

Full Length Research Paper

The impacts of climate change and variability on crop farming systems in Semi-Arid Central Tanzania: The case of Manyoni District in Singida Region

Jackson Sawe^{1*}, Claude G. Mung'ong'o² and Godfrey F. Kimaro³

¹Department of Geography, University of Dar es Salaam, P.O. Box 35049, Dar es Salaam, Tanzania.

²Institute of Resource Assessment, University of Dar es Salaam, P.O. Box 35097, Dar es Salaam, Tanzania.

³College of Natural and Applied sciences, University of Dar es Salaam, Tanzania.

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This paper focuses on the impacts of climate change and variability on crop farming. The main objective of this paper is to assess the impacts of climate change and variability on crop farming systems in Manyoni district, Tanzania. This paper used mixed research design with both quantitative and qualitative research approaches. The research used different methods in collecting information concerning the impacts of climate change and variability on crop farming systems such as key informants interviews, focus group discussions and observations methods. Secondary data were collected through documentary review. Questionnaires were administered to 362 heads of households from four study villages namely Lusilile, Udima, Makanda and Magasai. Findings of the research revealed that majority of the farming households acknowledged occurrences of climate change and variability in their localities for the past 30 years. Heads of households perceived that rainfall has decreased while temperature has been increasing. This findings are in collaboration with that from the Tanzania meteorological data. Moreover, the findings revealed that climate change and variability have impacted crop farming system in different ways such as, damaging of crops and persistent low yields, reduction of crop varieties and species, decreasing soil fertility, increasing crop pests and diseases and drying of water sources. Therefore, this paper recommends that, collective efforts from government and other stakeholders should be harnessed and implemented in order to respond to these impacts so as to improve households' food security in the study area.

Key words: Climate change, climate variability, crop farming systems, Manyoni district.

INTRODUCTION

Climate change is one of the substantial global challenge in the twenty first century. As stipulated in the IPCC third

assessment report, changes in rainfall and temperature are anticipated to have an extensive impacts on crop

*Corresponding author: E-mail: jacksonsawe@yahoo.com. Tel: +255763495116.

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Production (IPCC, 2007). The report also forecasts that mean annual global surface temperature will increase by 1 to 3.5°C by 2100 and the global mean sea level will rise by 15 to 95 cm (Apata et al., 2009). The projected increase in global average surface temperature is expected to bring or increase spatial and temporal variations in patterns of precipitation. Due to this report, farmers who depend on rainfed agriculture are considered as the most vulnerable group to climate change impacts because agriculture is highly sensitive to climate variability (Bates et al., 2008).

Crop farming is the main economic activity in Africa. It contributes 20 to 30% of Africa's gross domestic product (GDP) and 55% of the total value of African exports, with 70% of the continent's population depending on the sector for their livelihood (OECD, 2014). However, due to unpredictable rainfall and changes in temperature, crop production has been severely affected resulting in decrease in food security. Africa has thus become the most vulnerable continent to impacts of climate change. Furthermore, the vulnerability of the region is aggravated by the fact that the climate is predictably becoming hotter (Lyimo and Kangalawe, 2010). Authors like Nelson et al. (2009) as quoted by Cooper et al. (2016) projected that climate change and variability will reduce agricultural production by 10 to 20% by 2050 by changing rainfall patterns and increasing frequency of extreme weather events.

The projected reduction will mainly result from the changing rainfall patterns and the increase in the frequency of extreme weather events. This will also increase the prevalence of crop pests and diseases. The effects of these changes are expected to be particularly severe in SSA, where persistent poverty makes populations more vulnerable than in other parts of the world, and importantly the huge reliance on agriculture in this region. The sector contributes about 40% of gross domestic product of sub-Saharan Africa (SSA) countries and employs 62% of the population (Cooper et al., 2016)

The most vulnerable areas in the region have been rural SSA, especially for the arid and semi-arid lands in countries such as Sudan, Somalia, Ethiopia and Tanzania (Agrawala et al., 2003; IPCC, 2007; Molua, 2002). These areas have frequently been exposed to climate variation-induced food shortages and famine. These areas are considered among the most food insecure regions in the world (Devereux and Edward, 2004; Deressa et al., 2008). According to some observers, climate change and variability have also exacerbated extreme poverty in their rural communities (Hellmuth et al., 2007). For Tanzania, specifically, the National Adaptation Programme of Action (NAPA) projected that, the mean daily temperature will rise by 3 to 5°C throughout the country (URT 2007), with annual rainfall decrease of between 5 and 15% in areas of unimodal rainfall and between 5 and 45% in areas of

bimodal rainfall. Such rainfall decreases will not only pose intensive effects on crop farming but they will impact the whole agricultural sector in general.

However, it should also be noted that such climatic impacts will not affect the region uniformly due to East Africa's diverse climatic patterns, from equatorial to semi-arid and arid climates (WFP/ICPAC, 2014). Therefore, communities living in these different climatic regimes will be affected differently by climate change. Hence, they will be adapting their systems of production to match with the shortage of rainfall and other climate change factors. Thus, East Africa has and will continue to have some of the most multifaceted production systems in the world. They include systems such as the perennial farming systems, mixed crop farming systems, and the agro-pastoral and pastoral production systems.

Therefore, these systems have been impacted differently by climate change and variability (Majule, 2008). So far, the impacts of climate change and variability have been revealed through droughts, floods, erratic rains and extreme events. For instance, URT (2011) reported that famine as a result of food shortage have drastically increased since the mid-1990s thus affecting the livelihoods of the farming community, especially in semi-arid central Tanzania. Furthermore, a number of studies that have been done in Tanzania revealed that climate change and variability are real and are accompanied by significant impacts on a diversity of sectors including agriculture which is considered as the major source of peoples' livelihood (Wambugu and Muthamia, 2016). Following the impacts of climate change and variability, farmers in semi-arid and arid east Africa have developed and adopted various adaptation strategies as a mechanisms to respond to impacts of climate change and variability. Such adaptation mechanisms includes, adoption of mixed crop farming system, growing of drought tolerant crops, changing of farming calendar and operating non-farm activities (Lyimo and Kangalawe, 2010).

Generally, most of the literature has highlighted impacts of climate change and variability on agriculture at global level. Moreover, these impacts are based on agriculture in general which combine both crop farming and livestock keeping. Hence, this paper aimed at assessing in detail, the impacts of climate change and variability on crop farming systems at community level which are often not well documented. Specifically, the paper examines the perception of farmers on climate change and variability, establishes the trends and patterns of rainfall and temperature and assesses their impacts on crop production. It is anticipated that information gathered from the study will not only add knowledge to the existing literatures but it will also be used by various stakeholders such as the government, policy makers and non-government organizations to address issues related to impacts of climate change and

variability on crop farming in an effort to promote food production so as to enhance household food security.

MATERIALS AND METHODS

Description of the study area

Geographical location of Manyoni District

Manyoni District is one of the six districts of Singida Region in Tanzania. The district capital is the town of Manyoni. The district lies between Latitude 54°0'0"S and longitude 33°40'0"E covering an area of 28,620 km² that is about 58% of the entire area of Singida Region. The district is bordered to the north by the Ikungi and Kondoa Districts, to the east by Dodoma Rural District, to the south by Iringa District, to the southwest by Chunya District, and to the west by Sikonge District. According to the 2012 National Census Report, Manyoni District was administratively divided into 20 wards. Four villages, namely Lusilile, Udima, Makanda and Magasai were purposively selected from Kintinku Makanda wards for the study (Figure 1). The two wards are located in two distinct agro-ecological zones. Kintinku is located in the rift valley while Makanda is located in the plateau.

Climatic characteristics

The district experiences low and often erratic rainfall with fairly widespread droughts in one year out of four. The average annual rainfall ranges from 500 to 700 mm per annum with high geographical, seasonal and annual variations. There are two well defined seasons: the short rainy season during the months of December and March which fades away in May, followed by the long dry season to November (Benedict and Majule, 2015). The district forms part of the semi-arid central zone of Tanzania (Manyoni District Profile, 2014). The long-term mean annual rainfall is 624 mm with a standard deviation of 179 mm and a coefficient of variation of 28.7%. The long-term mean number of rainy days is 49 with a standard deviation of 15 days and a coefficient of variation of 30.6%. However, there is some variation in terms of rainfall distribution in the district over years. In some areas, rainfall amount is high while in other areas, it is low. Rainfall distribution for the district is presented in Figure 2.

Temperatures in the district range from about 20°C in July to 30°C during the month of October. Temperatures are almost constant throughout the year. August, September and October are the hottest months due to relatively small difference in elevation. There is also a well-defined difference in temperatures between day and night. Maximum temperatures during the day can go up to 32°C and decrease in nights; going down to 15°C (Manyoni District Profile, 2014).

Data collection and analysis

The study used both primary and secondary data in order to ensure the study objectives were addressed appropriately. Secondary sources used in this study includes various published research paper and reports, rainfall and temperature data collected from Tanzania Meteorological Agency, crop yield data (maize, millet and groundnuts) collected from National Bureau of Statistics, internet search and other relevant sources. Primary data sources includes focus group discussions (n=8 for each village), trend analysis (n=8

per village), interviews with key informants (n=10) consisting of village leaders, agricultural extension officers and village elders. Household survey (n=362) and direct field observation through transect walks were other sources of primary data. Field observation was deemed necessary in order to confirm some of the issues raised during in-depth interviews, focus group discussions and the household survey. The sample size of the household survey consisted of 10% of the total number of heads of households in each study village. Simple random sampling procedure was used in the selection of the sample whereby about 59.5% of males and 40.3% of females were interviewed.

Quantitative data collected from the questionnaire survey were coded and analyzed with the help of SPSS version 20. A spread sheet was used for the analysis. Descriptive statistics was run in order to get the frequencies and then cross tabulation was done so as to compare the study themes in the four study villages. Multiple response questions were analyzed so as to get frequencies and percentages. Rainfall, temperature and crop yield data were analyzed by using Microsoft Office Excel, 2007, to examine patterns and trends of the variables. Tables and figures were used to present the findings.

RESULTS AND DISCUSSION

Socio-economic profile of respondents in the study area

Educational level

Education is anticipated to be an important factor in accessing advanced information on new improved agricultural technologies and increased agricultural productivity (Norris and Batie, 1987; Elahi et al., 2015). The study revealed that, there were clear distinctions on levels of education amongst the interviewed heads of household. The results showed that majority of heads of household (68%) in the study area attained primary education, 8% attained secondary, while 24% admitted to have not attended school at all (Table 1).

Economic activities

The findings revealed that crop farming was the leading economic activity performed in the study area which accounted for 76.8% of the 362 interviewed heads of households (Table 2). Agro-pastoralism was the second economic activity conducted in the study area which accounted for 19.6% of the total heads of households. Small business and casual labour both accounted for 1.4% while formal employment accounted for 0.8% of the interviewed respondents and this was mostly practised in Lusilile village (2.8%) due to the presence of many public institutions like hospitals and schools (Table 2). According to Table 2, crop farming was practiced more in Makanda village (81.2%), while agro-pastoralism was practiced more in Magasai village. This difference was due to the presence of more Sukuma immigrants from

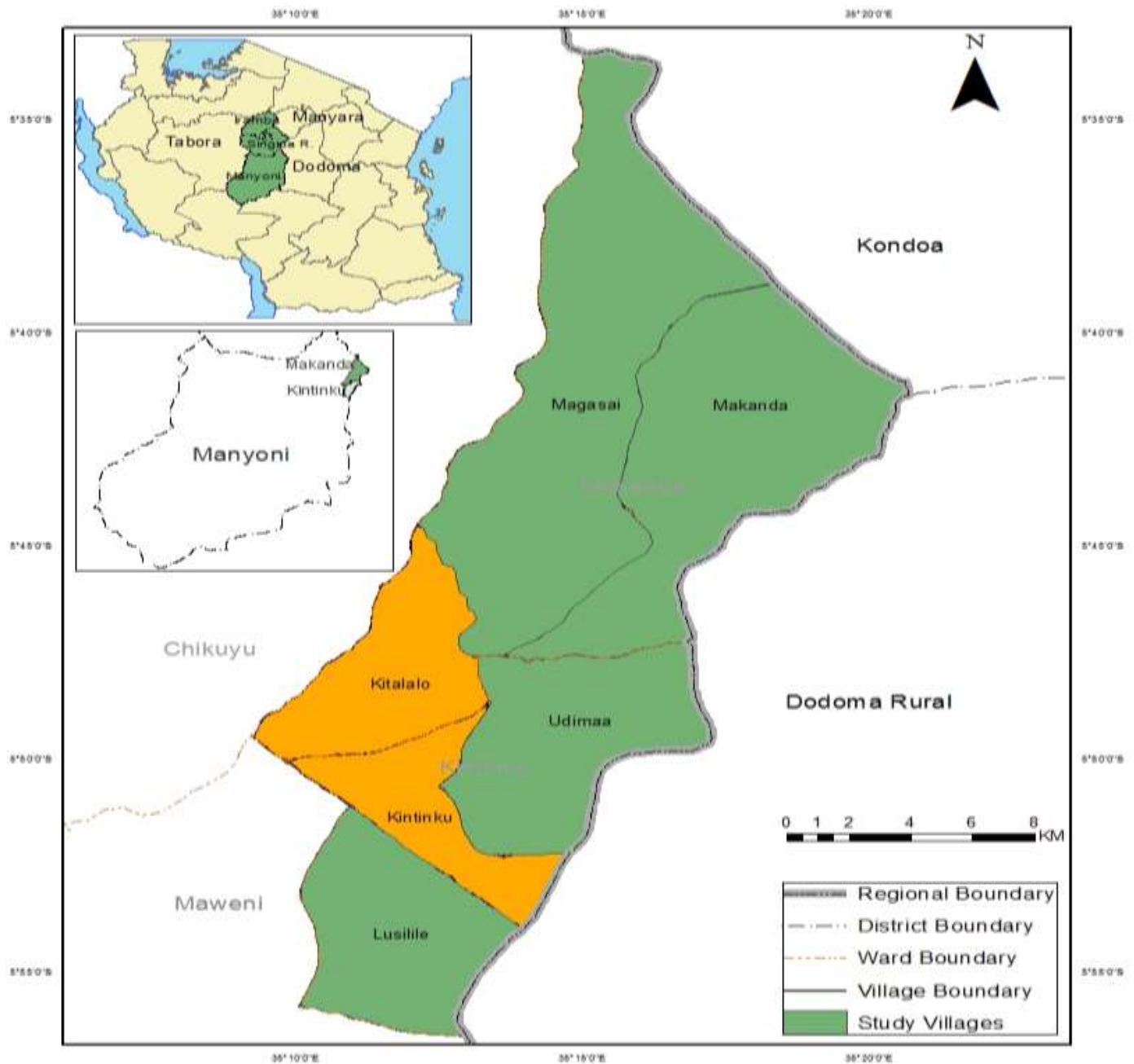


Figure 1. Map of Manyoni District showing the study villages.

Lake Zone regions who are traditionally agro-pastoralists. Small businesses and casual labour were conducted mostly in Udimaa village as the village is urbanized than the rest and is located near the tarmac road that connect Dodoma and Singida regions.

Farmers perceptions on climate change

The findings revealed that about 98% of the total

respondents perceived that climate has been changing, while only 2% perceived that climate had not changed. Majority of the farmers associated the concepts of climate change and variability with, changes in climatic elements. It was thus reported that 48.9% of the heads of households perceived climate change as long term changes in rainfall, while 33.6% perceived it with long term changes in temperature. About 10.5% perceived climate change through changes in wind intensity, while 2.1 and 1% of heads of households perceived it is through

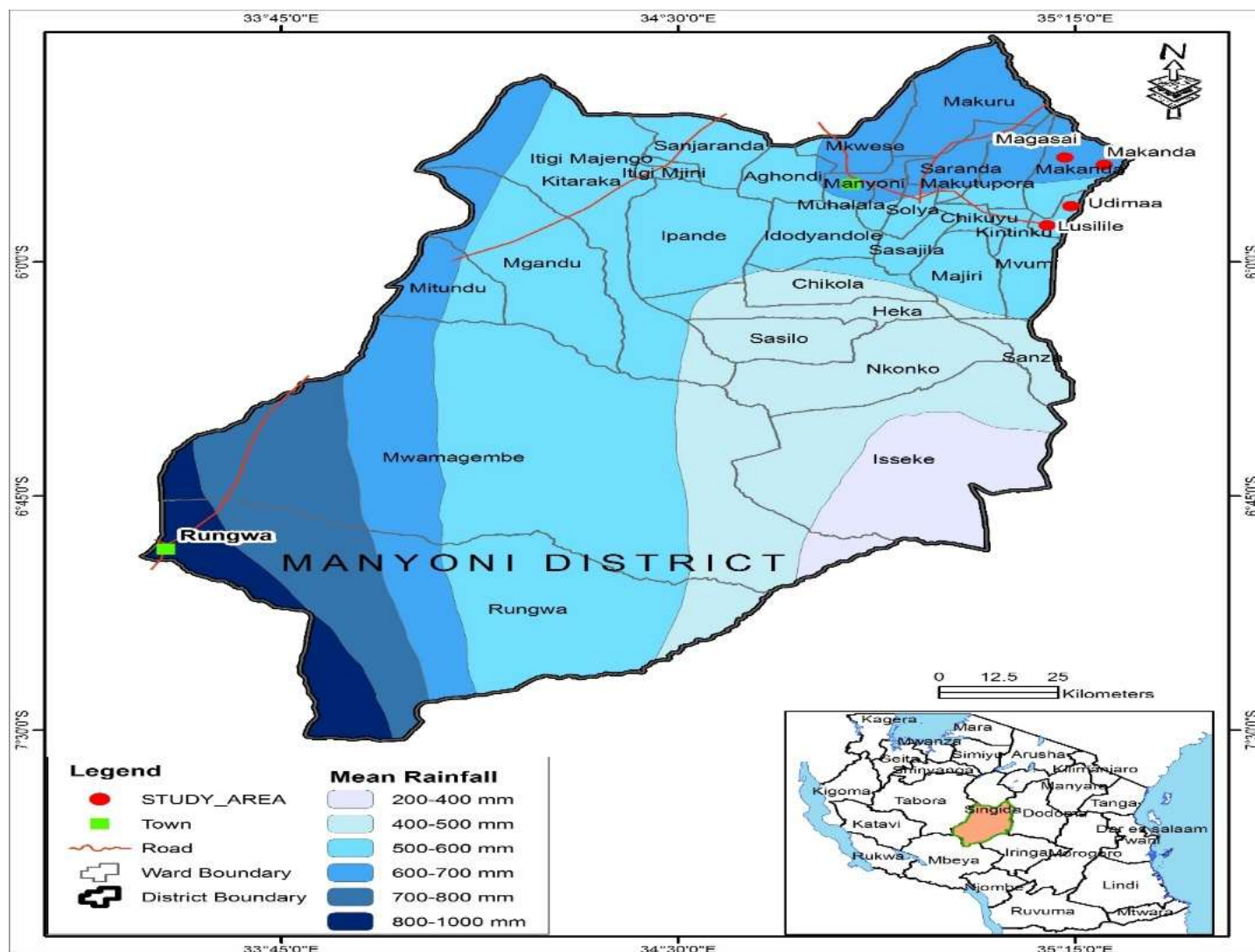


Figure 2. Mean rainfall distribution in the study area.

flood incidences and change in humidity, respectively (Figure 3)

Farmers’ perceptions on long-term changes in rainfall and temperature

Specifically, while the findings revealed that 81.0% of the farmers perceived that rainfall had been decreasing as compared to thirty years ago, 18.2% perceived rainfall had been fluctuating while about 0.8% affirmed to have not noted any changes at all in rainfall amounts and patterns. Similar results were reported by Lema and Majule (2009) who mentioned that there had been a decreasing trend in rainfall amounts and intensity in most parts of Tanzania and Africa generally. Moreover,

Nhemachena and Hassan (2007) observed that in the Southern Africa region, majority of smallholder farmers perceived that there were decreases in rainfall amounts from the year 1976 to 2006.

The findings of this study was also supported during interview with key informants in Makanda village as narrated:

“... In the past when I was young, about thirty years ago, rainfall was sufficient, regular and predictable. Although there were some fluctuations in terms of amount in some years but generally, the rainfall was sufficient for crop production. My father was able to produce in surplus food whereby some amount of harvests were sold in the market at Kintinku while some amount were given to our relatives who were living at Manyoni Town. My dear

Table 1. Education levels of the heads of households.

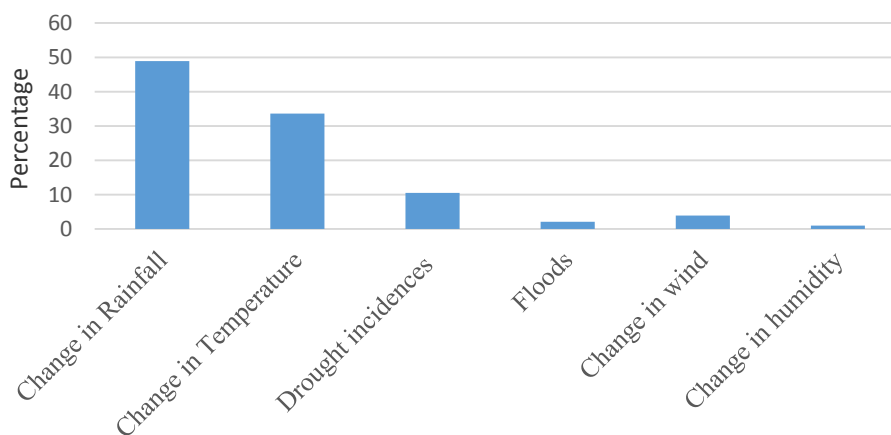
Education level	Study Villages								Sample Size (N=362)	Total
	Lusilile		Udimaa		Makanda		Magasai			
	N	%	N	%	N	%	N	%		
No education	15	13.8	24	33.8	16	15.8	32	39.5	87	24.0
Primary education	83	76.1	41	57.7	76	75.3	46	56.8	246	68.0
Secondary and above	11	10.1	6	8.5	9	8.9	3	3.7	29	8.0
Total	109	100.0	71	100	101	100	81	100	362	100.0

Source: Field data (2017).

Table 2. Main economic activities in the study area.

Occupation	Study Villages								Total	
	Lusilile		Udimaa		Makanda		Magasai		(N=362)	%
	N	%	N	%	N	%	N	%		
Crop farming	88	80.7	57	80.3	82	81.2	51	63	278	76.8
Formal employment	3	2.8	0.0	0.0	0.0	0.0	0.0	0.0	3	0.8
Agro-pastoralist	15	13.8	11	15.5	16	15.8	29	35.8	71	19.6
Small business	1	0.9	1	1.4	3	3	0.0	0.0	5	1.4
Casual labor	2	1.8	2	2.8	0.0	0.0	1	1.2	5	1.4
Total	109	100	71	100	101	100	81	100	362	100

Source: Field data (2017).

**Figure 3.** Farmers' perceptions on climate change and variability.
Source: Field data (2007).

researcher, currently, we are suffering a lot, rainfall has decreased and totally not sufficient. This season (2016/2017), the situation is more than worse because up to now (February, 2017), we have experienced rainfall only for three days" (Interview with village executive officer, Magasai village).

With regard to temperature, the findings revealed that about 88.7% of heads of households perceived temperature to have increased as compared to thirty years ago, 10.5% perceived temperature had been fluctuating and 0.8% perceived no changes. The same results were found by Shemdoe (2011) and Mongi et al.

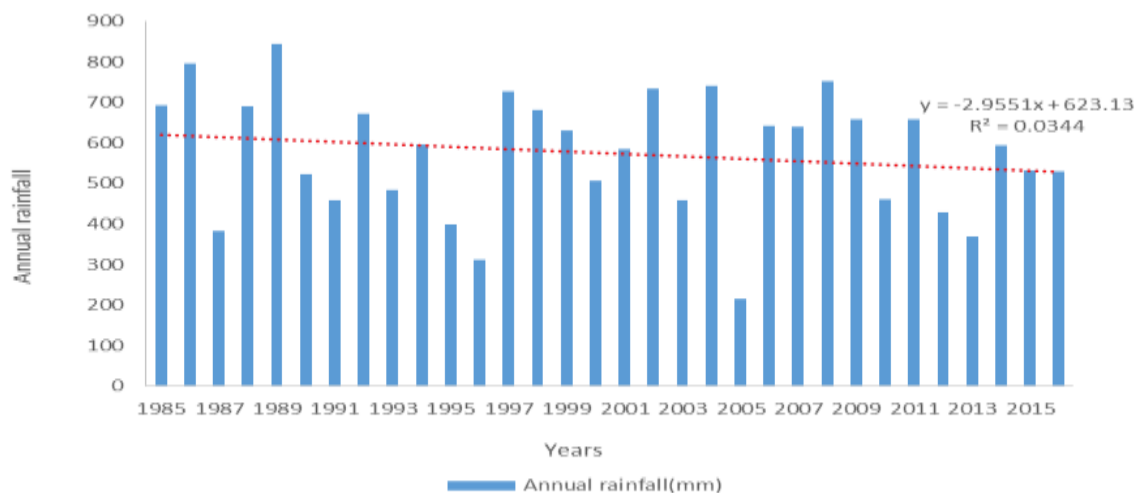


Figure 4. Average annual rainfall trends in the study area.

Source: Field data (2017)

(2010). Both authors reported that majority of the heads of households in semi arid Tanzania perceived temperature to have increased.

Moreover, during in-depth interviews with key informants and focus group discussions, it was stated that the amount of temperature has currently increased as compared to thirty years ago which is associated with recurrent droughts and frequent food shortages:

..... "There is no doubt that the amount of temperature in our village has increased dramatically in recent years as compared to thirty years ago. You know temperature used to be high mostly in November and early December both day and night. But now, day's temperature has become unpredictable because even those months which were used to have low temperature like January, April and May, the situation has changed, we are also experiencing high temperature in those months" (In-depth interview with Female, 67 years in Magasai village).

..... "I can say that when I was in primary school about 39 years ago, we were facing a minimum amount of temperature. When I compare with the current temperature, surely, the temperature has increased that's why we are getting poor harvests" (Male 42 years in Lusilile village).

..... "What my fellow speaker has said is true but he has forgotten to say that due to increase in temperature our natural water sources like river Bubu and other natural wells which depend on water from the river have dried up very early this year as compared to twenty years ago. Normally, we were able to access water from our sources

for almost four months once the rainfall end" (Female 52 years in Lusilile village).

....."Let me also say something concerning the topic, I remember my late father was a fisherman and he was getting a lot of money from such activity but nowadays because the ponds has dried up due to increase in temperature, we are no longer getting fish. Actually, the increase in temperature have further accelerated the increase in drought incidences in our village to the extent that agriculture has become unpredictable because even the rainfall amount has decreased to the maximum any way let us pray that God will hear us " (Female, 69 years in Lusilile Village).

Statistical analysis of rainfall and temperature trends in the study area

Analysis of scientific rainfall and temperature data obtained from Tanzania Meteorological Agency was done in order to determine if there was consistency between these data with the farmers' perceptions on changes in rainfall and temperature collected during the household survey.

Rainfall trends

The analysis of rainfall data was done by using simple regression model. The results are presented in Figure 4. In general, the findings indicated a slight decrease trends in the pattern of rainfall as shown by $y = -2.9551x + 623.13$ mm. Moreover, the decrease in trend is described

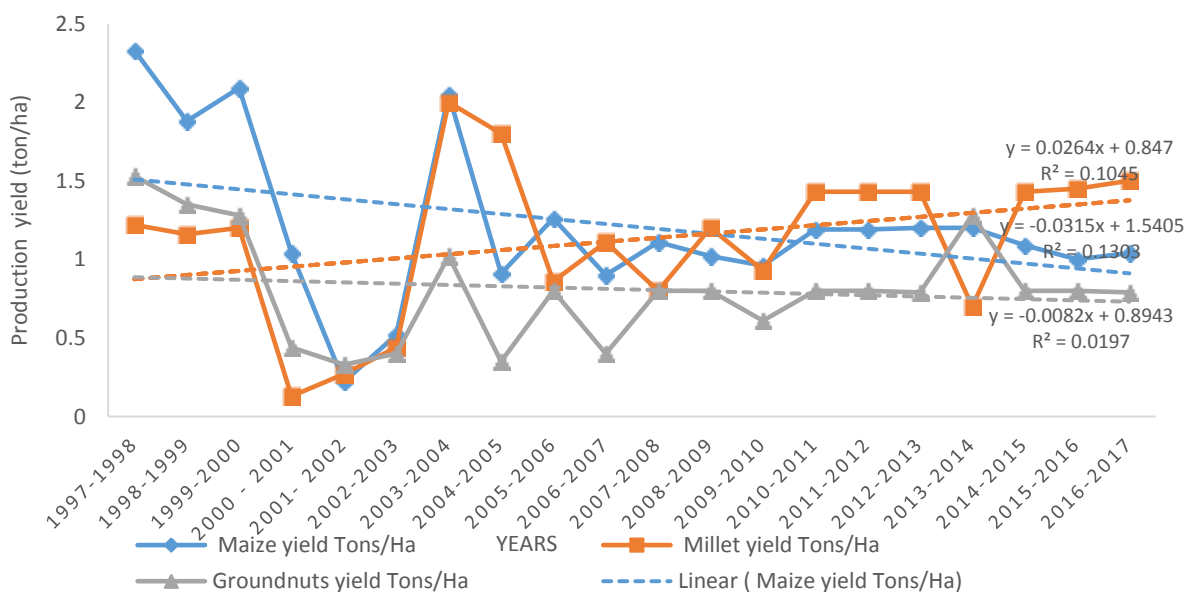


Figure 5. Trends of major crops produced in Manyoni district (1997/1998-2016/2017).
Source: Field data (2017).

by 3.4% of variance observed in Manyoni District. The findings from this study are in line with the findings from Lyimo and Kangalawe (2010) who conducted their study in nearby Shinyanga Rural District and observed that rainfall amount and intensity decreased at a non-significant rate of $R^2 = 0.18$, F probability > 0.47 . Even though such trends were not statistically significant to some extent, they showed a decrease in trend. In addition, Myeya (2013) who conducted a study in Dodoma Region, observed a statistically insignificant decrease in rainfall trends of -3.328 y^{-1} and -2.165 y^{-1} for Mpwapwa and Bahi Districts, respectively.

Moreover, the findings indicate that there had been some variations in terms of rainfall amounts and patterns from 1985 to 2016.

In some years, rainfall appeared to increase while in others, it seemed to decrease (Figure 4). In particular, the study observed that about 12 years in that period had received rainfall below average (577.3 mm). These years are were 1987 (381.6 mm), 1990 (521.4 mm), 1991 (458.4 mm), 1993 (484.1 mm), 1995 (399.6 mm), 1996 (312.3 mm), 2000 (505.3 mm), 2003 (459.1 mm), 2005 (215.0 mm), 2010 (459.6 mm), 2012 (427.9 mm) and 2013 (368.9 mm). In addition, four years appeared to have received very little rainfall. These included 1987, 1996, 2005 and 2013. Meanwhile, 2005 was observed to be the driest year experiencing a total rainfall amount of only 215.0 mm. On the other hand, the rainfall analysis indicates that rainfall was very high in the years 1989 and 1986 which received a total amount of 843.8 and 795.2 mm, respectively. Based on such observations, it can be

argued that the analysis of meteorological data on annual trends and patterns of rainfall and that of smallholder farmers' perceptions on changes of rainfall appear to be in line.

Temperature trends

Figures 5 shows the trends in temperature change in the period of 1985 to 2016, whereby there is a general increase in annual mean temperatures. Moreover, the fitted linear trends indicate that both annual mean maximum temperatures and annual mean minimum temperatures were statistically significant at 0.05 significance level with p value = 0.001. The annual mean minimum temperature showed a higher increase, $y = 0.0399x + 16.473$ as compared to the annual mean maximum temperature, $y = 0.023x + 28.679$. Therefore, this is explained by 66% of observed variance in the annual mean minimum temperature, $R^2 = 0.657$ than the observed 32% in the maximum annual temperature, $R^2 = 0.315$ in the period 1985 - 2016.

The data further indicated that for the period of 32 years, the mean minimum temperature in Manyoni District had increased by 1.3°C, while the mean maximum temperature increased by 1.1°C. Therefore, the annual mean minimum temperatures tend to have increased at a higher rate than the annual mean maximum temperatures which seem to support the concern of the majority of respondents who perceived that temperatures were increasing.

Table 3. Impacts of climate change on crop farming in the study area.

Types of crops	Study Villages								Total %
	Lusilile		Udimaa		Makanda		Magasai		
	N	%	N	%	N	%	N	%	
Damaging crops and persistent of low harvest	102	37.2	68	36	98	38.6	71	35.1	36.7
Reduction of crop varieties and species	40	14.6	44	23.3	46	18.1	47	23.3	19.8
Decrease in soil fertility	15	5.5	11	5.8	17	6.7	10	5.0	5.7
Increase in crop pests and diseases	41	15	31	16.4	47	18.5	33	16.3	16.6
Drying of water sources	76	27.7	35	18.5	46	18.1	41	20.3	21.2
Total	274	100	189	100	254	100	202	100	100

Source: Field data (2017).

Perceived impacts of climate change and variability on crop production system

Damaging of crops and persistence of low yields

It was noted that more than a third (36.7%) of the heads of households who were surveyed pointed out damage of crops and persistence of low yields is the major impacts of climate change and variability. The most mentioned climatic factors impacting agricultural production in all study villages were increasing temperatures and decreasing amounts and intensity of rainfall. For example, it was noted that about 38.6 and 37.2% of the heads of households in in Makanda and Lusilile villages acknowledged crop damage and persistence of low harvests, respectively, while about 36 and 35.1% were reported in Udimaa and Magasai villages, respectively (Table 3). These results collaborated the results of Malley et al. (2009) who observed that productivity of crops in Tanzania was increasingly becoming threatened by increasing drought frequency in semi-arid areas of central Tanzania. The pains of climate change to households in Magasai village were observed to be less as compared to other study villages due to the nature of farming system practiced by agro-pastoralists which gave more weight to livestock keeping than crop farming.

Drying of water sources

Water is an important input essential for crop production, especially in irrigation farming. Decrease in water supply will surely impact crop production as stated by 21.2% of the respondent heads of households who were interviewed in the study area (Table 3). On the other hand, the findings from village analysis revealed that about 27.7 and 20.3% of the heads of households in Lusilile and Magasai villages, respectively, acknowledged that water sources had dried up as a result of increase in temperature and decline in rainfall. Similarly, about 18.5

and 18.1% of heads of households in Udimaa and Magasai villages, respectively, reported drying of water sources as among the impacts of climate change and variability. Information from both focus group discussion and in-depth interviews in Lusilile village revealed that the higher percentage of heads of households in the village who perceived drying of water sources as among the impacts of climate change and variability was due to the presence of many dried water sources such as rivers, natural springs and wells causing shortages of water for domestic activities and for irrigation farming as stated below:

.....“Some years ago before my marriage, it was very difficult to see sands and small stones in the Bubu river and it was hardly to cross over the river, this is because for all seasons, the river was full of water and there were many vegetable farming near the river where farmers used to plant tomatoes, onions, cabbages and spinach and many small scale irrigation farming were established nearby. Unfortunately, currently, the situation has changed because the river has been drying up frequently especially from May to September. Furthermore, even for the remaining months, the river have been receiving a very small amount of water which are insufficient for vegetable growing and irrigation farming that’s why I am experiencing frequent family conflicts due to food shortages but do not give anyone this information” (Key informants, 78 years in Lusilile village).

Reduction in crop varieties and species

One other effect of climate change and variability mentioned by 19.8% of the households interviewed was reduction of crop varieties and species. In terms of specific villages’ analysis, the data showed that reduction in crop varieties and species was higher in Udimaa and Magasai villages than the remaining villages as expressed by 23.3 and 23.3% of the respondent heads of households, respectively (Table 3). The two villages were

Table 4. Analysis of variance of the impacts of climate change on crop farming in the study villages.

Source	Type III sum of squares	Df	Mean square	F	Sig.	Partial Eta squared
Corrected Model	244.573 ^a	12	20.381	26.983	0.000	0.488
Intercept	1058.003	1	1058.003	1400.730	0.000	0.805
Village	0.042	3	0.014	0.019	0.997	0.000
Impacts of climate change	161.905	3	53.968	71.451	0.001	0.387
Village * Impacts of climate change	1.937	6	.323	0.427	0.861	0.007
Error	256.810	340	.755			
Total	7808.000	353				
Corrected Total	501.382	352				

a. R Squared = 0.488 (adjusted R squared = 0.470).
 Source: Field data, 2017.

closely followed by Makanda village with 18.1% and Magasai at 14.6% of the interviewed heads of households.

During focus group discussions, participants were asked the types of crops they produced and if there were any crops that had recently been abandoned. In terms of abandoned crops, the respondent heads of households mentioned beans, onions, bulrush millet, sweet potatoes and some local maize varieties. Different reasons for abandoning such crops were mentioned, including decline in soil fertility and increase in pests and diseases. Farmers, however, pointed out increased drought incidences as the major factor. Other crops that were reported to have been affected by drought conditions were groundnuts, cowpeas, peanuts and sesame. Similar findings were noted by Kangalawe and Lyimo (2013) in their study in Shinyanga Rural and Manyoni Districts.

Increase in incidence of crop pests and diseases

Outbreak of crop as well as animal pests and diseases were mentioned to be among the impacts of climate change and variability. Generally, results from the households survey showed that about 16.6% of the respondent households commented that there had been frequent outbreaks of crop pests and diseases in the study area. The findings revealed that increase in pests and diseases had mostly been due to increase in temperature. The most serious pests and diseases mentioned by the farmers were weevils, birds and stalk borers (*Calidea dregii* locally known as mpipi) attacking maize and millet, and ants (locally known as nkeki) attacking paddy and sesame. Other emerging pests mentioned by smallholder farmers were rodents, armyworms, bollworms, larger grain borers and leaf hoppers. However, it should be noted that though these pests were mentioned by some smallholder farmers as emerging pests, it does not necessarily mean that these

pests were absolutely absent from the area in the past. The fact is that their rate of occurrence had increased with climate change and variability as observed by Kangalawe and Lyimo (2013) in the case of Shinyanga Rural District.

Decrease in soil fertility

Fertile soil is a fundamental element for plant growth. Generally, the findings revealed that about 5.7% of the respondent heads of households acknowledged that soil fertility had decreased (Table 3). During focus group discussions, it was further noticed that majority of the smallholder farmers who acknowledged decrease in soil fertility were associated with the occurrence of floods which washed away soil nutrients and contributed to decline in nutrient supply in the crops grown in those soils. Insufficient nutrient status in arable soil did not only decrease food production for human consumption but also, it increased vulnerability levels to human diseases and food insecurity for the population depending on food produced via such soils. However, it should be noted that decrease in soil fertility per se is not a sole factor for decrease in crop production. There are other contributing factors such as pests and diseases, poor farming skills and poor utilization of insecticides and pesticides.

A two-way analysis of variance was performed to explore the impact of climate change on crop farming and in different villages which were Lusilile, Udimaa, Makanda and Magasai. There was a statistically significant difference at the $P < 0.05$ level in the main effects of impacts on crop farming [$F(3, 362) = 71.451, P = 0.001$], with the effect size of 0.38 (partial eta squared) (Table 4). In addition, Post-hoc comparisons using the Tukey HSD test indicated that the mean score for impacts on the reduction of crop variety and species were statistically different at 0.05 level with mean score impacts of damaging crops and persistent of low yields, also

statistically different from the mean scores impacts of decrease in soil fertility as well as statistically different with the mean score impacts of drying of water sources all the same alpha level. Furthermore, there was a statistically significant difference on the mean scores of impacts of drying of water sources with the means scores impacts of damaging crops and persistent of low yields as well as statistically differences with the mean score impacts of decrease in soil fertility. On the other hand, the main effect for villages was not significant [F (3, 362) = 0.019, P = 0.997] for main effects for villages. Finally, interaction effect [F (4, 362) = 0.427, P = 0.861] did not reach statistical significance.

Statistical analysis of yield trends for maize, millet and groundnuts

An analysis of archival data from the district records were performed in order to observe if they were in coherence with farmers' perceptions on crop yield trends. In this case, the production yields data used covered twenty years/seasons (1997/1998) to (2016/2017). The analysis of production (yield in ton/ha) was done for some selected crops because these were major crops cultivated by the majority in the study area. Figure 5 presents the results of the analysis which revealed that there was a slightly decline in maize and millet yields while millet production showed a slight increase. Decline in maize yields was indicated by a regression equation $y = -0.0315x + 1.540$. The decline is explained by a 13.03% coefficient of determination ($R^2 = 0.1303$). On the other hand, the decline in groundnuts production was indicated by the regression equation, $y = -0.0082x + 0.894$. This decline is explained by a 1.97% coefficient of determination ($R^2 = 0.0197$). Moreover, the slight increase in production yields for millet was indicated by the regression equation, $y = 0.0264x + 0.847$ which is explained by a 10.45% coefficient of determination ($R^2 = 0.1045$). The increase in production of millet yields indicates its high tolerant capacity in semi-arid areas while the decline in trends of maize and groundnuts production yields indicated their low tolerant capacity in semi-arid areas like Manyoni District. Generally, it can be concluded that farmers perceptions on the impacts of climate change and variability on crop production were in consistence with that of the scientific analysis for the two crops, maize and groundnuts.

CONCLUSION AND RECOMMENDATION

This study aimed to assess the impacts of climate change and variability on crop farming systems at community level which were deemed to be often not well documented. Specifically, the study aimed at examining

the perception of farmers on climate change and variability, establishing the trends and patterns of rainfall and temperature and assessing their impacts on crop production in selected villages of Manyoni District, Tanzania. The study concludes that majority of the smallholder farmers perceive climate change and variability through observed decrease in rainfall, increase in temperature and increase in incidences of droughts. Furthermore, the study has established the patterns and trends of rainfall and temperature in the study area by using data accessed from the Tanzania Meteorological Agency in Dar es Salaam for Manyoni District. The data have generally shown a decrease in rainfall amounts and an increase in temperature, which are in conformity with the findings from the farmers' perceptions. Moreover, the study has presented various perceived impacts of climate change and variability on farming systems in the study villages. Crop yield data for maize and ground nuts have shown a decreasing trend while that of millet has shown an increasing trend proving that the crop was indeed versatile enough for this type of climate regime. Therefore, the study recommends that collective efforts from government and other stakeholders should be harnessed and implemented in order to respond to these impacts so as to improve food production and enhance households' food security in the district.

CONFLICT INTERESTS

The authors have not declared any conflict of interests.

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