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Agricultural Commercialization and Adaptation to Climate Change and Variability in Semi-Arid Central Tanzania

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Authors' contributions

This work was carried out in collaboration between both authors. Author ABC designed the study, wrote the protocol and wrote the first draft of the manuscript. Author ETL contributed to analysis of the study findings, discussions and the conclusion. Both authors read and approved the final manuscript.

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ABSTRACT

Aims: The study was conducted to investigate the implications of smallholder agricultural commercialization on adaptation to climate change in semi-arid central Tanzania.
Study Design: Descriptive survey and observational designs were used in this study. Moreover, analytical design was used to analyze the trends of climate and commercialization in the area.
Place and Duration of Study: Hembahemba and Manyata villages in Kongwa district, Dodoma region, Tanzania were selected for the study. The study was conducted between October 2012 and October 2013.
Methodology: A variety of methods were used in the study including participatory assessment techniques, field visits and household surveys. Primary data collection involved the use of key informant interviews, household questionnaires, focus group discussions and field observations. Secondary data were collected through literature and documentary review. Temperature and rainfall data from 1970 to 2012 were analysed by simple linear regression performed using

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Microsoft Excel. Non-numeric data were coded and analyzed by Statistical Package for Social Sciences (SPSS). Household Commercialization Index (HCI) was used to analyze levels of agricultural commercialization.

Results: The experience of the interviewed respondents on rainfall and temperature trends corresponded to the analysis of climatic data from Tanzania Meteorological Agency (TMA). The analysis indicated an increase of temperature at a rate of 0.0137°C annually for the past 42 years and a decrease of rainfall at a rate of 1.5062 mm annually from 1983 to 2012. However, rainfall decreased more rapidly at a rate of 4.597mm annually between 1995 and 2012, putting agricultural sector into risk. On the other side, agricultural commercialization influenced mechanization and changes of agricultural practices in diverse ways. Changes, such as abandonment of mixed farming and drought tolerant traditional crop varieties exposed the farmers into risks of climatic shocks while changes on tillage practices and crop diversification contributed to adaptation.

Conclusion: Taking into account the climatic changes and market forces, it is likely that agricultural diversification can further contribute to resilience.

Keywords: Agricultural commercialization; climate change; resilience; adaptation.

1. INTRODUCTION

Developing countries will account for about 85 percent of the 690 million ton increase in the global demand for cereals between 1995 and 2020 [1]. The demand for food is likely to motivate farmers to respond to market needs, hence causing agriculture to become more commercialized. World Bank [2] further reports that income growth and urbanization in developing countries have enlarged markets for agricultural commodities. As economies grow, there is a gradual but definite movement from subsistence farming to a diversified market oriented production system [3].

Alongside agricultural commercialization, climate change and variability are also posing a challenge in trends and patterns of agriculture worldwide. According to the recent review of IPCC, global agriculture faces the prospect of changing climate that may adversely affect the goal of meeting global food needs in the coming decades [4]. Sub Saharan Africa, where climate change has already affected and is expected to affect more of the rural communities that depend on agriculture for their livelihood, agricultural commercialization can positively or negatively affect adaptation to climate change due to its influence on farmer's decision.

Analysis of trends in agricultural production like maize production in Tanzania according to URT [5] shows that the increase in temperature and reduced rainfall as well as change in rainfall patterns will decrease average yields by up to 84% in the central regions. Despite these projections, the study done in Dodoma region of central Tanzania by Liwenga et al. [6] revealed the expansion of maize fields and the change of crop varieties as a result of agricultural commercialization. According to this study, only about 17.5% of the farmers had maize fields of more than 20 acres (8ha) before 1990 while about 24% had maize fields bigger than 20 acres (8ha) in 2009. Apparently, drought that occurred in the late 1970s in Dodoma, central Tanzania caused the maize prices to increase sharply hence more land was allocated to produce maize [7].

The response to market requires informed farmers who are aware of the climate change and its associated risks. This study was designed primarily to develop the implications of agricultural commercialization on the adaptation to climate change for communities located in semi-arid areas of central Tanzania. Significantly, the study was designed to establish how commercialization can take into account the adaptation strategies to improve agricultural production and financial ability of semi-arid communities under changing climate.

2. METHODOLOGY

2.1 Study Area

The study was carried at Kongwa district which is located in Dodoma region, central Tanzania. The district lies between the geographical coordinates of 6° 12' 0" S, 36° 25' 0" E / 6° 20' 0" S, 36° 41' 7" E. It is bordered to the north by the Manyara region, to the east by the Morogoro region, to the south by the Mpwapwa district and to the west by the Dodoma rural district.

As a whole central Tanzania including Kongwa district is categorized as a semi-arid zone with a savannah climate which is characterized by a short rainy period between November and May. The microclimate of Kongwa district is greatly influenced by its altitude. The mean temperature is about 26.5°C but temperature can sometimes go down to as much as 11°C. The annual average rainfall is 450 mm, whereas the average relative humidity is 70% [8]. According to the population and housing census of Tanzania in 2012, Dodoma region has a population of 2,083,588 people with 309,973 people living in Kongwa district which accounts for about 14.88%. Major livelihood activities in the area are farming and livestock keeping. The area is also very popular economically due to the presence of Kibaigwa international crop market. The area was purposively chosen due to its vulnerability to climate change and the ongoing, large-scale agricultural commercialization. Hembahemba village located at Njoge ward and Manyata village located at Ngomai ward were selected for the study. Selection of the villages was based on social economic activities, such as farming being the primary source of livelihood, diversity of cultivated crops, severity of the impacts of climate change and access to the market.

2.2 Sampling Procedure

The study mainly used two types of sampling techniques, namely purposive sampling and systematic random sampling. Purposive sampling was used to select the key informants, the participants of the focus group discussion and the individuals for an in-depth interview. With the assistance of village and sub-village chairmen, systematic random sampling was used to select the households from household lists to constitute the sample. A sample proportion of about 7% of the households in each of the two villages was used for the household interviews. According to Black [9], sampling through this technique starts by selecting an element from the list at random and then every k^{th} element in the frame is selected using the following formula shown in Equation i.

$$K=N/n \quad (1)$$

Where,
K= Interval size
N= Total population (Total number of households)
n= Sample size = (7/100 x N)

Hence, an integer between 1 to K was randomly selected to constitute the first item in the sample for the household survey followed by every K^{th} unit as shown in Table 1.

2.3 Data Collection

This study employed a variety of data collected from different sources because of the variation in the nature of data required. Therefore, several data collection techniques were used. The data were obtained from farmers, Tanzania Meteorological Agency (TMA), officers of agricultural extension, Kibaigwa crop market and literatures. Data collection methods ranged from literature search and participatory assessments to field observations and interviews. Unstructured questions were used during focus group discussion and key informant interviews. Structured questions were used to collect information at household level.

2.4 Analytical Procedure

Temperature and rainfall trends from 1970 to 2012 were analyzed by simple linear regression analysis that was performed by using Microsoft Excel. Non-numeric data were coded, summarized and analyzed by using Statistical Package for Social Sciences spreadsheet. Household Commercialization Index (HCI) was used to analyze the levels of specific crop and total agricultural commercialization (Equation ii). The index measures the ratio of the gross value of crop sales by household (hh) *i* in year *j* to the gross value of all crops produced by the same household (hh) *i* in the same year *j* expressed as a percentage [10].

$$HCI_i = \left[\frac{\text{Gross value of crop sales } hh_i \text{ year}_j}{\text{Gross value of all crop production } hh_i \text{ year}_j} \right] * 100\% \quad (2)$$

The index measures the extent to which household crop production is oriented toward the market. A value of zero signifies a totally subsistence oriented household and the closer the index is to 100, the higher the degree of commercialization is [10]. Total agricultural commercialization of each crop was obtained by finding the average HCI for all households per year from 2008 to 2013 in each village with the help of Microsoft Excel. Thereafter the average HCI for six years was calculated for each village. The advantage of this approach is that

commercialization is treated as a continuum thereby avoiding crude distinction between "commercialized" and "non-commercialized" households [10].

3. RESULTS AND DISCUSSION

3.1 Temperature Trends

According to the data obtained from Dodoma station of TMA, the analysis of temperature showed an increase in temperature from 1970 to 2012. Minimum temperature increased at a higher rate ($y=0.0183x + 16.5$ where $R^2 =0.3105$) when compared to maximum temperature ($y=0.0091x + 28.729$ where $R^2 =0.0929$) as shown in Fig. 1. Generally temperature increased gradually. Annual average temperature from 1970 to 2012 increased by $y=0.0137x + 22.615$ where $R^2 =0.2341$ (Fig. 2).

Similar observations were made by Mary and Majule [11] whose analysis of average, annual temperature from 1984 to 2004 in Manyoni district showed an increase of average, annual temperature by 0.7°C. This observation is further in accordance with URT [5] in its National Adaptation Programme of Action (NAPA), which reports the upward trend of monthly minimum and maximum temperatures over the last 30 years (between 1974 and 2004). About 52.7% and 46.9% of the respondents from Hembahemba and Manyata villages, respectively also confirmed the findings. The respondents claimed to experience the increase in temperature in their villages.

Table 1. The proportion of sampled respondents in the study villages

Village	Total number of households (N)	Sample size (n=0.07*N)	Interval size (K=N/n)
Hembahemba	786	55	14
Manyata	693	49	14
Total	1470	104	--

Source: fieldwork (2013)

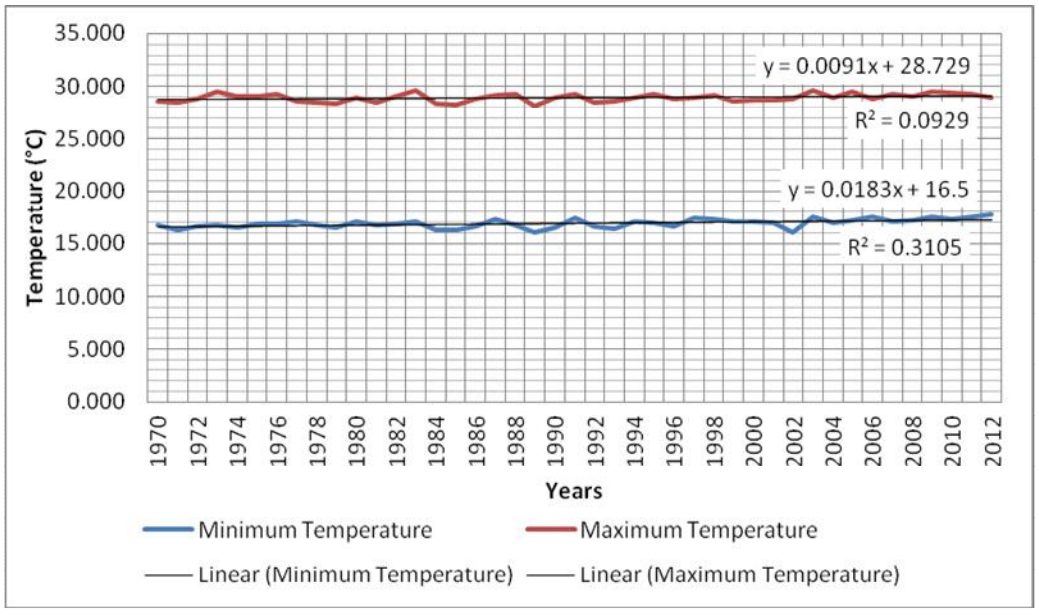

Fig. 1. Minimum and maximum temperature trends from 1970 to 2012
Source: TMA-dodoma station (2013)

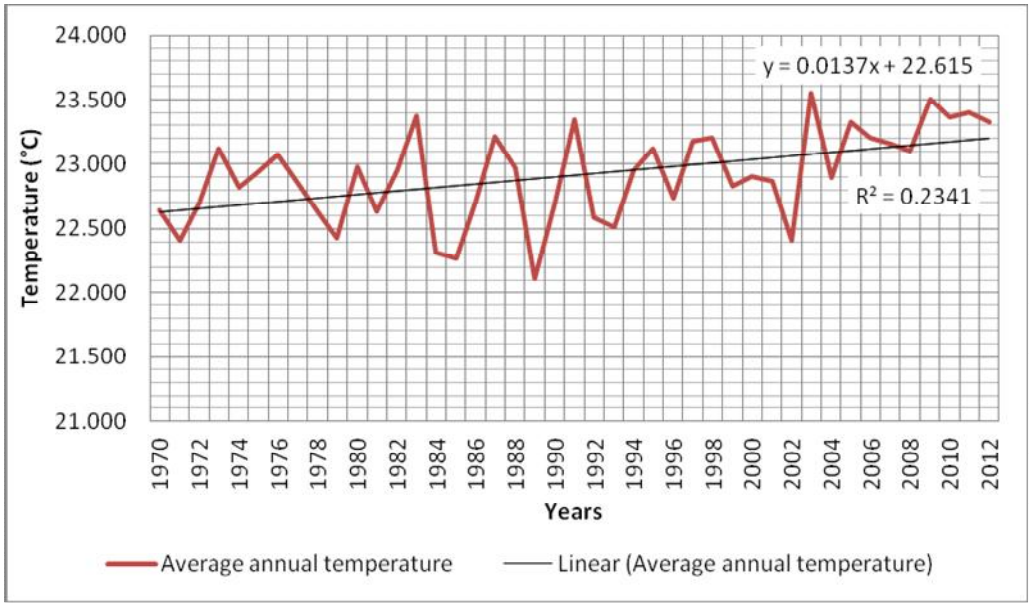

Fig. 2. Annual temperature trend from 1970 to 2013
Source: TMA-dodoma station (2013)

3.2 Monthly Rainfall Patterns

Analysis of monthly rainfall patterns showed great variations on onset and cessation of rainfall. The participants of the focus group discussion mentioned that the rainfall began in October and ended up in May in a normal year. Rainfall was reported to reach the peak in December before it dropped away in February when weeding took place. It was thereafter reported to increase again until March before it dropped away and ended in May. According to meteorological data, very little rainfall, which was below the average throughout the rainy season, was recorded in 1970s. In 1980s, rainfall began nearly at the end of October. However, it remained higher above the average throughout the season except February when it dropped away to below the average. The rainfall ended in May as usual so that the farmers experienced a short growing season. The same pattern as the one in 1970s was recorded in 1990s except in February when the rainfall deviated positively and higher above the average, a situation, which was unusual, compared to other years.

In 2000s rainfall went far higher above the average in December and lower below the average throughout the rainy season. There was also a sharp drop in the amount of rainfall from March to April and ended up earlier than usual. Therefore, farmers experienced a short growing season in 2000s. Generally the trend showed the shift of rain onset from October to November and the shift in cessation from May towards April, hence shortening of the rainy season (Fig. 3).

These findings also correspond to the experience of farmers so that 98.2% of the respondents from Hembahemba village and 100% of the respondents from Manyata village claimed to experience early cessation of rainy season in recent years. The same case is reported in Manyoni district, central Tanzania where rainfall used to start in October and faded away in May in the past. Currently, the onset of rainfall has shifted from October to November and the rainy season is shorter, ending in March or April [11].

3.3 Variability of Annual Rainfall

Dodoma region is generally subject to frequent drought. According to meteorological data from TMA, average annual rainfall from 1970 to 2012 was found to be 575.14 mm. However, the area received annual average rainfall of 528.02 mm in 1970s, which was below the average. The average annual rainfall between 1982 and 1989 was found to be 611.9 mm, 572.8 mm between 1990 and 1999 and 584.9 mm between 2000 and 2012 (Fig. 4).

Despite the observed variations in annual rainfall, the analysis of rainfall pattern shows major significant changes in the amount of annual rainfall over the past 18 years from 1995 to 2012. The linear equation in Fig. 5 (y= -4.5976x + 640.71) shows that the decreasing trend of rainfall from 1995 to 2012 is three times the decreasing trend from 1983 to 2012 (y = -1.5062x + 618.46) as presented in Fig. 6. Therefore, the rainfall has been decreasing at an increasing rate for the past 30 years. The agricultural communities in the study area are likely to become more vulnerable and their livelihoods are adversely affected with this rate.

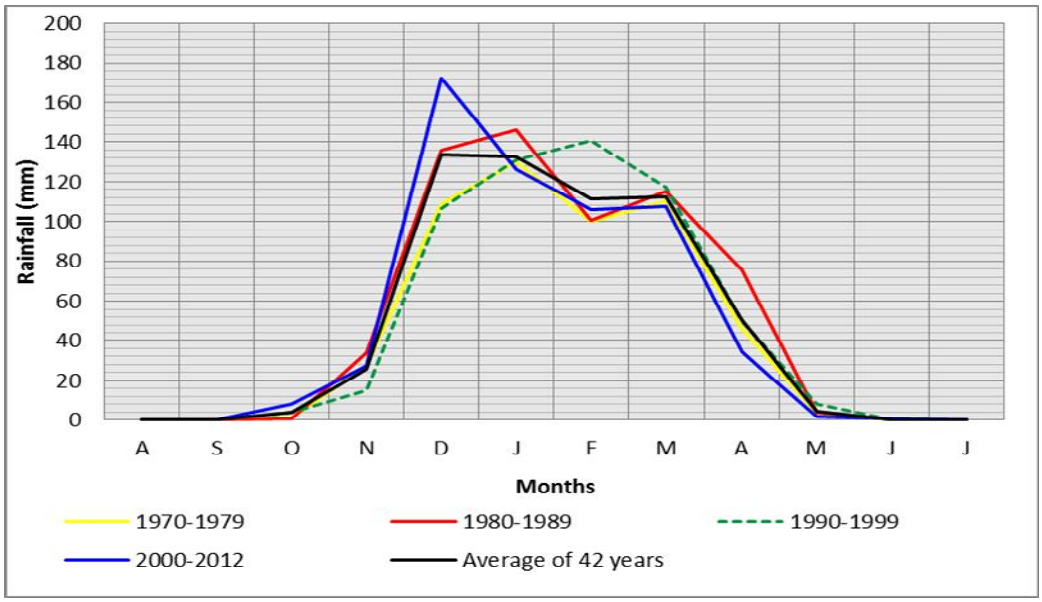

Fig. 3. Variations of monthly rainfall distribution from 1970 to 2012
Source: TMA- Dodoma station (2013)

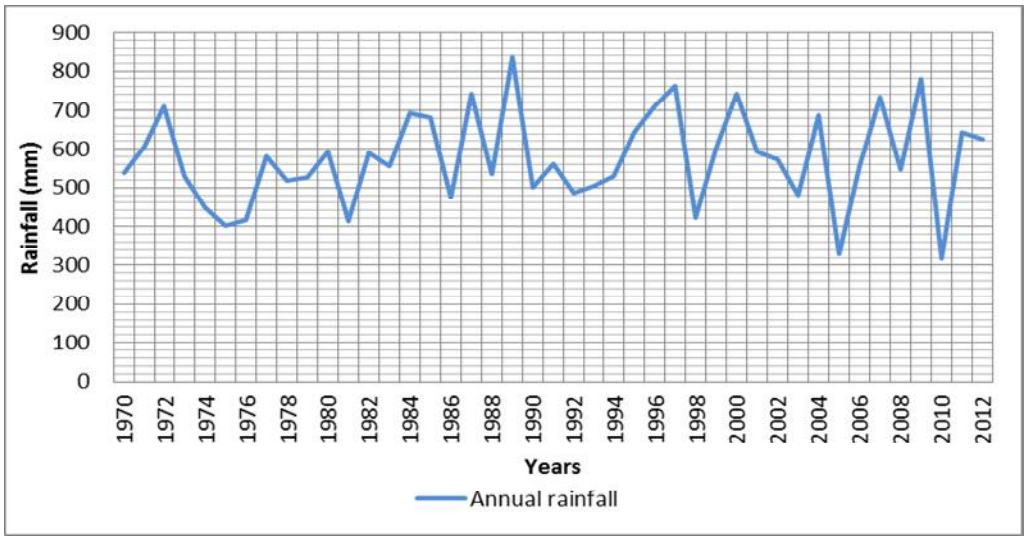

Fig. 4. Annual rainfall variability from 1970 to 1912
Source: TMA- Dodoma station (2013)

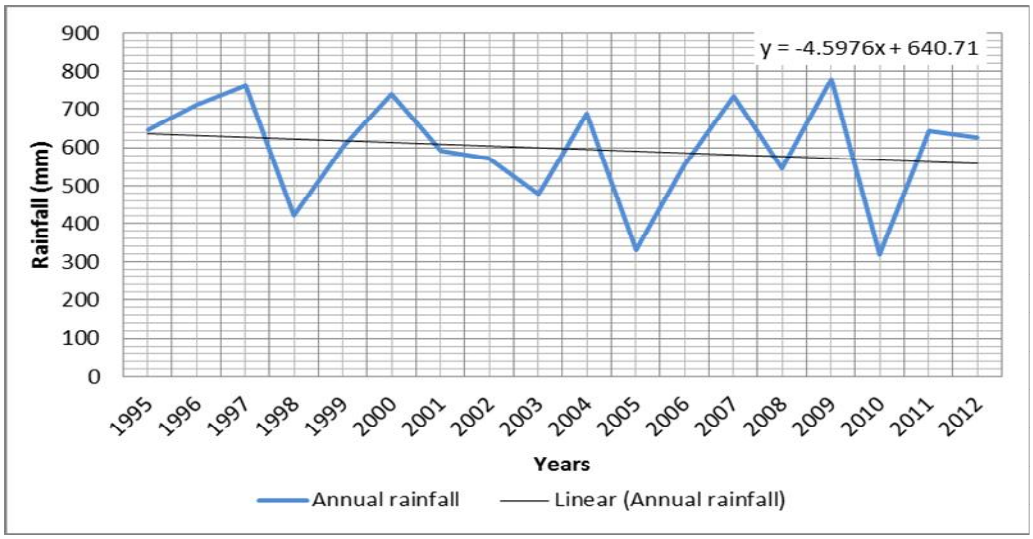

Fig. 5. Annual rainfall trend from 1995 to 2012
Source: TMA-Dodoma station (2013)

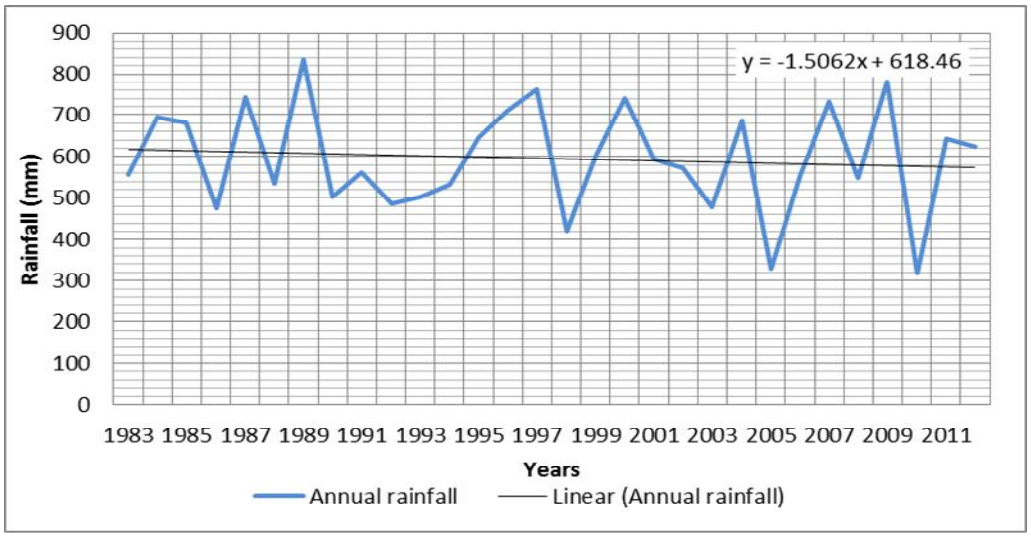

Fig. 6. Annual rainfall trend from 1983 to 2012
Source: TMA- Dodoma station (2013)

These findings were supported by the findings of Mongi et al. [12] which also reveal the decreasing trend of annual rainfall in semi-arid Tanzania. Similarly, Lema and Majule [13] establish decreasing rainfall trend in Manyoni district of central Tanzania. To a large extent, the analysis of rainfall from meteorological data corresponded to the experiences of farmers so that 98.1% of the interviewed respondents from Hembahemba and 95.9% of the respondents from Manyata villages confirmed the decreasing rainfall trend.

3.4 Agricultural Commercialization in the District

Through consultation with Kibaigwa crop market authorities, it was revealed that the agricultural commercialization in central Tanzania and Kongwa district in particular was largely attributed by the location of Kibaigwa international crop market. Kibaigwa crop market is the country's biggest crop market, selling crops both inside and outside the country. The market started to operate officially in 2004 and focused

mainly on the marketing of maize, although the popular traditional crops by then were sorghum and bulrush millet. While maize was the only product to be sold in the market in 2004, sunflower, groundnuts, pigeon peas, cowpeas and sorghum were introduced to the market between the years 2005-2010. Despite the introduction of other crops in the later years, maize was still leading in terms of both quantity and marketability and it was followed by sunflower. Market oriented production as well as the focus on maize, which triggered shifts from the production of traditional crops, such as sorghum and bulrush millet, is what raises questions since adaptation is concerned in the context of existing climatic changes.

3.5 Levels of Specific crop Commercialization

The analysis of Household Commercialization Index (HCI) of the produced crops from 2008 to 2013 showed many variations in the commercialization among crops. The analysis further demonstrated the variation between HCI and the marketability of the analysed crops. The marketability should not be confused with HCI because HCI is based on the amount produced to the proportion, which is sold. On the other side, marketability is based on the availability of a ready and neighbouring market. Therefore, some crops were found to have a high HCI despite being least marketable while others were found to have a low HCI despite being highly marketable. For instance, maize was the least commercialized crop according HCI because it was also the main food crop. Despite this fact, the focus group discussion, interview with key informants and field observation revealed that maize was the highly marketable crop when compared to other crops. The marketability of maize was influenced by its demand at the Kibaigwa crop market and its assurance for the market since it could be sold throughout the year.

Generally, HCI ranged from 31% to 99%. HCI ranged from 51% to 97% in Hembahemba village while it ranged from 31% to 99% in Manyata village. It should also be noted that HCI is affected by the amount produced. When the production is high, the HCI value also becomes high. Therefore, higher agricultural production in Hembahemba village leads to a higher HCI value there. The summary of average HCI of maize, sunflower, pigeon peas and groundnuts in the two villages is presented in Figs. 7 and 8.

3.6 Influence of Agricultural Commercialization on Change in Crops/Crop Varieties

According to URT [14], Kongwa district became a centre for colonial activities in 1942 following the establishment of groundnut estates. During an in-depth interview, the village elders revealed that most of the households preferred to cultivate bulrush millet as the cash crop and sorghum as the food crop after the independence. For instance, it was reported that the name of the village “Hembahemba” originates from the Kaguru tribe “uhemba” which means “sorghum”. Therefore, sorghum was the main food crop when life began in the village. When production in the area became more commercialized, more crops, such as pigeon peas, sunflower, sesame and cowpeas were introduced for commercial purposes. Most of the households also chose to cultivate maize as a food crop rather than sorghum. Similar results were reported by Liwenga et al. [6] who revealed the transition from bulrush millet, sorghum and bambara nuts as traditional food crops to maize, groundnuts, cassava and sweet potatoes in Kondoa and Kongwa districts.

3.7 Reflection of Current Crops/Crop Varieties on the Adaptation to Climate Change

The field survey revealed that some of the cultivated crops and crop varieties were less resistant to climate change and variability when compared to traditional crop varieties. For instance, the cultivation of maize was in the expense of sorghum, which was more resistant to drought than maize. Even though 90% of the respondents in Manyata and 96% of the respondents in Hembahemba villages were aware of the risk of cultivating maize in the expense of sorghum, the market of maize influenced them. Majule et al. [15] also argues that sorghum and its short-term varieties in particular seem to adapt well but market for the crop still needs to be developed. However, diversification also took into account the other crops, which were more resistant to climatic shocks, pests and diseases. Cultivation of sunflower for commercial purposes largely corresponded to the climate of the area hence enabled the farmers to withstand climatic shocks.

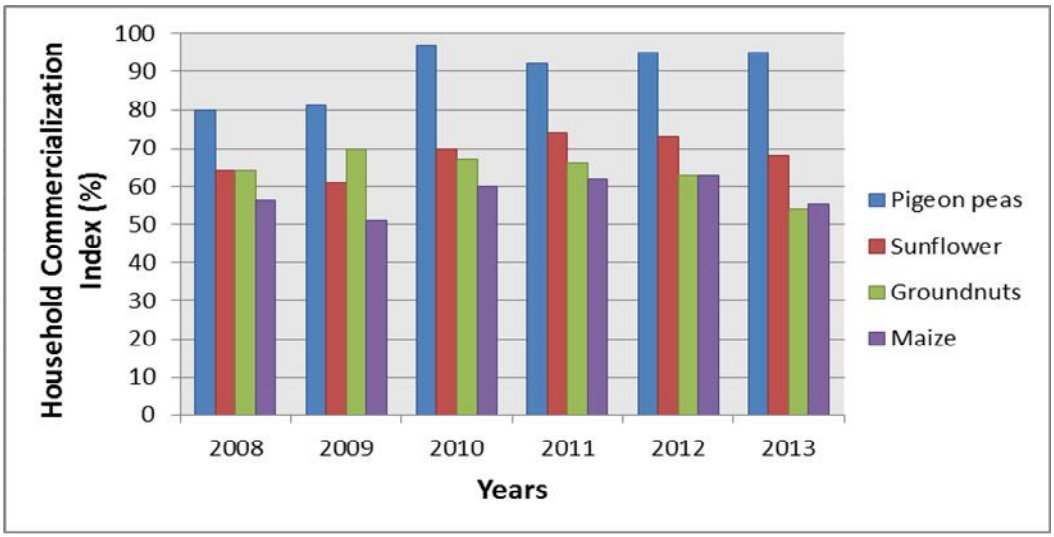

Fig. 7. Average of HCI in Hembahemba village
Source: fieldwork (2013)

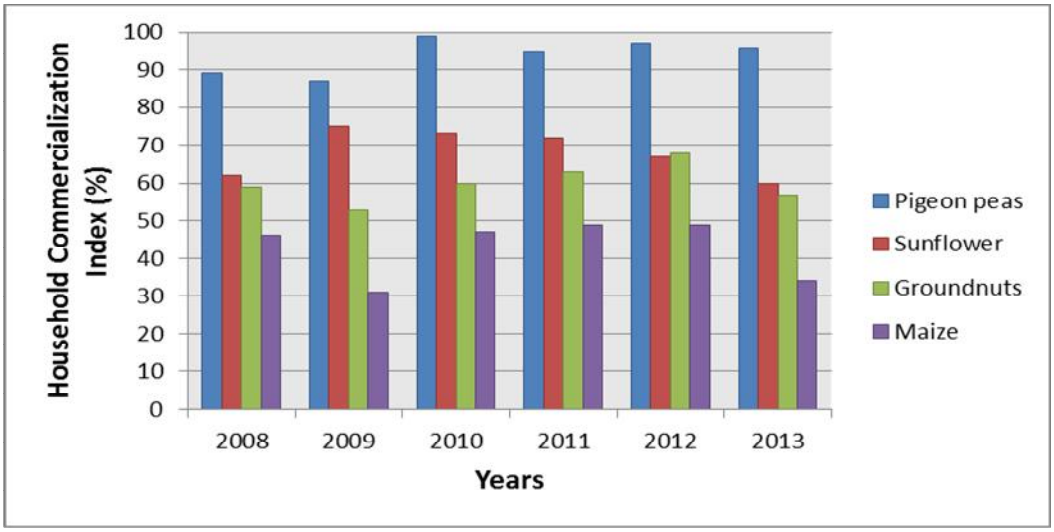

Fig. 8. Average of HCI in Manyata village
Source: fieldwork (2013)

3.8 Influence of Agricultural Commercialization on Change in Farming Systems

Traditionally, the Gogo that was the dominant tribe in Kongwa district until the early 1980s was agropastoralists. Their popular farming system was mixed farming. However, with the migration of Bena people who were the majority when this study was undertaken, only 23.2% of the respondents in Hembahemba and 29.7% of the respondents in Manyata continued to raise cattle. Moreover, majority of farmers who still engaged in cattle rearing were reported to raise oxen for farm and house works. Focus group discussion with farmers also revealed that agricultural commercialization was responsible from the expansion of farms hence land scarcity for incoming farmers. This was further reported to result into land business whereby farmers who wished to expand their fields were supposed to pay a rent fee to land owners for each growing season.

3.9 Reflection of Current Farming Systems on the Adaptation to Climate Change

From the analysis of the farming systems, it was discovered that transition from mixed farming to crop based farming system increased the over dependence on crop farming which in turn increased the vulnerability to climate change and variability. An in-depth interview with the indigenous village elders in both villages revealed that mixed farming systems largely helped the farmers to diversify their economic sources and use farmyard manure to improve the fertility of their farms in the past 30-40 years. This is supported by Singh et al. [16] who argue that the application of organic materials like farmyard manure considerably improves the physical properties of soil and nutrient uptake, resulting in greater growth, yield and yield components.

Renting land for farming, which was a very common tendency in both villages as reported earlier, has two major implications. Firstly, farmers cannot own land permanently. This exposes them into risk of not having land to cultivate for some growing seasons due to insufficient financial ability to pay a rent fee. Secondly, the use of land by outsiders leaves the villagers landless and results in land conflicts. This was confirmed during focus group discussion and household interviews, from which the villagers from both of the two villages reported the presence of land related conflicts due to the tendency of some land owners to rent one piece of land to more than one farmer as well as due to the invasion of fields in Kiteto district.

3.10 Influence of Agricultural Commercialization on Change in Farming Practices

From the household survey, the proportion of households using hand hoe was found to decrease in all two villages. The participants of the focus group discussion reported that the desire to produce more crops due to market demand influenced the expansion of fields, leading to an increase in farm's workload. Mechanization was reported to be the solution for increased workload. It was further revealed that mechanization in both villages also influenced the change of farming practices. For example, "*kubelega*", which is a traditional way of farm preparation, involves clearing the land and burning the wastes before planting. The seeds are left in the ground for the first rains. However, cultivation and planting are done during the onset of first rains with the mechanization. The responses of households to farming practice from both of the villages are presented in Table 2.

3.11 Reflection of Current Farming Practices on the Adaptation to Climate Change

Some of the farming practices were found to be in line with adaptation to climate change and variability while others were not. Farmers are able to cultivate large pieces of land in a short period of time with mechanization thereby increasing surplus production. The abandonment of land clearing practices (*kubelega*) brings the opportunity to keep the fertility of soil by conserving soil's microorganisms since farmers do not burn the wastes anymore.

Moreover, mechanization is reported to influence tillage practices. Tillage by disc plough increases infiltration rate by reducing surface run off and the accessibility of water and nutrients to cultivated crops through deep root penetration. Gwambene and Majule [17] also acknowledge that the use of tilling methods under proper tilling implements, such as Magoye ripper, Spring Jembe and Power tiller has the ability to retain moisture in the soils for every single rain drop available. Therefore, the influence of mechanization on tillage practices is also concluded to be beneficial to farmers.

On the other side, farmers are exposed to the risk of variability of rain onset unless weather forecast and access to it are improved because farmers do not put down the seeds before the rain onset anymore because of mechanization. Furthermore, farmers are able to cultivate several plots by differentiating planting dates which help them to spread the risks of irregularities of rain onset under staggered seed crop planting. Few farmers are reported to abandon this practice, the lack of which will make the farmers more vulnerable to climate change and variability.

Table 2. The response of households to farming practices before and after the establishment of Kibaigwa market (%)

Farming practice/village	Hembahemba village (n=55)		Manyata village (n=49)	
	Before Kibaigwa market	After Kibaigwa market	Before Kibaigwa market	After Kibaigwa market
Using hand hoe	60	1.8	73.5	16.3
Using tractors	40	98.2	8.2	73.5
Using ox-plough	7.3	19.3	22.4	34.7
Using industrial fertilizers	0	0	0	0
Farm preparation (Kubelega)	60	1.8	93.9	30.6
Staggered seed crop planting	78.2	58.2	93.9	91.8
Timing of farm operations	98.2	98.2	100	100

Source: fieldwork (2013)

4. CONCLUSION AND RECOMMENDATIONS

The study has established that changes of rainfall patterns, increasing temperature and decreasing rainfall trends have negatively affected agricultural production in the area. Apparently, agricultural commercialization influenced several changes in farming practices, mechanization and agricultural input usage. Agricultural commercialization influenced the abandonment of some traditional farming practices and crops/crop varieties. Though some of the new practices and crops/crop varieties had a positive implication on the adaptation to climate change and variability, most of them were found to expose the farming communities more vulnerable to climatic shocks. Nevertheless, crop diversification is likely to enhance adaptation in the context of climatic changes and market forces. Apparently, it was established that farmers' vulnerability to climate change and variability were influenced by lack of reliable and accurate weather forecast. With regard to limited focus of this study on agricultural commercialization, further research on the accessibility and reliability of weather information in improving the adaptive capacity to climate change and variability among the farming communities of semi-arid environment will be the right decision.

However, there is a need of providing regular training to farmers on sustainable farming methods, cropping patterns and farming practices in order to enhance commercialization and adaptation to climate change. Furthermore, the markets of sorghum, millet, sunflower, cassava and other drought tolerant crops/crop varieties should be improved to encourage more farmers to cultivate them and hence to promote diversification to drought tolerant crops/crop varieties. Besides, diversifying farmer's economic sources to reduce overdependence on crop farming through the promotion of mixed farming will be beneficial because the area has a high potential for livestock keeping.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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