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Potentials of Growing Drought-Tolerant Crops in Climate Change Adaptation in Semi-arid Tanzania

Godfrey Gosbert*

Abstract

This paper unfolds the potentials of growing drought-tolerant crops (DTCs) as one of the climate change adaptation strategies used widely in semi-arid Tanzania. It draws data from a study conducted in Chamwino District through a triangulation of methods such as household survey, focus group discussions, in-depth interviews, field observations, and document review. Qualitative data were analysed using content analysis, and quantitative data were analysed using SPSS and Microsoft Excel. The results suggest that from 1996 to 2025 rainfall has declined at a significant rate of $R^2 = 0.0014$, implying that the study area is increasingly becoming drier and susceptible to drought incidents: all of which pose potential impacts on crop production, including crop failure and low yields. The findings show most farming households (99.5%) were growing DTCs—such sunflower, groundnuts, sorghum, millet, sweet potatoes, sesame, cassava, and cowpeas—as an adaptation strategy to drought impact on crop farming. These DTCs had enhanced water conservation, soil health, yield stability, food security, and financial security in the study area; leading to improved farmers' livelihoods and enhanced adaptive capacity to climate change. In general, DTCs can potentially help most farmers improve crop production irrespective of extreme climate change scenarios. To further exploit the potentials of DTCs and enhance effective adaptation to climate change, it is important for the government and other stakeholders to provide the necessary resources and services, including weather information, to farmers in semi-arid areas.

Keywords: *climate change, drought, adaptation, drought-tolerant crops, semi-arid area.*

1. Introduction

Drought is a natural hazard that has the potential to cause detrimental impacts on environmental and human systems than any other hazard (Limbu, 2024; URT, 2025). It results from deficiency of rainfall for a prolonged period of time, usually a season or more (Pedersen et al., 2022). Such deficiency occurs naturally due to various factors, including shift in wind systems that can bring dry instead of moist air mass, strong winds that can blow away moist air mass, and intense sunlight and high air pressure that prevent condensation (Masih et al., 2014). Once dry conditions have been initiated, less water in the soil, vegetation and water bodies cause less evapotranspiration, leading to more intensive droughts (Lusiru, 2018).

* Department of Geography, University of Dar es Salaam: kabigumila.godfrey@udsm.ac.tz

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Droughts have been recurring since time immemorial (Eckstein et al., 2019). However, their intensity, duration, spatial coverage and frequency have currently increased due to climate change and variability that take place at very rapid rates since the last half of the 19th century (Limbu, 2024). Drought is a unique natural hazard due to its large spatial coverage compared to other natural hazards (Pedersen et al., 2022). For instance, it was reported that the 2009 drought affected almost all continents (Sheffield & Wood, 2011). Besides, drought causes massive damages to the environment, economy, and lives than any other natural hazard (Magnan et al., 2020; Iqbal et al., 2022). For example, about 291 droughts reported in Africa between 1900 and 2013 caused damages of approximately US$2.92bn, and affected over 362 million people, out of which 847,143 died (Masih et al., 2014). In sub-Saharan Africa (SSA), droughts affected over 40 million people within few years between early and mid-1980s, and about 20 million people in southern Africa in 1991–1992 (Wilhite, 2000).

Crop production is drastically impacted due to over-dependence on rainfall (Pauline & Grab, 2018; Li et al., 2021). For example, in 1991 and 1992, drought caused the shortage of more than 6.7 million tons of cereals in southern Africa (Wilhite, 2000). According to Nelson et al. (2009), climate change and variability are projected to reduce crop production in SSA by 10–20% by 2050 through changing rainfall patterns and increasing frequency of extreme weather events such as drought. It is worth noting that agriculture is the mainstay of the economy of many developing countries (Destaw & Fenta, 2021). Thus, droughts affect not only food production and farming livelihoods, but also the economies of countries.

Evidence of increasing climate change in Tanzania manifests itself through the increase of the frequency and intensity of weather extreme events such as droughts and floods (URT, 2007, 2012, 2021, 2025). Since the 1970s, Tanzania has been experiencing severe droughts with devastating effects on agriculture, water and energy sectors. Severe droughts occurred in 1971, 1973–1976, 1983, 1985, 1987, 1992, 1996/1997, 1999/2000, 2003, 2005/2006, 2009, 2017, and 2021–2023 (Mlengule, 2017; Zuberi et al., 2022; URT, 2025). According to URT (2007), severe drought slowed the targeted growth of GDP from 6.9% to 6.8% in 2005. Also, the growth of the agricultural sector slowed to 5.2% in 2005 compared to 5.8% in 2004. Zakari et al. (2022) concluded that the decrease of crop production due to drought leads to rises of food prices, which in turn affects household livelihoods and food security.

Various adaptation strategies have been used to adapt to drought impacts on crop production, including changing of planting dates, intercropping, planting early maturing and high yielding crops, soil conservation, irrigation, terracing, application of organic and inorganic fertilizers, diversification of farming, and agricultural intensification (Kihupi et al., 2015; Destaw & Fenta, 2021; Kaganzi et al., 2021; Zakari et al., 2022). However, the performance of such adaptation initiatives is threatened by extreme and frequent weather events (Haule, 2018). According to Lusiru (2018), poor crop production has been frequently reported due to high intensity of current droughts and rainfall variability despite the adaptation measures put in place. Worse still, crops grown in many places require relatively high amount of water. For instance, maize (whose water demand is high) is the main cereal crop in large parts of SSA, even in arid and semi-arid regions due to strong preference as a food crop over other cereal crops like sorghum and millet (Hadebe et al., 2016; Lana et al., 2017). Hence, due to its high water demand, its production is highly impacted by droughts.

According to Kangalawe et al. (2017), many adaptation strategies will face challenges due to increasing climate change. In view of the current and future climate changes, including increased severity of droughts, it is imperative that farmers adopt strategies beyond what they are familiar with (ibid.). In this regard, the adoption of drought-tolerant crops (DTCs)—including sorghum, sunflower, sweet potatoes, millet, and cassava—can be a convenient strategy to adapt to droughts. This is because such crops have anatomical and physiological characteristics that can endure drought conditions (Saleem et al., 2020; Iqbal et al., 2022). Moreover, DTCs are less expensive, easy to adopt (Lusiru, 2018), and offer a vital lifeline for climate change resilience (Sawe, 2019; Shalua et al., 2026). DTCs stabilize yields in water-scarce environments, reduce total crop failures, reduce reliance on irrigation, stabilize food security, and safeguard farmers' incomes during erratic weathers (Kaganzi et al., 2021; Gosbert, 2024; Shalua et al., 2026). Moreover, many of these crops are also bred to mature faster, thereby reducing their exposure to dry spells during critical growth phases like flowering or grain filling (Iqbal et al., 2022).

There are various studies on the adoption of DTCs in different places (URT, 2012; Masendeke & Shoko, 2014; Lusiru, 2018; Sawe, 2019; Kaganzi et al., 2021; Gosbert et al., 2022; Gosbert, 2024; Shalua et al., 2026). Some of these studies only marginally highlight on the importance of growing DTCs as part of climate change adaptation strategy (Kaganzi et al., 2021; Gosbert, 2024; Shalua et al., 2026). However, there is still a scant scientific information on the potentiality of growing DTCs in improving agricultural production in the era of climate change. It is this that necessitated the need for a study to comprehensively establish and unfold the potentials of growing DTCs. This study employs a scientific approach to fill the noted knowledge gap. Such knowledge is vital for effective adaptation and sustenance of community livelihoods in drought-prone areas such as in semi-arid regions. The study is guided by the innovation-diffusion theory, which provides a framework for understanding the potentials that influence farmers to adapt DTCs in the face of climate change.

2. Theoretical Framework

As mentioned above, this study is guided by the innovation-diffusion theory propounded by Everett Rogers in 2003. The theory was basically developed to explain the way innovations are diffused and adopted by farmers. The major assumption of the theory is that information access about climate change adaptation is a major factor that determines farmers' adoption decisions of new agricultural technologies. On the other hand, access to information among farmers differs depending on households' characteristics such as age, gender, and education level; as well as on economic and social factors (Sawe, 2019).

Rogers (2003) argues that innovation as a process constitutes five stages: knowledge, persuasion, decision, implementation, and confirmation. The knowledge stage is when a farmer gets an idea about an innovation (in this case, DTCs), especially on how it works. Persuasion involves a farmer's perception about the innovation; this involves assessment of the potentials and weaknesses of the innovation over others. At the decision stage, a farmer decides to either agree or disagree with the innovation. The implementation stage occurs when a farmer puts into application the innovation. The last stage is confirmation, which involves a farmer's evaluation of the outcomes of one's choice taken concerning the innovation. The theory puts it clear that adoption of an innovation takes place over time. Rogers (ibid.) further argues that a prosperous innovation obeys a bell-shaped curve that categorizes adopters into five distinct groups: innovators, early adopters, early majority adopters, late majority adopters, and laggards.

The theory's strengths include promoting knowledge sharing that informs farming households on the potentialities of various adaptation strategies. This helps farmers to make informed decisions regarding the adoption of adaptation strategies; thus supporting adaptation and enhancing resilience to climate change. This also encourages the design of interventions (innovations) aimed at strengthening adaptive capacities and reducing drought impacts on agriculture, and consequently farmers' livelihoods. The theory was deemed appropriate for this study as it offers a conceptual foundation for assessing how farmers have responded to recurring droughts; the extent to which they have adopted DTCs in response to droughts; and the outcomes/potentialities that influenced farmers to adopt DTCs. The theory has been widely applied in agricultural practices and equipment, rural development, and climate change adaptation in various locales. For example, Sawe (2019) employed it to assess the potentials of mixed crop farming in adapting to climate change and variability in Manyoni District. Also, Mwamfupe (2014) and Lusiru (2018) applied it in their studies.

3. Context and Methods

This paper draws data from a study that was conducted in Chamwino District, a semi-arid area of central Tanzania. The district is generally dry and receives

400mm to 650mm of rainfall per annum; with high geographical, seasonal and annual variations. The temperatures in the district generally range from 15^{0}C in July to 30^{0}C in October (URT, 2019). Chamwino District was selected as the study area due to its relatively high frequency of intensive droughts and high rainfall variability (CDC, 2013). Such conditions have resulted into a reduction of crop production, and consequently recurrent food shortages and insecurity in the district (Kahimba et al., 2015). Moreover, farmers in the district have adopted DTCs in response to drought impacts (ibid.). Four villages were selected for the study: Wiliko, Idifu, Mwegamile, and Haneti (Figure 1).

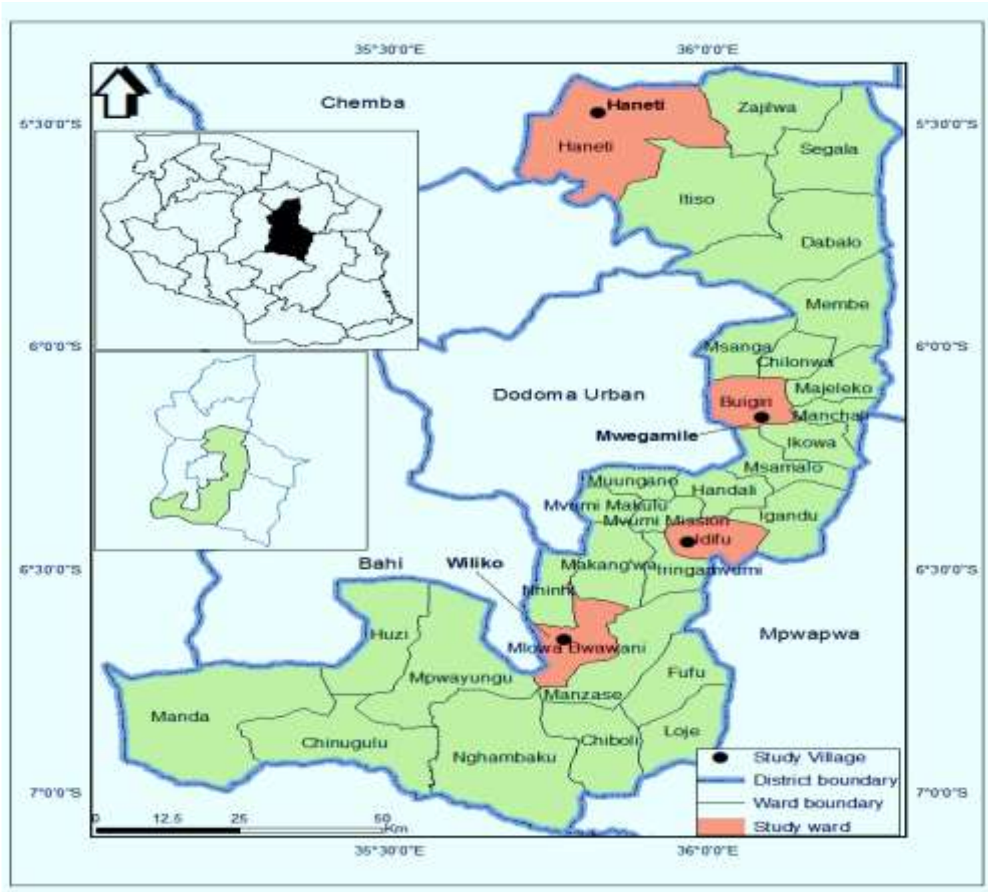


Figure 1: Location of the Study Area

Source: Cartographic Unit, Department of Geography, UDSM, 2026

The study employed mixed-methods research approach, which incorporated both quantitative and qualitative research methods, to capitalize on strengths and reduce weaknesses that stem from using a single research approach. This study suited the use of a mixed-methods research approach as it addressed issues related to a vulnerable population, and involved community participation (Kabir, 2016). The targeted study population was crop farmers, whereby farming households were used as sampling units. The selection of farmers—as elements in the sample—was conducted randomly, whereby each name on the list of names of heads of farming households in the study villages was assigned a unique identification number. Eventually, tables of random numbers—which were generated by a computer—were used to select a representative number of farming households.

The selection of the study area involved the main two geographical zones in Chamwino District; namely the southern zone, and the northern zone. These were stratified based on physical (such as soil) and climatic characteristics. The southern zone is drier and receives little rainfall; as opposed to the northern zone that receives slightly higher rainfall, and has a fertile moist soil. The study wards and villages were selected randomly through the fishbowl draw method, whereby two study wards were selected from each geographical zone: Mlowa Bwawani and Idifu wards from the southern zone; and Buigiri and Haneti wards from the northern zone. Further, one study village was sampled from each study ward. Villages sampled from Mlowa Bwawani and Idifu wards were Wiliko and Idifu, respectively; while those from Buigiri and Haneti wards were Mwegamile and Haneti, respectively.

The sample size (n) of 362 households was derived from the total households (N) of 3,803 by using the sample size formula propounded by Yamane (1967) at 95% confidence levels; and the levels of precision (e) were measured by the probability scale of 5% (0.05) as exemplified below:

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

$$n = \frac{3{,}803}{1 + 3{,}803(0.05)^2} = 362 \text{ household}s.$$

Therefore, the sample size was 362 households.

The number of households used from each study village (n_i) was then derived from the number of households of a village (N_i), divided by the total number of households of three villages (N); and then multiplied by the total sample size (n) as shown below:

$$n_i = \frac{N_i}{N} \times n$$

Thus,

(a) Haneti village had 1,129 households $n = \frac{1{,}129 \times 362}{3{,}803} = 108$

(b) Mwegamile village had 404 households $n = \frac{404 \times 362}{3{,}803} = 38$

(c) Idifu village had 1,327 households $n = \frac{1{,}327 \times 362}{3{,}803} = 126$

(d) Wiliko village had 943 households $n = \frac{943 \times 362}{3{,}803} = 90$

The primary data were collected through a household survey, focus group discussions (FGDs), in-depth interviews, and field observations; while secondary data were collected through document review. The household survey interviews (n = 362) were conducted using a semi-structured questionnaire. A total of four (4) FGDs (n = 32) were conducted; one in each study village. A group of eight (8) farmers (both males and females) in each sampled village participated in the discussions. The discussions primarily focused on the paybacks of planting DTCs in the face of climate change. The in-depth interviews (n = 27) were administered at district, ward, and village levels; whereby one (1) District Agricultural Officer (DAO), four (4) ward/village agricultural officers, eight (8) ward and village government leaders, two (2) climate experts, and twelve (12) elder farmers from the study villages, were recruited for interviews. These were people with experiences and outstanding knowledge about the theme of the study. Field observations were also employed to observe various phenomena corresponding to the study, including livelihood activities, impacts of climate change, and the types of DTCs grown in the study area. The secondary data collected from different offices—such as the District Agricultural Office, Tanzania Meteorological Authority (TMA), and ward/village offices—were used to supplement the primary data.

The qualitative data were analysed through content analysis, while the quantitative data were analysed using the Statistical Product and Service Solution (SPSS, version 23), together with the Microsoft Excel 2013 Worksheet software. Descriptive statistics were run to give frequencies, and then cross-tabulated to assess the performance of DTCs in improving agricultural production. Also, a Paired-Samples T-test analysis was performed to compare farm production before and after the adoption of DTCs. 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 hypothesis was: (Ho) – there is no difference between the total farm productions before and after adaptation; and the alternative hypothesis (Ha) – there is a difference between the total farm productions before and after adaptation. According to Khosravi et al. (2018), if there is a p-value of less than 0.05, then there is a statistically significant difference between the two variables.

4. Results and Discussion

4.1 Livelihood Activities

The findings revealed that crop farming was being carried out by 100% of the respondents. Apart from DTCs, farmers were also growing maize and vegetables. The in-depth interviews revealed that crop farming in the study area was mostly rain-fed. Livestock keeping was the second livelihood activity pursued by 34.8% of all respondents. Livestock kept were mainly cattle, goats, pigs, sheep, and chicken. This implies that most occupants in the study area were potentially vulnerable to the impacts of drought since crop farming and livestock keeping are heavily sensitive to drought and climate change. Hence, the adoption of DTCs was inevitable. The results of this study on the supremacy of crop farming and livestock keeping in the study area are also supported by URT (2019), which underscored that about 90% of all inhabitants in Chamwino District run their lives depending on crop farming and livestock keeping. Other livelihood activities were casual labour (26.8%), petty businesses (25.7%), fuelwood production (7.7%), formal employment (4.1%), and beekeeping (1.1%). Casual labour mostly involved working on other people's farms, brick-making, butchery, and assisting in house construction/repair. Petty businesses involved food vending, tailoring, brew-making and selling, and running retail shops and kiosks. The FGDs uncovered that farming households that engaged in other income-generating activities, such as casual labour and petty businesses, were slightly less susceptible to drought impacts since their livelihoods were dependent beyond agriculture, a sector that is climate sensitive (Gosbert et al., 2022). Again, engaging in other activities and crops reduce pressure on the dependence on DTCs, and guarantee yields in seasons of high rainfall.

4.2 Rainfall Trend

Moreover, the study findings indicated that about 84.6% of all respondents perceived that rainfall had dwindled in the past 30 years (from 1996 to 2025). This was also the consensus of most discussants during FGDs, who opined that in the recent years rainfall has become more erratic and unevenly distributed; and also that the amount, frequency and duration have declined. In an in-depth interview, the DAO similarly reported that rainfall is currently insufficient; a situation that has stifled crop production, and consequently intensified poverty in the district. These findings imply that the study area is increasingly becoming drier and susceptible to drought incidents. Likewise, an analysis of meteorological data revealed a general decline of total annual rainfall trend as indicated by $y = -0.6648x + 597.19$, at a significant rate of $R^2 = 0.0014$ (Figure 2).

Also, the meteorological data revealed the decline of total annual rainfall from an average of 652.9mm in 1996–2000, to 559.0mm in 2021–2025. This denotes a decrease of an average of 93.9mm. The trend analysis also revealed that the total annual rainfall has been fluctuating in the study area in the past 30 years.

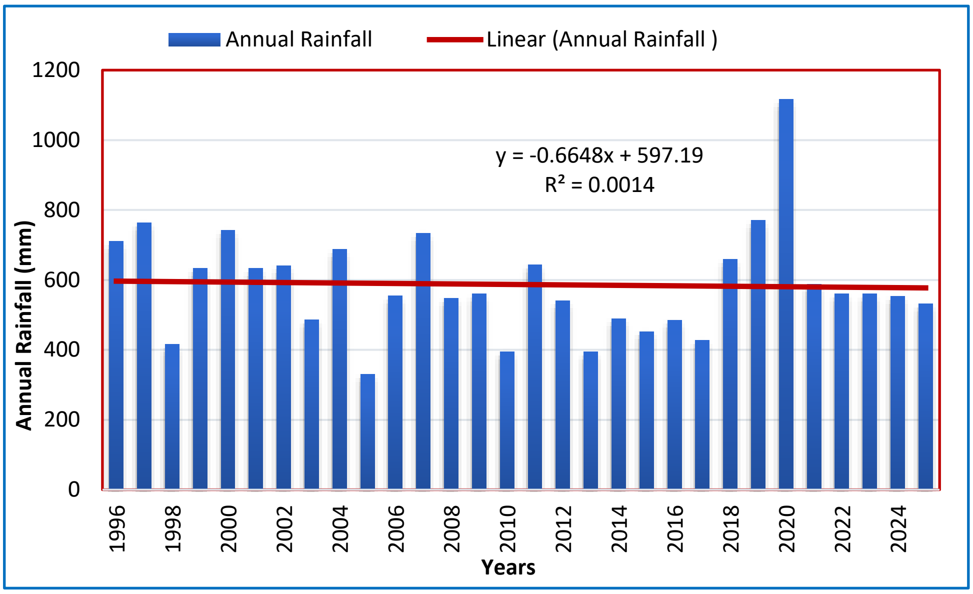


Figure 2: Annual Rainfall Trend in Chamwino District: 1996–2025
Source: Field data, 2026

The area has been experiencing annual rainfall below 400mm in some years, including 2005 (329.7mm), 2010 (394.6mm), and 2013 (394.5mm). Other years which recorded low amounts of rainfall included 1998 (415.4mm), and 2017 (428.0mm). Such fluctuations of rainfall may, however, indicate a normal climatic variability rather than a change. These findings on the trend of rainfall imply the occurrence of drastic droughty conditions that lead to crop failure, calling for increasing the adoption of DTCs. These findings align with the innovation-diffusion theory, which posits the need to design and communicate innovations that support climate change adaptation. In general, the fluctuations and overall decline of rainfall are supported by other studies in semi-arid areas in Tanzania by Kahimba et al. (2015), and Gosbert et al. (2022).

An analysis of the mean monthly rainfall from 1996 to 2025 showed that the study area has been receiving rains mainly in six (6) months. Rainfall commences in November and ceases in April (Figure 3). Farmers prepare farms from October, and start sowing in the low rains of November. These findings imply that the study area has a single rainy season annually, and this is what determines the growing season among farming households. Moreover, the analysis revealed that the months of June (0.2mm), July (0.2mm), August (0mm), and September (0.1mm) are the driest. Most farmers disengage from farming activities in the dry season. Those who continue with farming activities in the dry season need to employ irrigation, which is expensive and therefore impractical to most farming households. Besides, water is a scarce commodity in the dry season.

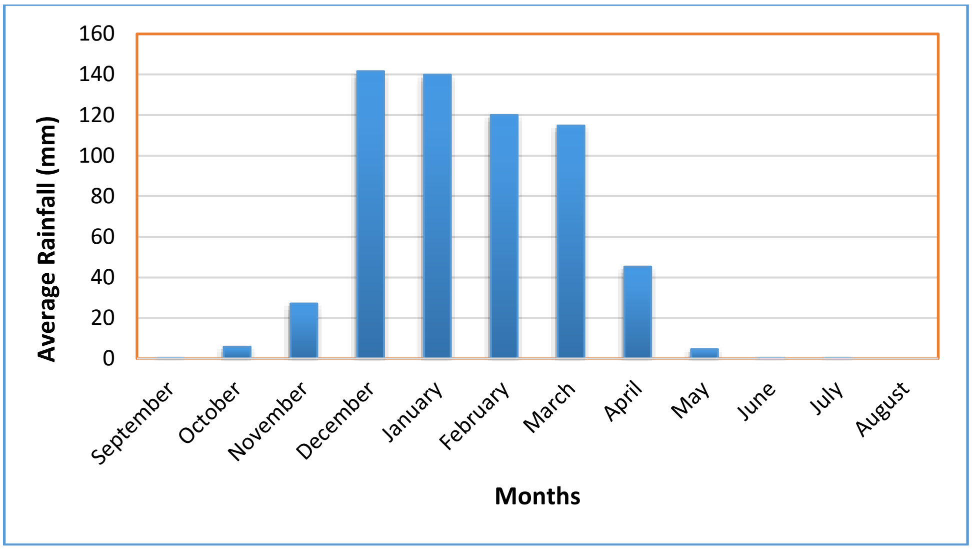


Figure 3: Mean Monthly Rainfall in Chamwino District
Source: Field data, 2026

These findings also imply that when rainfall is inadequate in the rainy/growing season, poor crop production is experienced, and farmers encounter life hardships year-round. Rainfall shortages influence extensive growing of DTCs among farmers to stabilize agricultural yields in such water-scarce periods. This is consistent with the innovation-diffusion theory, which stipulates that environmental factors influence the adoption of innovations. Similar observations of mean monthly rainfall are found in the studies of Lema (2008) and Sawe (2019): both conducted in the semi-arid area of Manyoni District.

4.3 Drought Impacts on Crop Production

The results further indicated that rainfall insufficiencies and the associated drought events pose detrimental impacts on crop production through damaging of crops and low production (96%), increase of crop pests and diseases (80%), drying of water sources (64%), and decrease of soil fertility (50.8%). The decline in crop production was an outcome of crop failure caused by prolonged aridity, strong winds, and the eruption of crop pests and diseases during drought conditions. The drying of water sources also contributed to crop failure, and consequently persistent food insecurity. Equally, a dearth of soil moisture due to drought conditions compromises the capability of soil quality to support plant growth. The same results on crop failure were reported by Shabani and Pauline (2022) in Iringa District. Hence, due to these impacts, most farmers adopted DTCs as a strategy to minimize drought-induced shocks. These findings match with those of Shalua et al. (2026), who found that farmers had adopted DTCs to reduce crop failures in the semi-arid area of Iramba District, Tanzania.

4.4 Types of DTCs Grown

The findings indicated that most farming households (99.5%) were growing DTCs as an adaptation strategy to drought impacts on crop farming. All respondents (100%) in Mwegamile, Idifu and Wiliko villages were growing at least one drought-tolerant crop; while Haneti village was having about 98.2% of DTCs growers. The findings indicated that various DTCs were being grown in the study area as shown in Table 1.

Table 1: DTCs Grown in the Study Villages

DTCs Grown	Villages								Total (N=362)	
	Haneti		*Mwegamile*		*Idifu*		*Wiliko*			
	N	*%*	*N*	*%*	*N*	*%*	*N*	*%*	*N*	*%*
Sunflower	101	93.5	34	89.5	126	100	75	83.3	**336**	**92.8**
Groundnuts	85	78.7	35	92.1	124	98.4	81	90.0	**325**	**89.8**
Sorghum	18	16.7	27	71.1	126	100	75	83.3	**246**	**68.0**
Millet	4	3.7	15	39.5	126	100	44	48.9	**189**	**52.2**
Sweet Potatoes	86	79.6	0	0	5	4.0	21	23.3	**112**	**30.9**
Sesame	50	46.3	26	68.4	0	0	24	26.7	**100**	**27.6**
Cassava	41	38.0	20	52.6	10	7.9	13	14.4	**84**	**23.2**
Cowpeas	16	14.8	16	42.1	11	8.7	9	10.0	**52**	**14.4**

Note: Based on Multiple Response Analysis

Source: Field data, 2026

Table 1 shows the eight DTCs grown in the study area. In Haneti village, the most grown DTCs were sunflower, sweet potatoes, and groundnuts; while millet (3.7%) was the least grown DTC in the village. This was because Haneti village receives relatively high amount of rainfall, which disfavours the growth of millet. In Mwegamile village, the most grown DTCs were groundnuts, sunflower, sorghum, sesame, and cassava. The interviewed respondents in Mwegamile village were not growing sweet potatoes. The higher percentage of sweet potato growers in Haneti village was due to the presence of a number of Sukuma immigrants who pioneered the growth of sweet potatoes in the village. The situation was quite the reverse in Mwegamile village.

Moreover, millet, sorghum, sunflower and groundnuts were mostly grown in Idifu village than in any other village as reported by a majority of the respondents. Idifu village is relatively drier most of the time, thus these DTCs endure such a climate. However, the villagers here were not growing sesame. The crop was reported to be susceptible to pests and diseases, especially during rainfall shortages, thus the farmers abandoned the crop to avoid losses. In Wiliko village, most of the respondents were growing groundnuts, sunflower, and sorghum. Cowpea (10%) was the least grown DTC in the village due to the drier climatic nature that becomes worse during drought situations. The diversity of DTCs grown in the study villages was thus associated to the climatic conditions (including subsequent consequences of their change) of such villages, coupled with food preferences.

Therefore, apart from maize, the other crops grown in the study area were mostly DTCs due to the nature of the climate in the area. During FGDs, participants argued that most of them were growing DTCs due to poor climatic conditions. They argued that the area experiences erratic rainfall, increases in temperature, and increased frequencies of drought and dry conditions: hence it was imperative to grow crops that tolerate such harsh conditions of poor water supply. According to the findings from in-depth interviews and FGDs, planting DTCs is one of the oldest adaptation strategies in the study area. The practice started with the growing of sorghum and millet, and has now extended to DTCs such as cassava and sweet potatoes that were rarely grown in the area before. Thus, this was not a new strategy but one that was intensified by an emphasis from the government to introduce more DTCs to improve food security following the increasing impacts of climate change. The increasing number of DTCs grown in the study area speaks by itself on the alarming and unfavourable conditions for traditionally preferred non-DTCs such as maize. Consequently, climate change induced droughts have also led to shifts in food preferences in the area. More shifts in food preferences are still expected if climate change perseveres. For instance, the struggle of the sesame crop against climate-change-induced pests and diseases is real, and its production will still face challenges amidst climate change. Similar observations on the adoption of DTCs were reported by Masendeke and Shoko (2014), and Kaganzi et al. (2021).

4.5 Potentials of DTCs

The study results also revealed that DTCs were of great potential in the study area. Planting DTCs was found to be the most popular adaptation strategy in the area as compared to others. This is because Chamwino district is located in a semi-arid zone of central Tanzania, where rainfall is erratic and insufficient. So the growing of DTCs was a feasible adaptation strategy for a drought condition. This aligns with the innovation-diffusion theory, which proposes the adoption of strategies that can effectively enhance resilience to climate change. Besides, the findings of this study revealed that the adoption of DTCs is relatively cheaper and simpler for farmers to adopt compared to many other adaptation strategies. Similar observations are found in the study of Lusiru (2018).

To have a deeper insight into the performance of DTCs in the study area, respondents were asked to compare total farm production before adopting DTCs and after adopting DTCs. This is in consideration of the fact that some farmers had to abandon some crops and adopt DTCs, while others were growing DTCs and other crops concurrently to supplement food production. The results of the paired-samples t-test analysis indicated that the Sig. (2-tailed), or the two-tailed p-value was less than 0.05 (i.e., .000). This denotes that the mean difference between total farm production before adopting DTCs, and total farm production after adopting DTCs, was statistically significantly different from zero (Table 2).

Table 2: Results of Paired-Samples T-Test Analysis - Paired Samples Test

Paired Samples		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 (bags) before adopting DTCs - Total farm production (bags) after adopting DTCs	-4.819	13.257	.699	-7.144	-4.395	-8.257	359	.000

Source: Field data (2026)

Moreover, paired samples correlation shows the Bivariate Pearson correlation coefficient (with a 2-tailed test of significance) for each pair of variables entered. The results of the paired samples correlations indicated that the total farm productions before and after adopting DTCs were significantly positively correlated (r = .014) as shown in Table 3.

Table 3: 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

Source: Field data (2026)

In addition, the results of the paired-samples t-test analysis indicated an increase in the mean of total farm production from 16.35 bags before adopting DTCs, to 21.17 bags after adopting DTCs. This denotes an increase of 4.82 bags mean total farm production after the adoption of DTCs (Table 4).

Table 4: 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	16.35	360	9.799	.516
	Total farm production (bags) after adopting DTCs	21.17	360	9.067	.478

Source: Field data (2026)

In short, growing DTCs, as a climate change adaptation strategy, was performing well in the study area. The increase of average total farm production of about 4.82 bags meant improved crop production. This has a positive implication on food production and income generation amongst farmers. It also has a far-reaching implication on reduced vulnerability to climate change impacts. The good performance of DTCs is supported by Shabani and Pauline (2022), who reported that the strategy was most effective in Iringa District. During FGDs, discussants argued that growing DTCs was viable for them to adopt. It should also be remembered that the adoption of DTCs does not take farmers out of farming. Farming is a vital source of food and income for the farming households in the study area. Thus, adaptation strategies, which can deal with rainfall insufficiency and drought within farming itself, are more useful and worth promotion.

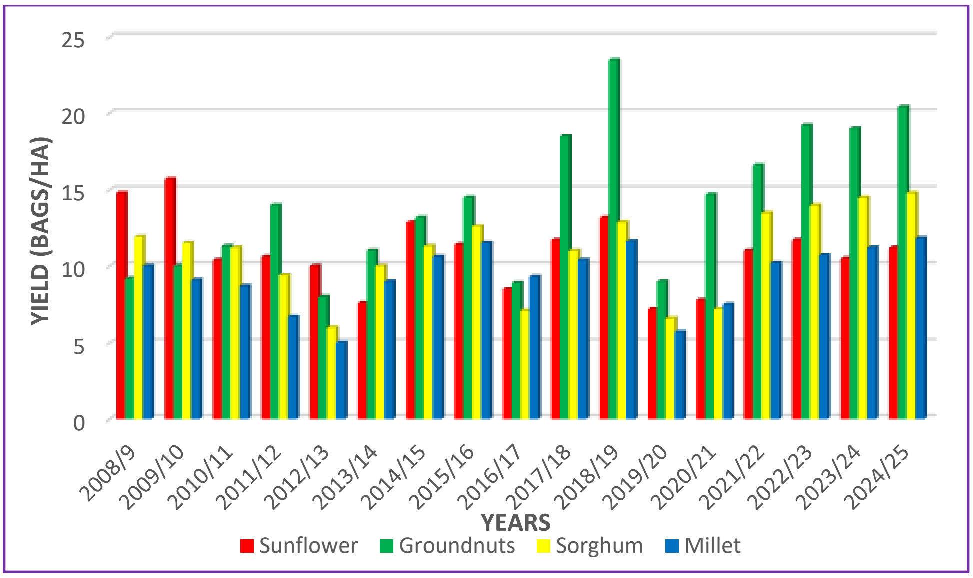
The adoption of DTCs is widely known to be a sustainable drought adaptation strategy. During the in-depth interview with the DAO, it was reported that the adoption of DTCs has a potential of *enhancing water conservation and increasing water productivity*. DTCs are bred to thrive with less water, helping reduce reliance on irrigation; and preserving vital freshwater sources. The adoption of DTCs also ensures efficient water use as these reduce water loss through physiological adaptations. This implies that farmers can get good harvests with DTCs without the need to increase water input. This is important because water is the main challenge to crop production in drought conditions. The findings on water conservation and productivity match with those of Hadebe et al. (2016).

Furthermore, DTCs have potentials of *enhancing soil health and environmental conservation*. The findings of this study showed that DTCs (such as millet) have robust and deep root systems that improve soil structure, limit erosion, and require fewer synthetic inputs. An in-depth interview with the Idifu ward agricultural officer revealed that deep root systems help DTCs to access moisture stored further underground. This denotes that deep-rooted crops can access subsoil water that help them recover from droughts. The findings on enhancing soil health match with those of Masendeke and Shoko (2014), who reported that cowpeas boost soil fertility, and also provide a good protein supplement in Mberengwa district, Zimbabwe. On the other hand, DTCs act as catalysts of environmental conservation as they require significantly less irrigation, thus reducing water use and energy costs associated with water pumping.

Further, DTCs have a potential of *enhancing yield stability during drought conditions*. The findings of this study confirmed that DTCs are specifically bred or naturally selected to maintain reliable harvests during dry spells. During FGDs, the discussants revealed that DTCs assured farmers of harvests by reducing total crop failures due to their endurance to drought. Some DTCs also have accelerated growth cycles, thus maturing earlier to avoid peak drought periods. Likewise, DTCs have a potential of *ensuring food security* by assuring consistent food supply even under tough climatic conditions. Similar findings were reported by Shalua et al. (2026).

Furthermore, DTCs have a potential of enhancing the financial security of farmers. The findings in Table 1 indicate that sunflower, groundnuts, sorghum, and millet were the main DTCs grown in the study area. While sunflower and groundnuts were mainly grown for cash, sorghum and bulrush millet were as well important for food and income generating practices through beer brewing: hence, they were helpful in boosting household livelihoods in hard times of rainfall shortages. Likewise, it was reported that DTCs mitigate the risk of total crop failure during drought conditions, hence preventing catastrophic income shocks for smallholder farmers, and allowing for more predictable revenues. Similar observations are found in the studies of Kaganzi et al. (2021) and Gosbert (2024). These potentials of DTCs influence farmers to adopt/grow DTCs amid climate change. This aligns with the innovation-diffusion theory that emphasizes on farmers assessing the strengths of adaptation strategies before adoption.

This study also analysed crop yield data of staple DTCs grown in the study area. The crop yield data were obtained from the DAO; and were for the 2008/9 to 2024/25 farming seasons. Staple DTCs analysed were sunflower, groundnuts, sorghum, and millet. Figure 4 presents the results.



Note: 1 bag = 70kg (sunflower); 1 bag = 100kg (other crops)

Figure 4: Yield Trends of Staple DTCs Grown

Source: Field data, 2026

The results in Figure 4 indicate the overall increasing trends of groundnuts, sorghum, and millet yields with seasonal variations due to rainfall variability in the study area. Groundnuts, sorghum, and millet are DTCs that can tolerate severe climatic conditions such as drought and high rainfall variability of semi-arid areas. For example, millet 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. Again, this study realized that millet is mostly grown solely without being mixed with other crops unlike sunflower; which contributed to its good harvest. According to the agricultural officers, the increasing trend of sorghum yields was due to the introduction of improved early maturing sorghum varieties such as *Macia, Tegemea, Okoa,* and *Nako*. Improved short white sorghum matures within a period of 60–90 days, as compared to local sorghum seeds that mature within a period of 90–120 days. Therefore, farmers have the likelihood of harvesting even in shorter rain seasons. These findings complement those of Kahimba et al. (2015), who reported that the *Macia* variety is the commonly used one as early maturing sorghum seeds in Chamwino District; and hence as an adaptation strategy to rainfall scarcities. Also, the FGDs revealed that the application of manure had helped increase groundnuts yields.

On the other hand, the findings indicated a general decreasing trend of sunflower yields with seasonal variations (Figure 4). The agricultural officers mentioned the causes of such a decline as excessive aridity, misuse of improved sunflower varieties such as *Zebra* and *Record*, untimely agricultural practices, poor incomes, and neglect of farming rules. For instance, intercropping sunflower and maize/sorghum—which was practiced by most of the farmers—was not a recommendable way of mixing crops in small farms. According to the DAO, sunflower and maize/sorghum do not perform well most of the time when intercropped in one farm field as the crops struggle for space. Such noncompliance with farming guidelines contributed to poor sunflower yields irrespective of the crop being grown by the majority of the farmers in the study area. On the other hand, FGDs identified limited access to agricultural extension services to have contributed to uninformed farm practices.

However, the findings from in-depth interviews revealed that DTCs are not always high-yielding due to their nature of enduring droughts: the only advantage is that they assure some harvests in hard times of drought unlike non-DTCs. During household survey interviews, respondents were asked to differentiate between DTCs and other crops in terms of productivity, and the results are as shown in Table 5; which somewhat support the findings of the in-depth interviews. This is because, most of the respondents (51.1%) either had not observed any difference between DTCs and other crops, or perceived DTCs to be less productive. Therefore, DTCs were found to be reliable during severe climatic conditions, though not having high yields.

Table 5: Difference between DTCs and Other Crops

Difference	No. of Respondents (N=362)	Percentage
DTCs are highly productive	168	46.4
No difference	87	24.0
DTCs are less productive	98	27.1
No idea	9	2.5
Total	**362**	**100**

Source: Field data, 2026

However, although DTCs have high tolerance level for drought when drought conditions persist, they also fail or perform poorly. The FGDs and household survey interviews identified the driest years—such as 2005, 2013, and 2017—to have had poor crop production irrespective of the use of DTCs. This implies that the productivity of DTCs, despite their differential requirements, is also likely to be influenced by climate change. The effects of climate change on DTCs are not only due to drought conditions and rainfall inadequacies, but also due to heavier than normal rains. The findings from in-depth interviews revealed that DTCs do not perform well under heavy rains. The moisture requirement levels of DTCs range between 350mm and 1000mm of rainfall per annum (Stefan et al., 2016). Hence, once these levels are exceeded, DTCs are more likely to fail or perform poorly. In-depth interviews with the Mlowa Bwawani and Idifu WAOs revealed that farmers plant DTCs each year regardless of weather specifics. For example, the year 2020 had high rainfall amount of 1116.6mm, but still farmers grew millet, sorghum, sunflower and other DTCs that require low rainfall: hence, the overall performance was poor in the 2019/20 farming season. These findings are consistent with the innovation-diffusion theory that underscores the need to understand the weaknesses of adaptation strategies before applying them.

5. Conclusion and Recommendations

All respondents in the study area were farmers; and they have been experiencing a decline in rainfall in the past thirty (30) years. In view of such changes in rainfall, and the impact on crop production, farmers have been growing a variety of DTCs as an adaptation strategy to rainfall insufficiencies and drought conditions. Most of the farmers were acquainted with the attributes of DTCs as stipulated by the innovation-diffusion theory. Generally, DTCs had good performance and great potential in the study area. The study findings revealed that most of the farmers had improved crop production irrespective of drastic climate change scenarios. Hence, the adoption of DTCs had enhanced water conservation, soil health, yield stability, food supply, and financial security. All these had a far-reaching implication on improved livelihoods and reduced vulnerability to drought impacts in the study area.

The DTCs found to have greater potential of improving farming livelihoods in the face of climate change included groundnuts, sorghum, millet, sunflower, cassava, and sweet potatoes. However, the study found that no single adaptation strategy can 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 for effective adaptation to climate change. DTCs are likely to perform to their maximum level only if their specific requirements are considered and met by farmers. Considering the nature of rains in Chamwino District, DTCs can be planted a little late in January to February after the heavy rains of December, as reported by some farmers. Planting DTCs in November like maize makes them vulnerable to the heavy rains of December that cripple their growth and productivity, thereby resulting into food insecurity. Therefore, it is imperative to strengthen agricultural extension services and weather/ agricultural education so that farmers can acquire the pertinent information on when and how best to grow DTCs. Again, policymakers and decision-makers should assimilate DTCs into agricultural policies to support farmers in coping with climate change induced droughts.

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