Journal of the Geographical Association of Tanzania, Vol. 42, No. 1: 22–44

Adaptation to Climate Change Impacts: The Performance of Local-based Strategies in Enhancing Agricultural Production in Semi-arid Tanzania

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Abstract

This study assesses the performance of various adaptation strategies used by farmers to improve agricultural production amid changing climate. Data were collected through household survey, key informant interviews, focus group discussions, field observations, and review of relevant documents. Quantitative data were analysed using SPSS and Microsoft Excel, while qualitative data were analysed using content analysis. Results showed that, from 1990 to 2020, both mean annual minimum and maximum temperatures have increased at non-significant rates of $R^2 = 0.7569$ and $R^2 = 0.2279$, respectively; while rainfall has decreased at a significant rate of $R^2 = 0.0121$. Such changes in climate parameters affect agricultural production through damaging crops and persistent low yields. Responding to these changes, farmers have adopted several adaptation strategies, including planting drought-tolerant crops (99.4%), changing planting dates (93.6%), planting early-maturing crops and high-yielding varieties (92.9%), mixed-crop farming (63.8%), application of manure (27.9%), and irrigation (8.3%). Planting drought-tolerant crops, changing planting dates, and the application of manure were found to be effective, and contributed to the increase of millet and groundnuts yields. Planting early-maturing crops and high-yielding varieties, and mixed-crop farming were found to be ineffective; and contributed to the decrease of maize, sunflower, and sorghum yields. In general, despite using several adaptation strategies, the majority of farmers had not improved agricultural production. This study urges that improving agricultural extension services; and providing credits and timely, relevant, and user-friendly weather information to farmers, can enhance effective adaptation to climate change.

Keywords: *climate change; adaptation strategies; agricultural production; semi-arid.*

1. Introduction

Agriculture is the backbone of almost all nations and rural development (ILO, 2011). The sector plays a serious role in enhancing economic development of developing countries, where it accounts for more than 25% of Gross Domestic Product (GDP) in some countries (World Bank, 2021). In Africa, the agricultural sector provides employment for about two-thirds of the continent's

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 ▪ https://doi.org/10.56279/jgat.v42i1.215

working population. In particular, the sector employs about 65% of the Sub-Saharan Africa (SSA) inhabitants (Chauvin et al., 2012). Similarly, agriculture remains as the mainstay of the East African economy, with an estimated GDP share of 25.9% in Kenya (KNBS, 2013), 26.7% in Tanzania (URT, 2009) and 14.6% in Uganda (Balikowa, 2011). In Tanzania, for instance, agriculture contributes about 30% of export earnings, 95% of the food consumed in the country, 65% of raw materials for Tanzanian industries; and more than 75% of Tanzanians directly or indirectly depend on agriculture for their livelihood (URT, 2009; Salami et al., 2010). Despite the significance of this sector, climate change significantly impedes its growth (Dethier & Effenberger, 2011).

Apart from overpopulation, deforestation, pollution, and soil degradation, climate change is one of the most serious environmental problems the world is currently facing (Shabani & Pauline, 2022), and has significantly affected global agriculture (IPCC, 2007; IPCC, 2021). It is projected that billions of people—particularly those in the global south, including East African countries—will experience changes in rainfall patterns leading to droughts, flooding in other places, and an increase in average temperature that will cause shifts in crop growing seasons (IPCC, 2007, 2014). In Tanzania, agro-ecological zones with bimodal rainfall patterns are expected to experience an increase of rainfall by 5%-45%, while zones with unimodal rainfall pattern are expected to experience decreased rainfall of 5%–15%. Moreover, the mean daily temperatures are projected to rise by 3^{0}C–5^{0}C, and mean annual temperature to increase by 2^{0}C–4^{0}C (URT, 2007). As such, the productivity of various crops will decline, particularly in semi-arid areas where the climatic condition is generally dry, while agricultural production is mainly rain-fed (Mongi et al., 2010; Mushi, 2012). The decline in agricultural production has the likelihood of escalating food insecurity, outbreak of diseases, abject poverty; hence thereby intensifying vulnerability to climate change impacts (Mushi, 2012; Zinyengere et al., 2014).

Following the impacts of climate change on agricultural production and livelihood, farmers in semi-arid areas of Tanzania have been adopting various farm-level adaptation strategies. These strategies are such as planting drought-tolerant crops (DTCs), intercropping, changing planting dates, use of improved seeds, conservation agriculture, and irrigation (Kihupi et al., 2015; Rashid, 2015; Lusiru, 2018). However, farmers hardly get good harvests due to high frequencies of intensive droughts (Mbilinyi et al., 2013) despite the adaptation measures put in place. According to Kangalawe et al. (2017) and Liwenga (2017), many adaptation strategies will face challenges due to increasing climate change. Therefore, an assessment of the performance of local-based adaptation strategies applied by farmers is critical to understand how helpful these strategies are in enhancing agricultural production in semi-arid areas of Tanzania.

Recent studies on climate change adaptation in semi-arid areas of Tanzania—such as by Kangalawe and Lyimo (2013), Kihupi et al. (2015), and Ringo et al. (2018)—have mainly focused on identifying adaptation strategies taken by farmers to address climate-related hazards. Hence, there is a scant scientific information on the performance of various local-based adaptation strategies in improving agricultural production. This study is a scientific approach to fill such noted knowledge gap of the performance of various farm-level adaptation strategies amid climate change threats. Such knowledge is indispensable for effective adaptation and sustainable community livelihoods in semi-arid areas. In view of that, this study identified adaptation strategies used by farmers in the study area, and assessed their performances.

2. Methodology

This study was conducted in Chamwino District, in the semi-arid areas of central Tanzania. The study involved four villages: Haneti, Mwegamile, Idifu and Wiliko (Figure 1).

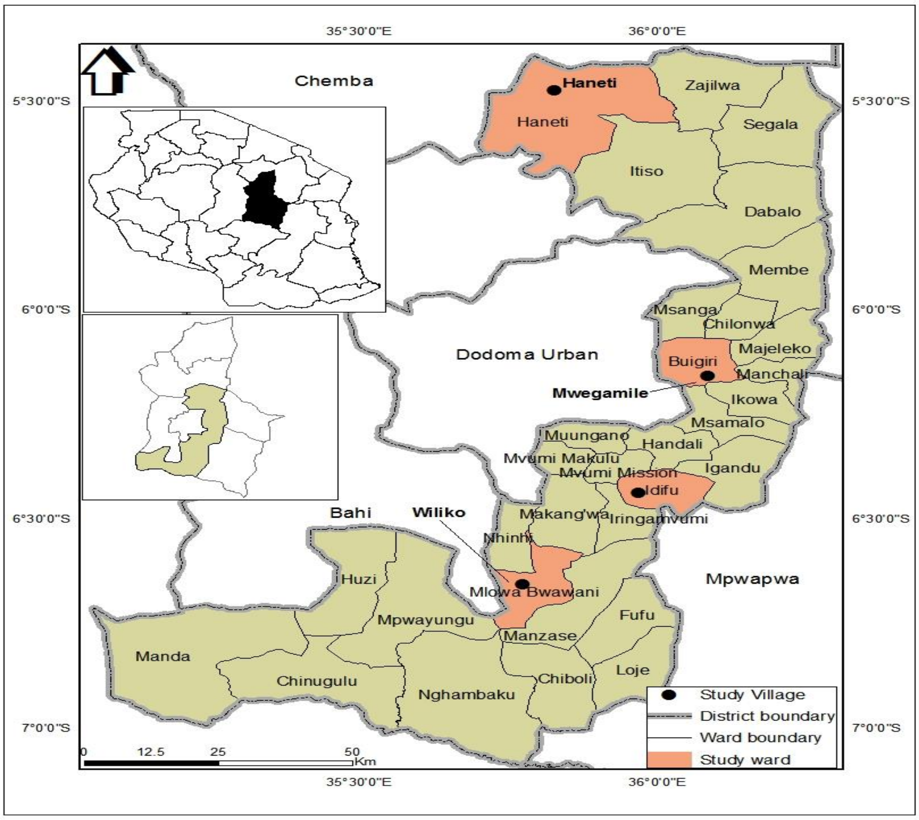


Figure 1: Location of the Study Area

Source: Cartographic Unit, Department of Geography, UDSM, 2021

To obtain the four study villages, the study area was stratified into two major geographical zones: northern zone, and southern zone. The zones were stratified basing on physical (such as soil) and climatic characteristics of the Chamwino District. The southern zone is drier and receives little rainfall, as opposed to the northern zone that receives slightly higher rainfall and has fertile moist soil. Two study wards were selected from each geographical zone: Haneti and Buigiri wards, from the northern zone; and Idifu and Mlowa Bwawani wards from the southern zone. Further, one study village was sampled from each study ward. Villages sampled from Haneti and Buigiri wards were Haneti and Mwegamile, respectively; while those from Idifu and Mlowa Bwawani wards were Idifu and Wiliko, respectively. The selection of the study wards and villages was conducted randomly through fishbowl draw method. After sampling of the study villages, the village government offices were consulted to provide lists of heads of households. The sample size (n) of 362 households was derived from the total households (N) of 3,803 by using sample size formula propounded by Israel (1992) at 95% confidence levels; and the level of precision (e) measured by the probability scale of 5% (0.05) as illustrated in equation (1).

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

Data were collected using a combination of methods. Household survey, key informant interviews, focus group discussions (FGDs), and field observation were used to collect primary data; while document review was used to collect secondary data. Key informant interviews (n = 31) were administered at district, ward and village levels; whereby, one (1) district agricultural officer, four (4) ward/village agricultural officers, eight (8) ward and village government leaders, two (2) climate experts, and sixteen (16) elder farmers, were recruited for interviews. These were people with experiences and outstanding knowledge about the theme of the study. A total of four (4) FGDs (n = 32) were conducted; one in each study village. A group of eight (8) farmers in each sampled village participated in the discussions. Knowledgeable people within the villages were recruited to participate in the FGDs, while considering the gender issue. Discussions mainly focused on climate change trends and perceptions, impacts, adaptation strategies and their performances. Household survey interviews (n = 362) were conducted using a structured questionnaire.

Field observations were also employed to observe various phenomena corresponding to the study, including the indicators of climate change, types of crops grown, livelihood activities, and adaptation strategies used by farmers. On the other hand, secondary data were obtained through a review of books, journals, government documents and internet materials; as well as from archives of meteorological and crop-yield data. Qualitative data were analysed through content analysis, and quantitative data were analysed using the Statistical Product and Service Solution (SPSS), version 23, together with the Microsoft Excel 2013 Worksheet softwares. Descriptive statistics were run to give frequencies, and then cross-tabulated. To assess the performance of farmers' adaptation strategies in improving agricultural production, a Paired-Samples T-test analysis was performed to compare farm production before and after adoption of various adaptation strategies. The Paired-Samples T-test was run to find out if the mean difference between paired variables (before and after adaptation) was statistically significantly different from zero. The null hypotheses were: (Ho) – there is no difference between the means of farm productions before and after adaptation; and the alternative hypothesis (Ha) – there is a difference between the means of farm productions before and after adaptation. If there was a sig. (2-tailed), or a p-value less than 0.05, then there was a statistically significant difference between the two variables (Khosravi et al., 2018).

3. Results and Discussion

3.1 Socio-economic Characteristics of Respondents

3.1.1 Level of Education

The findings revealed that about 74.3% of the respondents had attained either primary, secondary or tertiary education (Figure 2). This implies that most of the respondents had an understanding on the impacts of climate change on agricultural production on their livelihoods, and had the ability of obtaining and utilizing information related to climate change adaptation. On the other hand, about 91.2% of the respondents had either primary education (65.5%), or had never attended school (25.7%) (Figure 2). Such low levels of education limit one's exposure to new agricultural technologies/innovations, and consequently impedes agricultural transformation. Thus, low levels of education represent low adaptive capacity to climate change impacts (Deressa et al., 2008).

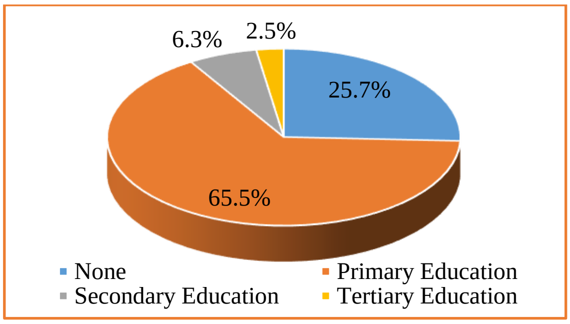


Figure 2: Levels of Education of the Respondents
Source: Field data, 2021

3.1.2 Livelihood Activities

Results indicated that crop farming was being carried out by 100% of the respondents. Major crops grown included maize, sunflower, groundnuts, sorghum, millet, cassava, sweet potatoes, cowpeas, grapes, sesame, and vegetables. Interviews with key informants revealed that crop farming in the study area was mostly rain-fed. This implies that the majority of farmers were potentially vulnerable to climate change since crop farming is heavily sensitive to climate change (Benedict & Majule, 2015). Livestock keeping was the second livelihood activity pursued by 34.8% of all respondents. Major livestock kept included cattle, goats, sheep, pigs and chickens. Other activities conducted in the study area were casual labour (26.8%), petty businesses (25.7%), fuelwood production (7.7%), formal employment (4.1%), and bee keeping (1.1%). FGDs revealed that farming households that engaged in other income-generating activities, e.g., petty businesses, were somewhat less vulnerable to climate change impacts since their livelihoods were beyond agriculture; a sector that is climate sensitive.

3.2 Analysis of Rainfall and Temperature Trends

3.2.1 Rainfall Trend

The findings of this study indicated that about 84.6% of all respondents perceived that rainfall has decreased in the last 30 years (from 1990 to 2020). Whereas 12.4% reported that rainfall has been fluctuating, 2.5% admitted to have experienced an increase in rainfall, and 0.5% had not noted any changes in rainfall. These findings imply that the study area has been experiencing rainfall variability. Respondents who perceived that rainfall has decreased were supported by meteorological data, which revealed a general decrease of total annual rainfall trend as indicated by $y = -1.8308x + 628.72$, at a significant rate of $R^2 = 0.0121$ (Figure 3).

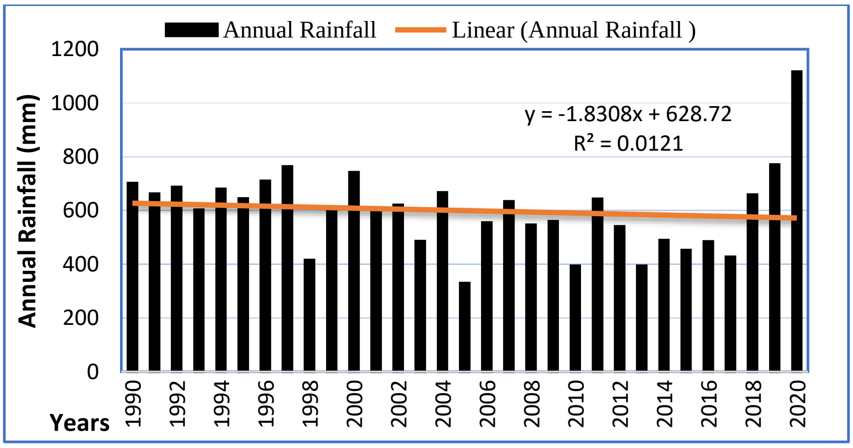


Figure 3: Annual Rainfall Trend in Chamwino District: 1990–2020

Source: Field data, 2021

Meteorological data revealed the decline of total annual rainfall from an average of 647.3mm in 1990–1999, to 525.8mm in 2010–2019. This signifies the decrease of an average of 121.5mm. A trend analysis also revealed that the total annual rainfall has been fluctuating in the past 30 years (Figure 3). Such fluctuations of rainfall may, however, indicate a normal climatic variability rather than a change. The variability of rainfall portrays that farmers in Chamwino district are vulnerable to both drought and heavy rains, which negatively affect their livelihoods. In general, fluctuations and overall decrease of rainfall are supported by studies conducted in semi-arid Tanzania by Zacharia (2011) and Jackson (2019).

An analysis of mean monthly rainfall from 1990 to 2020 indicated that the study area has been receiving rains mainly in six (6) months. Rainfall starts in November and ends in April (Figure 4). Farmers prepare farms from October, and start planting in the low rains of November. The study found that the majority of respondents perceived February to be a dry month. This may be due to the fact that rainfall is at its peak in the months of December and January, and drops in February (Figure 4). Such an abrupt drop is what farmers term as 'drought in the rainy season'. Moreover, the analysis indicated that June (0.2mm), July (0.2mm), August (0mm) and September (0.1mm) are the driest months. A majority of farmers disengage themselves from farming activities in the dry season. Similar observations of mean monthly rainfall are found in the studies of Lema (2008) and Jackson (2019); both conducted in the semi-arid area of Manyoni District.

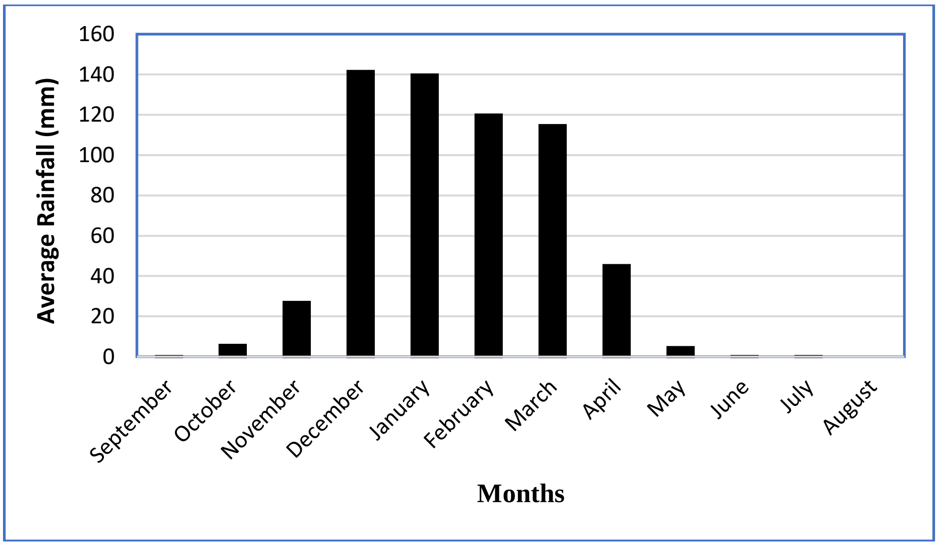


Figure 4: Mean Monthly Rainfall in Chamwino District
Source: Field data, 2021

3.2.2 Temperature Trend

The findings revealed that about 85.9% of the respondents perceived that temperature has had an increasing trend in the last 30 years. Inversely, some respondents perceived that temperature has been decreasing (7.7%) and fluctuating (5.3%), while 1.1% had not noticed any changes in temperature. Trend analysis of temperature data from 1990 to 2020 indicated that the trends of both mean annual minimum and maximum temperatures had increased at non-significant rates of $R^2 = 0.7569$ and $R^2 = 0.2279$, respectively, as perceived by the majority of the respondents. Trends of mean annual minimum and maximum temperature had increased as shown by $y = 0.0479x + 16.568$ and $y = 0.0188x + 28.815$, respectively (Figures 5 and 6). These findings comply with the results of various studies (Mongi et al., 2010; Zacharia, 2011; Lusiru, 2018) conducted in semi-arid areas of Tanzania.

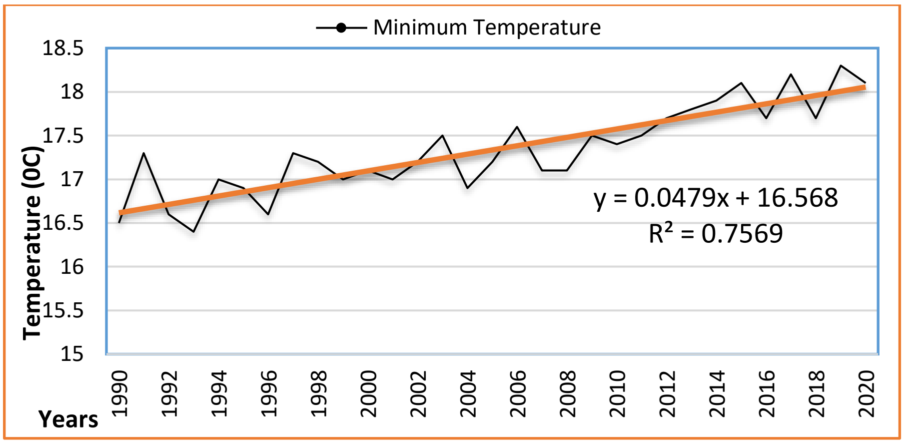


Figure 5: Mean Annual Minimum Temperature Trend in Chamwino District from 1990 to 2020

Source: Field data, 2021

URT (2007) showed that, an average annual temperature will increase by 3.5⁰C throughout the country, while the annual temperature will increase by 4⁰C in central Tanzania. However, this study found that the mean annual temperature increased by 1.3⁰C between 1990 and 2020. Likewise, the mean annual minimum temperature increased by 1.6⁰C (Figure 5), and the mean annual maximum temperature increased by 0.9⁰C (Figure 6). Such increases of temperature have implications on biodiversity, crops, pasture, and human life in general. For instance, crops have their optimal temperature requirements for growth. As such an increase in temperature could have detrimental effects on their different growth stages, and consequently result in poor yields and quality (Harrison et al., 2008). Also, high temperatures make favourable environment for crop pests to survive and complete their lifecycles, which in turn affect crop production (Mung'ong'o, 2013).

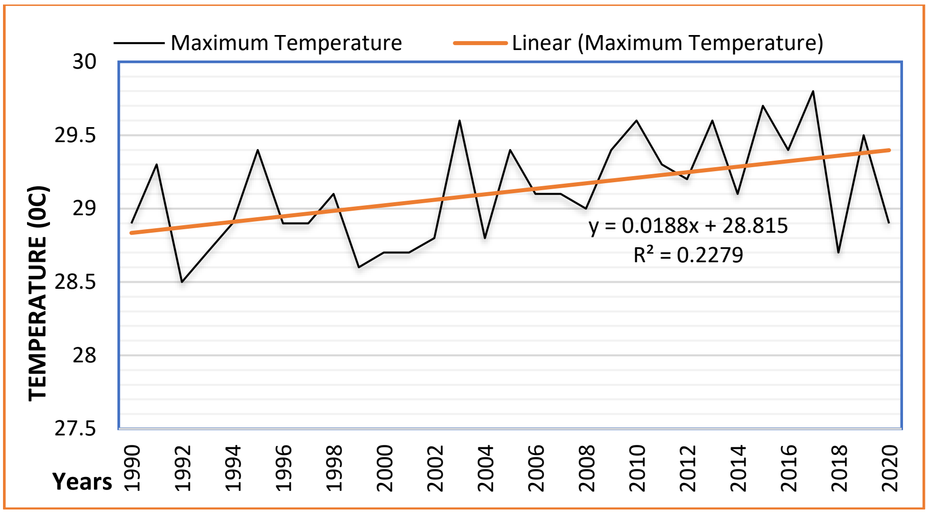


Figure 6: Mean annual maximum temperature trend in Chamwino District from 1990 to 2020

Source: Field data, 2021

3.3 Local-based Adaptation Strategies

This study revealed that several local-based strategies were being used by farmers to improve agricultural production in the face of climate change in the study area (Table 1). All the respondents (100%) in Mwegamile, Idifu, and Wiliko villages; and 98.2% of the respondents in Haneti village, were growing at least one drought-tolerant crop (DTC). DTCs grown were sunflower (92.8%), groundnuts (89.8%), sorghum (68%), millet (52.2%), sweet potatoes (30.9%), sesame (27.6%), cassava (23.2%) and cowpeas (14.4%). The findings of FGDs suggested that, due to rainfall variability and increased frequencies of drought, the majority of farmers grow DTCs that endure such harsh conditions of poor water supply. These findings correspond with those of Mung'ong'o (2013), which highlighted that due to the decrease of maize production by 17% in the southern highlands of Tanzania, farmers in Mufindi District have switched to DTCs such as sorghum, sunflower, millet, and cassava. The same results on the adoption of DTCs by farmers living adjacent to Kilimanjaro and Udzungwa mountains were also reported by Kaganzi et al. (2021). Changing planting dates was also reported by all the respondents (100%) in Mwegamile and Wiliko villages, 96.8% of the respondents in Idifu, and 82.4% in Haneti village. Farmers change planting dates in response to rainfall variability and shifts in agricultural seasons. About 68.5% of the respondents reported to have changed the planting dates from early November to late November, and 31.5% reported to have shifted the planting dates from early November to December due to irregular rainfall onset. This strategy has also been reported by Kangalawe and Lyimo (2013) in Manyoni and Shinyanga districts; and Kihupi et al. (2015) and Shabani and Pauline (2022) in Iringa district.

Table 1: Proportion (%) of Local-based Adaptation Strategies Used by Farmers

Adaptation strategies	Villages			
	Haneti	*Mwegamile*	*Idifu*	*Wiliko*
Planting drought-tolerant crops	98.2	100	100	100
Changing planting dates	82.4	100	96.8	100
Planting early-maturing and high yielding varieties	91.5	97.2	100	83.1
Mixed-crop farming	73.2	84.2	40.5	76.7
Use of ridges	70.4	0	4.0	23.3
Application of manure	10.2	39.5	40.5	26.7
Irrigation	0	2.6	15.9	10.0
Rainwater harvesting	0	10.5	9.5	3.3

Note: Based on multiple response analysis
Source: Field data, 2021

Table 1 shows that respondents in Haneti (91.5%), Mwegamile (97.2%), Idifu (100%) and Wiliko village (83.1%) were growing early-maturing and high-yielding crop varieties (EMC&HYV) as an adaptation strategy to climate change. The findings showed that various improved varieties of maize, sorghum and sunflower were being grown in the study area (Table 2). While *situka* was the mostly grown maize variety, *macia* and *zebra* were the most grown sorghum and sunflower varieties, respectively. Kahimba et al. (2015) reported that *macia* is the commonly used early-maturing sorghum seeds in Chamwino District as an adaptation strategy to rainfall shortages. Moreover, the findings revealed that these early-maturing crops (EMCs) use 60 to 90 days to mature, thus the possibility of harvesting is higher than with the old traditional seeds that mature within 90–120 days. Likewise, under optimum rainfall conditions, HYVs can produce 10–15 bags/acre, while the old traditional varieties only produce 3–6 bags/acre. Similar observations are found in the study by Jackson (2019). Further, the study findings indicated that respondents Haneti (73.2%), Mwegamile (84.2%), Idifu (40.5%), and Wiliko (76.7%) were practicing mixed-crop farming (Table 1). The study realized that farmers have decided to adopt mixed-crop farming as a strategy to ensure sufficient crop production and minimize crop failure.

The study further found that the majority of respondents (30.6%) in the study villages mix maize and sunflower. Interviews with agricultural officers (AOs) unfolded that combining maize and sunflower in one farm is not recommended as the crops need space altogether; and usually sunflower overpowers maize in the struggle for space, hence resulting into low productivity of the latter. Instead, AOs recommended intercropping maize and groundnuts/ cowpeas/ beans in one field. Such findings match with those of Masendeke and Shoko (2014) who found that cowpeas were intercropped with maize and *rapoko* in Mberengwa district, Zimbabwe, to boost soil fertility and provide a good protein supplement.

The use of ridges was also reported in Haneti (70.4%), Idifu (4%) and Wiliko (23.3%) villages (Table 1). Ridge-farming is a type of conservation agriculture that provides protection of the soil from the ravages of water and wind erosion (Levick, 2011). Through field observation, the study noted that ridges were mostly applied by farmers who were growing sweet potatoes. This elucidates as to why Haneti village had higher number of ridge users, while Mwegamile village had no farmers practicing ridge-farming. Moreover, about 10.2% of the respondents in Haneti, 39.5% in Mwegamile, 40.5% in Idifu, and 26.7% in Wiliko villages were applying manure in their farms. Following the decrease in crop productivity, some farmers assumed soil fertility had declined, and thus used organic manure to supplement nutrients in the soil and enhance soil productivity. The major sources of manure were cattle, goats, sheep, pigs and chicken wastes. The findings of this study on the application of manure correspond with those of studies conducted by Rashid (2015), and Benedict and Majule (2015), which reported that communities in Iramba and Manyoni districts, respectively, were using manure to increase crop production amid changing climate conditions.

Table 2: Early-maturing and High-yielding Crop Varieties Grown by Farmers (%) in the Study Villages

Crop Varieties Grown	Villages			
	Haneti	*Mwegamile*	*Idifu*	*Wiliko*
Maize varieties				
Situka	20.4	5.3	19.0	23.3
Seed-Co	16.7	2.6	9.5	13.3
Rubango	12.0	13.2	11.9	4.4
DK	1.9	2.6	9.5	5.6
Kilima	2.8	5.3	3.2	5.6
Sorghum varieties				
Macia	4.6	44.7	69.1	53.3
Tegemea	6.5	31.6	20.6	16.7
Okoa	0	15.8	8.7	2.2
Pato	0.9	23.7	0	0
Sunflower varieties				
Zebra	11.1	15.8	11.9	8.9
Record	5.6	7.9	7.1	5.6
Super Sun	2.8	10.5	6.4	2.2

Note: Based on multiple response analysis
Source: Field data, 2021

Irrigation was another strategy used by farmers in Mwegamile (2.6%), Idifu (15.9%) and Wiliko (10%) villages (Table 1). Farmers applying irrigation were mostly growing tomatoes, grapes and vegetables. Haneti village did not have any farmer practicing irrigation because the village had neither grape nor tomato growers. Irrigation was generally of small-scale in the study area due to limited financial resources, and poor water acquisition technologies among farmers.

Small traditional water reservoirs, hand-dug wells, and Mkalama dams were being used as sources of water for small-scale irrigation. The use of reservoirs and dams was reported to decline with time because they dry-up due to increase in temperature and frequent droughts. These findings tally with those of the study by Lusiru (2018), which reported that smallholder farmers in Same district have been using irrigation as an adaptation strategy to drought impacts. The study revealed that farmers were using both traditional and modern water reservoirs as sources of water for irrigation. However, both reservoirs were reported to dry-up more often in recent years due to intensive and frequent droughts.

Lastly, the findings in Table 1 indicates that respondents in Mwegamile (10.5%), Idifu (9.5%) and Wiliko (3.3%) villages were harvesting rainwater as an adaptation strategy to climate change-induced water shortages. Rainwater harvesting undertaken in the study area was generally of small-scale. Field observation noted that farming households had poorly developed rain-harvesting practices due to the nature of the roofs of their houses, and low financial capacities. However, respondents stated that rainwater harvesting, especially through Mkalama dams, helps in crop farming in some months after rain cessation. The study by Kangalawe and Lyimo (2013) also observed the same on the adoption of rainwater harvesting for small-scale irrigation and livestock uses in Manyoni and Shinyanga districts.

Generally, it was found that farmers were using various on-farm strategies to adapt to climate change impacts. On the whole, it was noted that various adaptation strategies were implemented in the study area on an impromptu basis, with limited planning and preparedness. This was possibly due to the pressure laid by climate change impacts that required immediate coping/ adaptation measures to ensure survival. This was due to the fact that climate change impacts had become more unpredictable, thus could hit a place any time: be it at the start, middle or towards the end of a growing season. Therefore, many adaptation strategies were facing challenges due to both limited planning and climate change perseverance. However, such strategies could lead to long-term sustainability if enhanced and well-planned. To enhance long-term sustainability of adaptation strategies, agricultural education, among others, needs to be strengthened amongst farmers for informed farm care.

3.4 Performance of Farmers' Adaptation Strategies in Improving Agricultural Production

3.4.1 Planting Drought-Tolerant Crops (DTCs)

To have a deeper insight into the performance of DTCs in the study area, respondents were asked to compare total farm production before and after adopting DTCs. Tables 3, 4 and 5 present the results.

Table 3: Results of Paired-Samples T-Test analysis: Paired Samples Statistics

Paired Samples		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Total farm production (bags) before adopting DTCs	18.26	360	9.799	.516
	Total farm production (bags) after adopting DTCs	24.03	360	9.067	.478
Pair 2	Farm production (bags/acre) before adoption of EMC&HYV	6.67	337	2.908	.158
	Farm production (bags/acre) after adoption of EMC&HYV	3.91	337	2.509	.137
Pair 3	Farm production (bags/acre) before adopting mixed farming	6.38	231	2.530	.166
	Farm production (bags/acre) after adopting mixed farming	4.41	231	2.457	.162
Pair 4	Farm production (bags/acre) before use of ridges	4.46	102	2.590	.256
	Farm production (bags/acre) after use of ridges	9.00	102	4.791	.474
Pair 5	Farm production (bags/acre) before use of manure	5.48	101	2.598	.259
	Farm production (bags/acre) after use of manure	9.50	101	3.969	.395

Source: Field data, 2021

Table 4: Results of Paired-Samples T-Test Analysis: Paired Samples Correlations

Paired Samples		N	Correlation	Sig.
Pair 1	Total farm production (bags) before adopting DTCs & Total farm production (bags) after adopting DTCs	360	.014	.792
Pair 2	Farm production (bags/acre) before adoption of EMC&HYV & Farm production (bags/acre) after adoption of EMC&HYV	337	.365	.000
Pair 3	Farm production (bags/acre) before adopting mixed farming & Farm production (bags/acre) after adopting mixed farming	231	.407	.000
Pair 4	Farm production (bags/acre) before use of ridges & Farm production (bags/acre) after use of ridges	102	.645	.000
Pair 5	Farm production (bags/acre) before use of manure & Farm production (bags/acre) after use of manure	101	.741	.000

Source: Field data, 2021

Results of the Paired-Samples T-test analysis indicated that the Sig. (2-tailed) or the p-value was .000 ($p<0.05$) (Table 5). This denotes that the mean difference between total farm production before and after adopting DTCs was statistically significantly different from zero.

Table 5: Results of Paired-Samples T-test Analysis – Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	*Upper*			
Pair 1	Total farm production before adopting DTCs Total farm production after adopting DTCs	-5.769	13.257	.699	-7.144	-4.395	-8.257	359	.000
Pair 2	Farm production before adoption of EMC&HYV Farm production after adoption of EMC&HYV	2.754	3.069	.167	2.425	3.083	16.472	336	.000
Pair 3	Farm production before adopting mixed farming Farm production after adopting mixed farming	1.965	2.715	.179	1.613	2.317	11.001	230	.000
Pair 4	Farm production before use of ridges Farm production after use of ridges	-4.539	3.696	.366	-5.265	-3.813	-12.405	101	.000
Pair 5	Farm production before use of manure Farm production after use of manure	-4.030	2.689	.268	-4.560	-3.499	-15.062	100	.000

Source: Field data, 2021

Further, the results in Table 4 show that the total farm production before and after adopting DTCs were significantly positively correlated (r = .014). Furthermore, the results indicate an increase in the mean of total farm production from 18.26 bags before adopting DTCs, to 24.03 bags after adopting DTCs (Table 3). This signifies an increase of an average of 5.77 bags of total farm production after the adoption of DTCs. In a nutshell, planting DTCs was performing well in the study area. This is supported by Shabani and Pauline, (2022) who reported that the strategy was most effective in Iringa district. However, an interview with the District Agricultural Officer (DAO) revealed that the tolerance level that DTCs had for droughts was also low: when drought conditions persist, DTCs similarly fail or perform poorly. FGDs identified the driest years—such as 2005, 2013 and 2017—to have had poor crop production irrespective of the use of DTCs. Also, the effects of climate change on DTCs are not only due to drought conditions and rainfall insufficiencies, but also due to heavy-than-normal rains (Lusiru, 2018).

Moisture requirement levels of DTCs range between 350mm and 1000mm of rainfall per year (Stefan et al., 2016). Once these levels are exceeded, DTCs are more likely to fail or perform poorly. Interviews with the AOs for Idifu and Mlowa Bwawani wards revealed that farmers plant DTCs each year regardless of weather specifics. For example, the year 2020 had a high rainfall amount of 1116.6mm, but still farmers grew millet, sorghum, sunflower and other DTCs, which require low rainfall, and the overall performance was poor. To sum up, the performance of DTCs was good in the study area but not satisfactory. Hence, weather/agricultural education needs to be strengthened so that farmers can acquire pertinent education on how best to grow DTCs.

3.4.2 Changing Planting Dates

The ranking of farm production indicated that after changing planting dates, about 7.1% of the respondents recorded very good harvests, 67.3% recorded good harvests, 21.2% recorded average harvests, 3.8% recorded poor harvests, and 0.6% recorded very poor farm production (Figure 7).

These findings imply that this strategy has enhanced agricultural production in the study area. Shabani and Pauline, (2022) also observed the same in Iringa district. Nevertheless, the challenges associated with this strategy should not be underestimated. Since humans have no control over rainfall attainability, and weather forecast is still uncertain, it is doubtful to keep depending on rainfall and think that the best remedy is changing planting dates, which is also unreliable because rainfall onset/cessation and duration vary (Lusiru, 2018). An interview with the DAO revealed that if rainfall does not meet the expectations of farmers after changing planting dates, it always result into a food disaster.

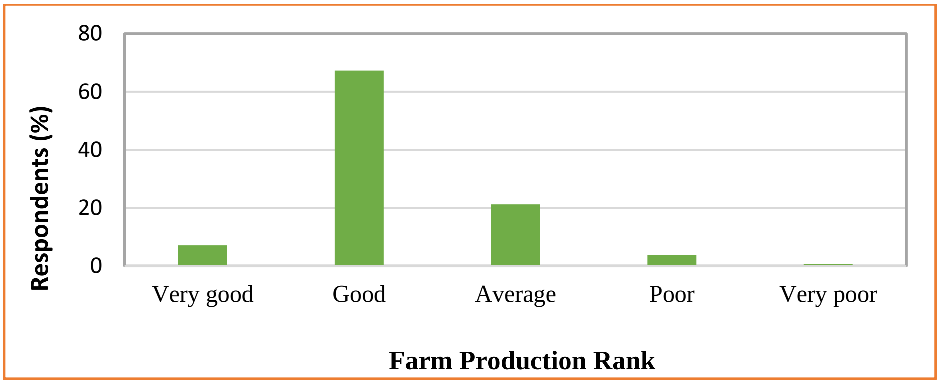


Figure 7: Responses on Farm Production After Changing Planting Dates

Source: Field data, 2021

For example, farmers in the study area were planting crops immediately after the commencement of a rainy season. This is not a bad practice, but Lana et al. (2017) posed a cautioning remark on this. Lana and colleagues argued that germination may be initiated by rainfall that is not the actual onset of a rainy season, and seedlings may wither or even die due to subsequent dry conditions. Likewise, some farmers in the study area had to wait and plant crops late in December after they were assured of the onset of rainy seasons. This practice was likely to affect farmers, especially when the rainy seasons became shorter than normal; or when the dry spells (of February) within the rainy seasons became severe.

3.4.3 Planting Early-maturing and High-yielding Crop Varieties

The results of the Paired-Samples T-test analysis indicated that the p-value was .000 ($p<0.05$) (Table 5). This connotes that the mean difference between farm productions before and after adoption of EMC&HYV was statistically significantly different from zero. Likewise, the results in Table 4 showed that farm productions before and after adoption of EMC&HYV were significantly and positively correlated (r = .365). Moreover, the results indicated a decrease in the mean of farm production from 6.67 bags/acre before the adoption of EMC &HYV to 3.91 bags/acre after the adoption of EMC&HYV (Table 3). This signifies a decrease of 2.76 bags/acre.

These results imply a general decrease of farm production after the adoption of EMC&HYV. On the contrary, a study by Benedict and Majule, (2015) reported an improvement in crop yield in Manyoni district as a result of the adoption of this strategy. Interviews with AOs unfolded several factors that influenced such performance of EMC&HYV. Among them were the lack of agricultural knowledge among farmers, particularly on how to grow EMC&HYV, untimely agricultural practices, and climate change perseverance.

Regarding the influence of climate change, AOs argued that sometimes growing seasons become very short to the extent that even early-maturing crop varieties do not mature before rainfall ceases. Thus, the decrease in the length of rainy seasons, which is related to current intensive droughts, reduces the effectiveness and reliability of this strategy. As such, growing EMC&HYV has become uncertain, and its future use will be more uncertain given that future droughts are projected to be more severe (IPCC, 2007).

3.4.4 Mixed-crop Farming

The results of the Paired-Samples T-test analysis indicated that the p-value in this category was .000 ($p<0.05$) (Table 5). This denotes that there was a statistically significant difference between the means of farm productions before and after adopting mixed-crop farming. Also, the results in Table 4 revealed that farm productions before and after adopting mixed-crop farming were significantly and positively correlated (r = .407). Moreover, the results indicated a decrease in the mean of farm production from 6.38 bags/acre before adopting mixed-crop farming, to 4.41 bags/acre after adopting mixed-crop farming (Table 3). This connotes a decrease of an average of 1.97 bags/acre after the adoption of mixed-crop farming. These results imply a general decline of crop production after the adoption of mixed-crop farming. On the contrary, a study by Jackson (2019) found that mixed-crop farming had improved soil fertility and crop production in Manyoni district. This was because farmers were intercropping legumes (beans, cowpeas, and peanuts) with cereals (maize and millet) (ibid.). Masendeke and Shoko (2014) indicated that legumes are important sources of soil fertility, which in turn supports the cereals. The DAO asserted that mixed-crop farming has a potential of increasing crop production per unit area only if the crops intercropped perfectly match. This assertion implies that there are some crops that perform well together when intercropped, and vice versa. For instance, maize/sorghum and sunflower do not perform well most of the time when intercropped. However, this study found that the majority of respondents (30.6% out of 63.8% of respondents who were practicing mixed-crop farming) were still intercropping maize and sunflower in one farm field, which resulted into poor performance.

3.4.5 Use of Ridges

The results of the Paired-Samples T-test analysis in this aspect indicated that the p-value was .000 ($p<0.05$) (Table 5). This means that there was a statistically significant difference between the means of farm productions before and after the adoption of ridges. Also, the results in Table 4 revealed that farm productions before and after the adoption of ridges were significantly and positively correlated (r = .645). Further, the results indicated an increase in the mean of farm production from 4.46 bags/acre before the adoption of ridges, to 9.00 bags/acre after the adoption of ridges (Table 3). This denotes an increase of an average of

4.54 bags/acre after the adoption of ridges. Thus, the results in Table 5 imply an overall increase of crop production after the adoption of ridges. The use of ridges, apart from improving soil health through maintaining water and nutrient levels in the soil (Kihila, 2018), also guarantees good harvests because ridges make the soil loose, making it easier for root crops with tubers that develop from stems (such as cassava, carrot, and Irish potatoes) to penetrate the soil (Vogeler et al., 2009). Nevertheless, the strategy is time and labour demanding.

3.4.6 Application of Manure

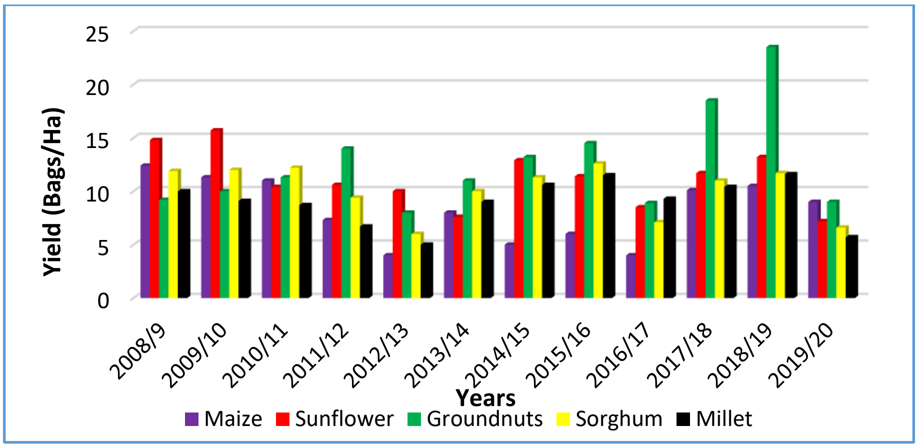
Here, the results of the Paired-Samples T-gest analysis indicated that the p-value was .000 ($p<0.05$) (Table 5). This connotes that the mean difference between farm productions before and after the use of manure was statistically significantly different from zero. Also, the results in Table 4 showed that farm productions before and after the use of manure were significantly and positively associated (r = .741). Moreover, the results indicated an increase in the mean of farm production from 5.48 bags/acre before the use of manure, to 9.5 bags/acre after the use of manure (Table 3). This signifies an increase of 4.02 bags/acre. These results show an overall increase of crop production after the use of manure. These results coincide with those of Benedict and Majule (2015), who observed that this strategy had contributed to an improvement in crop yield in Manyoni district. However, the main challenge to the majority of smallholder farmers is access to manure, which demands some financial resources.

3.4.7 Irrigation and Rainwater Harvesting

Grape and tomato growers who were practicing small-scale irrigation had never grown such crops without irrigation, thus could not compare farm production before and after the adoption of irrigation. However, irrigation is believed to be the best adaptation strategy in this era of climate change where water is a scarce commodity (Aseyehegn et al., 2012). Irrigation ensures that food production continues, irrespective of the season or climatic condition. Several studies have reported on the performance of irrigation in increasing agricultural productivity. The study by Bacha et al. (2011), conducted in Ethiopia, found that small-scale irrigation had enhanced food security and household incomes of smallholder farmers in Ambo district. Likewise, a study by Gbetibouo (2009), conducted around the Limpopo River Basin in South Africa, reported that irrigation projects had helped to increase yields and sustain food security in the area. Therefore, irrigation is crucial in sustaining food security, and is likely to reduce rural poverty (Aseyehegn et al., 2012). However, the strategy is financially demanding; making it difficult for smallholder farmers to adopt (Yami, 2013). Water for irrigation was obtained through different sources in the study area, rainfall inclusive. Rainwater harvesting was generally of small-scale, making it difficult for farmers to establish its significance on crop farming. However, grape and tomato growers appreciated the fact that the strategy had helped to supplement moisture in the soil unlike before. Rainwater harvesting is advantageous because it can prolong the cropping season, and thereby enhance food production and food security (Kihila, 2018).

3.5 Yield Trends of Staple Crops

Figure 8 presents an analysis of maize, sunflower, groundnuts, sorghum and millet yield trends in the study area. Crop yield data were obtained from the District Agricultural Office; and were for the 2008/9 and 2019/20 farming seasons.



Note: 1 Bag = 70 Kilograms (Sunflower); 1 Bag = 100 Kilograms (other crops)

Figure 8: Yield Trends of Staple Crops Grown
Source: Field data, 2021

The findings indicated a general decreasing trends of maize, sunflower and sorghum yields, with variations due to seasonal rainfall variability (Figure 8). The AOs mentioned climate change perseverance; misuse of improved maize, sunflower and sorghum varieties; untimely agricultural practices; and poor incomes to be the causes of such a decline. FGDs pinpointed limited access to agricultural extension services to have contributed to uninformed farm care. Moreover, rainfall variability have tremendously affected crop production in the study area. Maize requires 800–1000mm of rainfall per year, and sunflower and sorghum require 500–1000mm of rainfall per annum (Stefan et al., 2016). Thus, low yields in the 2012/13 and 2016/17 seasons were due to low rainfall amounts recorded in 2013 (394.5mm) and 2017 (428.0mm), respectively. Likewise, the year 2020 recorded the highest amount of rainfall (1116.6mm), thus the moisture requirement levels for the aforesaid crops were exceeded, leading to poor harvests in the 2019/20 farming season. In general, the poor performance of EMC&HYV and mixed-crop farming, as revealed by this study, meant poor performance of maize, sunflower and sorghum varieties: the staple crops grown under these strategies. Further, the findings indicated overall increasing trends of millet and groundnuts yields, with seasonal variations (Figure 8). Millet and groundnuts are drought-tolerant crops that can endure/ resist harsh climatic conditions such as drought and high rainfall variability of semi-arid areas. Millet, for example, requires low rainfall amount of 350–800mm per year (Stefan et al., 2016); thus farmers have the possibility of harvesting even in seasons with low rainfall amounts. FGDs revealed that the application of manure had helped increase the yields of millet and groundnuts.

4. Conclusion and Recommendations

All respondents in the study area were farmers: and they have been experiencing a decrease in rainfall and an increase in temperature in the last thirty (30) years. In view of such changes in climate, farmers have been adopting various local-based adaptation strategies. As a whole, the majority of farmers had not improved agricultural production despite using such strategies. The diversity of the reported adaptation strategies indicates that no single adaptation strategy may be sufficient for farming households to be able to completely adapt to climate change. Thus, complementarities to the diverse sets of adaptation strategies are a crucial strategy for effective adaptation to climate change. Furthermore, collective efforts involving different stakeholders are needed to improve agricultural production and enhance adaptive capacity of smallholder farmers, who in most cases have inadequate information on appropriate farming practices for effective adaptation to climate change.

Acknowledgements

This paper is a part of a PhD study by the first author under the sponsorship of the University of Dar es Salaam. Exceptional gratitude goes to the University of Dar es Salaam for the financial support. Sincere thanks are also expressed to all respondents in the study area for their full support.

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