods. On the other hand there could be extended dry spell within the same season. The farmers' recorded flood and drought frequencies are in agreement with meteorological reports in similar area as reported in the literature(Mary and Majule, 2009; Mongi et al., 2010; Tilya and Mhita, 2007). Similar observation have been reported in Tanzania and other countries in sub Saharan Africa (Bryan et al., 2009; Chang'a et al., 2010; Mary and Majule, 2009; Patt et al., 2010).

In the maize based farming system, heavy rains were accompanied with strong winds which caused soil erosion due to surface runoff and damages to the growing maize plants. On the other hand in the sorghum based farming system the dry spell was accompanied with strong wind dusting the leaves of the growing plants and causing severe wind erosion which would have adverse effects to the photosynthetic efficiency of the crop plants as also reported in the literature that deposition of roadside dusts due to wind blow reduce caused a reduce dry weight(Prajapati and Tripathi, 2008; Rai et al., 2010). Dust accumulation on a leaves of crops would lead to reduced photosynthetic efficiency and finally the total plant productivity. Not only that but also the dusts could lead to health problems to the residents frequently exposed to dust as it is reported that any potential increase in aerosols and emitted dust resulting from climate related changes like drought and desertification have generated concern and interest in potential local and long distance public health effects(De Longueville et al., 2010; Morman and Plumlee, 2014).

The Figure 7 indicates that vulnerability of the farming activity in different farming system were different.

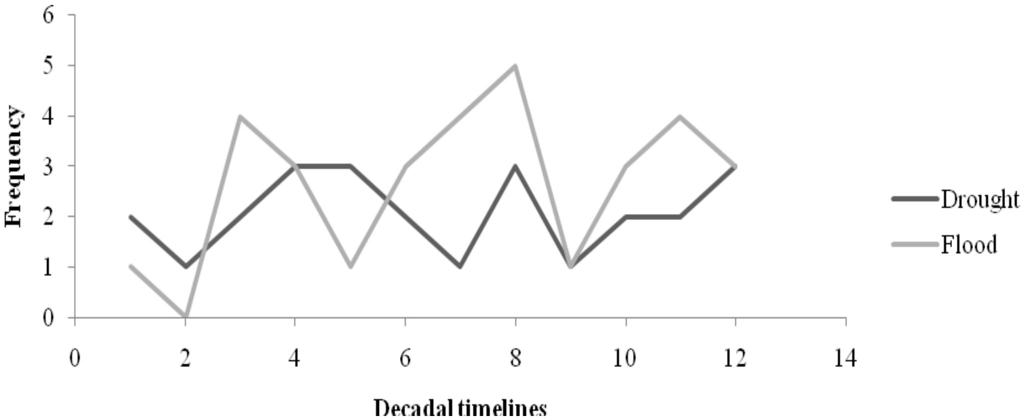

Figure 7: Decadal drought and floods as experienced by farmers

Impacts on biodiversity and phenology of plants

The results in

Figure 8 show that farmers had experience loss of plant species from the ecosystem as well as introductions of new species in the area. However the number of farmers who had no knowledge of new introductions and disappearance of plant species was up to 60% exceeding by 20% to the number of farmers who noted such phenomenon. It was revealed that plants which were considered new were horticultural crops likes Avocado (*Persia americana*) and Ginger (*Zingiber officinale*). Others were the newly introduced drought tolerant and early maturing varieties of maize (*Zea mays*), sorghum (*Sorghum bicola*), finger millet (*Eleucine corocana*) were considered new. Also new species of weeds such as striga (*Striga hemotheca*) were noted particular high in dry climate sorghum based farming system. The introduction can be strategies to adapt to climate change but also winning new market opportunities. It was also reported that there were changes on the phenology, flowering pattern and fruit production of some plants leading to delayed or early maturity time of some crops. A case in the high altitude southern highland where avocado (*Persea americana* Mill**.)** which were not bearing infertile flowers and had change to bearing fertile flowers which produced fruits probably due to positive change in temperatures. It is established that the greatest limiting factor of avocado production is extreme cold condition (Alcaraz and JI, 2009; Ish-Am, 2005; Pinheiro et al., 2009), therefore the shift from none bearing to bearing is a true indicator that average temperature in the area had increased. In the absence of barriers it may be possible for species to migrate in response to changing environment, food security and market conditions(Ericksen et al., 2009). Possibly, as a result of changing climate, vegetation community in the low altitude areas may move to higher latitudes or vice versa following shifts in average temperatures.

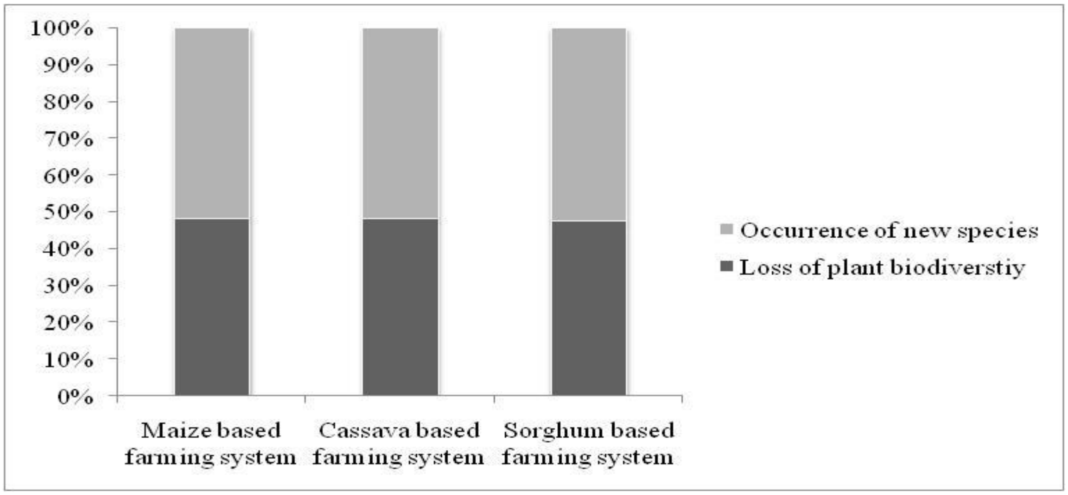

Figure 8: Assessment of loss and occurrence of new plant species

Occurrence of new diseases infecting mankind

Farmers in maize based farming system in southern highland of Tanzania reported prevalence of malaria (Figure 9). The disease was earlier used to be a disease along the lowlands especially the coastal area of Tanzania. This observation is in agreement with a report by Yanda and his colleagues (Yanda et al., 2006) which indicate that lowland malaria in East Africa has a long record dating from1920s and is prevalent in high-altitude areas (above 1,100m above sea level). Such resurgence of highland malaria epidemics over the past two decades is closely associated with climate variability and El Niño events that lead to elevated temperatures and enhanced precipitation, which increase malaria transmission (Chaves and Koenraadt, 2010; Hay et al., 2005; Pascual et al., 2006). The farmers' associated occurrence of diseases like cholera with climate variability, and was in agreement with studies in south Africa(Mendelsohn and Dawson, 2008), west Africa(De Magny et al., 2007) and East Africa (Olago et al., 2007).

Although the farmers linked prevalence of HIV/AID with climate **(**Figure 9), the literature does not provide such direct relationship except that the literature links the pandemic with climate indirectly through impacts of climate on food security and poverty(Shackleton and Shackleton, 2012). More than 40% and 30% of farmers in Cassava based farming systems were concerned of new outbreak of cholera and HIV/AIDS respectively while around 10% of the farmers in both maize and cassava based farming systems noted new occurrence of the two diseases. These differences could be associated to the environment and life style of the cassava producers along the coast with more humid climate. Only minority (<2%) of cassava producers considered malaria a new disease probably because the area is low altitude coast which is a known malaria zone (Aranda et al., 2005; Bhattarai et al., 2007; Kulkarni et al., 2010; Williams et al., 2005)

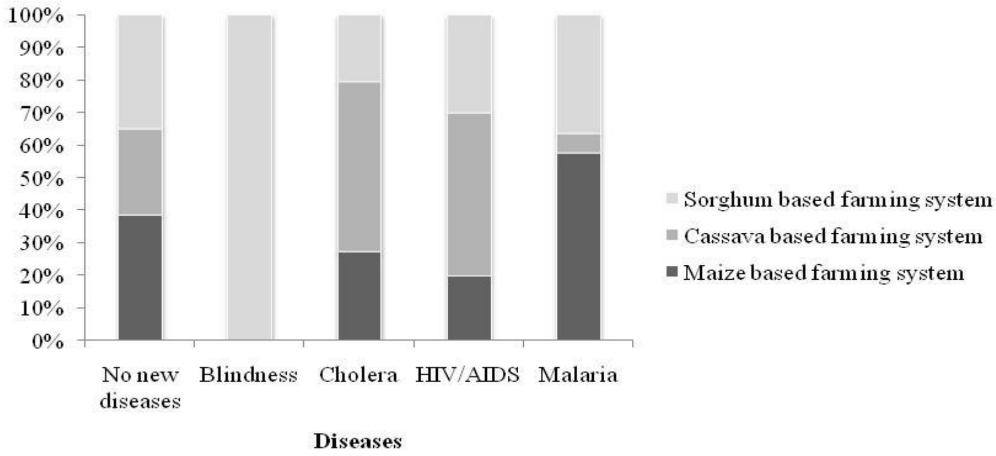

Figure 9: Emergence on new diseases in the three farming systems

Farm level coping strategies to reduce the impacts of climate change

Table 6 shows that the farmers in the farming systems under study were switching to new land uses geared to improve soil fertility. The differences in the use rate of particular strategies between farming ecosystems were significant ($P \leq 0.05$). The differences in use rate of the different strategies within farming system were as well significant ($P \leq 0.05$). Ridge cultivation, use of improved seed and fertilizer application were more pronounces in all farming systems. However, the results point out that there were few adopters of different adaptation measures in cassava based farming system. The low use rate could be associated with low exposure to extension services hence many farmers lack awareness of different measures to adapt to the impacts of climate change. Another reason could be low education level as it is reported that education has positive association with adoption a new technology(Sahin, 2006). However, the maize based farming system had majority adopters of ridge cultivation (76.8%), use of improved seed (81.2) and use of inorganic fertilizer (94.1%). High adoption of ridge cultivation could be due to high water erosion in the farmers fields because maize is produced largely in highlands (Baffes et al., 2015) and majority of the maize farms are located in erosion prone hilly areas (Egodawatta et al., 2013). High adoption of inorganic fertilizers and improved seeds could be associated with food and commercial value of the crop in the region(Delgado et al., 2005). Although not documented in the literature, it could imply that the area may have very low soil fertility such that in order to produce optimally chemical fertilizer and improved nutrient efficient seeds have to be applied as note in other countries in Eastern Africa (Duflo et al., 2008; Xu et al., 2009).

Table 6: Adoption levels of different farm level measures to adapt to impacts of climate change

Practice	MFS	CFS	SFS	P value
Ridge cultivation	76.8b	6.4b	44.0a	0.03
Contour farming	17.2c	1.8d	21.1c	0.001
Crop rotation	9e	3.7b	3.7e	0.042
Shifting cultivation	4.0f	3.7b	10.1d	0.053
Fallowing	8.0e	1.8	2.8e	0.026
Manuring	19.2c	4.6b	13.8d	0.041
Agro-forestry	15.0cd	2.8c	11.0d	0.002
Reforestation	13.0d	2.8c	11.0d	0.002
Use improved seed	81.2b	23.9a	46.4a	0.004
Use fertilizer	94.1a	5.5b	30.0b	0.001

Columns with the same letters are not significantly different at 5%; MFS= Maize based farming system, CFS = Cassava based farming system, SFS = Sorghum based farming system

Linkage analysis of the coping mechanisms with socioeconomic attributes

Correlation analysis revealed a significant ($P \leq 0.05$) positive and negative relation between adoptions of particular coping mechanisms with socio economic characteristics. Household's annual and farm incomes had a significant ($P \leq 0.05$) positive correlation with use of fertilizer and improved seeds (Table 7). The result implies that household income has significant influence of ability of farmers to used fertilizer and is in agreement with other authors who reported that where labour is not limiting other agro inputs can be easily purchased by cash(Marenya and Barrett, 2007). Their income has a role to play in adaptation to the impacts of climate change especially loss of soil fertility due excessive rainfall caused by climate change. The result is in agreement with several other who have dealt with influence of household income in different adaptation to impacts of climate change and adoption of different technologies (Paavola, 2003). Age of respondents has significant relationship with ridge cultivation at $P \leq 0.05$ and also the relationship with contouring, manuring and agro forestry were significant at 1% level of significance. The result show that both shifting cultivation and fallowing were significantly $P \leq 0.05$ and 0.01 respectively and negatively correlated with farm size. This could be associated with the growing population in the area which does not match with the available land resources.

Table 7: Correlation coefficients of household characteristics against farm level measures to adapt to climate change

Agricultural practices	Socioeconomic characteristics									
	Sex	Age	Marital status	Education	Household size	Farm size	Farm income	Livestock income	Off farm income	Total annual income
Ridging	-0.04	0.13*	0.06	-0.32**	0.04	-0.06	-0.15*	-0.04	0.09	-0.14*
Contour	0.05	0.34**	0.13*	-0.10	-0.03	-0.06	-0.06	-0.00	-0.015	-0.09
Crop rotation	0.04	0.09	0.00	-0.01	-0.03	-0.13*	-0.09	0.01	-0.08	-0.08
Shifting cultivation	0.08	0.01	0.05	-0.07	-0.03	-0.23**	-0.01	0.04	-0.25**	-0.07
Fallowing	0.03	0.03	0.02	-0.06	-0.04	0.01	-0.08	0.07	0.079	0.02
Manuring	-0.07	0.21**	0.06	-0.06	0.03	-0.06	-0.08	-0.04	0.098	-0.13*
Agroforestry	0.07	0.21**	0.11	-0.12*	0.05	-0.06	-0.12*	-0.08	0.077	-0.13*
Reforestation	0.11	0.052	0.06	0.04	0.021	-0.04	-0.09	-0.07	0.876**	-0.11*
Fertilizer use	-0.03	0.047	0.06	-0.09	-0.00	-0.10	0.74**	-0.02	0.037	0.83**
Use improved seeds	-0.06	-0.067	-0.04	-0.13	0.15*	0.00	0.14	-0.03	0.175	0.14*

* Correlation is significant at the 0.05 level. ** Correlation is significant at the 0.01 level

From this analysis there is little reliability of evidence that age, sex, household size, farm size, off farm income and annual household income have close linkage with adoption of particular technologies. This result is not in agreement with the evidence from Ghana which suggested that gender-linked differences in the adoption of modern maize varieties and chemical fertilizer result from gender-linked differences in access to complementary inputs(Doss and Morris, 2001).

CONCLUSION

The study has established that climate change is real happening and farmers are already feeling the impacts. However, majority of the smallholder farmers are not aware of the correct definition of climate change and its underlying causes. Despite the ignorance on what it is, the impacts of climate change make them devise mechanisms to survive in the changing environment. The mechanisms vary between farming system depending on socioeconomic characteristics of the farmers in question. Due to these differences it is therefore evident that recognition of the indigenous knowledge and the socioeconomic characteristic of the target community need to be taken on board when considering appropriate adaptation measure in a particular rural setting.

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