Vol. 13(5), pp. 201-219, May 2019
DOI: 10.5897/AJEST2019.2650
Article Number: B4CB2AB60686
ISSN: 1996-0786

http://www.academicjournals.org/AJEST

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African Journal of Environmental Science and Technology

*Full Length Research Paper*

# Innovative pathways for enhancing climate change and variability resilience among agro-pastoral communities in semi-arid areas of Kiteto and Kilindi Districts, Tanzania

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Received 13 January, 2019; Accepted 4 March, 2019

**Climate change and variability threatens food security globally making life uncertain mostly for agro-pastoral communities in semi-arid areas. This has necessitated exploration of designed pathways with potentials to increase resilience among agro-pastoralists. This work investigates agro-pastoralists' innovative pathways for enhancing resilience to the impacts of climate change and variability in Kiteto and Kilindi districts. Mixed method research approach under correlation case study design was employed. Primary data were collected using household survey which sampled 384 households, Focus group discussion (n=6), in-depth interviews (key informants) and field visits. Descriptive statistics and thematic analysis were used in analyzing and presenting the findings. Majority of the respondents (81%) noted a decline and changes in seasonal rainfall and amount and increase in temperature trends (91.4%) in their areas for the past 30 years linked to reduced livestock production and cereals and pulses crop yields. These findings corroborate that from the Tanzania meteorological data (TMA). About 91.1% of the respondents said the major impacts of climate change and variability are decline in grazing/pasture lands, cultivated lands and water resources causing decreasing number of their livestock and crop productivity, ultimately food insecurity for a decade. To increase resilience, agro-pastoralists developed different innovative pathways, though most are similar. The main innovated pathways were livestock seasonal mobility, construction of traditional water points (Njoro), traditional grazing management system through traditional by-laws for pastures conservation/rotational use, growing of droughts-resistant mixed crops, Maasai traditional constructed water reservoirs (Mboutu), reducing stock numbers by selling, drought-tolerant forage species(cactus plants for Animal's fodder), keeping mixtures of herds and women transporting water by donkeys from traditional wells/Njoro. Government and other stakeholders are called upon to improve agro-pastoralists' adaptive capacity and increase households' food security status in the study areas.**

**Key words:** Agro-pastoralist, climate change, climate variability, pathways, Njoro, Mboutu, Alalili, lopolol, Kiteto District, Kilindi District.

## INTRODUCTION

Climate change and variability is increasingly being recognized as a critical global challenge in the twenty first century especially to agro-pastoral communities living in the arid and semi-arid lands (ASAL). As stipulated by FAO (2014a) and IPCC (2007a) in the third assessment report that, changes in rainfall patterns and seasons as well as temperature increase are expected to have substantial effects to both livestock and crop production. The rate of changing climate is not uniform around the globe and the magnitude of change varies in spatial temporal (Agrawala et al., 2003). The reports also forecast that mean annual global surface temperature has risen by about 0.71°C over the last 100 years with the largest share of the increment (0.55°C) observed just in the past three decades and it will increase by 1 to 3.5°C by 2100 and the global mean sea level will rise by 15 to 95 cm. Despite substantial uncertainty about future global temperature trends the IPCC's best estimates predict temperature increase ranging between 1.8 and 4°C by 2090-2099 compared to the 1980-1999 trends with increased extreme events such as tropical cyclones, increasing rainfall intensity, droughts, floods and increased probability of dry spells. Still it is projected that if greenhouse gases emissions (GHE) remain the leading cause of climate change and variability the mean annual global temperature will increase by 1.42-5.82°C by the end of the 21$^{th}$century (IPCC, 2007a).

Due to these reports on climatic variability, agro-pastoralists who depend on livestock keeping and rainfed agriculture production are considered as the most vulnerable group to climate change impacts because the two sectors (agriculture and livestock) are highly sensitive to climate change related extremes. Reports from World Bank (2015a) and FAO (2014b) show that there was a decline in the contribution of agriculture and livestock sub-sector to GDP from 45.1% in 2000 to 26.7% in 2007 due to changes in climatic parameters and other non-climatic stressors. Hence, semi-arid dry lands which support over 50% of the world's livestock and crop farming which 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 are all under stress due to global environmental climate. Therefore, due to unpredictable rainfall and changes in temperature, livestock and crop production has been severely affected resulting in decrease in food systems and security.

Africa continent has been most vulnerable to the impacts of climate change and variability because of low adaptive capacity and most people already are living in drought-prone areas and 220 million are exposed to drought each year and are highly vulnerable to food insecurity. Forexample, the noted impacts are fall in crop yield estimated at 10-20% by 2050 (Jones and Thornton, 2003), about 90% of people are prone to famine in the semiarid reside in Asia and Sub-Saharan Africa. Currently livestock keeping is a central livelihood activity to agro-pastoralists in Kiteto and Kilindi study districts that rely on it for income generation mainly from sales of milk, meat and blood consumption (Sangeda and Molel, 2014). Therefore, these semi-arid districts are among the most vulnerable districts in the country because of high dependence on this climate sensitive livelihood activity with low adaptive capacity. Climate stress affects the study districts in terms of amount, patterns and distribution of rainfall, longer dry spells and droughts and low livestock production through decreasing grazing land and water resources and damaging of crops (Sangeda et al*.,* 2013) all resulting to food shortage (Liwenga, 2003; Kangalawe and Liwenga, 2005).

Tanzania has taken several efforts to minimize the adverse effects of temperature and rainfall variations on various sectors including agriculture and livestock. The government and many non-government institutions have to some extent been supporting agro-pastoral communities through provision of weather forecast information education on good methods of farming and livestock keeping, food aids during chronic or transitory food shortages as well as improved crop seeds and livestock varieties; however the coverage of all these efforts is very limited to remote rural areas especially agro-pastoralists who dwell in very remote areas which lack accessibility/lack good infrastructures such as roads. As a response to all these effects of climate change and variability, several governments of Africa in particular have managed to introduce and establish policies, plans and programs to reduce the emerging effects across different sectors of productions including livestock and crop farming.

Building resilience has become very paramount to a great extent aiming to reduce vulnerabilities and increasing adaptive capacity, therefore enhancing resilience through various pathways to livestock and crop production means to increase the capacities of agro-pastoralists to adapt to different types of environmental shocks. Agro-pastoral communities in these semi-arid areas have been employing various traditional pathways through their indigenous knowledges systems (IKS) such as extending the cultivation of land into marginal areas, increased livestock mobility, mixed cropping, pastures conservation/rotational uses, off-farm/livestock keeping. However, the efficacy of all these innovated structures in

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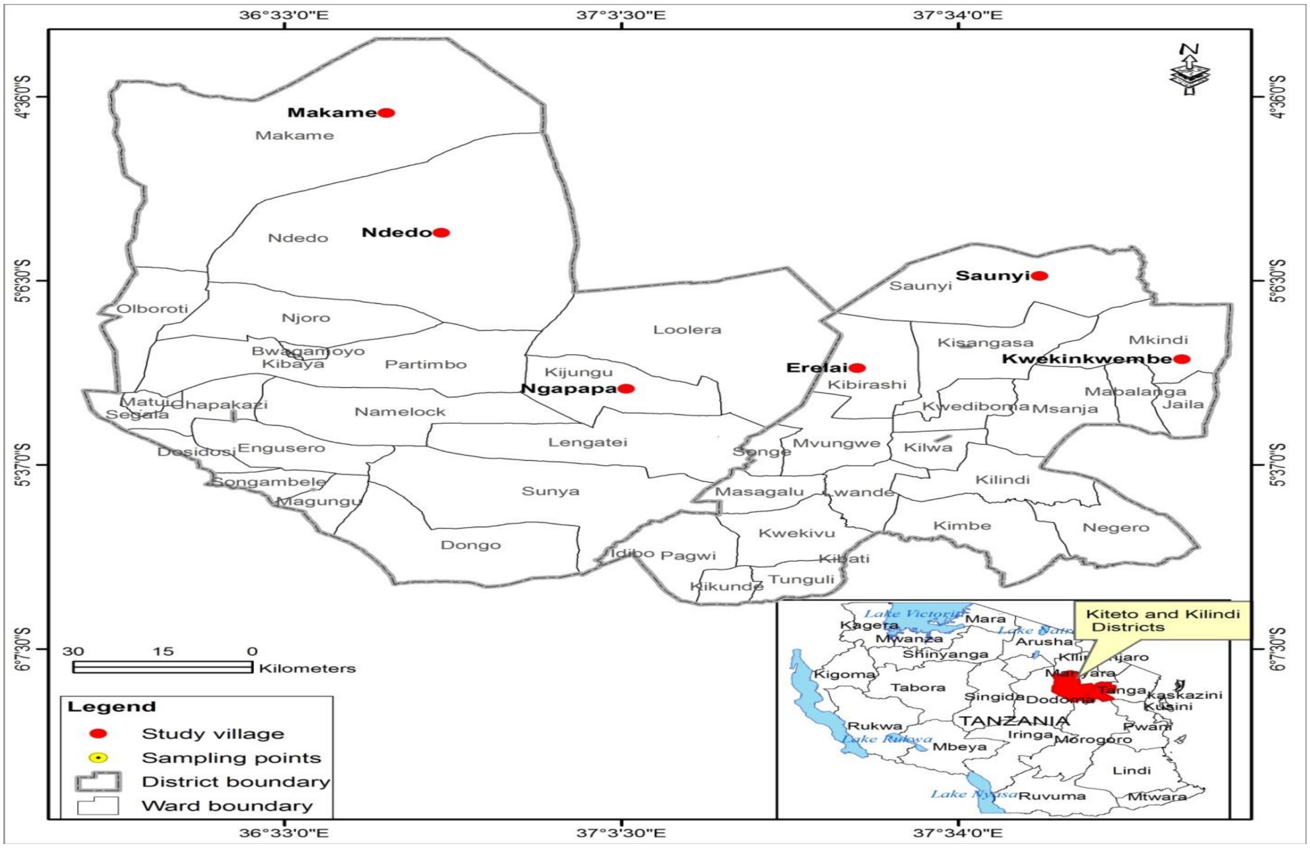


**Figure 1.** Kilindi and Kiteto Districts administrative areas and the sampled study villages.

guiding future adaptation strategies in accordance with the projected extreme events of climate change and variability is not well established and clearly understood. Hence, although few studies point the possibility that keeping heat-tolerant livestock is more prevalent in response to warming trends, still productivity of livestock has been down with reduced crops growing. This calls for effective and efficient pathways which will improve more livestock and crops productivity and improved food security and increasing resilience among agro-pastoral communities. Therefore, this paper aimed at investigating in detail the major traditional pathways to the impacts of climate change and variability on agro-pastoralism system at community level which are often not well documented especially in the study areas. Specifically, the paper examines the perception of agro-pastoralist on climate change and variability impacts, establishes the trends and patterns of rainfall and temperature and lastly come up with the innovated pathways to build resilience. 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 like the government, policy makers and non-government organizations to address issues related to pathways for increased resilience to the impacts of climate change and variability on agro-pastoralism in ASAL as an effort to enhance household food security.

## MATERIALS AND METHODS

### Description of the study areas

#### *Geographical location of Kiteto and Kilindi Districts*

Kiteto District is located in northern Tanzania, Manyara region; it covers an area of 16,685 km$^2$ which is about 34.1% of the whole area of Manyara region whereby out of 61,770 km$^2$ area coverage 80% is potential for animal keeping (Pastoralism) and 20% is for crops growing and 946 km$^2$ area is covered by water. It lies between Latitudes 04° 36'00''and 06° 7'30'south of the Equator and Longitudes 36° 33'00'' and 37° 36'00'' East of the Greenwich (Figure 1). It lies between 1,000 – 1,5000 m above sea level and the low land areas rise from 1,100 - 1,300 m a.s.l` while the high land areas rise from 1,300- 1,500m a.s.l. Most parts of the districts are not accessible by roads especially during the rainy seasons (KDC, 2017).

Kilindi District is located in south west of Tanga region; it was re-surveyed and declared as an independent district on 2003 covering 6,129 km$^2$. Kilindi district is one of the eight districts of Tanga region Tanzania; it is the second largest district in the region after Handeni with an area of 6,129 square kilometers and occupies 22.9% of the total regional area. It is located in north eastern of Tanzania. It lies between Latitudes 5$^0$ 18'00''and 6$^0$ 48'00'' south of the Equator and

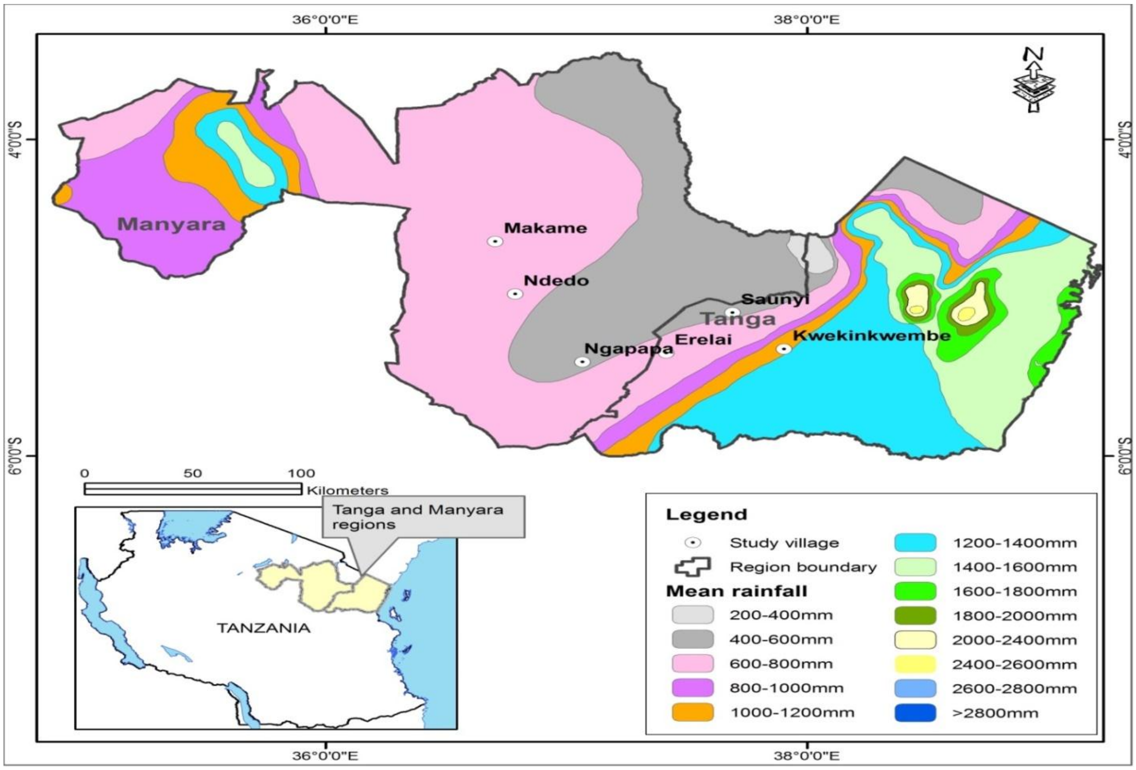


**Figure 2.** Mean Rainfall Distribution in Kiteto and Kilindi study districts.

Longitudes $37^0$ 55° 15'00'' and 38°45'00'' E degrees east of the Greenwich prime meridian (Figure 1). It is found within an altitude ranging from 300-1700 m above the sea level. Surface area is 6443.52 $km^2$ land coverage, of which 47% is potential for animal keeping, most is good soil for agriculture and agro-pastoralism is very dominant (KDC, 2017).

### *Climatic characteristics*

Kiteto District is considered to be arid to semi – arid type of climate. The average day and night temperature in the district is 25°C. To a large extent the type of climate is directly related to the topography of the area. The hot months are July, August, September, October and November. The cool months are March, April, May and June. Although there are remarkable variations in the amount of precipitation; the district is receiving an average of 350-700 mm of rainfall (Figure 2).

According to KDC (2017) Kilindi District is semi-arid with total area covered by 8,919,820 $km^2$, average annual rainfall of 500 mm ranging from 400 to 700 mm, and temperature ranging from 13 to 30°C. It has dual periods of unreliable rain seasons comprising short rains between October to January, and long rains from February to June. The cold months are May to July while the hottest months are from August to February (Figure 2).

### Data collection methods and analysis

This study employed a correlation-case study design constituting a mixed method research approach. Mixed research approach was applied in this study to provide triangulation and complementarities of the research findings (Creswell, 2013). Purposive sampling was used in the selection of the study area (Kiteto and Kilindi districts) due to its semiarid vulnerability condition, thus being more prone to climate change and variability.

Thereafter, key informants, particularly agricultural and livestock officers, livestock field officers, village leaders and elders were purposively involved in the study due to their potentiality to the research theme. Also, focus group discussions (FGD) and in-depth interviews were done in all study villages aiming to capture qualitative information. Simple random sampling was used in the selection of agro-pastoral communities. The sampling frame of this study comprised 3843 households selected from six villages, namely Saunyi, Kwekinkwembe, Erelai, Makame, Ndedo and Ngapapa. Based on the sampling frame above a total of 384 households were technically selected by using a formula proposed by Israel (2009). The formula which is based on 95% confidence level and P = 0.05 read as:

$$n = \frac{N}{1 + N(e)^2}$$

Where n is the sample size to be calculated, N is the total population of the study (households), and e is the level of precision or margin of error measured by probability scale of 5%. Therefore, plugging data into the formula, the following was in order;

$$n = \frac{3843}{1 + 3843(0.05)^2}$$

$$n = \frac{3843}{10}$$

$$n = 384$$

The calculated sample size was used to compute the proportion number of households in all study villages that was determined by the number of households in each village. The formula used read as;

$$n_h = \frac{N_h}{N} n$$

This resulted in a proportional sample size selected in each village where Saunyi was represented by 83 household heads, Kwekinkwembe 90, Erelai, 43, Makame, 75, Ndedo, 50 and Ngapapa, 43 making a total of 384 household heads used in the sample size. Primary data were the main source of information for this study based on qualitative and quantitative approaches and were also collected through focus group discussion (n=6 for all study village), in-depth interviews (n=10), field observation through transect walks deemed necessary to confirm some of the issues raised during in-depth interviews, focus group discussions and structured questionnaires for socio-economic survey (n=384). Both closed and open-ended questionnaires were administrated to agro-pastoral communities and government officials who were key informants. In-depth interviews, FGD and field observations were used to complete and control the quality of information collected by household socio-economic survey. Secondary information/data were obtained from published and unpublished documents and reports from different sources like rainfall and temperature data collected from Tanzania Meteorological Agency, crop yield data (maize and beans) livestock data(cattle, goats and sheeps) were collected from National Bureau of Statistics, Ministry of Agriculture, Food and Cooperatives; District Agricultural and Livestock Development Offices (DALDOs). Different publications, books, theses and journals from the libraries of University of Dar es Salaam (UDSM), Institute of Resource Assessment (IRA), government policy documents and and websites were reviewed. In all the information collected were perceived impacts/vulnerability, innovated pathways and challenges.

Quantitative data collected from the questionnaire survey were edited, to improve the quality for coding. The collected data were edited to improve the quality for coding. Analysis was carried out through the use of two software packages for data analysis namely Statistical Package for Social Sciences (IBM SPSS version 20) and Microsoft excel 2010. The software packages enabled the data to be summarized using summary statistics (frequencies and percentages) which simplified the description and presentation of the study findings as well as making patterns and trends analysis. Rainfall, temperature, livestock 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. Qualitative data from focus group discussions, in-depth interviews and field observation were analysed through thematic analysis. Simple random sampling procedure was used in the selection of the sampled households whereby about 90.7% of males and 9.3% of females were interviewed.

## RESULTS AND DISCUSSION

### Socio-economic profile of respondents in the study areas

#### *Household heads education levels*

Village-wise household heads education levels show that across all study villages the highest rate of illiteracy was above 60%. This implies low adaptive capacity to the effects of climate change and variability with lowest resilience status; Erelai leads by 84% followed by Saunyi (81%) (Figure 3). These findings concur with Deressa et al., (2008) who noted that, low level of education in Ethiopia represented low adaptive capacity to climate change and variability. Furthermore, Mwalukasa (2013) confirms that reasonable education levels enable agro-pastoralists to receive and transmit farming and animal keeping education at local levels.

In general the findings indicate that the majority (76%) of the agro-pastoral communities in the study districts had no formal education level, followed by holders of primary education (17.7%); those with adult education were 3.6%; secondary education were 1.8% while very few had post-secondary education (0.8%) confirmed through per village-wise in Figure 3. Also, all study villages almost have the highest rate of illiteracy above 60%, which imply low adaptive capacity to the effects of climate change and variability.

### *Major livelihood activities in the study areas*

Livestock keeping is a primary livelihood activity carried out in Kiteto District. The economy of this district depends almost entirely on livestock and crop farming in a small scale. Animals kept are cattle, goats, sheep, donkeys and chicken which are mostly done by Maasai; major crops grown are maize, beans, sunflower, cassava, millet and finger millet. Agro-pastoralism in the district accounts for 60%; crop growing (22.8%), and pure pastoralism (17.2%) hence, agro-pastoralism is mostly dominant livelihood activity. Notably agriculture is characterized by low productivity due to unreliable rainfall (URT, 2016).

In Kilindi District, agriculture is a primary activity carried out in the district, followed by animal keeping. It is reported that in the district agriculture accounts for more than 60% having the largest number of smallholders who also keep animals (agro-pastoralists) (40%) and is the main producer in the region as National Food Reserve Authority (NFRA) singled out the district as main collector of food crops in Tanga region (URT, 2014). This implies that the majority of the people in the area are smallholders characterized as depending on rain-fed agriculture which is so vulnerable to climate change and variability effects. Major crops grown are maize, beans, sunflower, cassava, sweet potatoes, millet and finger millet, mangoes, bananas, sugarcane. However, currently there is introduction of new crops like cashwenut, Haricot bean pigeon peas and cow pease as drought resistant crops and animals kept are cattle, goats, sheep and donkeys

The study confined to two agro-pastoral districts namely Kiteto and kilindi districts, taking three wards from each district based on different agro-ecological zones. About six study villages were selected, one village from each ward, namely Saunyi Kwekinkwembe Erelai Makame Ndedo and Ngapapa. The occupation

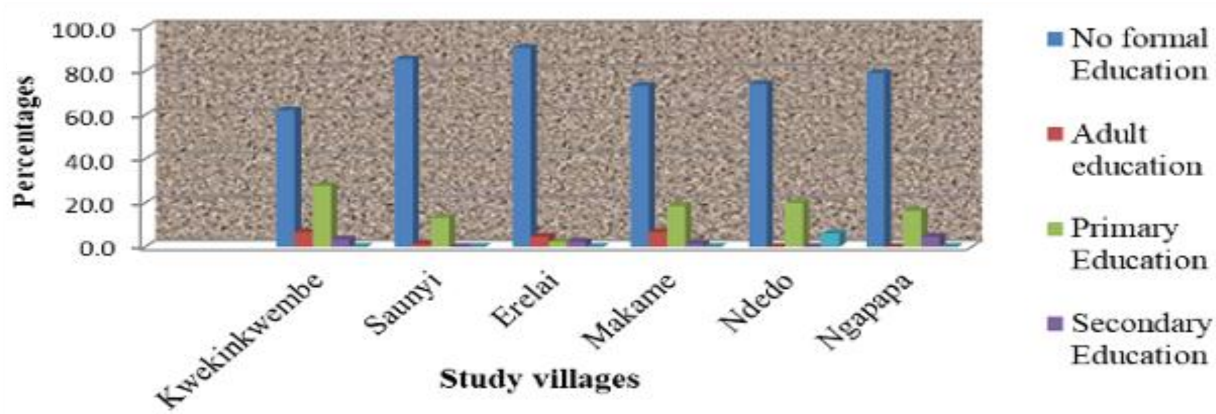


**Figure 3.** Village-wise household heads education levels.

performed by the household heads determines the income levels which in turn, influences vulnerability of the household to climate change and variability effects. The results indicate that, majority, about 44.4% were pure pastoralists and the remaining were the said agro-pastoralists (37.5%) and other non-farming activities. This implies that due to persistence of drought extreme, majority of agro-pastoralist have drifted to pure pastoralist. This is new observation as it is contrary to most literatures. Based on income levels in the study areas, the agro-pastoralists were wealthier than livestock keepers only thus being able to easily adapt to climate change and variability and food insecurity. The agro-pastoralists were able to sell part of their livestock to buy food in time of crop failure; the agro-pastoralists were much food secured than pure livestock keepers.

Referring to Table 1 on respondents' occupation, the results show a variety of livelihood activities that varied among and within study vilages. The findings indicate that about 44.4% of major activity was pure pastoralists who keep livestock only, and the second was agro-pastoralists (37.5%) who keep livestock and cultivate in small farms as supplement. These findings are contrary with the results from study districts report which shows more than 60% are purely crop farmers. This findings are in line with Mwakaje (2013) who found that, about 97% of the agro-pastoralists had lost at least 50% of their farm crop harvest due to drought and 44.5% had lost them due to pests and diseases which made them to drift from crop cultivation to pure pastoralism. One of the reasons for this change could be related to the limited land for cattle grazing or pastures and mobility. Starting farming could probably enhance the agro-pastoralists' livelihoods; it could also mean more pressure on natural resources in terms of clearing the bush for agriculture. It may also lead to conflicts between other land users such as investors and hunting operators in the areas.

Livelihood diversification has been one of the recommended in this era of climatic stresses as it increases resilience. The results show that, agro-pastoral communities have increased livelihoods diversification with smallest number from various activities like keeping animals only and mixing both keeping animals and cultivation, petty business (5.1), hunting (4.4%), beekeeping (4%), collecting and selling firewood (1.7%), arts and craft works (1.4), making and selling charcoal(1.2%), casual labour (0.8%), wage employment and mining (0.4%). Increased diversification among agro-pastoralist means increased resilient towards responding to stresses caused by climate change and variability in semi-arid areas. The study results show that agro-pastoralists have been increasing their diversification as a response to climatic stresses; however the extent of diversification is still low as shown in Table 1. Village-wise the findings indicate variation in major livelihood activity (livestock keeping) depending on vulnerability from climate change and variability specifically droughts such as Ndedo village (55.1%), Ngapapa (55.6%), Saunyi (65.4%) and Erelai (67.4%); other study villages like Kwekinkwembe (15.1%) had smallest number of pure livestock keepers due to less vulnerability from droughts.

Reflecting from the same (Table 1) it is interesting to see Erelai village which is most vulnerable to droughts has the lowest level of diversification than all other study villages (livestock keeping only and both keeping livestock and crop growing); this implies increased vulnerability to food insecurity. These findings also suggest that the agro- pastoralists' economy is gradually switching or drifting to expanding agriculture in marginal areas which depend on to rainfall availability in a particular year to which precaution should be provided to agro-pastoralists (Majule, 2008; Myeya et al., 2016).

### *Agro-pastoralists perceived impacts of climate change and variability*

Field results indicated that, climate change and variability

**Table 1.** Respondent's occupation.

| Economic activities | Districts | | | | | | | | | | | | Total N=384 | Total % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Kiteto | | | | | | Kilindi | | | | | | | |
| | Ndedo | | Makame | | Ngapapa | | Kwekinkwembe | | Saunyi | | Erelai | | | |
| | N | % | N | % | N | % | N | % | N | % | N | % | | |
| Livestock keeping only | 38 | 55.1 | 33 | 37.1 | 25 | 55.6 | 19 | 15.1 | 62 | 65.4 | 29 | 67.4 | **206** | **44** |
| Both livestock keeping and crops growing | 11 | 15.9 | 41 | 46.1 | 17 | 37.8 | 71 | 56.3 | 20 | 21.4 | 14 | 32.6 | **175** | **37.3** |
| Casual labour | 0 | 0 | | 0 | 0 | 0 | 2 | 1.6 | 2 | 2.2 | 0 | 0 | **4** | **0.8** |
| Petty business | 5 | 7.2 | 6 | 6.7 | 1 | 2.2 | 10 | 7.9 | 2 | 2.2 | 0 | 0 | **24** | **5.1** |
| Wage employment | 0 | 0 | 0 | 0 | 0 | 0 | 1 | .8 | 1 | 1.1 | 0 | 0 | **2** | **0.4** |
| Beekeeping | 4 | 5.8 | 3 | 3.4 | 0 | 0 | 6 | 4.8 | 1 | 1.1 | 0 | 0 | **14** | **3** |
| Mining | 0 | 0 | 0 | 0 | 0 | 0 | 1 | .8 | 1 | 1.1 | 0 | 0 | **2** | **0.4** |
| Arts Craft works | 1 | 1.4 | 1 | 1.1 | 0 | 0 | 4 | 3.2 | 1 | 1.1 | 0 | 0 | **7** | **1.4** |
| Making and selling charcoal | 2 | 2.9 | 1 | 1.1 | 1 | 2.2 | 1 | .8 | 1 | 1.1 | 0 | 0 | **6** | **1.2** |
| Collecting and Selling firewood | 4 | 4.4 | 0 | 0 | 0 | 0 | 5 | 4.0 | 0 | 0 | 0 | 0 | **8** | **1.7** |
| Hunting | 5 | 7.3 | 4 | 4.5 | 1 | 2.2 | 8 | 4.7 | 3 | 3.3 | 0 | 0 | **21** | **4.4** |
| Total | **70** | **100** | **89** | **100** | **45** | **100** | **128** | **100** | **94** | **100** | **43** | **100** | **469** | **100** |

impact in the study areas were felt by agro-pastoralists in the 1980s' and still felt till date. It was also observed that all villages studied have been experiencing the impact of climate change and variability. Findings further indicate that majority of the respondents mentioned decline in number of their livestock (91.1%) to be the major indictor of climate change and variability in the study areas. Decline in the number of animals based on the extent of food insecurity has been faced for six years consecutively. This is linked to decreased rainfall amount and duration which affects pastures and water availability to animals.

Moreover, increased droughts were noted to be the second felt impact indicator mostly pointed by 89.1% of the respondents. The respondents linked increased drought that has been existing for a very long time in a repetitive way. It has great effect on water and pastures which form the basis for animals' food. Recurrent food shortage was also one among the major impact of climate change and variability in Kiteto and Kilindi districts as pointed by 87.2% of the respondents. Respondents reported that, due to prolonged droughts which result in crop failure like maize and beans as well as deaths of their animals especially cattle and goats which they depend on for food through meat, milk and blood, they have been facing food insecurity since 1990s. Apart from depending on cattle for food directly, they sell so as to buy other food sources like sugar, maize flour from shops; now they fail because of low income as the price of cattle and goats during dry season becomes very low.

Respondents further reported on the emerged new livestock diseases which were reported by 86.5% of the respondents. The agro-pastoralist emphasized that, nowadays due to changing environment. There is emergency of new animal diseases that never existed in their locality. This has caused deaths of large number of their animals. Such new diseases are rinder pests (Maasai locally known Olodwa), heart water (Maasai locally known Olmiro) Anaplasmosis (Maasai locally known as Emonywa); the old ones which have been killing their animals are lung sickness CBPP (Maasai known as Olikipei), tsetsefly/Ndorobo, Anthrax, East Coast Fever (Ndigana kali, ECF) and Foot and Mouth disease (Alerobi). Generally, livestock and crop production has been in declining trend with great variability throughout the period of study; however the decline is not similar among crops and livestock category; they all impact negatively food security of agro-pastoral communities.

### *Agro-pastoralists' perceptions of long-term changes in rainfall and temperature*

71.1% of the respondents reported increased temperature. The agro-pastoralist emphasized that, nowadays' temperature is very high affecting growing of pastures; thus they construct traditional wells for their animals and for domestic use. The respondents lamented that dry spells have increased compared to previous years. Based on their experience, dry spells happened in February lasting for two to three weeks. Dry spells are unpredictable as they occur even in January (crops and pastures growing season), thus affecting the whole growing season and pastures. The study analysed agro-pastoralists' perceptions of temperature and rainfall variability and change for the past 30 years. The results show that the majority of the respondents (91.4%) felt that temperature was increasing. Village-wise, more than 85% of agro-pastoral communities in each village reported to have noted increased temperature rates (Figure 4). Agro-pastoralist perceived an increase in duration of hot days, indicating that generally temperature was on the increasing trends. Also, Lema and Majule (2009) reported this concern in Manyoni district.

Apart from temperature trends and patterns, majority of agro-pastoralist (81%) noted decreasing rainfall while about (3.6%) reported to have noted no changes. Decreasing in rainfall was explained based on rainfall amount, duration, distribution and intervals. They further reported that rainfall onset and cessation dates were unpredictable (seasonal changes) (Figure 5). Different studies reported similar observation from various parts of Africa. For example, studies undertaken by Deressa et al. (2011) and IPCC (2007b) indicated that there has been a decline in rainfall amount in other parts of Tanzania and Africa in general. Swai et al. (2012) also noted that, rainfall has been more erratic, more unpredictable and continues to decrease in amount in Bahi and Kondoa districts, Tanzania. The findings of this study were also supported during interview with key informants in Ngapapa village as narrated:

*"………Really, there is an increase in temperature and reduced rainfall in Kiteto district especially in Ndedo village. Increased temperature and reduced rainfall have caused water decrease in our wells locally known as Njoro for every year in a very short period of time. Actually, water from the mentioned wells was used for 6 months after the rainfall cessation for animals drinking and domestic uses, but nowadays it takes only 2 to three months for our wells to dry off"…Female 53 years in Ngapapa village.*

### *Statistical analysis of rainfall and temperature patterns and trends as scientific evidences of climate change and variability in the study areas*

Temperature and rainfall data were obtained from TMA Offices and covered two weather stations one from each study district, namely, Kibaya weather station for Kiteto district and Kwediboma weather station for Kilindi District of which all covered over a period of 30 years (1986-2016). Scientific analysis of rainfall and temperature data was done in order to determine if there was consistency between these data with the agro-pastoralist's perceptions on changes in rainfall and temperature collected during the household survey.

### *Temperature trends*

Figures 6 shows the trends in temperature change in the period of 1986 to 2016, of Kibaya weather station(Kiteto district) whereby the fitted linear trends in the Maximum temperature (Tmax) is statistically significant at the 5% level of significant (P=0.0124) with $R^2$=0.0575. This is presented by higher percentages (5.7%) of observed variance throughout the study period. Based on the minimum temperature for Kibaya weather station/Kiteto District, it shows statistically significance at 5% level with slop increasing faster (slope 0.0393°C $y^{-1}$) than the maximum (0.0124°C $y^{-1}$). This is presented by higher percentages (61.6%) of observed variance in the minimum ($R^2$=0.6161) than that observed, 5.7% in the maximum ($R^2$=0.0575) throughout the study period 1986 to 2016.Again, the maximum temperature trends for Kwediboma weather station for the period of 30 years from 1986 to 2016 in Kilindi district, the fitted linear trends is statistically significant at the 5% level of significance (P=0.0161) with $R^2$=0.2239. Also for the minimum temperature trends increased very faster (slope 0.0758°C $y^{-1}$) than the maximum (0.0161°C $y^{-1}$). This is presented by a higher percentages (74.02%) of observed variance in the minimum ($R^2$=0.7402) than that observed, 22.3% in the maximum ($R^2$=0.2239) throughout the study period 1986 to 2016 (Figure 7).

Generally, from the meteorological data analysis, it is evident that the minimum temperatures increased at a higher rate than the maximum at both weather stations. These results concur with previous studies done in semi-arid areas worldwide by Owusu-Sekyere et al. (2011), Kangalawe and Lyimo (2013). The increase in both the minimum and maximum temperature implies the increase of more frequent warmer days and nights and decreased cold days and nights. Also looking for seasonal mean for minimum and maximum temperature for the two study districts it shows increasing temperature in the rain seasons which are all significant. Therefore, changes in either minimum or maximum temperature have negative effects on the grown crops, water and pastures for livestock especially when the change amount exceeds the optimum value for particular crop and animal species.

### *Rainfall patterns and trends*

Rainfall patterns and trends are important guides to agro-

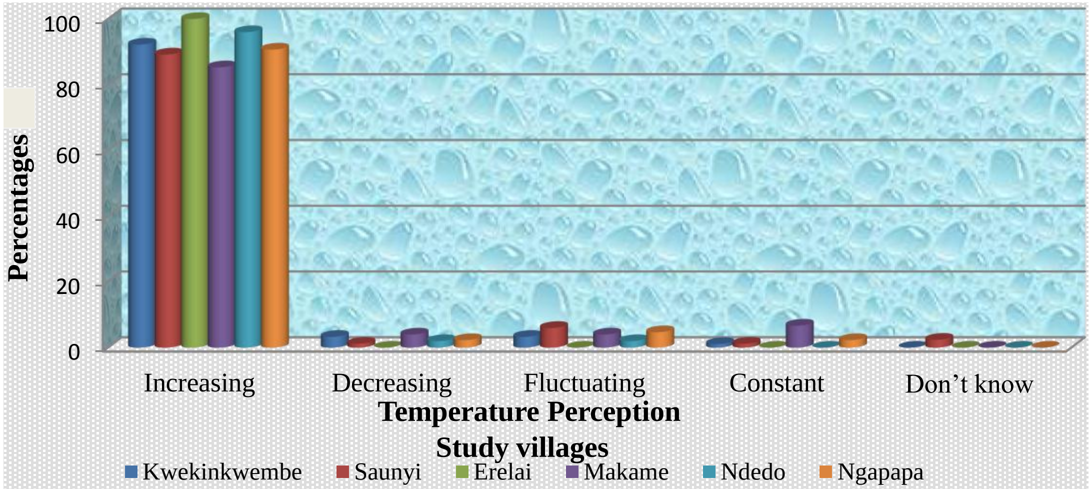


**Figure 4.** Agro-pastoralist perception on temperature variability.

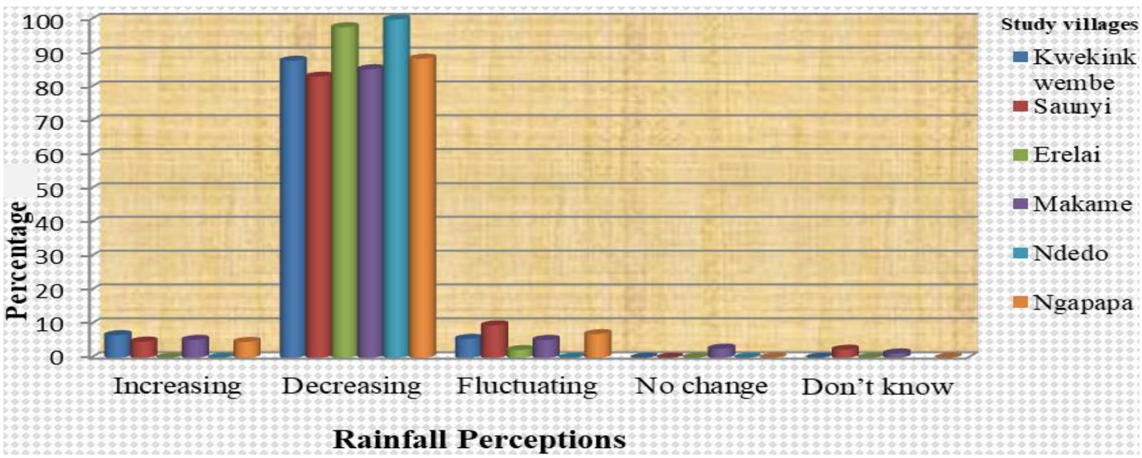


**Figure 5.** Agro-pastoralist perception on rainfall variability.

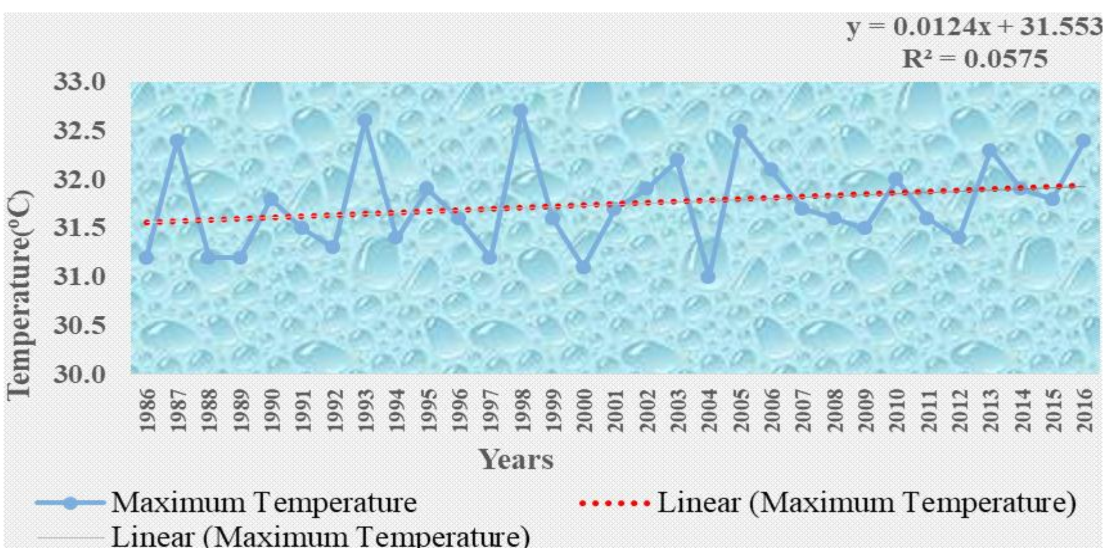


**Figure 6.** Kibaya weather station annual mean maximum temperature 1986 to 2016.

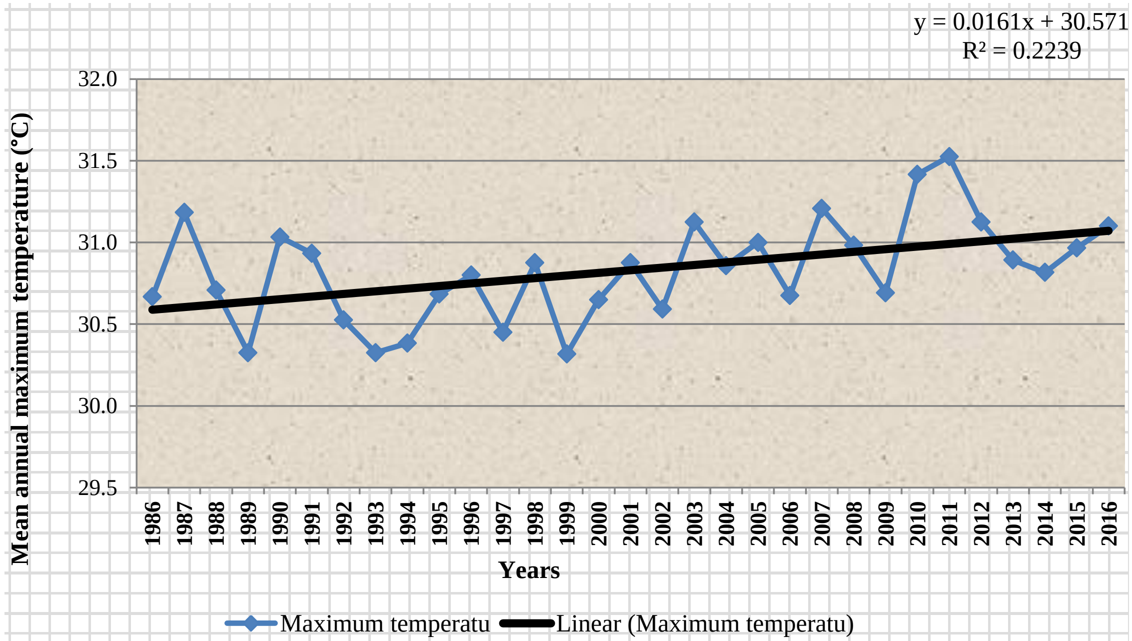


**Figure 7.** Kwediboma Village Annual Mean Maximum Temperature 1986 to 2016.

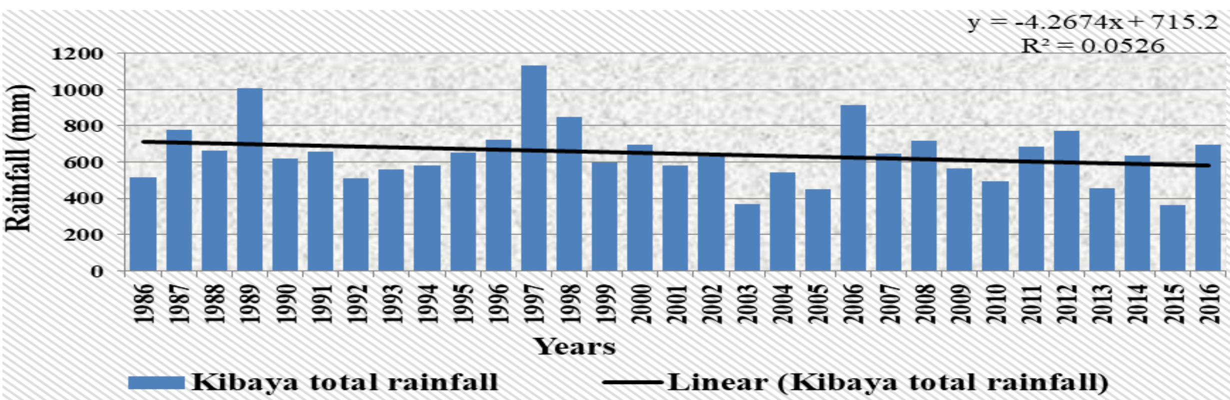


**Figure 8.** Annual rainfall for Kibaya weather station, 1986 to 2016.

pastoralists because they determine timing of different farming and animal keeping activities like pastures and water conservation and use, farm preparation, planting, weeding and harvesting. This study focused on quantity (amount) and distribution of rainfall, that is the total amount and their distribution. Analysis of meteorological data shows a non-significant decline in the trends of total annual rainfall in both weather stations. Using simple regression model, the analysis showed a slight decreasing trend in the pattern of annual rainfall. In Kibaya weather station (Kiteto District) the decrease was more noticeable as it shows a decline trend of $R^2$= 0.005 (y = -4.2674 + 715.2) (Figure 8).

The same finding was observed in kwediboma weather station (Kilindi District), whereby the patterns and trend were $R^2$= 0.1383 (y = -6.873 + 660.49) (Figure 9). As a comparison of the rainfall patterns in the two recorded rainfall stations, each station indicates that rainfall started from higher at the beginning of the study periods through varying levels, Kwediboma weather station for Kilindi District was leading to Kibaya weather station in Kiteto District. Rainfall decreased much from 2002 (356 mm) and 2016 (333 mm) for kwediboma weather station and 2003 (367 mm) and 2015 (363 mm) for Kibaya weather station, but a higher decline was observed in Kibaya weather station because it is purely located in semi-arid climate whereby rainfall is below 700 to 350 mm. However, Kibaya weather station received higher rainfall

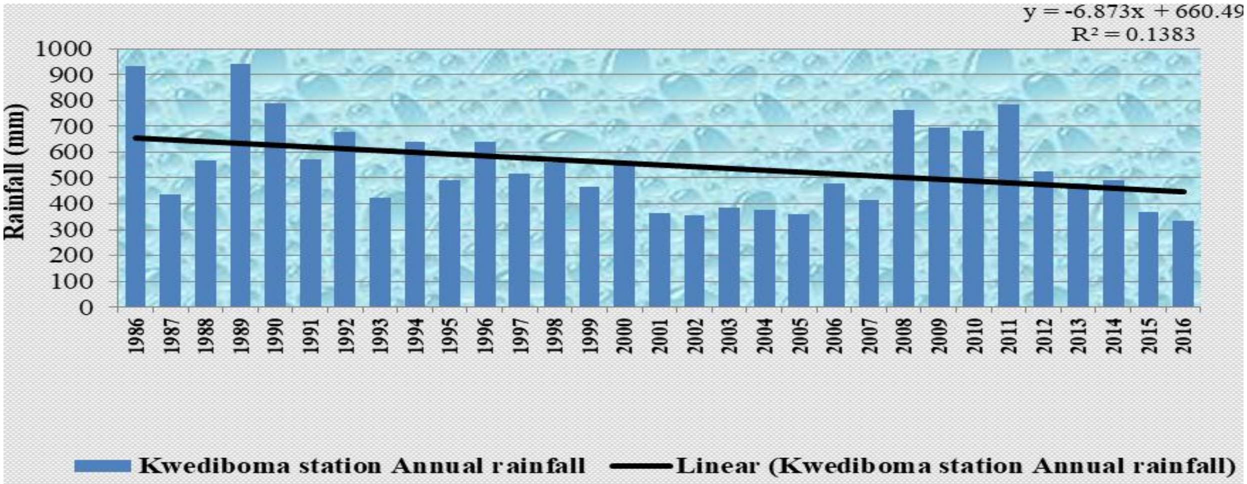


**Figure 9.** Annual Rainfall for Kwediboma Weather Station, 1986 to 2016.

in 1997/1998 years which was termed as Elnino years as well as Kwediboma which shows an increased rainfall amount. Kilindi District is located in different climatic zones which receive highest rainfall of 941 mm yearly, but also within Kilindi District northern part of the district receives total rainfall of 400 to 600 mm than the southern part which receives total rainfall of between 800 to 1200 mm; and it is this part where agro-pastoralism is practiced and the northern being pure Maasai pastoralist as minimal total rainfall limit crop growing (Figure 2). Kiteto District northern part of the district receives total rainfall of below 600 mm where pure Maasai pastoralists are dwelling and southern part receives total rainfall of between 650 to 800mm which allows agro-pastoralist dwellings. Generally, the two study districts experience great variability in rainfall amount and distribution which are typically indicators of climate change and variability as geographically all are found in semi-arid climates, the situation which has historically caused transitional food insecurity in the study areas.

### *Innovated pathways for enhancing climate change and variability resilience among Agro-pastoralist in Kiteto and Kilindi Semi-arid areas*

The agro-pastoral communities have been described as "masters of innovative traditional adaptation strategies in dry lands", actively relying on variability to maximize animals productivity during periods of plenty and scarcity and carefully managing rangelands during periods of food shortage (Lyimo and Kangalawe 2010; Msangi et al., 2014). The findings from the study revealed that agro-pastoralists in the study areas employ a number of highly specific risk spreading strategies to safeguard their herds and family food security in the face of unpredictable and sometimes extreme climatic change and variability events such as drought, temperature rise, emerged livestock disease and shortage of water and pastures. Increased sustainable innovative pathways as to develop resilience upon climate change and variability for ensuring the rational use of the natural resource base on which the herds depend and also build strong social networks and food security. Overall, the main innovated pathways in order of importance were seasonal livestock mobility, construction of traditional wells/points, use of traditional by-laws for pastures conservation/rotational use, reducing stock number by selling and transporting water by donkeys from traditional wells (Figure 10).

Like in other parts of semi-arid areas of the world, agro-pastoralists in study villages areas have implemented various measures in adapting to climate change and variability impacts. Village-wise as shown in Figure 10, seasonal migration/mobility with livestock was one of the most practiced by 90%; however, Saunyi, Erelai and Ndedo use seasonal migration for 100% as adaptation to the impacts of climate change and variability due to adverse effects of droughts in these villages (Figure 10).

### *Seasonal migration with livestock to distant areas (livestock mobility)*

Results from households, focus group discussion and key informants indicated that agro-pastoralists migrate to distant areas for search of water and pastures during dry seasons when water sources have been depleted and pastures dry up or are not enough to sustain their livestock in the areas. The findings indicate that about 95% of respondents mentioned agro-pastoral mobility as main resilient strategy against droughts. Village-wise, about 100% of respondents from Saunyi, Erelai and Ndedo practice mobility as main adaptation strategy especially during dry season. These villages are found in

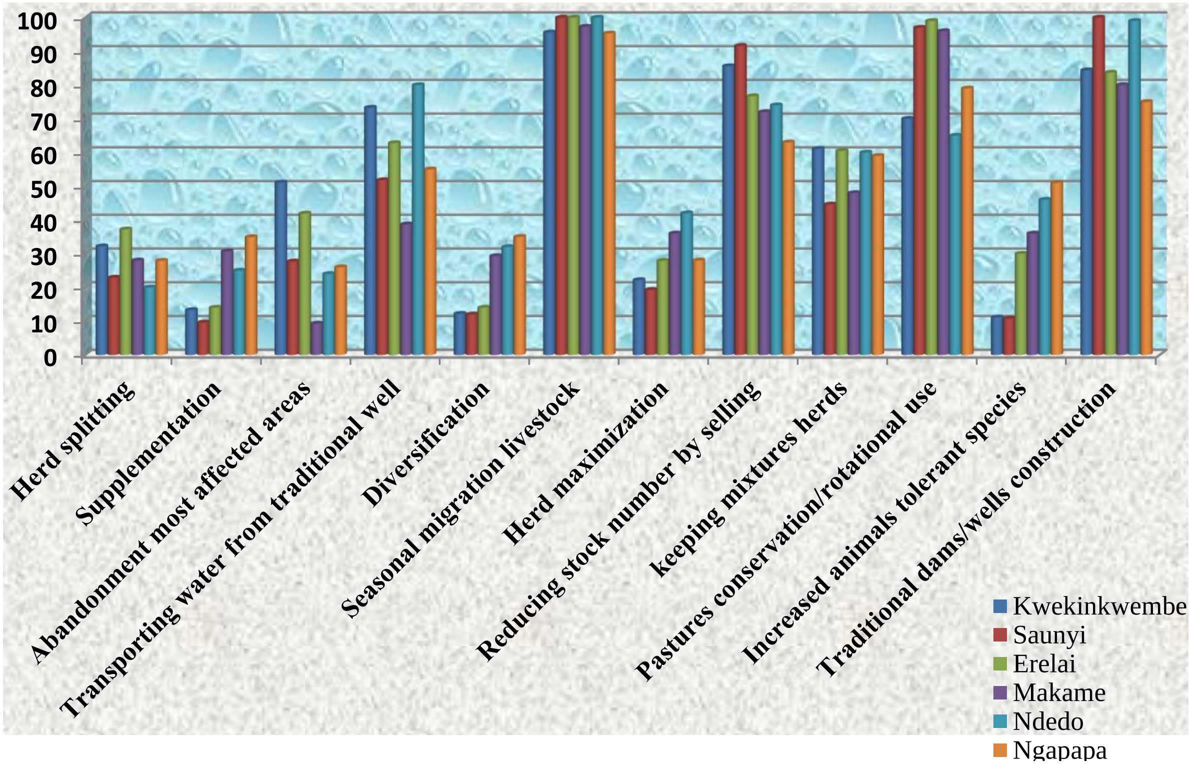


**Figure 10.** Village-wise agro-pastoralist perceived innovated pathways among study villages.

areas with rainfall between (400- 700 mm) (Figure 2), other villages were less because droughts were not much bigger as it was in other study villages. Through ArcGIS, there is great change in land cover due to increase of settlements, farming lands caused by population increase and urbanization making decline of both pastures and water sources, resulting to changes in livestock routes in response to changes in grazing land and water resources.

Generally, the assessment of spatial data changes over livestock routes in response to water resources and pasture lands availability revealed that about 7% of stock routes have been lost, 2% have been narrowed, and 91% are now used as roads within villages. These changes are attributed to the increase of settlements and cultivated lands. These findings concur with the study of Ernest et al. (2015) who found anthropogenic activities (settlements and cultivated areas) increased between 1980 and 2010 causing greater changes in land cover. Therefore under these changes, agro-pastoral mobility has been increasing in different parts of the country.

For example during FGD it was observed that since 1980s agro-pastoralists' mobility in search of water and pastures was on the increasing trend when compared to previous years back to 1970s. The agro-pastoralists' migration for search of pasture and water was classified into two categories: internal migration (within the country moving in short distances) and external (beyond country's borders long distances); it was practiced by group of agro-pastoralists. Internally, agro-pastoralists migrated to new emerging routes in different regions and districts of Morogoro, Tanga, Coast, Dodoma, Iringa and Kilimanjaro regions and externally the destination is Kenya and few to Uganda. In the process of migration on the way crashes with smallholder farmers happened which involved fighting and sometimes deaths. Saringe (2011) observed that mobility remains the most important agro-pastoralists' adaptation to spatial and temporal variations in rainfall and during drought years. Martin (2012) also observed that agro-pastoral season mobility is one of the best adapted and useful means of obtaining what livestock need in an ever-variable environment.

Since agro-pastoralism is adapted to variable forage supplies and water distribution, the ability of agro-pastoralists to survive in these marginal lands is attributed to their opportunistic mobility and diversified livestock husbandry. Rainfall unpredictability, both in space and time causes uneven and unpredictable levels of productivity. Also according to Meena et al. (2006), agro-pastoral seasonal mobility has proven to be the best form of land use of highly variable and heterogeneous pastoral lands in the arid and semi-arid regions as well as in the mountainous regions due to the fact that it enables the livestock to grade the diffuse and scattered vegetation of the regions rangelands or take refuge to more favorable sites during drought. However despite mobility being the most practiced among agro-pastoral communities (Maasai) there is a need to design better ways of seasonal mobility especially planning special areas for animal keeping with specified animal routes as well to review current multi-sectoral policies and laws.

***The use of traditional by-laws for pastures conservation/rotational use***

The establishment and enactment of traditional by-laws for pastures conservation in Maasai land that regulate livestock grazing was revealed by household respondents as one of resilience and adaptive system that has been used by agro-pastoralists against the impacts of climate change and variability. This was pointed out by 65% of respondents in both study villages/sites; however the practice was not similar among villages; the technique was mostly applied by Erelai (99%), Saunyi (97%) and Makame (96%). It was noted that agro-pastoralists had traditional knowledge on how to preserve their pasture/forage for reducing forage shortage during pasture stress times especially during dry season in almost all study villages (Figure 10). Examples of the by-laws are those related to pasture conservation and water conservation. As for pastures, grazing areas are divided into restricted and non-restricted zones (*lopolol*). In each zone there are by laws guarding the utilization of each zone. Defaulters of the by-laws are normally fined for Tsh 200,000 when one grazes animals to restricted pastures for dry season. Regarding water conservation, constructions of traditional water points (Njoro) are common in the study area especially was observed in Saunyi, Ndedo, Makame and Erelai. In the study areas, some local excavated dams are restricted to use until dry season (*Serenge*) and others are not restricted and these are used during the rainy season. Defaulters are normally fined. This is supported by Mahonge et al. (2014) who assert that some strategies like excavation of small dams are the initiatives of the pastoralists themselves based on their long-term interaction and experience with the environment. These are meant to avoid walking long distances in search of water. Therefore, despite having modern day by-laws, the agro-pastoralists have their own designed innovative adaptation structures which have been existing for time immemorial, and should be integrated with modern-one to increase environmental sustainability (Figure 11a-d).

***Traditional water points (wells) construction (locally known as Njoro)***

During this study, it was revealed that the constructed wells/water points (varying in size and depth) were used only by the agro-pastoral community members in all study villages. For outsiders, they must seek permission from the village leaders who would provide permission, however these wells mostly are under particular clan, hence sometimes one to get water needs permission from the clan which constructed such well. It was revealed that, about 75% mentioned this pathway as potential strategy during dry season as majority used these water points for livestock sometimes even domestic uses. It was found that most of these villages have wells which differ in terms of size and depth. Construction of wells are ways of ensuring a year round supply of water for the community domestic use and livestock as have been one of the strategies to adapt water availability problems especially during dry season. Village-wise, Saunyi (100%), Ndedo (99%), Kwekinkwembe (84.4%) and Makame (96%) had more than 45 constructed wells under different clans.

These wells are usually constructed by the agro-pastoralists themselves sometimes in collaboration with NGO's like RED CROSS in Ndedo village. The most water points were constructed locally without being built by concrete walls as they are dug deepward until it reaches the water table (Figure 12a-d). This technology is very material as it assures water availability all the time from rainy season to dry season. But things to note is that, during rainy season these wells are closed since livestock use other natural sources of water like natural streams and ponds. Normally the management of these wells is under traditional by-laws guided by Maasai believes because they are closed and opened through traditional cerebrations involving traditional prays. It is a new and preferred strategy due to several reasons: it protects water from extensive evaporation as trees are planted around the wells; acts as a slow filter for water resulting in potable water; water becomes clean for domestic use.

***Reducing stock number by selling during dry season to buy food***

Food insecurity has been one of the push factors for the most of agro-pastoral communities in study villages to sell their livestock especially during dry season as it was mostly observed in Erelai, Ngapapa, Makame and Saunyi villages. About 60% of respondents mentioned reducing livestock numbers to be an alternative way especially during dry season. Based on village-wise analysis the practice varied among study villages: Saunyi (91.6%), Kwekinkwembe (85.6%), Erelai (76.7%) and Ndedo (74%). However, agro-pastoralists in Tanzania have been reluctant to reduce the number of their livestock until the dry season whereby the prices of cattle fall down due to poor health as a result of poor pastures and water shortage. District livestock and fisheries officer in Kilindi district said that, droughts which hit 2009, 2014 and 2016 caused prices of cattle to be very low, from TSH 80000-120000 per cattle. However reduction in livestock


**Figure 11.** Pastures rotational use for conservation basing to livestock category.


**Figure 12.** Innovated traditional water points (Njoro) at Ndedo and Makame villages.

numbers requires alternative sources of food for agro-pastoralist in Tanzanian and thus may lead to changes in national food policy and laws.

### *Maasai women transporting water with donkeys from innovated traditional water points (locally known as Njoro) for domestic use*

Water resources availability for domestic use in study villages has been a problem in semi-arid climates and it is influenced by variable factors, including climate change and variability through droughts and other livelihood activities. Therefore, being the problem, respondents in study villages had to move for long distance searching water for domestic uses; it was revealed by 52% being practiced by women Maasai. Hence because vulnerability to drought was not similar, the use of this strategy varied such that Ndedo (80%), Kwekinkwembe (73.3%), Erelai (63%) and Ngapapa (55%). Agro-pastoral districts such as Kilindi, Monduli, Kiteto, Simanjiro and Ngorongoro receive below 700 mm of rainfall. The impact is felt non-linearly and drier areas within this range experience significantly greater loss in surface drainage with a decrease in rainfall than wetter areas. Experience has shown that communities in Kiteto and Kilindi (rangeland areas) are experiencing decline in ground water level due to drying of water in wells, river streams that used to give water throughout the year. The drying has affected both people and livestock including wild animals.

Agro-pastoral women move very long distances with donkeys fetching water in constructed wells for more than 6 h. A village executive officer at Ndedo village (40 years old) said most nearby wells which were used previously now do not exist due to prolonged dry lands (Figure 13). Modern wells are needed in these communities especially in this era of global environmental change which will reduce distance for fetching water which affects Maasai women.

### *Traditional Maasai constructed water reservoirs for Livestock (locally known as Mboutu)*

The influence of water availability on livestock productivity within rangelands/grazing lands has been reported to be of paramount importance. Volume of water in natural sources nowadays goes down due to prolonged droughts affecting livestock and crop farming. Therefore, because of persisting droughts which have resulted in shortage of water, agro-pastoralists through their own indigenous knowledge systems (IKS) have developed their own new water reservoirs for their livestock adaptation practices locally known as Mboutu. Mboutu has been serving agro-pastoralist for a very long time especially during dry season when water becomes very scarce resource in semi-arid areas.

Previously, Mboutu was built with natural vegetation/ small sticks with the help of mud, then pouring water from water points to Mboutu where livestock used to drink. However due to increased environmental change because of the current climate change and variability, agro-pastoralists have been required to improve much their traditional knowledge system as to go with the prevailing environment as the old water reservoirs/ Mboutu currently are not effective and efficient. Therefore they have improved much this water reservoir/Mboutu which nowadays is built using concrete and cement preventing water loss (Figure 14a). The old Mboutu has been abandoned by majority nowadays due to loss of water and inability to serve large number of livestock, hence the agro-pastoralists have innovated the new/ modern Mboutu using improved building materials like cement and concrete (Figure 14b).

### Drought-tolerant forage species, cactus plants for animal's fodder

Agro-pastoralism under semi-arid conditions faces poor quality and inadequate supply of feed and shortage of water to livestock production. Therefore, spineless cactus plants (*Opuntia fícus-indica*) provide important feed materials for ruminants in drought regions especially, during the dry season due to forage shortage (Dubeux et al., 2006).

Cactus plants (Opuntia ficus-indica) are used as modern method of animal feeds because they are easy, cheap to grow, palatable and can withstand prolonged droughts (Taasoli et al., 2007). Such characteristics make these species a potential alternative important feed supplement for livestock keepers in semi-arid climates, particularly during periods of drought and seasons of low feed availability. According to district livestock officer in Kiteto district, due to persisting droughts in the district specifically in the study villages, they have adopted this new technique of making animal folder from cactus plant which normally grows well in arid and semi-arid climate/areas (Figure 15). Findings from respondents revealed that 89.3% are not aware of this technology and 10.7% are aware of this technology. The reason why few have been educated and the majority are not yet educated is due to shortage of experts from the district. Livestock officers went for training in Morocco two years ago. Ndedo and Saunyi villages were selected as pilot study village.

## CONCLUSION AND RECOMMENDATION

Kiteto and Kilindi districts currently are highly dominated by pure pastoral Maasai communities than agro-pastoral as most of them have drifted from growing crops due to persistence of droughts becoming pure pastoral

**Figure 13.** Maasai women fetching and transporting water with donkeys from innovated traditional water points (Njoro) at Ndedo, Saunyi and Makame villages.

**Figure 14a.** The old Water Reservoir/Mboutu at Makame, Ndedo and Saunyi villages.

communities; hence they have been experiencing climate change and variability impacts for nearly three decades now.

The study concludes that majority of the agro-

**Figure 14b.** The modern water reservoir/Mboutu at Makame, Ngapapa, Erelai and Saunyi villages.

**Figure 15.** Spineless cactus plants for making livestock folder.

pastoralists perceived climate change and variability through observed decrease in rainfall with changes in rain seasons, increase in temperature and increase in incidences of droughts and dry spells. Furthermore the study has established the patterns and trends of rainfall and temperature in the study areas by using data accessed from the Tanzania Meteorological Agency in Dar es Salaam for Kilindi and Kiteto Districts. The data have generally shown a decrease in rainfall amounts and distribution as well as an increase in temperature, which concur with the findings from the agro-pastoralists' perceptions. Moreover, the study has presented various perceived impacts of climate change and variability on agro-pastoralism systems in the study villages. Drought stress has been pointed as a major challenge in the study districts and it has negatively affected grazing resources and agro-pastoralists livelihoods in various ways such as drying of water points (Njoro), drying of livestock pastures emergency of new livestock diseases, and increased livestock mobility as to escape from droughts and searching for water and pastures. All these have led to reduced livestock and crops production and yields differently. Therefore, impacts of climate change and variability are real and negatively affect livestock and crops production which results in frequently food insecurity hence, innovated pathways have been serving them or working well, but not effectively and efficiently as per their indigenous knowledge system (IKS). What is missing in this communities is integration of scientific knowledge in adaptation to harsh environment which has caused frequently food insecurity. Therefore, the study recommends a more integrated scientific pathway practices which involve building capacity on diversification of their sources of livelihoods like engaging with crop growing through droughts resistant crops; also integrating multi-sectoral through interventions that target agro-pastoralists' resilience by integrating academic research and other developmental activities through civil society and community based organizations which could be the most important pushing pathways for increased resilience upon climate change and variability impacts in arid and semi-arid lands (ASALs).

## CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

## ACKNOWLEDGMENTS

This work is part of a PhD study of the corresponding author which is being funded by the African Climate Change Adaptation Initiative (ACCAI) project through the centre for climate change studies (CCC's University of Dar es salaam for capacity building in semi-arid areas. The authors would like to thank them for their financial support which made this study possible.

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