

Original Research Article

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

ABSTRACT

Aims: The study was conducted to investigate the implications of smallholder agricultural commercialization on climate change adaptation in Semi-arid Central Tanzania.

Study design: In this study descriptive survey and observational designs were used. 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 2014.

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 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 between 1995 and 2012, rainfall decreased more rapidly at a rate of 4.597 mm annually 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: The implications to adaptation are that agricultural diversification taking into account combined climatic and market forces could likely to 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 (Andersen and Rosegrant, 1999) [1]. Demand for food is likely to motivate farmers to respond to market needs, hence agriculture becoming more commercialized. World Bank (2007) [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 out of subsistence food crop production, to a diversified market oriented production system

(Cohen, 1988; Braun et al., 1994; Delgado, 1995; Von Panasat, 2011 cited in Okezie et al., 2012) [3].

Alongside agricultural commercialization, climate change and variability is 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 might adversely affect the goal of meeting global food needs in the coming decades (Gitay et al., 2001) [4]. In Sub Saharan Africa, where climate change has already affected and expected to affect more rural communities who depend in agriculture for their livelihood, agricultural commercialization can affect positively or negatively climate change adaptation due to its influence on farmer's decision.

Analysis of trends in agricultural production for instance maize production in Tanzania according to URT (2007) [5] shows that with increase in temperature and reduced rainfall as well as change in rainfall patterns, average yields will decrease by up to 84% in the central regions. Despite of these projections, the study done in Dodoma region, central Tanzania by Liwenga et al., (2009) [6] revealed the expansion of maize fields and the change of crop varieties as a result of agricultural commercialization. According to this study, before 1990 only about 17.5% of the farmers had maize fields of more than 20 acres (8ha) while in 2009 about 24% had maize fields bigger than 20 acres (8ha). Apparently, drought that occurred in the late 1970s in Dodoma, central Tanzania caused maize prices to increase sharply hence more land was allocated to produce maize (Kaliba et al., 1998) [7].

Response to market needs informed farmers who are aware of climate change and its associated risks. This study was designed primarily to develop the implications of agricultural commercialization on climate change adaptation for communities located in Semi-arid areas of Central Tanzania. Significantly, the study was designed to establish how commercialization could take into account adaptation strategies in order to improve agriculture 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.

Central Tanzania as a whole including Kongwa district is categorized as a semi-arid zone with a savannah climate 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 26.50C, but at times temperature can go down to as much as 110C. The annual average rainfall is 450 mm whereas the average relative humidity is 70% (Goromela et al., 2007) [8]. According to Tanzania 2012 population and housing Census, Dodoma region has a population of 2,083,588 people with 309,973 people in Kongwa district, which accounted to about 14.88%. Major Livelihood activities in the area are farming and livestock keeping. Economically the area is also very popular 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 particularly



68 farming being the primary source of livelihood, diversity of cultivated crops, severity of
69 climate change impacts and access to market.

70 2.2 Sampling procedure

71 The study mainly used two types of sampling techniques namely purposive sampling and
72 systematic random sampling. Purposive sampling was used to select key informants,
73 participants of the focus group discussion and individuals for an in-depth interview. With the
74 assistance of the village and sub-village chairmen, systematic random sampling was used to
75 select the households from household lists to constitute the sample. A sample proportion of
76 about 7% of the households in each of the two villages was used for household interviews.
77 According to Black (2004) [9], sampling through this sampling technique starts by selecting
78 an element from the list at random and then every kth element in the frame is selected using
79 the following formula shown in Equation i.

$$80 \quad K = N/n \dots\dots\dots (i)$$

81 Where, K = Interval size

82 N = Total population (Total number of households)

83 n = Sample size = $(7/100) \times N$

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

86 Table 1: Proportion of sampled respondents in the study villages

Village	Total number of Households (N)	Sample size ($n = 0.7 \times N$)	Interval size ($K = N/n$)
Hembahemba	786	55	14
Manyata	693	49	14
Total	1470	104	--

87 Source: Fieldwork (2013).

88

89 2.3 Data Collection

90 This study employed a variety of data collected from different sources. Different data
91 sources were used due to the variation in the nature of data required. Therefore several data
92 collection techniques were also used depending on the nature of data required. Data were
93 obtained from farmers, Tanzania Meteorological Agency (TMA), agricultural extension
94 officers, Kibaigwa crop market and literatures. Data collection methods ranged from
95 literature search, participatory assessments, field observations and interviews. Unstructured

96 questions were used during focus group discussion and key informant interviews. Structured
97 questions were used to collect information at household level.

98 2.4 Analytical Procedure

99 Temperature and rainfall trends from 1970 to 2012 were analyzed by simple linear
100 regression analysis performed using Microsoft Excel. Non-numeric data were coded,
101 summarized and analyzed using Statistical Package for Social Sciences spreadsheet.
102 Household Commercialization Index (HCI) was used to analyze levels of crop specific and
103 total agricultural commercialization (Equation ii). The index measures the ratio of the gross
104 value of crop sales by household (hh) i in year j to the gross value of all crops produced by
105 the same household (hh) i in the same year j expressed as a percentage (Martey, 2012)
106 [10].

$$107 \quad HCI_i = \left[\frac{\text{Gross value of crop sales } hh_i \text{ year}_j}{\text{Gross value of all crop production } hh_i \text{ year}_j} \right] * 100\% \quad \dots\dots\dots(ii)$$

108 The index measures the extent to which household crop production is oriented toward the
109 market. A value of zero signifies a totally subsistence oriented household and the closer the
110 index is to 100, the higher the degree of commercialization (Martey, 2012) [10]. Total
111 agricultural commercialization was obtained by finding the average HCI for all households
112 per year from 2008 to 2013 in each village with the help of Microsoft Excel. Thereafter the
113 average HCI for six years was calculated for each village. The advantage of this approach is
114 that commercialization is treated as a continuum thereby avoiding crude distinction between
115 “commercialized” and “non-commercialized” households (Martey, 2012) [10].
116

117 3. RESULTS AND DISCUSSION

118 3.1 Temperature trends

120 The analysis of temperature according to the data obtained from TMA, Dodoma station
121 showed an increasing amount of temperature from 1970 to 2012. Minimum temperature
122 increased at a higher rate ($y=0.0183x + 16.5$ where $R^2=0.3105$) as compared to maximum
123 temperature ($y=0.0091x + 28.729$ where $R^2=0.0929$) as shown in Figure 1. Generally
124 temperature increased gradually. Annual average temperature from 1970 to 2012 increased
125 by $y=0.0137x + 22.615$ where $R^2=0.2341$ (Figure 2).

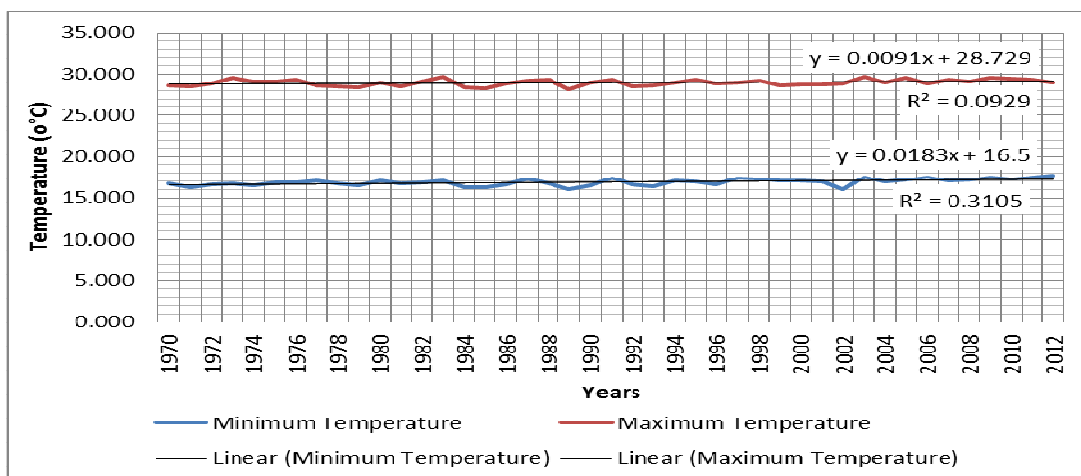


Figure 1: Minimum and maximum temperature trends from 1970 to 2012.
Source: TMA-Dodoma station (2013).

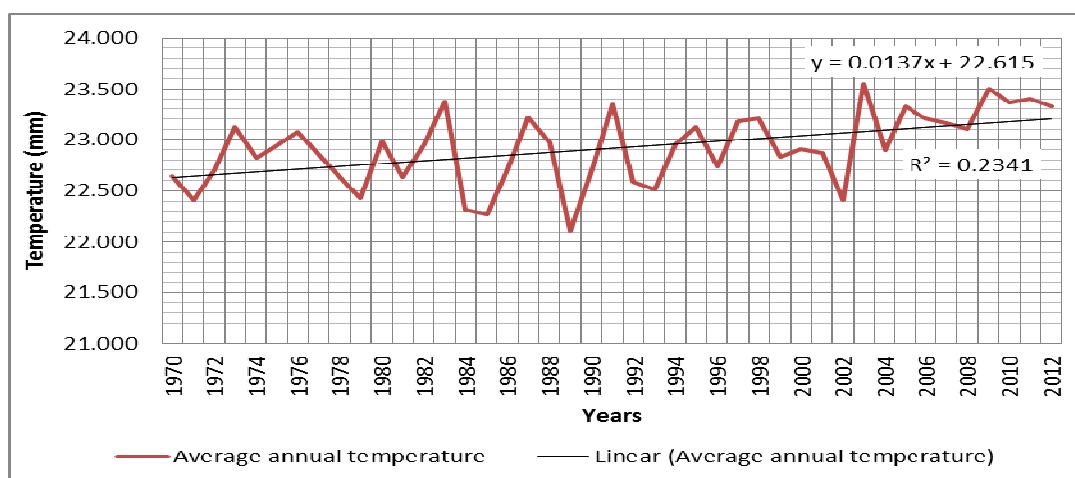


Figure 2: Average annual temperature trend from 1970 to 2012.
Source: TMA-Dodoma station (2013).

Similar observations were made by Mary and Majule (2009) [11] whose analysis of annual average 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 to URT (2007) [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). The findings were also confirmed by 52.7% and 46.9% of the respondents from Hembahemba and Manyata villages respectively who claimed to experience the increase in temperature in their respective villages.

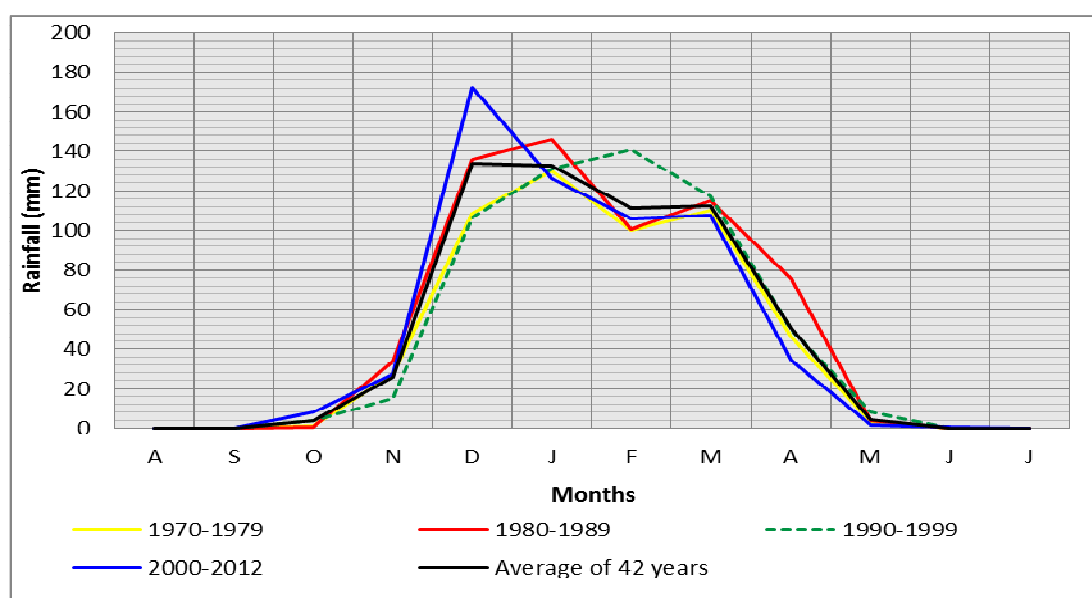
3.2 Monthly rainfall patterns

Analysis of monthly rainfall patterns showed great variations on on-set and cessation of rainfall. According to participants of the focus group discussion, in a normal year rainfall begun at October and ended up at May. Rainfall was reported to reach the peak at December before it dropped at February when weeding took place. It was thereafter reported to increase again up to March before it dropped and ended in May. According to

meteorological data, very little rainfall was recorded in 1970s, which was below average throughout the rain season. In 1980s, rainfall began nearly the end of October; however it remained higher above average throughout the season except at February when it dropped to below average. Rainfall ended at May as usual; therefore the farmers experienced a short growing season. The same pattern as that of 1970s was recorded in 1990s except in February when rainfall deviated positively and higher above average, something, which was unusual, compared to other years.

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

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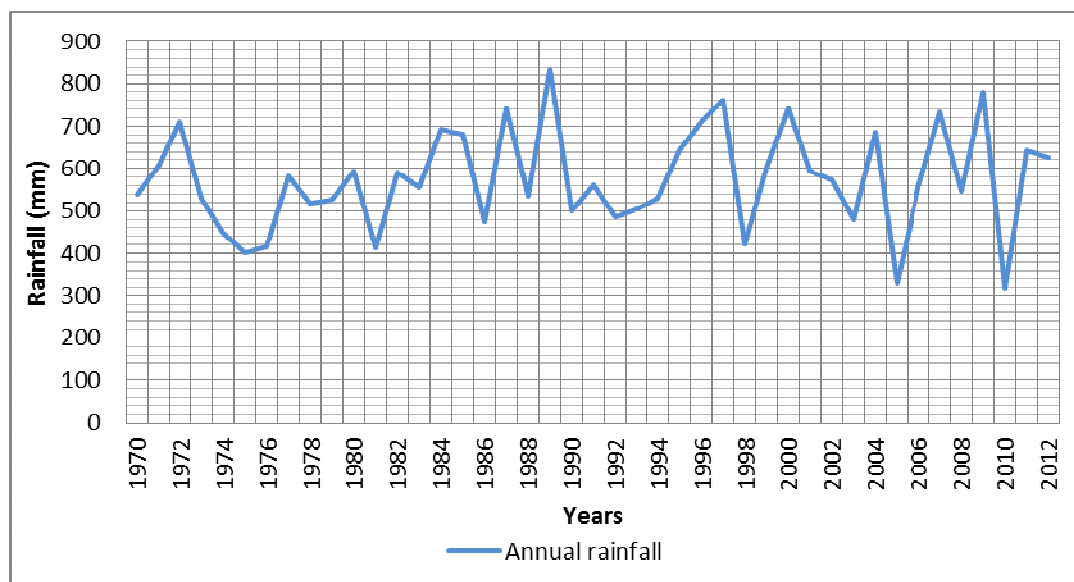
161 Figure 3: Variations of monthly rainfall distribution from 1970 to 2012.

162 Source: TMA-Dodoma station (2013).

These findings also corresponds to the experience of farmers whereby 98.2% of the respondents from Hembahemba village and 100% of the respondents from Manyata village claimed to experience early cessation of rain season in recent years. The same case is reported in Manyoni district, Central Tanzania whereby in the past, rainfall used to start in October and fades away in May while currently the onset of rainfall has shifted from October to November and that the rainy season is shorter ending in March or April (Mary and Majule, 2009) [11].

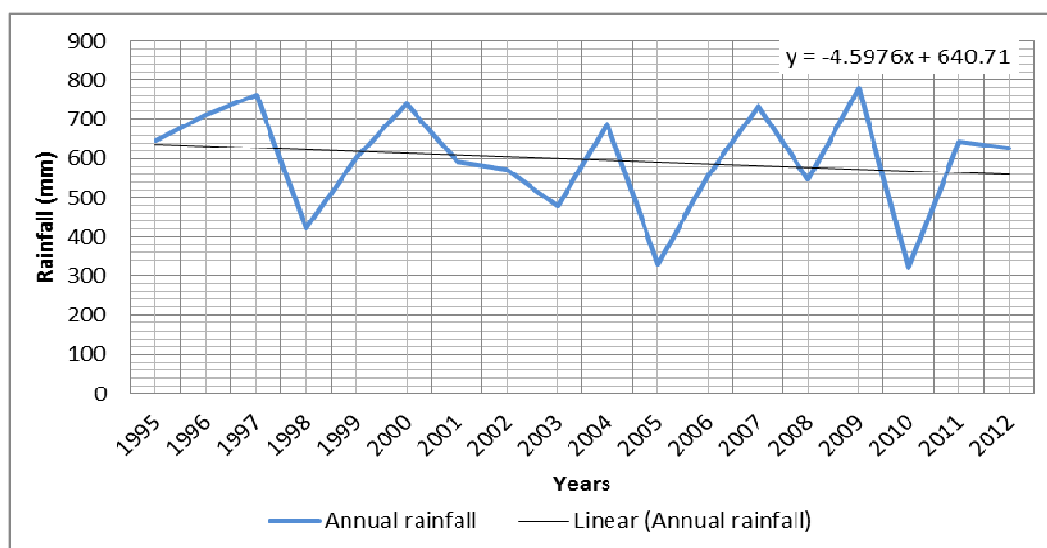
170 3.3 Annual rainfall variability

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



176
177 Figure 4: Annual rainfall variability from 1970 to 2012.
178 Source: TMA-Dodoma station (2013).

179 Despite the observed variations in annual rainfall, the analysis of rainfall pattern shows major
180 significant changes in annual rainfall amount over the past 18 years from 1995 to 2012. The
181 linear equation in Figure 5 ($y = -4.5976x + 640.71$), show that the decreasing trend of rainfall
182 from 1995 to 2012 is three times the decreasing trend from 1983 to 2012 ($y = -1.5062x +$
183 618.46) as presented in figure 6. Therefore rainfall has been decreasing at an increasing
184 rate for the past 30 years. With this rate, agricultural communities in the study area were
185 likely to become more vulnerable and their livelihoods adversely affected.



186
187 Figure 5: Annual rainfall trend from 1995 to 2012.
188 Source: TMA-Dodoma station (2013).

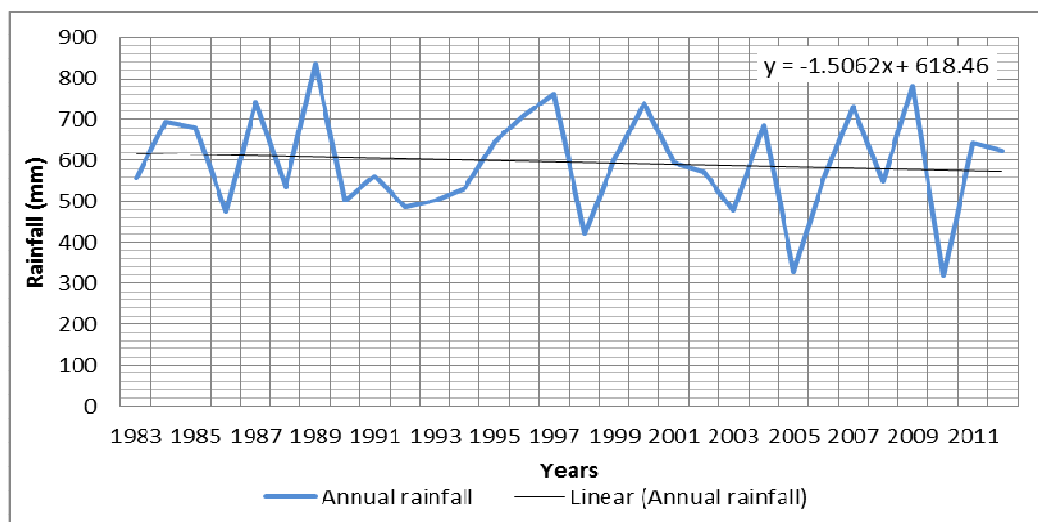


Figure 6: Annual rainfall trend from 1983 to 2012.
Source: TMA-Dodoma station (2013).

These findings were also supported by the findings of Mongi et al., (2010) [12] which reveal the decreasing trend of annual rainfall in Semi-arid Tanzania. Similarly, Lema and Majule (2009) [13], establishes decreasing rainfall trend in Manyoni district Central Tanzania. To a large extent, analysis of rainfall from meteorological data corresponded to farmer's experiences whereby 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, 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, which sells crops both inside and outside the country. The market started to operate officially in 2004 and focused mainly on marketing of maize although the popular traditional crops by then were sorghum and bulrush millet. In 2004, for instance only maize was sold in the market. Between 2005 and 2010, sunflower, groundnuts, pigeon peas, cowpeas and sorghum were introduced in the market. However, despite the introduction of other crops, maize was still leading in terms of quantity and marketability followed by sunflower. Market oriented production as well as the focus on maize which triggered shifts from production of traditional crops such as sorghum and bulrush millet is what raises questions as far as adaptation is concerned in the context of existing climatic changes.

3.5 Levels of crop specific commercialization

Analysis of Household Commercialization Index (HCI) of the produced crops from 2008 to 2013 showed a lot of variations in commercialization between crops. The analysis further showed the variation between HCI and marketability of the analysed crops. 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 availability of ready and vicinity market. Therefore some crops were found to have high HCI while least marketable while others were found to have low HCI while highly marketable. For instance, maize was the least commercialized crop according HCI because it was also the main food

crop. However, despite of being the least commercialized crop, focus group discussion, interview with key informants and field observation revealed that maize was the highly marketable crop compared to other crops. Marketability of maize was influenced by its demands at the Kibagwa crop market and its assurance for market since it could be sold throughout the year.

Generally, HCI ranged from 31% to 99%. HCI in Hembahemba village was found to be higher than in Manyata village. In Hembahemba village HCI ranged from 51% to 97% while 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 because agricultural production was high in Hembahemba village than in Manyata village, so did the HCI. The summary of average HCI of Maize, sunflower, pigeon peas and groundnuts in the two villages are presented in Figures 7 and 8.

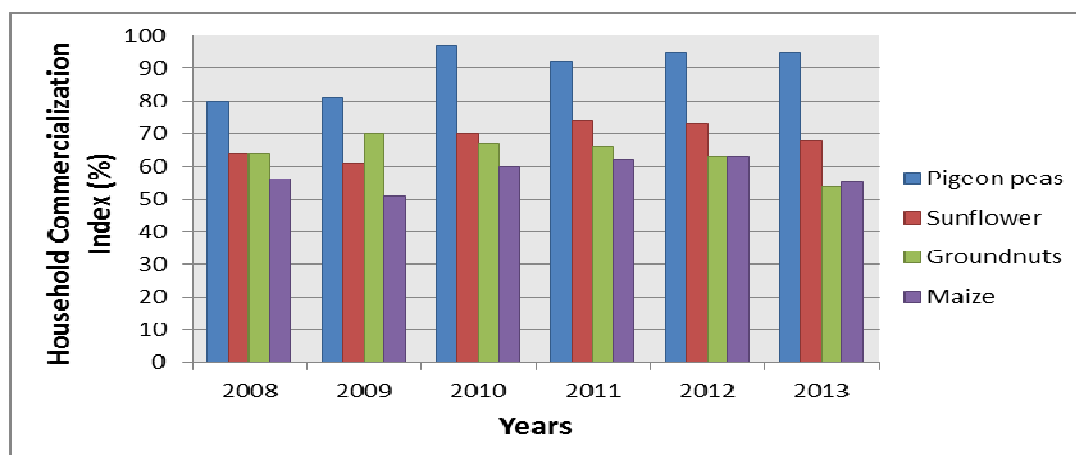


Figure 7: Average of Household Commercialization Index (HCI) in Hembahemba village. Source: Fieldwork (2013).

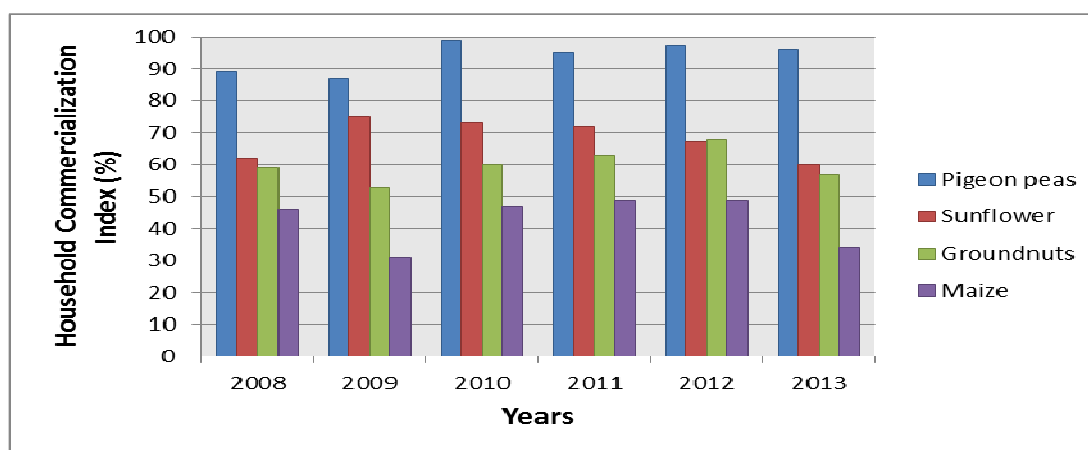


Figure 8: Average of Household Commercialization Index (HCI) in Manyata village. Source: Fieldwork (2013).

3.6 Influence of agricultural commercialization on change in crops/crop varieties

According to URT (2010) [14], historically Kongwa district started as a centre for colonial activities in 1942 following establishment of groundnut estates. In-depth interview with village

elders revealed that after independence most of the households preferred to cultivate bulrush millet as the cash crop and sorghum as the food crop. In Hembahemba village the name itself originated from the Kaguru tribe “uhemba” which means “sorghum”. Therefore sorghum was the main food crop when the village begun. When production in the area became more commercialized more crops were introduced for commercial purposes including pigeon peas, sunflower, sesame and cowpeas. Most of the households also turned into cultivating maize as a food crop rather than sorghum. Similar results were reported by Liwenga et al., (2009) [6], who revealed the change 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 climate change adaptation

Field survey revealed that, some of the cultivated crops and crop varieties were less resistant to climate change and variability compared to traditional crop varieties. Cultivation of maize was in the expense of sorghum, which was more resistant to drought condition compared to maize. According to findings 90% and 96% of the respondents in Manyata and Hembahemba villages respectively were aware of the risk of cultivating maize in expense of sorghum. They were however influenced by the market of maize. Majule et al., (2013) [15] also argues that sorghum in particular short-term varieties seem to adapt well but market for the crop still needs to be developed. However on the other side diversification also took into account the crops, which were more resistant to climatic shocks, pests and diseases. Cultivation of sunflower for commercialization largely corresponded to the climate of the area hence enabled the farmers to withstand climatic shocks.

3.8 Influence of agricultural commercialization on change in farming systems

Traditionally the Gogo who were the dominant tribe in Kongwa district up to early 1980's were agropastoralists. Therefore the 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 for 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 rent fee to land owners for each growing season.

3.9 Reflection of current farming systems on climate change adaptation

From the analysis of the farming systems, it was discovered that shifting from mixed farming to crop based farming system increased the over dependence on crop farming which in turn increased their vulnerability to climate change and variability. An in-depth interview with the indigenous village elders in both villages revealed that in the past 30 to 40 years, mixed farming systems largely helped the farmers to diversify their economic sources and use farmyard manure to improve the fertility of their farms. This is supported by Singh et al., (1994) [16] who argue that application of organic materials such as farmyard manure considerably improves soil physical properties 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. First farmers could not own land permanently. This exposed them into risk of not having land to cultivate for some growing seasons due to

insufficient financial ability to pay rent fee. Land to be used by outsiders leaving the villagers landless was the second risk and would result into land conflicts. This was confirmed during focus group discussion and household interviews, from which the villagers from both two villages reported the presence of land related conflicts due to the tendency of some landowners to rent one piece of land to more than one farmer as well as due to 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. During focus group discussion participants reported that, desire to produce more crops due to market demand influenced expansion of fields hence increase in farm workload. Mechanization was reported to be the best solution for the increased workload. It was further revealed through focus group discussion that mechanization in both villages also influenced the change of farming practices including farm preparation traditionally known as “kubelega”. Kubelega involved clearing the land and burning the wastes before planting. Thereafter, the seeds were left in the ground for timing the first rains. With mechanization, cultivation and planting were done during the onset of first rains. Household responses to farming practice from both villages are detailed presented in Table 2.

Table 2: 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).

3.11 Reflection of current farming practices on climate change adaptation

Some of the farming practices were found to be in line with adaptation to climate change and variability while others were not. With mechanization, farmers were able to cultivate large pieces of land in a short period of time thereby increasing surplus production. Also, with the abandonment of land clearing practices (kubeleka), farmers were no longer burning the wastes therefore soil fertility was able to be sustained by conserving soil micro-organisms.

Moreover according to Agricultural Extension Officer of Njoge ward, mechanization was reported to influence tillage practices. Tillage by disc plough was reported to increase infiltration rate by reducing surface run off and accessibility of water and nutrients to cultivated crops through deep root penetration. Gwambene and Majule (2010) [17], also acknowledges that the use of tilling methods under proper tilling implements such as Magoye ripper, Spring Jembe and Power tiller has ability to retain moisture in the soils for every single rain drop available. Therefore the influence of mechanization on tillage practices was also concluded to be beneficial to farmers.

On the other side, since the farmers were no longer putting down the seeds prior to rain onset, they were then exposed to the risk of variability of rain onset unless weather forecast and access of weather information are improved. In addition, under staggered seed crop planting farmers were able to cultivate several plots by differentiating planting dates. This helped the farmers to spread the risks of irregularities of rain onset. Although few farmers were reported to abandon the practice, without an alternative measure of timing rain onset, farmers would become more vulnerable to climate change and variability.

4. CONCLUSION AND RECOMMENDATIONS

The study has established that changes of rainfall patterns, increasing temperature and decreasing rainfall trends, has negatively affected agricultural production in the area. Apparently, agricultural commercialization influenced several changes in farming practices, mechanization and agricultural input usage. Agricultural commercialization has influenced 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 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, vulnerability to climate change and variability was also found to be influenced by unreliable and lack of timely weather information. Therefore because the conclusion is limited to agricultural commercialization the study suggests further research on accessibility and reliability of weather information in improving the adaptive capacity to climate change and variability among the farming communities of semi-arid environment.

However in order to enhance commercialization and climate change adaptation, there is a need of providing regular training to farmers on sustainable farming methods, cropping patterns and farming practices. 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 hence promoting diversification to drought tolerant crops/crop varieties. Also diversifying farmer's economic sources to reduce overdependence on crop farming through promoting mixed farming will be beneficial because the area is also very potential for livestock keeping.

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