Smallholder Farmers' Adaptation Strategies to Climate Change in Semi-Arid Areas of Chamwino District, Tanzania

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ABSTRACT

*Climate is the main determinant for agricultural productivity worldwide. This paper presents the findings of a study conducted in Chamwino District in Dodoma Region to examine smallholder farmers' adaptation strategies to climate change. The study used long term weather data obtained from Dodoma Airport meteorological stations and the free online satellite weather data from the Climate Forecast System Re-analysis (CFSR) as well as primary household data from a sample of 125 smallholder farmers collected through structured interviews. The satellite climate data was used to overcome the bottleneck of ground station weather data after removing the bias on data. The bias of the CFSR data was corrected by a linear bias correction approach. Climatic data were analyzed to establish the relationship between crop production and changes in the climatic variables using correlation analysis. The results revealed that most of the farmers were slightly aware (61%) about climate change and mostly referred to it as changes in temperature (50%) and recurrence of drought (22%). The weather data showed a declining trend in temperature of 3.6^{0}C and rainfall (*20–27 mm per annum*) over the span of 38 years indicating evidences of climate change. Paddy, sorghum and legumes showed an increasing trend while other crops showed a declining trend. Most of farmers adapted the use of drought tolerant crop varieties and early planting of crops as on-farm adaptation strategies while petty business and casual labour were the main off-farm climate change adaptation strategies. This study concludes that the declining rainfall and increased temperature in Chamwino District is affecting smallholder farmers by reducing crop yield. Nevertheless, farmers were well aware and understood about climate change and its impacts. Most of farmers had adopted appropriate copping strategies to sustain their livelihood amidst the challenges brought about by the effects of climate change. It is recommended that the Tanzania government through the Ministry of Agriculture and Food Security to improve extension services so as to enhance adoption of climate change smart technologies among smallholder farmers in order to sustain their livelihood.*

Keywords: Climate change adaptation, on-farm and off-farm strategies, livelihood; semi-arid

1.0 INTRODUCTION

Agriculture plays a central role in the economy of many developing countries as a source of economic growth, food security and livelihood (Coulibaly *et al.*, 2015). In many developing countries, it is estimated that 73% of the workforce engages in agricultural activities, and majority of them are poor smallholders and labourers. For most rural populations of these countries, agriculture is the primary source of food, direct and/or indirect employment and income. Yet, the sector remains underdeveloped and vulnerable to the whims of nature, including climate change and variability. It is estimated that over 70% of rural populations in sub-Saharan Africa rely on rain fed smallholder agriculture for subsistence and livelihood (Shuaibu *et al.*, 2014). This dependence makes farmers vulnerable to the adverse effects of climate change through its impact on farming activities and increased poverty in the already vulnerable communities (Shuaibu *et al.*, 2014).

The impacts of climate change have been experienced widely across the globe and posed serious drawbacks to the achievements of Millennium Development Goals (MDGs) (Africa Partnership Forum Support Unit, 2007). Africa is the most affected continent as it lacks the capacity to adapt the necessary measures needed to recover from the devastating climate change related effects. Evidence from various models for climate change prediction indicates that climate change is likely to increase the risk of crop and livestock production unless appropriate and timely adaptation or coping strategies are employed (Chambwera and Stage, 2010). For example, a study by Bryan *et al*. (2013) shows that in Sub-Saharan Africa, agriculture systems are more sensitive and vulnerable to impacts of climate change due to the fact that communities have limited adaptive capacity. In the semi-arid areas of Tanzania, which cover about 50% of the country land area, the onset of human-induced climate change has greatly aggravated the situation, resulting into more stress on the fragile environment that has limited natural resources (FAO, 2012). Although communities in the semi-arid areas have managed to withstand the harsh environmental conditions for many decades, the current intensity of climate change and variability has badly affected their livelihood strategies (Paavola, 2003).

In Tanzania, the livelihood strategies for the rural poor in the semi-arid areas are largely premised on increasing productivity of small-scale agriculture. Agriculture sector provides about 67% of employment in the country, accounts for about 23% of GDP, 30% of exports, 65% of inputs to the industrial sector and produces an average of 95% of the national food demand (URT, 2016). Approximately, between 75% and 80% of Tanzanians earn their livelihood through small-scale agriculture (URT, 2016). However, high dependence on agricultural production, and hence on natural resources makes livelihoods of farming communities in the country potentially vulnerable to negative impacts of climate change associated with decreased agricultural productivity, food insecurity and constrained water availability (Kangalawe *et al.*, 2016). In recent years, decline in crop productivity has been observed more in food crops such as maize, cassava, beans, sweet potatoes and bananas. In the semi-arid areas of Tanzania like Dodoma and Tabora regions, average yield decrease was estimated at 84% (Kangalawe *et al*., 2016). A climate vulnerability assessment in Dodoma showed that Chamwino District has been mostly affected in terms of food production due to prolonged drought caused by climate change (Njau *et al*., 2014).

In response to climate change, communities in many areas of the world, including Tanzania, have developed multiple adaptive strategies, including growing of drought tolerant and early maturing crop varieties, water harvesting for small-scale irrigation and livestock keeping, terracing, growing of perennial crops, crop rotation, planting cover crops, minimum tillage, weed control, use of mulching, agroforestry, use of fertilizers and forest clearing for agriculture (Baruani and Senzia, 2013). Despite this recognition, however, there is dearth of information in the academic literature on the adaptation strategies used by smallholder farmers to overcome low agricultural productivity due to climate change in Tanzania, and Dodoma region in particular. This study was, therefore, conducted to examine the adaptation strategies used by small-scale farmers to overcome climate shocks so as to sustain their livelihoods in semi-arid areas of Chamwino

District. Specifically, the study intended (i) to examine smallholder farmers' awareness about climate change; (ii) to examine changes in weather variables and their implication on crop production; and (iii) to examine the local adaptation strategies to climate change used by small-holder farmers.

2.0 METHODOLOGY

The study was conducted in five selected villages in the semi-arid areas of Chamwino District in Central Tanzania (Figure 1). Chamwino District is one of the seven districts of Dodoma region. It is located on the eastern part of the region with Latitude and Longitude of 6.0986^{0}S and 36.0431^{0}E as the central coordinates of the district. The district is bordered on the West by Bahi and Dodoma Urban Districts, on the North by Chemba District, on the East by Kongwa and Mpwapwa Districts while on the South it shares borders with Iringa District (URT, 2012a).

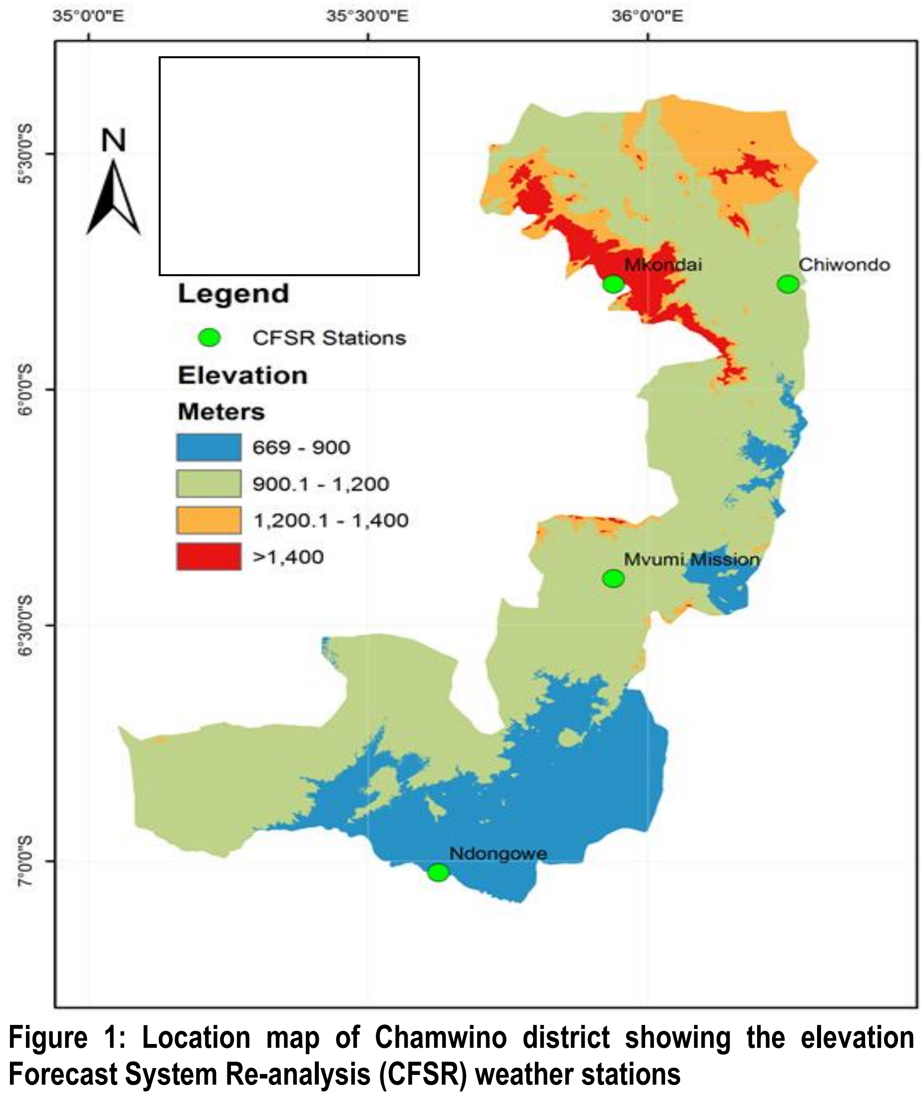

Figure 1: Location map of Chamwino district showing the elevation and the Climate Forecast System Re-analysis (CFSR) weather stations

The main economic activities of the people in the district are farming, livestock keeping and business activities. The district has a dry Savannah type of climate which is characterized by low and unpredictable unimodal rainfall, persistent desiccating winds and low humidity, with average temperature ranging from 21°C to 23°C. The district experiences a long dry season from late April to early December and short single wet season during the remaining part of the year. The average annual rainfall falls in the ranges of 200mm – 800mm (URT, 2012a).

The study adopted a cross sectional research design. A sample of 125 small-scale farmers was selected to represent small-scale farmers in Chamwino district. Data were collected through structured interviews using a structured questionnaire which was designed to solicit information about respondents' characteristics, adaptation strategies to climate change and crop production. Documentary review was used to obtain secondary information related to climatic data and agriculture production from weather stations and district council offices, respectively. Focus-group discussions and key informant interviews were used to collect qualitative information from the study area. Both descriptive and inferential analyses were applied in this study. Socio-demographic characteristics of farmers (age, sex, education and marital status) were analyzed through descriptive analysis. Smallholder farmers' awareness about climate change was measured using a 4-point Likert scale question, ranging from 'not aware at all' to 'very aware'. The climatic data were analyzed to establish the relationship between crop production and changes in the climatic variables using correlation analysis. In this study, two weather variables were considered as they play a key role in crop production: temperature and rainfall. With regard to temperature, the mean minimum and mean maximum temperature in Chamwino district covered the period from 1979 to 2017 which was found to be appropriate in depicting climate change. Trend analysis was used through Excel to analyze temperature and rainfall patterns together with crop production.

Weather data were obtained from two main sources namely, the ground-based weather gauging station at Dodoma Airport and the Climate Forecast System Reanalysis (CFSR) global weather data for SWAT available at http://globalweather.tamu.edu/. The ground-based gauging stations data were provided by the Tanzania Meteorological Agency (TMA). It was necessary to include the CFSR global rainfall and temperature data because Chamwino district had no any ground gauging station for weather data. Using only TMA data for Dodoma Airport to study climate of Chamwino district could not represent the actual local climate. Thus, CFSR data for Chamwino district were obtained from the four stations namely: Mkondai, Chiwondo, Mvumi Mission and Ndongowe stations (Figure 1). The CFSR data often capture the rainfall pattern very well; however, they often overestimate the gauged rainfall (Worqlul *et al*., 2014, 2017a). In the case of overestimation, a nearby station rainfall data is used to perform bias correction of the CFSR precipitation data. In this study, Dodoma Airport station data, a nearby weather station which had daily series data from 1998 to 2017, was used to perform bias correction of the CFSR precipitation data of four CFSR weather stations in Chamwino district. The bias of the CFSR data was corrected by a linear bias correction approach as described by Worqlul *et al.* (2017b). This approach reduces the volume difference between CFSR and gauged rainfall data while keeping the pattern. The two datasets (uncorrected CFSR and gauged rainfall data) involved in the linear bias correction process covered the same time window (1998–2017). The annual volume difference between the observed and bias corrected data was minimized to zero. In addition, the mean monthly data (observed and corrected CFSR) were highly correlated due to their close mean monthly values as shown in Figure 2. GIS technology was also used for interpolation analysis of CFSR weather data.

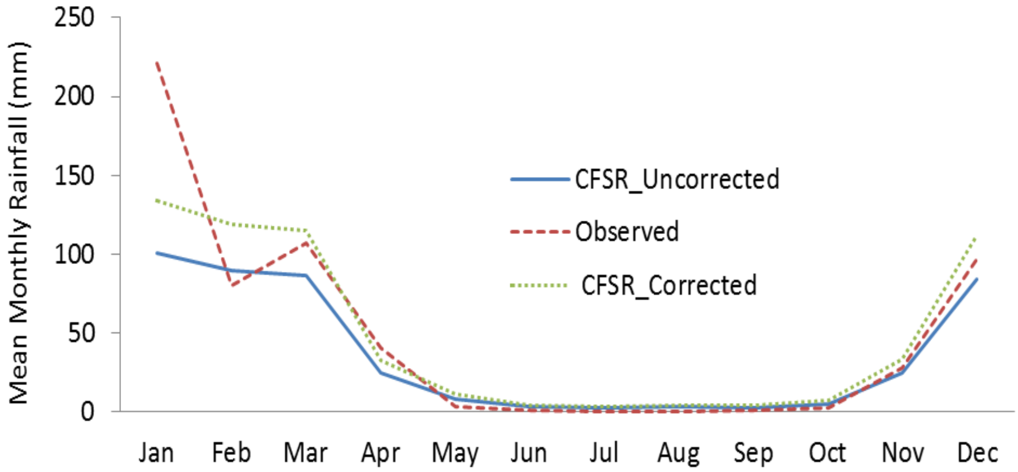

Figure 2: Climate Forecast System Reanalysis rainfall data before and after bias correction

3.0 RESULTS AND DISCUSSION

3.1 Socio-demographic Characteristics of Farmers

The socio-demographic characteristics of smallholder farmers examined in this study are presented in Table 1. The results show that more than half of the smallholder farmers were males (58%) whereas female smallholder farmers accounted for 48% of the respondents. The findings depict the true picture for most farming communities and land ownership in Tanzania, which is largely male dominated. Majority of the respondents were married (85%) and very few were widowed (3%). Almost three quarters of smallholder farmers were aged between 31 and 50 years (73%) and the mean age was 40 years. This shows that majority of smallholder famers are within the productive age group. The results further showed that majority of the farmers had at least primary school education (82%), about one in every ten smallholder farmers had no formal education (10%) and very few had tertiary education (2%). This shows that literacy level, a requisite for promotion and adoption of agricultural innovations was generally high in the study area. In general, the characteristics of the respondents show inclusion of the various social groups in the surveyed communities, suggesting representativeness of views on the issues under this study.

3.2 Smallholder Farmers' Awareness on Climate Change

Smallholder farmers' awareness about climate change was measured using a 4-point Likert scale question, ranging from "not aware at all" to "very aware". The results showed that most of the smallholder farmers in Chamwino district were "slightly aware" (61%) about climate change. Over one quarter (26%) were "moderately aware" and few were "not aware at all" (9%). Most of the smallholder farmers with primary school education were aware about climate change than other categories (Table 2). This is justified given the higher percentage of farmers with primary school education as indicated in Table 1. Through focus group discussion, smallholder farmers indicated that they understood climate change as increase in temperature and droughts rather than climate change *per se*. This implies that farmers who seemed to understand more about climate change could easily be ready to adopt climate change technologies at their disposal. Whereas smallholder farmers with tertiary education were expected to be "very aware" about climate change, the findings on awareness depicted a different picture as they were "moderately aware" indicating that probably the knowledge on climate change needed to be formally introduced. These findings are in line with those by Mertz *et al.* (2009) and Kadi *et al.* (2011) which revealed that individual level of awareness can affect one's ability to acquire knowledge and adopt innovations towards climate change.

Table 1: Socio-demographic characteristics of respondents (n=125)

Variable	Description	Frequency	Percent (%)
Sex	Male	73	58.4
	Female	52	41.6
Age (years)	20-30	19	15.2
	31-40	41	32.8
	41-50	50	40.0
	51-60	10	8.0
	61-70	4	3.2
	More than 70	1	0.8
Marital status	Single	10	8.0
	Married	106	84.8
	Divorced	5	4.0
	Widowed	4	3.2
Education level	No formal education	12	9.6
	Primary education	103	82.4
	Secondary education	8	6.4
	Tertiary education	2	1.6

Table 1: Farmers' awareness on climate change (n=125)

Level of Awareness	Not attended School	Primary School Education	Secondary Education	Tertiary Education	Total
Not aware at all	2(18.2)	8(72.7)	1(9.0)	0(0.0)	11(8.8)
Slightly aware	9(11.8)	65(85.5)	2(2.6)	0(0.0)	76(60.8)
Moderately aware	1(3.0)	25(75.8)	5(15.2)	2(6.1)	33(26.4)
Very aware	0(0.0)	5(100.0)	0(0.0)	0(0.0)	5(4.0)
Total	12(9.6)	103(82.4)	8(6.4)	2(1.6)	125(100.0)

Figures in parenthesis are respective percentages

3.3 Farmers' Understanding on Climate Change

Smallholder farmers in the study area understood climate change differently based on different changes they observed in their environment (Table 3). More than half of the respondents understood climate change as high temperature (50%), close to a quarter as low rainfall (22%) and very few as extremely low temperature (2%). Contrary to the expectation, only about 5% of the respondents indicated decrease in crop yield as the major effect of climate change probably because over the years, farmers have devised copying strategies to maintain or increase crop yield. A study in six different agro-ecological zones in Tanzania found that that farmers who have recognized climate change will take some actions to cushion themselves against its adverse effects (Komba and Muchapondwa, 2012). Studies by Coulibaly *et al*. (2015) in Malawi and Kangalawe *et al*. (2016) in Western Tanzania also revealed that farmers who noticed changes associated with climate change in their locality took some measures to curb the effects so as to sustain their livelihood.

Table 3: Farmers' understanding on climate change (n=125)

Farmers' Understanding	Not attended School	Primary School Education	Secondary Education	Tertiary Education	Total
High temperature	3(25.0)	5 (51.5)	7(87.5)	0(0.0)	63(50.4)
Low rainfall	3(25.0)	16(15.5)	0 (0.0)	1(50.0)	20(16)
Recurrent of drought	3(25.0)	23(22.3)	1(12.5)	1(50.0)	28(22.4)
Extreme low temperature	1(8.3)	2(1.9)	0 (0.0)	0(0.0)	3(2.4)
Decline in crop yield	1(8.3)	5(4.9)	0 (0.0)	0(0.0)	6(4.8)
Increased crop pests	1(8.3)	3(2.9)	0 (0.0)	0(0.0)	4(3.2)
Don't Know	0(0.0)	1(1.0)	0 (0.0)	0(0.0)	1(0.8)

Figures in parenthesis are respective percentages

3.4 Weather Variables in Chamwino District

In this study, two weather variables were considered as they play a key role in crop production, namely; temperature and rainfall. With regard to temperature, the mean minimum and mean maximum temperature in Chamwino district covered the period from 1979 to 2017 which was found to be appropriate in depicting climate change. The temperature data show an increasing trend with an estimated increase of 3.6^{0}C in the mean minimum temperature than mean maximum temperature of 2.4^{o}C for the period from 1979 to 2017 (Figure 3). This increasing trend implies that there is a likelihood of increasing in annual mean temperature in the future in the area as indicated by the trend line equations in Figure 3, which will consequently affect evapotranspiration and crop production**.** These results correspond with findings in comparable settings in Tanzania reported by Ehrhart and Twena (2006); Lema and Majule (2009) Swai *et al*. (2012); Shemsanga *et al.* (2015) and Craparo *et al*. (2015).

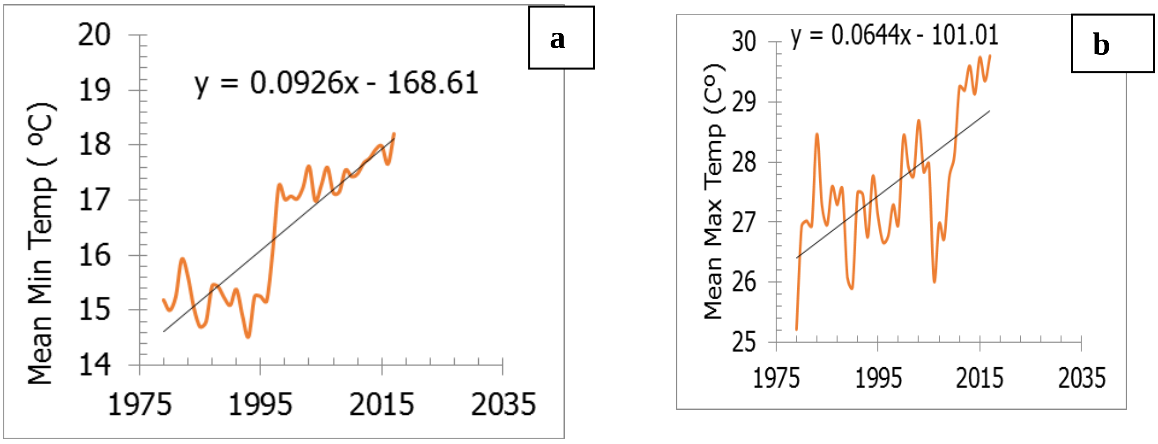

Figure 3: Mean minimum (a) and maximum (b) temperature in Chamwino district from 1979-2017. Source: TMA (2018)

Rainfall distribution data for Chamwino district are shown in Figure 4. The data show that almost half of the area in Chamwino district receives rainfall ranging from 20–27 mm per annum, suggesting that there is high spatial and temporal rainfall variability. Mvumi Mission station receives more annual average rainfall (29 mm/year) than the Mkondai and Chiwondo stations (23 mm/year) and Ndongowe station (7.6 mm/year). The rainfall data also show increasing trends in all four stations on annual and monthly basis as shown in Figure 5. Moreover, there is decreasing trend in monthly rainfall in November and December in most stations while January rains have more or less remained the same. This implies that there is reduced duration of rainfall season in the area. Thus, the changes in rainfall distribution in the remaining months will cause destructions of crops since there will be more rainfall than what was required to support growth of crops necessitating changes in the planting dates for some crops. These findings are also similar to what has been observed in previous studies (e.g. Rwebugisa 2008; Shemsanga *et al.*, 2015; Kangalawe *et al.*, 2016).

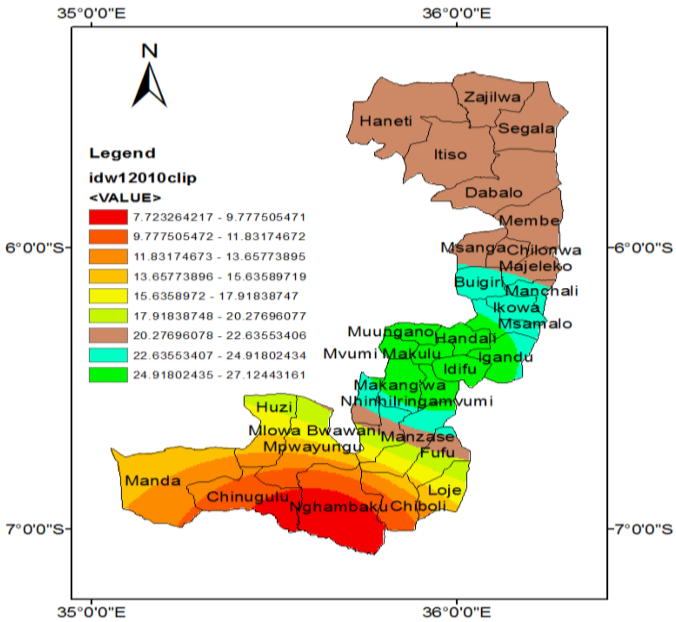

Figure 4: Rainfall distribution in Chamwino District (in mm)

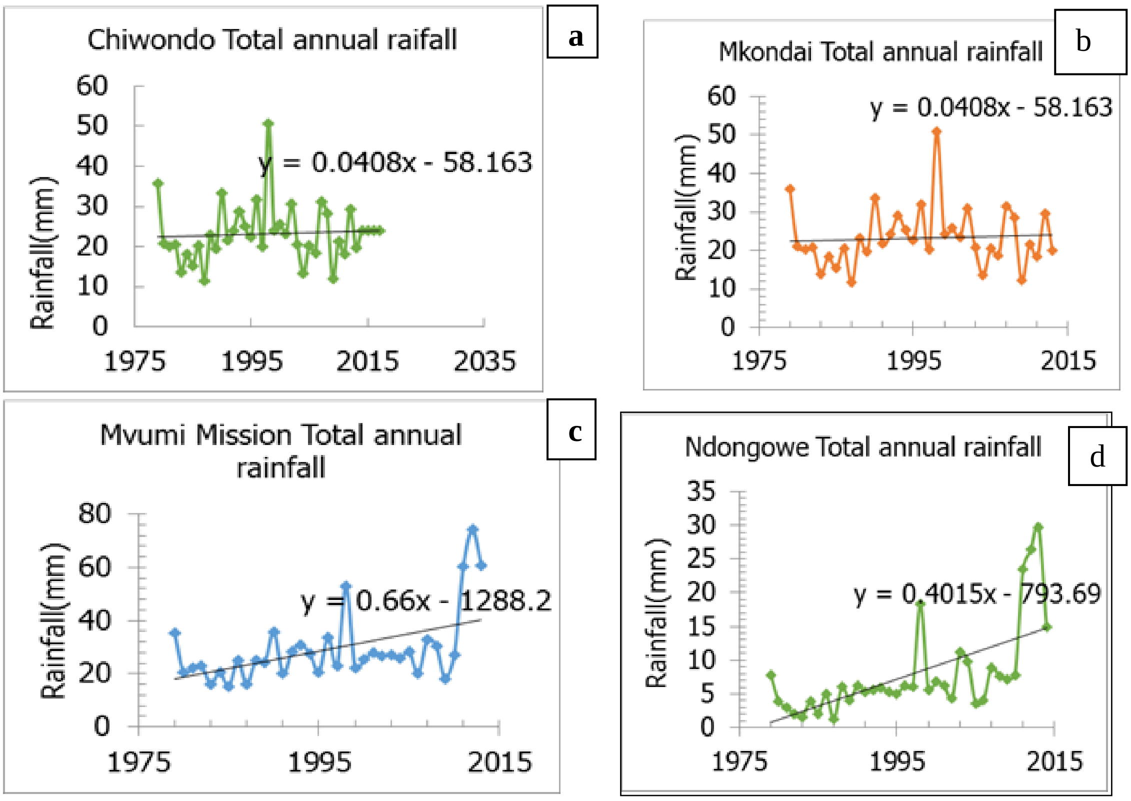

Figure 5: Total annual rainfall trends at different stations in Chamwino district

3.5 Food Crops Production by Smallholder Farmers

3.5.1 Farmers perception on trend of food crops production

The results in Table 4 show that majority of the farmers perceived that there was a declining trend in crops yield in Chamwino district. The most experienced farmers (61 years and above) agreed that decline in crop yield is a reflection of climate change in their area. Although decline in crop production can also be associated with non-climatic factors like changes in soil fertility and increase in crop pests, climatic factors seemed to play a major role as a mere fertile soil cannot influence yield unless the nutrients are taken by plants in a soluble form where water is a necessity. These findings concur with the results by Mongi *et al.* (2010), Mbilinyi *et al.* (2013), Sanga *et al*. (2014); Kangalawe and Lyimo (2013) and Coulibaly *et al*. (2015) who also noted that there was a decrease in food security as a result of climate change effects.

Table 4: Farmers' perception on crop yield trends based on age (n=125)

Age Category (Years)	Perception on Yield Trends			
	Decrease	No Change	Increase	Don't Know
20 - 30	14 (13.5)	4 (33.3)	1 (12.5)	0(0.0)
31 - 40	35 (33.7)	2 (16.7)	3 (37.5)	1 (100)
41 - 50	42 (40.4)	4 (33.3)	4 (50.0)	0(0.0)
51 - 60	8 (7.7)	2 (16.7)	0(0.0)	0(0.0)
61 -70	4 (3.8)	0(0.0)	0(0.0)	0(0.0)
>70	1 (1.0)	0(0.0)	0(0.0)	0(0.0)

Figures in parenthesis are respective percentages

3.5.2 Trend of yield for major food and cash crops

Results in Figures 6-13 show yields for food and cash crops between 2010/11 and 2016/17. The results revealed that groundnuts, sunflower and sesame are the major cash crops produced in the study area while legumes, millet, sorghum, maize and paddy are major food crops produced. The results revealed an increasing yield trend for paddy, sorghum and legumes (Figs. 6, 7 & 8) and a decreasing trend for other crops grown in the area (Figures. 9–13). Increase in yield trend for paddy is due to the fact that the crop is mainly grown under irrigation while sorghum and legumes are used as drought tolerant and early maturing crops. Increase in yield for these crops has also been attributed to among other things farmers' awareness and good understanding on the right crops to be grown given the unpredictable weather conditions prevailing in the area. Studies by Mongi *et al.* (2010), Sanga *et al.* (2014), Mbilinyi *et al.* (2013), Baruani and Senzia (2013), Kangalawe and Lyimo (2013) and Kangalawe *et al.* (2016) and also revealed decreasing trend in maize, sunflower and ground nuts yields.

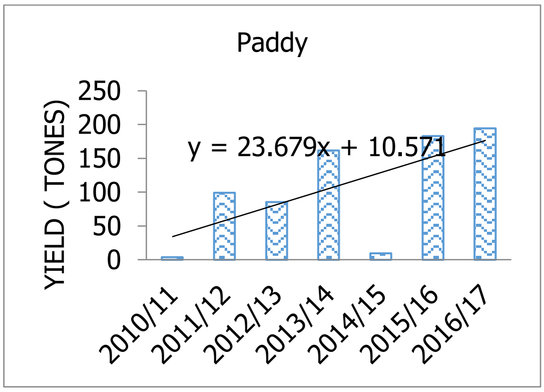

Fig 6: Yield trend for paddy

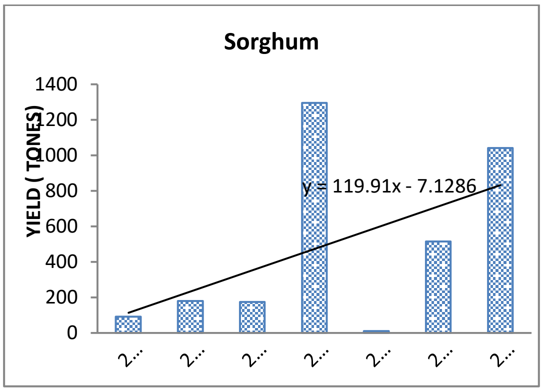

Fig 7: Yield trend for sorghum

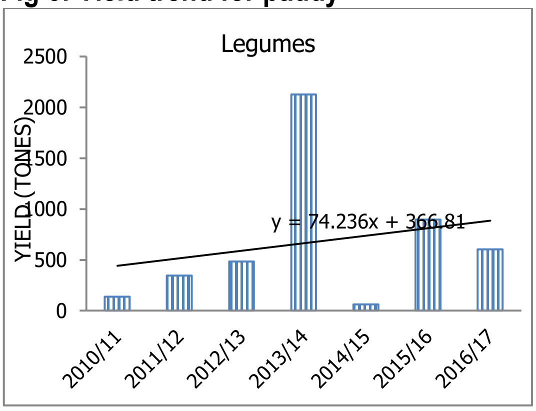

Fig 8: Yield trend for Legumes

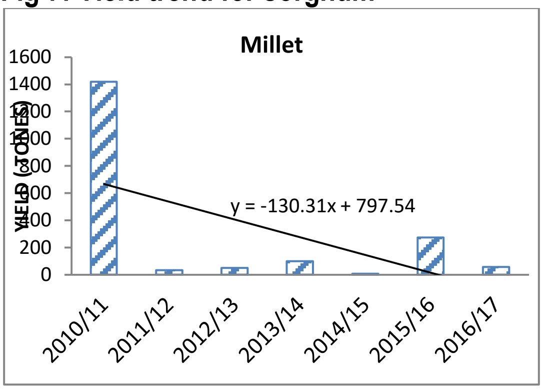

Fig 9: Yield trend for Millet

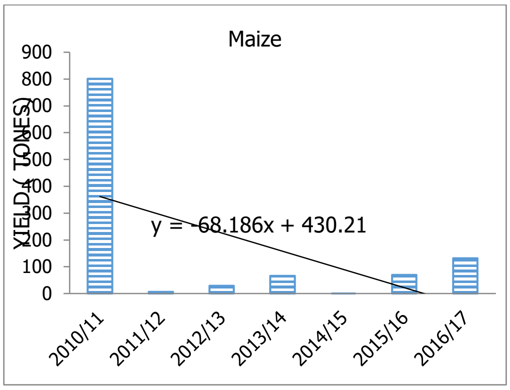

Fig 10: Yield trend for maize

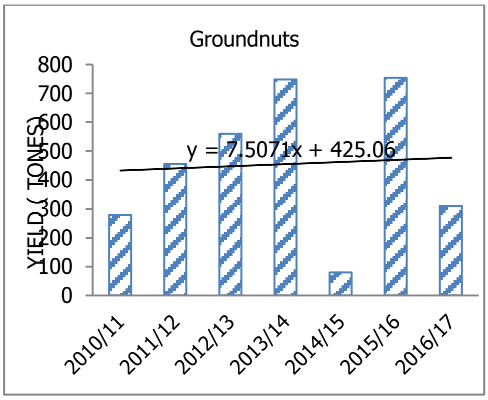

Fig 11: Yield trend for groundnuts

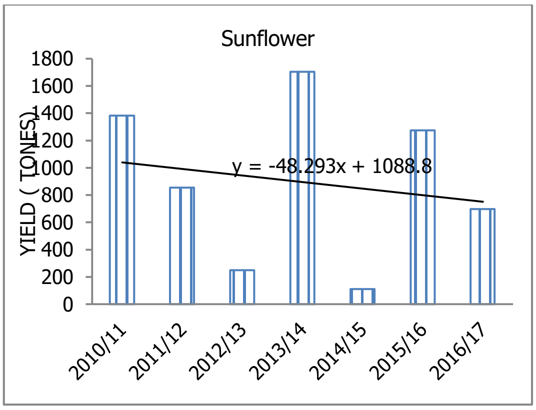

Fig 12: Yield trend for sunflower

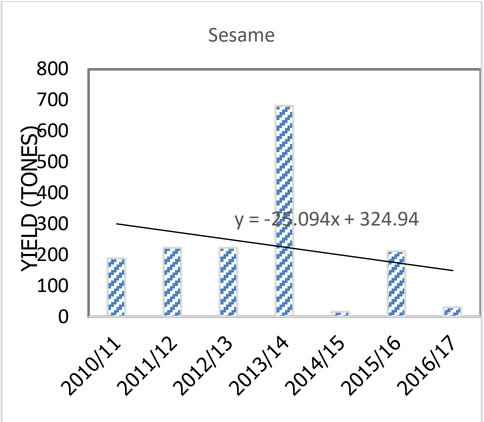

Fig 13: Yield trend for sesame

3.5.3 Relationship between rainfall, temperature and crop production

The results showed that temperature had a positive and significant correlation with maize and paddy yield in Chamwino district with R^2 values of 0.74 and 0.61 and p values of 0.01 and 0.03 for maize and paddy, respectively (Table 7). The R values for temperature in maize and paddy are 0.86 and 0.78, respectively, indicating that temperature explains much on the yield for the two crops. This observation could be due to the fact that rainfall distribution was not favourable for maize production while in paddy, the effect was minimized through the use of irrigation.

Table 7: Relationship between rainfall, temperature and crop yield

Crop	Climate variable	R	R^2	P- Value
Maize	Rainfall	0.65	0.42	0.11^{NS}
	Temperature	0.86	0.74	0.01**
Paddy	Rainfall	0.24	0.059	0.59^{NS}
	Temperature	0.78	0.61	0.03**
Sorghum	Rainfall	0.13	0.017	0.77^{NS}
	Temperature	0.54	0.29	0.20^{NS}
Sunflower	Rainfall	0.22	0.05	0.62
	Temperature	0.01	0.0	0.98

**Significant at 1%, NS = Not significant

3.6 Adaptation Strategies to Climate Change among Smallholder Farmers

Smallholder farmers in Chamwino district use a wide range of strategies in response to the current effects of climate change. The livelihood adaptation strategies used by farmers were very diverse depending on one's ability and capability. However, the main strategies observed in the study area were categorized as on-farm and off-farm strategies. The on-farm adaptation strategies used by smallholder farmers to overcome impacts of climate change in crop production included adopting use of drought tolerant varieties (25%) and early planting (21%). Minimum tillage, crop diversification, irrigation and use of cover crops were also reported by 13%, 10%, 9% and 9% of the farmers, respectively (Table 8). These strategies assisted farmers to sustain their livelihood and meet their food requirements. However, choice of a crop variety depends on farmer's choice and preference this is the reason why some farmers grew maize while it has been proved to be less desirable in the study area. Farmer's preference has been reported to play a key role in influencing the adoption of recommended crops suitable in the semi-arid conditions as reported by Burke and Lobell (2010). The use of drought tolerant varieties has also been reported as a copping strategy to climate change in Nepal (Manandhar *et al.*, 2010), Central Tanzania (Kangalawe and Lyimo, 2013) and Malawi (Coulibaly *et al.,* 2015), suggesting that it is a widely used strategy.

Table 8: On-farm adaptation strategies used by smallholder farmers (n=125)

Strategies	Frequency	Percent
Early planting of crops	83	20.9
Use of cover crops	35	8.8
Drought tolerant crops	98	24.7
Irrigation	37	9.3
Minimal tillage	52	13.1
Crop diversification	40	10.1
Rain water harvesting	19	4.8
Manure application	14	3.5
Agroforestry	7	1.8
Crop rotation	1	0.3
Early maturing varieties	11	2.8

Results based on multiple responses

The off-farm strategies were mainly adopted to cushion the deficit from less productivity due to climate change. Many farmers used off-farm income sources which are less climate sensitive to sustain their livelihood and capital for their on-farm activities (Baruani and Senzia, 2013; Kihupi *et al.* 2015). The results in Table 9 show that the most used off-farm strategies were petty business (32%) and casual labour (32%) and the least was bee keeping (1%) in order to earn income needed for various household needs. It was established that petty business was based on agricultural products such as buying and selling paddy or rice, vegetables, tomatoes, fruits, sunflower, groundnuts, sesame and maize. Casual labour activities were done by farmers involved providing manpower for planting, weeding and harvesting during the cropping season. Most of these off-farm activities were, however, done after the cropping season have ended. This shows that in addition to farm related strategies, smallholder farmers in the study area also had a number of off-farm activities that enabled them to contain the shocks of climate change and contribute to their livelihood.

Table 9: Off-farm adaptation strategies used by smallholder farmers (n=125)

Strategies	Frequency	Percent
Petty business	60	31.9
Local brewing	16	8.5
Casual labor	61	32.4
Charcoal and firewood selling	28	14.9
Livestock keeping	13	6.9
Crop selling middle man	2	1.1
Salt making	7	3.7
Bee keeping	1	0.5

Results based on multiple responses

4.0 CONCLUSION AND RECOMMENDATIONS

This study has examined adaptation strategies used smallholder farmers to overcome climate shocks so as to sustain their livelihoods in semi-arid areas of Chamwino district. The study found out that the level of smallholder farmer's awareness and understanding on climate change is generally good as most of them are aware about climate change and its effect. It was also found that the impact of climate change in Chamwino district are evident as revealed by the trend of crop production and changes in rainfall and temperature data. Partly because of this awareness and understanding, and the trend in weather data and crop yield, over the years, farmers have adopted various on farm and off farm measures to alleviate the impact of climate change and sustain their livelihood. It is therefore recommended that Chamwino District Council should enhance adaptation measures through extension services and research on appropriate technology and innovations to be used by smallholder farmers.

REFERENCES

Africa Partnership Forum Support Unit (2007). *Climate Change in Africa*. Brief Paper No. 1. A Paper presented at the 8th Meeting on the Africa Partnership Forum in Berlin, Germany on 22-23 May 2007.

Baruani, B. and Senzia, A. (2013). Study to generate recommendations on how district agricultural development plans [DADPS] can address climate change adaptation and mitigation in relation to small-scale farmers.

Below, T., Artner, A., Siebert R. and Sieber S. (2010). *Micro-level Practices to Adapt to Climate Change for African Small-scale Farmers*. IFPRI Discussion Paper 00953. International Food Policy Research Institute.

Boko, M., Niang, I., Nyong, A., Vogel, C., Githeko, A., Medany, M. and Yanda, P. (2007). Africa climate change: Impacts, adaptation and vulnerability. In: M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. van der Linden, & C. E. Hanson (Eds.), *Contribution of working group II* *to the fourth assessment report of the intergovernmental panel on climate change* (pp. 433–467). Cambridge: Cambridge University Press.

Bryan, E., Ringler, C., Okoba, B., Roncoli, C., Silvestri, S. and Hwheelererrero (2013). Adapting Agriculture to Climate Change in Kenya: Household strategies and determinants. *Journal of Environmental Management,* 114:26-35

Chambwera, M. and Stage, J. (2010). Climate change adaptation in developing countries: issues and perspectives for economic analysis London, UK: International Institute for Environment and Development (IIED). Retrieved from http://pubs.iied.org/pdfs/15517IIED.pdf.Google Scholar

Coulibaly, J., Gbetibouo, G., Kundhlande, G., Sileshi, G. and Beedy, T. (2015). Responding to Crop Failure: Understanding Farmers' Coping Strategies in Southern Malawi. *Journal of Sustainability* (7):620-1636.

Craparo, A.C.W., Van Asten, P.J.A., Läderach, P., Jassogne, L.T.P. and Grab, S.W. (2015). *Coffee Arabica yields decline in Tanzania due to climate change:* Global implications. *Agr Forest Meteorol*, 207:1–10.

Ehrhart, C. and Twena, M. (2006). *Climate Change and Poverty in Tanzania: Realities and responses by CARE.* Background Report, CARE International Poverty – Climate Initiative.

FAO (2012). *Adaptation to Climate Change in Semi-Arid Environments Experience and Lessons from Mozambique*. Rome: FAO.

IPCC, (2007). *Climate Change: Impacts, Adaptation and Vulnerability, Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC)*, Cambridge University Press. Cambridge.

Kadi, M., Njau, L., Mwikya, J., Kamga A. (2011). *The State of Climate Information Services for Agriculture and Food Security in East African Countries*. CCAFS Working Paper No. 5.

Kangalawe, R. and Lyimo, J. (2013). Climate Change, Adaptive Strategies and Rural Livelihoods in Semiarid Tanzania *Natural Resources journal*, 4: 266-278.

Kangalawe, R., Mung'ong'o, C., Mwakaje, A., Kalumanga, E. and Yanda, P. (2016). Climate change and variability impacts on agricultural production and livelihood systems in Western Tanzania, *Climate and Development Journal,* 9(3): 202-216.

Kihupi, M., Mahonge, C. and Chingonikaya, E. (2015). Smallholder Farmers' Adaptation Strategies to Impact of Climate Change in Semi-Arid Areas of Iringa District Tanzania. *Journal of Biology, Agriculture and Healthcare,* 5(2):123-131.

Komba, C. and Muchapondwa, E. (2012). *Smallholder Farmers in Tanzania.* ERSA working paper 299. Economic Research South Africa. 33pp. [http://econrsa.org/home/index.phd?option=comdocman&task=docdownload&gid=443&Itemid=67] Cite visited on 10/08/2017.

Burke, M. and Lobell, D (2010). *Food security and adaptation to climate change: What Do We Know?* New York: Springer. 133-154.

Lyimo, J. and Kangalawe, R. (2010). Vulnerability and adaptive strategies to impact of climate change and variability. The case of rural households in semi-arid Tanzania. *Environmental Economica Journal,* 1(2):87-97.

Manandhar, S., Schmidt, D., Perret, S. and Kazama, F. (2010). Adapting cropping systems to climate change in Nepal: a cross-regional study of farmers' perception and practices. *Regional Environmental Change*, 11(2):335–348.

Lema, M.A. and Majule, A.E. (2009). Impacts of climate change, variability and adaptation strategies on Agriculture in semi-arid Tanzania: the case of Manyoni District in Singida Region, Tanzania. *African Journal of Environmental Science and Technology,* 3(8):206–218.

Mertz, O., Mbow, C., Reenberg, A. and Diouf, A. (2009). Farmers' perceptions of climate change and agricultural adaptation strategies in Rural Sahel. *Environmental Management*, 43(5):804–816.

Mbilinyi, A., Saibul, G. and Kazi, V. (2013). *Impact of climate change to Small scale farmers*: voices of farmers in village communities in Tanzania. ESRF Discussion Paper No. 47

Mongi, H. Majule, A. and Lyimo J. (2010). Vulnerability and adaptation of rain fed agriculture to climate change and variability in semi-arid Tanzania. *African Journal of Environmental Science and Technology,* 4(6): 371-381.

Njau, F. and Masumbuko, I. (2014). Climate vulnerability and capacity analysis in the semi-arid Dodoma region of Tanzania.

Paavola, J. (2003). *Livelihoods, Vulnerability and Adaptation to Climate Change in the Morogoro Region*, Tanzania Centre for Social and Economic Research on the Global Environment, University of East Anglia, Norwich NR4 7TJ, UK Working Paper EDM 04-12.

Rwebugisa, R.A. (2008). *Groundwater re-charge assessment in the Makutupora Basin, Dodoma, Tanzania*, MSc thesis. International Institute for Geo-Information Science and Earth Observation, Enschede.

Sanga, G., Hella, J., Mzirai, N. and Senga, H. (2014). Change on Maize and Beans Production and Compatibility of Adaptation Strategies in Pangani River Basin, Tanzania, *International Journal of Sciences: Basic and Applied Research*, 17(2): 196-213.

Shemsanga, C., Muzuka, A., Martz, L., Komakech, H. and Omambia, A. (2015). Statistics in Climate Variability, Dry Spells, and Implications for Local Livelihoods in Semiarid Regions of Tanzania: The Way Forward. In: Chen, W., Suzuki, T. and Lackner, M. (Eds). *Handbook of Climate Change Mitigation and Adaptation*. Springer.

Shindo, S. (1994). *Study on the recharge mechanism and development of groundwater in the inland area of Tanzania*. Progress report of Japan-Tanzania joint research (3), Chiba University, Japan.

Swai, O., Mbwambo, J. and Magayane, F. (2012). Gender and perception on climate change in Bahi and Kondoa districts, Dodoma region, Tanzania. *Journal of African Studies and Development*, 4(9):218–231.

URT (2016). United Republic of Tanzania. *Tanzania Climate Action Report. Vice President's Office, Division of Environment,* Dar es Salaam.

Wheeler, T. and Kay. M. (2010). Food crop production, water and climate change in the developing world. *Outlook on Agriculture*, 39(4): 239-243.

Worqlul, A., Maathuis, B., Adem, A., Demissie, S., Langan, S. and Steenhuis, T. (2014). Comparison of rainfall estimations by TRMM 3B42, MPEG and CFSR with ground-observed data for the Lake Tana basin in Ethiopia. Hydrol Earth Syst Sci 18:4871–4881. https://doi.org/10.5194/hess-18-4871-2014

Worqlul, A., Yen, H., Collick, A., Tilahun, S., Langan, S. and Steenhuis, T. (2017a). Evaluation of CFSR, TMPA 3B42 and ground-based rainfall data as input for hydrological models, in data-scarce regions: the upper Blue Nile Basin, Ethiopia. *CATENA* 152:242–251

Worqlul, A., Ayana, E., Maathuis, B., MacAlister, C., Philpot, W., Leyton, J. and Steenhuis, T. (2017b). Performance of bias corrected MPEG rainfall estimate for rainfall-runoff simulation in the upper Blue Nile Basin. *Ethiopian Journal of Hydrology*, 556:1182–1191.