Journal of the Geographical Association of Tanzania, Vol. 46, No. 1: 23–45

Examining Smallholder Farmers' Drought Resilience Strategies in Iramba District, Tanzania

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Abstract

Despite promising crop yields experienced by smallholder farmers in semi-arid regions, escalating drought is still a threat to food security and is currently more pronounced in the central regions of Tanzania, necessitating the need to adequately explore specific farmer-driven strategies that may potentially promote sustained yields. This paper addresses the specified knowledge gap by examining drought adaptation strategies employed by smallholder farmers in Iramba District, over the period 1995–2024. The study adopted a descriptive research design and collected data using a mixed-methods approach; incorporating structured interviews, focus group discussions, field observations, in-depth interviews, and document reviews. Quantitative data were analysed using IBM SPSS (version 29), while Qualitative data were analysed through thematic analysis. The results demonstrate that most farmers utilise multiple strategies to withstand drought impacts, including the adoption of drought-tolerant crops, modification of planting dates, traditional irrigation, and improved crop varieties. Importantly, crop yields increased concurrently with a rising incidence of drought events. Based on these findings, this article recommends a broader implementation of effective drought adaptation measures through coordinated action among farmers, government institutions, and non-governmental organizations. Furthermore, policymakers and decision-makers should integrate proven adaptation strategies into national agricultural policies to enhance support for smallholder farming systems.

Keywords: *Drought impacts, Iramba district, Resilience strategies, smallholder farmers*

1. Introduction

Droughts represent one of the most significant threats to the well-being of smallholder farmers globally, raising concerns about their resilience to drought-induced shocks and stresses (Meuwissen et al., 2019; Aguilar et al., 2022). Approximately 80% of global crop losses are attributed to droughts (FAO, 2019), which disproportionately affect smallholder farmers in both developing and developed regions (ibid.). However, the impacts on crop production have been more severe in developing regions than in developed ones

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 ▪ https://doi.org/10.56279/jgat.v46i1.378

such as Europe, North America, and Australia. For instance, smallholder farmers in Honduras and Guatemala have enhanced their resilience to drought through agroforestry, water-harvesting systems, irrigation, and improved crop varieties (Harvey et al., 2018). Similarly, in the semi-arid tropics of India, farmers have maintained high crop yields during droughts by adopting crop diversification and irrigation (Ramilan et al., 2022).

In Africa, the impacts of drought are alarming. According to Mwasha (2021), droughts are expected to reduce food security across many African countries as rain-fed crop yields decline significantly. In response, some smallholders have adopted diverse resilience strategies. In Nigeria, for example, farmers use contour farming and multi-cropping to mitigate drought impacts (Mal et al., 2018); whereas Ethiopian farmers adopt water management, crop diversification, and drought-tolerant varieties (Berhanu et al., 2024). In Ghana, smallholders recover from drought through mixed cropping, integrated soil fertility management, livelihood diversification, climate-smart agriculture (CSA), traditional irrigation, and improved crop varieties (Amosah et al., 2023). Overall, farmers employ a suite of drought-mitigation strategies, with water harvesting, crop diversification, and the use of drought-resistant crop varieties contributing notably to resilience (Mdemu, 2021).

In Tanzania, droughts primarily affect the regions of Manyara, Arusha, Dodoma, Singida, Shinyanga, and parts of Kilimanjaro (Mdemu, 2021; Matata et al., 2019). As in other developing countries in Africa, smallholder farmers in Tanzania's semi-arid regions are adversely affected by droughts, which have sometimes reduced crop production by over 20% during severe periods (El-Rawy, 2023). This vulnerability stems mainly from the predominant reliance on rain-fed agriculture (Kihila, 2018).

According to Kabote (2015), Iramba District has experienced intensified drought conditions since the 1980s, with increased drought frequencies during the 2000s. Climate change impacts in the district include unpredictable rainfall, a shortening of the growing season by more than one month, dry spells extending into January and sometimes lasting until mid-March, and intensified strong winds (ibid.). Moreover, Nyangas and Chingonikaya (2017) report that, despite numerous adaptation strategies, the area has lacked significant improvement in crop production, facing a decline due to the intensification of drought conditions and severe adverse impacts since the 2000s.

Moreover, the district was found to exhibit low adaptive capacity, with smallholder farmers demonstrating maladaptive responses to drought impacts (ibid.). Nevertheless, recent production data from the Iramba District Council indicate an increase in crop production between 2017 and 2024 (URT, 2024). The annual production data show a rise from 22,311.2 tons in 1995 to 335,722 tons in 2024, which is attributed to a combination of farmer-employed strategies (URT, 2024). Consequently, the district currently experiences neither hunger nor a need for food aid from the government or non-governmental organizations, marking a significant transition toward resilient farming. Therefore, this paper evaluates the specific strategies employed by smallholder farmers in Iramba District to maintain and enhance crop yields under persistent drought conditions. The study is grounded in the resilience theory, which provides a framework for understanding how individuals, communities, and systems adapt to, and recover from, adverse climate conditions.

2. Theoretical Framework

As noted above, this article is grounded on the resilience theory proposed by ecologist C.S. Holling in 1973. Resilience is defined as a system's capacity to absorb shocks and adapt while preserving its essential functions and structures. The theory's central assumption is the potential to recover, adapt, or transform in response to challenges. Accordingly, it helps explain how ecosystems—such as farming systems—respond to disturbances without losing their core functionality.

The theory's strengths include promoting proactive risk management, valuing local knowledge, and supporting adaptive mechanisms that enhance resilience. It also encourages a systems-thinking perspective, which is critical for addressing complex, interrelated issues like drought impacts on agriculture. Therefore, the theory provides a framework for understanding how communities withstand and recover from environmental shocks, and it also usefully informs the design of interventions aimed at strengthening adaptive capacities.

In light of the above, the theory's relevance to this study lies in its capacity to offer a conceptual foundation for assessing: (a) how farmers have responded to recurring droughts; (b) the extent to which they have adapted their crop production practices; and (c) the effectiveness of their adaptation strategies over time. The theory has been empirically applied to agricultural adaptation in various settings. For example, Tambo and Wünscher (2017), employed it to evaluate adaptation strategies among smallholder farmers in Nigeria.

3. Methodology

3.1 Description of the Study Area

The study was conducted in three villages within Iramba District: Kidaru, Tyegelo, and Tulya. Iramba District is one of six districts in Singida Region; and it is situated between latitudes 3°45′ S and 5°00′ S, and longitudes 31°45' E and 34°45′ E (Figure 1).

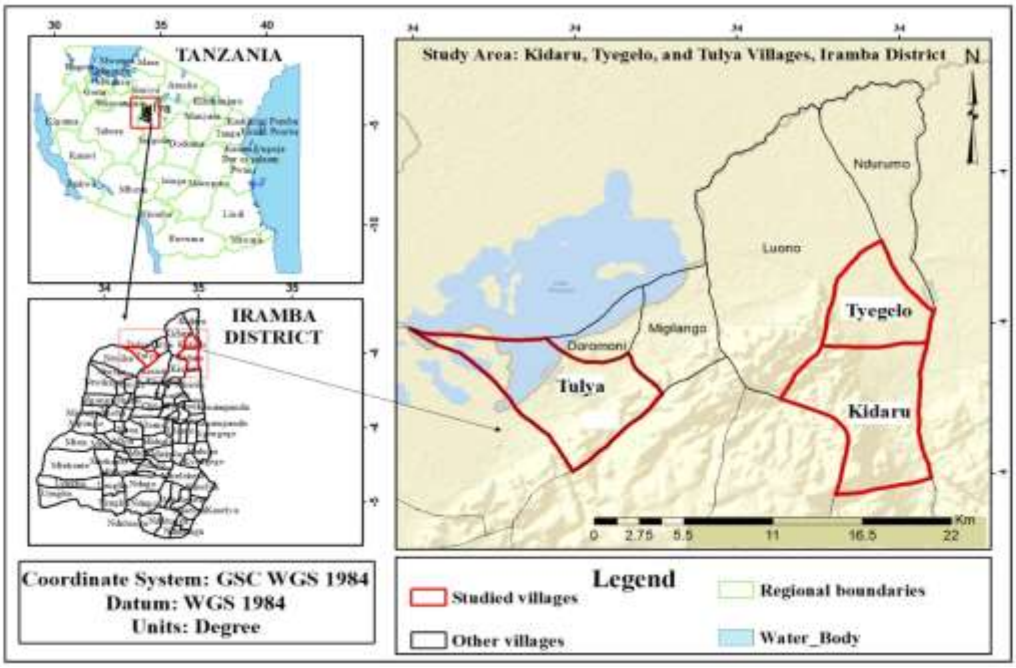

Figure 1: Locational Map of the Studied Villages in Iramba District

Source: Cartographic Unit, University of Dar es Salaam (2025).

The district receives a mean annual rainfall of 500–850mm, which is unpredictable and unreliable in both amount and timing (URT, 2018). Rainfall occurs between November and May, with two major seasonal peaks in December and March-April (Kabote, 2015). Temperatures range from 15°C in July to 30°C in October. The Ndurumo River—one of several seasonal rivers that historically flowed from winter through autumn—is now drying up, leaving Lake Kitangiri as the area's primary water body. The district comprises three major agro-ecological zones: the Western Great East African Rift Valley, the central highland, and the eastern zone. The Western Great East African Rift Valley is drier than the other two zones (Iramba District Council, 2009, 2024). The district's vegetation consists of thickets, shrubs, thorny bushland, and scattered or clustered cover in some areas; all of which indicate a semi-arid zone (URT, 2005). Agriculture is the main livelihood, engaging 95% of the population (Kabote, 2015), with most farmers cultivating sorghum, maize, sunflower, cassava, and millet.

3.2 Justification for Selection of the Study Area

Iramba District was selected as the study area due to its relatively high frequency of drought events compared to other semi-arid districts in Singida Region (Kabote, 2015). Situated within the drier Great East African Rift Valley zone, the district is more susceptible to moisture stress than other districts in the region (Kabote et al., 2017). This dry ecological condition heightens smallholder farmers' exposure to drought and inter-seasonal rainfall variability, a factor associated with low to moderate resilience in the district (Nyangas & Chingonikaya, 2017). Recurring drought and limited adaptive capacity have resulted in food insecurity in the studied villages (Kabote, 2015), which consequently relied on food aid between 2000 and 2014, a period during which district authorities and non-governmental organizations (NGOs) assisted on eight occasions (ibid.).

Moreover, the district experiences low and erratic mean annual rainfall (500–850mm), with frequent seasonal droughts that severely disrupt rain-fed agriculture, the primary livelihood for over 95% of the population (Kabote, 2015; Yohana & Saria, 2020).

3.3 Targeted Population

The target population for this study comprised smallholder farmers, local leaders, and Iramba District officials. The study focused on household heads irrespective of gender, with particular emphasis on those possessing long-term farming experience who could clearly articulate the resilience strategies they employ to mitigate drought impacts on crop production.

3.4 Sampling Frame

The sampling frame comprised all farmers in the three villages of Kidaru, Tyegelo, and Tulya. The household served as the sampling unit, being the most suitable and flexible unit for population-based studies. The study specifically targeted adult farmers, as they possessed the necessary information to address the research questions. The total number of households across the three villages was 2,000 (URT, 2022).

3.5 Sample Size

Structured interviews were conducted across three study villages located in two wards. The 2022 national census reported 548 households in Tyegelo, 851 in Kidaru, and 601 in Tulya; giving a total of 2,000 households. This total constituted the study population (N), which served as the basis for determining the sample size for the household survey. To obtain efficient sample estimates, a 10% allowable error (confidence interval) was applied. The sample size was calculated using Yamane's formula (Yamane, 1967), which offers a simplified approach for sample size determination as follows:

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

Where: N = total number of households; e = allowable error/margin error (standard error); n = sample size; and 1 = is constant.

Here we have: Total number of Households (N) = 2000.
Allowable error/margin error (standard error) (e) = 10%.
Confidence interval = 90%.
1= is constant.
Sample size (n) = Required.

Thus:

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

$$n = \frac{2000}{1 + 2000(10\%)^2}$$

$$n = \frac{2000}{1 + 2000(0.01)}$$

$$n = \frac{2000}{1 + 20}$$

$$n = \frac{2000}{21} = 95 \text{ Households}$$

Therefore, the sample size was 95 households.

Following the determination of the total sample size, proportional sampling was employed to select households from each study village. Using the household counts previously reported (548 for Tyegelo, 851 for Kidaru, and 601 for Tulya) the proportional allocation formula was applied to calculate the specific sample sizes for each village as follows:

Since:

$$nh = \frac{Nh}{N}$$

Whereby: nh = proportional sample size for each village; Nh = total households in each study village; N = total number of households in the study area; n = total sample size of the study population.

Hence: Nh = 548.

$$\text{For Tyegelo village}, nh = \frac{548 \times 95}{2000} = 26 \text{ Households}$$

$$\text{For Kidaru village}, nh = \frac{851 \times 95}{2000} = 40 \text{ Households}$$

$$\text{For Tulya village}, nh = \frac{548 \times 95}{2000} = 29 \text{ Households}$$

3.6 Sampling Procedures

This study employed both non-probability and probability sampling techniques. For the non-probability component, purposive sampling was used to select key informants, smallholder farmers, and focus group discussion (FGD) participants in Iramba District. Smallholder farmers for FGDs were purposively chosen based on their farming experience and sufficient knowledge, to provide detailed and accurate information during discussions. Key informants were similarly selected according to their official positions in the district, extensive experience, and adequate knowledge of farming, the characteristics that facilitated the collection of in-depth data on crop production trends and farmers' drought mitigation strategies.

For probability sampling, a multistage sampling approach was applied to select divisions, wards, and ultimately villages for inclusion in the study. Kisiriri division was selected at the district level; Tulya and Kidaru wards were subsequently sampled from the division; and finally, Tyegelo, Kidaru, and Tulya villages were sampled from the two wards. This multistage approach allowed to narrow the study's focus to a manageable population. Simple random sampling was then used to select smallholder farmers for structured interviews in each village. This technique ensured every respondent had an equal chance of selection, thereby minimizing bias and enhancing the validity and generalizability of the findings to the broader population.

After determining the sample size for each village, simple random sampling was again employed to select households. Household heads registered in village registers who qualified for inclusion in the structured interview sample were listed first, ensuring each household had an equal chance of selection. The farmer's household served as the unit of analysis. The names of household heads were written on paper slips and placed in a box. The selection process involved drawing one household at a time without replacement. This procedure was repeated across all studied villages until the required sample size of 95 households was achieved, with proportional allocation based on each village's calculated sample size.

3.7 Data Collection Methods

The study that generated the data for this paper employed structured interviews, focus group discussions (FGDs), in-depth interviews, field observations, and document reviews to collect data. Structured interviews were used to collect quantitative data primarily on crop production trends and resilience strategies for withstanding drought impacts in Iramba District, via a questionnaire. A field observation guide and checklist were also used to observe crop types, crop conditions, and farming practices related to drought adaptation. Data were recorded through notes and photographs to enhance their value, and these observations were validated through in-depth and structured interviews. FGDs were conducted using open-ended guiding questions to capture qualitative data on crop production trends, and resilience strategies adopted by smallholder farmers.

Each FGD lasted for no more than 60 minutes. One FGD was conducted in Tulya village with 11 participants, and another in Tyegelo village with 10 participants. The researcher audio-recorded the discussions using a mobile phone while simultaneously taking notes. Secondary data on crop production trends, long-term climate data, and resilience strategies were collected through document reviews from the District Agricultural Office and the Tanzania Meteorological Authority (TMA). Reviewed documents included Iramba District's annual agricultural reports, as well as other materials obtained through online searches—such as journal articles, books, and dissertations—to corroborate and complement the primary data collected in the field.

3.8 Data Processing and Analysis

The quantitative data collected through structured interviews were coded, cleaned, and entered into the Statistical Package for the Social Sciences (SPSS, version 29) to enable descriptive statistical analysis and linear regression. Descriptive statistics included frequencies and percentages of household heads' responses to the survey questions. Rainfall, temperature, and crop yield data were analysed using linear regression to identify trends over the preceding 30-year period. The qualitative data were analysed using thematic analysis, whereby themes were generated and linked to corresponding supporting statements extracted from the collected data.

3.9 Ethical Consideration

This study complied with all applicable research ethics principles, including those outlined in the University of Dar es Salaam's (UDSM) ethical code of practice for research. Research clearance was secured from the University of Dar es Salaam, the Singida Regional Administrative Secretary (RAS), and the Iramba District Council before commencing the fieldwork. Informed consent was obtained from all respondents before participation. The participants were explicitly informed that their involvement was voluntary; and that they could withdraw from the study at any time without penalty. They were also apprised of the study's objectives, and guaranteed confidentiality. Throughout the data collection process, the researcher observed all relevant ethical and research codes of conduct. Moreover, the authors are committed to honesty and accuracy in presenting the study's findings.

3.10 Validity and Reliability

The study sample consisted primarily of smallholder farmers, and the selection of a respondent was guided by the study's objectives to enhance validity. This enabled the researcher to collect relevant data, thereby ensuring content validity. Validity was further strengthened through the selection of appropriate data collection and analysis methods, which ensured consistency, unbiased sample selection, a systematic study timeframe, and the application of a mixed research design. Furthermore, the data collection instruments were pretested prior to the actual fieldwork. Reliability was ensured by employing multiple data generation methods. The use of diverse data collection and analysis techniques was essential for cross-validating the reliability and validity of the data.

4. Results and Discussion

4.1 Overall Trend of Crop Yields

An analysis of documents from the Iramba District Agricultural Office revealed that, despite a slight decline in cultivated farm size (r^2 = 1.01%), overall crop yields increased (r^2 = 8%) as shown in Figure 2.

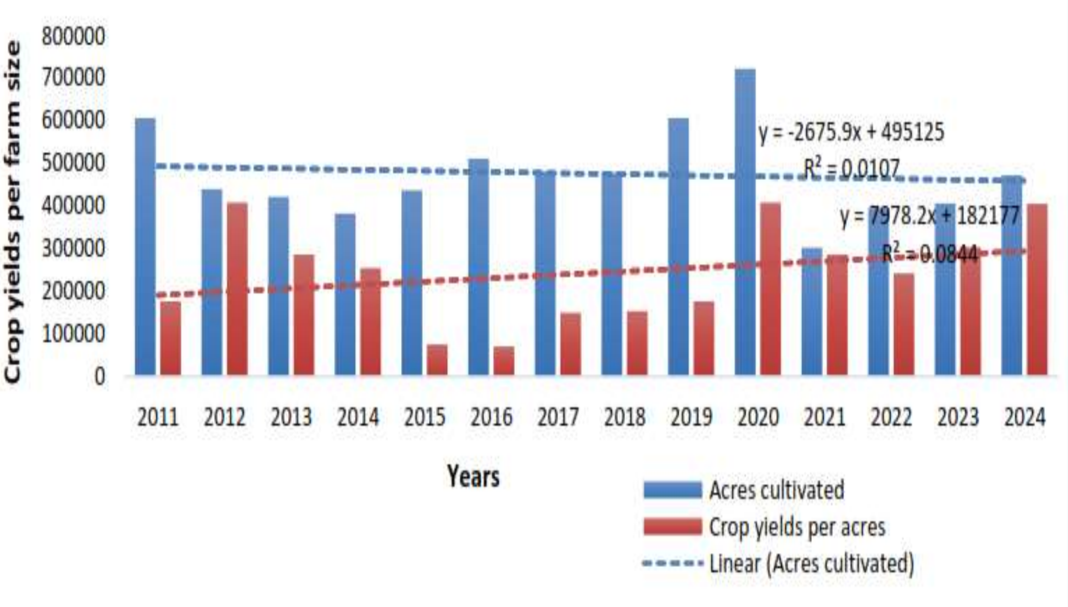

Figure 2: Trend of Crop Yields per Farm size in Iramba District from 2011 to 2024

Source: Iramba District Agricultural Office.

The crop yield data from the Iramba District Agricultural Office revealed an increase in yield per unit area. Although cultivated farm size showed little variation (R^2 = 0.0107), crop yields changed more substantially (R^2 = 0.0844). Thus, while farm size remained stable or decreased, crop yields continued to rise. This result was further supported by the corresponding yields per unit area (Figure 3).

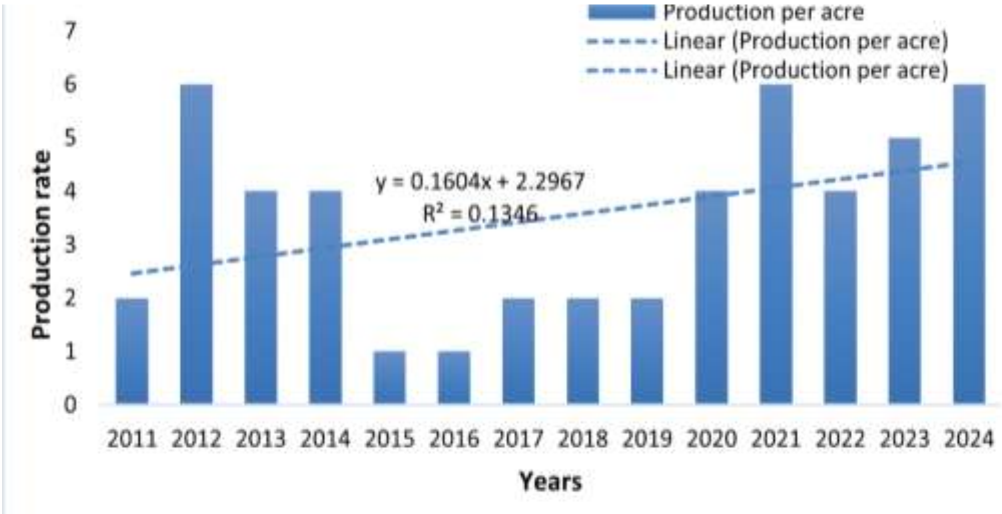

Figure 3: Trend of Crop Yields per Unit Area in Iramba District from 2011 to 2024

Source: Iramba District Agricultural Office.

The crop yield data from Iramba District indicate that per-unit crop production increased, with an R^2 value of 0.1346. This indicates a 13% rise in yields per unit area between 1995 and 2024. This finding aligns with the resilience theory, which holds that resilience strategies can enhance crop yields in drought affected areas. As a result, increased yields may be carried over into the next growing season, potentially ending the need for food aid from government or NGOs. Moreover, this result is consistent with Musana et al. (2024), who reported that the combined use of *Alnus acuminata* green manure, together with the use of improved crop varieties, led to the greatest increases in maize and bean productivity in Nyabihu District, Rwanda.

4.2 *Smallholder Farmers' Resilience Strategies*

This section discusses the findings on the resilience strategies employed by smallholder farmers in Iramba District to withstand drought impacts. The use of these strategies varied across the studied villages, as shown in Table 1.

Table 1: Farmers' Resilience Strategies

N	Resilience Strategies	Kidaru (%)	Tyegelo (%)	Tulya (%)	Overall (%)
1	Drought-tolerant crops	95	96.5	96.2	95.7
2	Changing planting dates	97.5	93.1	93.1	94.7
3	Improved crop varieties	92.5	86.2	92.3	90.4
4	Traditional irrigation	85.0	89.6	100	90.4
5	Cover cropping	85.0	89.6	96.2	89.4
6	Intercropping	82.5	86.2	84.6	84.0

Source: Field work (2025).

4.2.1 Adoption of Drought-tolerant Crops

The drought-tolerant crops adopted in the studied villages included bulrush millet, sweet potatoes, sorghum, and cassava. These crops generally helped farmers ensure yield stability and reduce total crop failures. This strategy was used in 95.7% of the villages studied (Table 2), with most farmers relying on bulrush millet (38.9%) and sorghum (31.9%) as their dominant drought-tolerant crops. Overall, these approaches offer a promising pathway to secure food production and food security amid increasing water scarcity.

Table 2: Farmers' Perceptions on Drought-tolerant Crops

Drought-tolerant crops	Kidaru	Tyegelo	Tulya	Total (%)
Bulrush Millet	14.9	6.4	17.6	38.9
Sweet Potatoes	0.7	6.4	1.4	8.4
Sorghum	8.5	15.6	7.8	31.9
Cassava	0.7	5.0	2.9	8.6
Sunflower	0.7	2.8	4.3	7.8
Total (%)	**25.5**	**36.2**	**34.0**	**95.7**

Source: Fieldwork (2025).

This finding suggests that farmers adopted drought-tolerant crops because they were confident in achieving yield improvements even under severe drought conditions. Although this strategy does not produce high yields, it assures farmers of at least some harvest. Farmers further reported that sorghum was the second-most adopted drought-tolerant crop, with a 31.9% usage across the studied villages, indicating a preference for minimizing the risk of total crop failure over maximizing yields. However, the use of drought-tolerant crops was not uniform across villages. Tyegelo village led the adoption rate, with 36.2% of the farmers utilizing such crops. During an in-depth interview, an elderly farmer in Tyegelo explained that farmers often grow bulrush millet, sorghum, and cassava because they tolerate drought. Also, the key informants explained that when rains cease early before the end of the growing season, farmers concentrate entirely on these crops to ensure food availability. One informant stated thus:

> *We often grow bulrush millet, sorghum, and cassava since they tolerate drought. For example, we are certain to harvest bulrush millet even if it rains for only two weeks of the season. For instance, in 2011, a drought destroyed my maize farm, which I had planted the same day as millet: the maize plants dried up. However, when it rained three days later, the millet flourished again, and I got 39 sacks* ***(In-depth interview with a 45-years-old female farmer in Tyegelo village, February 2025).***

Drought-tolerant crops are critical for enhancing food security in water-scarce environments, as they reduce yield losses and improve resilience under drought conditions. This finding aligns with Fisher et al. (2015), who reported similar benefits. During FGDs in Tyegelo village, smallholder farmers argued that drought-tolerant crops help restore their cultural practices, are effective under drought, and ensure food security across the studied villages. Farmers ultimately preferred these crops over others because of the assurance of obtaining at least some yield; as stated by one female farmer:

> *Drought-tolerant crops are the identity of these Great Rift Valley dry lowland areas. Farmers plant these tolerant crops since they tolerate scarce soil moisture, restore their culture, and provide food security. We plant with assurance of getting yields, which is unlike the case with other crops* ***(FGD with a 54-years-old female farmer in Tyegelo village, February 2025)***

The analysis confirmed that drought-tolerant crops, such as sorghum and bulrush millet, enabled farmers to exchange them for other food crops from nearby villages. This finding suggests that farmers adopted drought-tolerant crops due to confidence in yield improvements even under severe droughts. This result aligns with the resilience theory, which posits that to thrive in arid conditions, farmers need ecological adaptations such as deep-rooted crops capable of accessing subsoil water to recover from droughts. Empirically, this finding is consistent with Sawe (2019), who reported that farmers in Manyoni District used drought-tolerant crops to respond to climate change impacts. Similarly, Kaganzi et al. (2021) and Gosbert et al. (2022) documented the use of drought-tolerant crops to mitigate drought effects and increase yields in semi-arid areas adjacent to Mount Kilimanjaro, and in Chamwino District, respectively. However, Shilomboleni et al. (2024) caution that an exclusive focus on drought-tolerant crops may overlook critical socio-economic factors influencing adoption and resilience outcomes, advocating instead for integrated strategies that combine technological solutions with social equity considerations to enhance overall effectiveness.

4.2 Changing Planting Dates

The strategy of adjusting planting dates was used by 94.7% of the studied villages (Table 3). Smallholder farmers across these villages modified their planting dates to align with the growing season, considering rainfall onset and cessation to mitigate drought impacts. This affordable and cost-effective strategy enabled farmers to adjust farm preparation, planting, and harvest schedules. Specifically, 60.1% of respondents realigned their planting calendars to match the December-January rainy growing season.

Table 3: Farmers' Response to Changing Planting Dates

Villages	Late Oct.– Nov.	Dec.–Jan.	March	Total (%)
Kidaru	2.1	14.8	7.8	24.73
Tyegelo	4.2	21.9	7.1	33.21
Tulya	10.5	23.3	2.8	36.7
Total (%)	**16.96**	**60.01**	**17.7**	**94.7**

Source: Fieldwork (2025).

Farmers reported that while their typical planting dates in the 1990s fell in January, some now plant in late November or March to avoid the dry spells of February. Many farmers, who prefer drought-tolerant crops, have shifted planting dates, particularly to December or January. Others have opted for planting in early November or March to cope with seasonal shifts in the onset and cessation of rainfall.

Across the studied villages, almost all had adjusted planting dates to mitigate drought impacts. Smallholder farmers in Tulya village showed the highest adoption rate (36.7%). Overall, 16.96% of the farmers in the study area now sow crops in late October or November, outside the traditional December–January window to escape the February dry spell. Thus, some farmers have departed from the conventional December–January calendar, moving to late October–November or March. FGDs in Tyegelo village revealed that changing planting dates is an easy, affordable, and cost-effective strategy requiring no additional inputs. To determine the onset of the rainy season, farmers observe wind direction changes over several weeks and flowering patterns; while for cessation, they rely on the appearance of large bird invasions.

Some farmers divided their plots into sections to be planted at different times such as before, after, or during sufficient rainfall to spread risk. In-depth interviews with an elderly farmer in Kidaru village highlighted rainfall deficits and rising temperatures as the key adoption drivers. Farmers practice minimal tillage early for high-rainfall crops like maize; but for bulrush millet (which requires only a few rainy months and dry conditions during harvest), they wait until after the February dry spell.

Structured interviews and FGDs confirmed that altering planting dates helps align farming with the rainy season. This is consistent with resilience theory, which posits that extreme events like drought necessitate social and ecological adjustments to maintain yields. Sawe (2019) reported similar calendar adjustments in Manyoni district. Also, Gosbert et al. (2022) found that shifting planting dates increased production in Chamwino District, Tanzania. Likewise, Shabani and Pauline (2022) documented this strategy for drought adaptation in Iringa. However, Ahmed (2016) noted that in Ethiopia's Central Rift Valley, despite widespread adoption of planting-date changes, maize productivity declined overall, suggesting that timing adjustments alone are insufficient against climatic variability.

4.3 Improved Crop Varieties

Figure 4 presents the percentage of smallholder farmers adopting improved crop varieties as a drought-adaptation strategy across the studied villages. Overall, 90.4% of the respondents used improved varieties to enhance production and mitigate drought effects. Improved maize varieties included

Kagiri, Kilima, DK 77, Pundamilia, and Tembo; while improved sorghum varieties comprised Mkombituna and Tembe. Additionally, 29.9% of the farmers cultivated improved Sunbloom (sunflower) varieties.

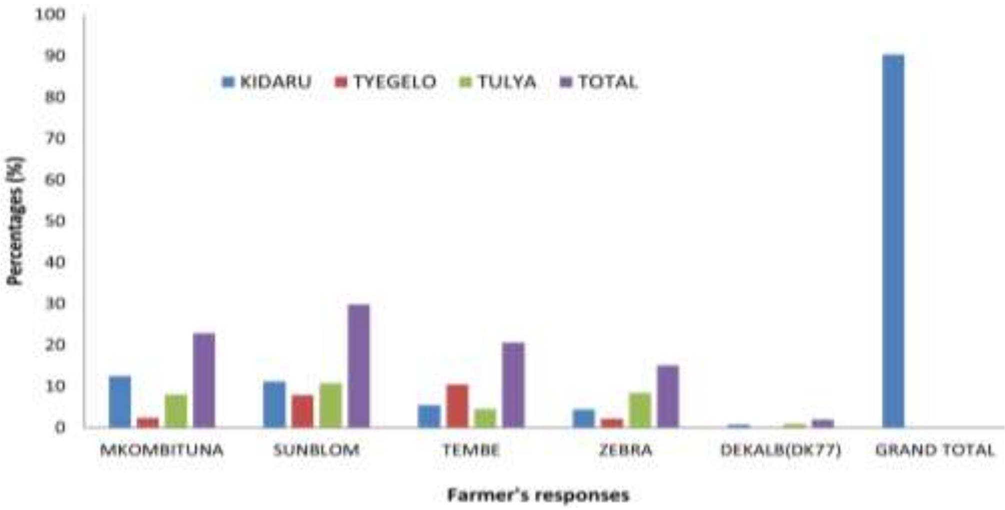

Figure 4: Improved Crop Varieties Grown by Farmers
Source: Fieldwork (2025).

Additionally, Figure 4 shows that farmers across the studied villages adopted multiple improved crop varieties to cope with drought impacts. The use of improved varieties represents a significant milestone for rain-fed agricultural farmers, enabling them to grow early-maturing crops that align with shortening rainy seasons. An in-depth interview with the Ward Agricultural Officer in Kidaru revealed that farmers used Dekalb and Kagiri for maize production in 2024, and Mkombituna and Tembe as improved sorghum varieties in 2025: all these to withstand drought and increase yields. A key informant corroborated this observation, stating:

> *[This] … is a wake-up call to other wards, even those with enough rain, because improved crop varieties provide high yields to farmers. They [Kidaru farmers] got 68 sacks of sorghum and 90 sacks of maize. Generally, most farmers have switched to improved crop varieties, which is why production is increasing in our ward* ***(Ward Agricultural Officer, Kidaru Ward, February 2025)***.

Therefore, the promise of higher yields from improved crop varieties has driven widespread adoption among farmers in the study villages, establishing their use as a key strategy for mitigating drought impacts. Field observations confirmed the presence of improved varieties and their seed on farms, as shown in Photo 1.

Photo 1: Sunbloom Sunflower Improved Crop Variety in Kidaru Village
Source: Fieldwork, (2025)

The Sunbloom sunflower variety (Photo1) was reported to mature within 60–90 days. The farmers further indicated that improved crop varieties align well with the growing season, mature rapidly, tolerate prolonged drought, and produce reliable yields. These findings align with resilience theory, which posits that improved varieties must be adapted to local ecological conditions and social preferences to enhance crop yields. Gosbert et al. (2022) similarly found that farmers in Chamwino District used improved varieties to increase yields; while Tibamanya et al. (2022) reported comparable results in semi-arid Singida District. However, a study in Zimbabwe by Nkonya et al. (2023) cautions that persistent vulnerability remains despite improved seed use due to environmental and socio-economic factors, and that seed improvements alone cannot fully offset drought impacts without complementary interventions.

4.4 Traditional Irrigation

Interviews with smallholder farmers confirmed that traditional irrigation serves as a key resilience strategy against drought impacts. This practice, primarily involving river water diversion, was commonly observed across the studied villages. Field observations verified this, revealing diverted river water used for paddy and maize cultivation (Photos 2a and 2b). Photo 2a shows diverted river water entering a paddy field. The farmers further reported that villagers work communally every Friday to divert water from the main river to their paddy and maize farms.

Photo 2a: Diverted River Water in Tyegelo Village

Photo 2b: Water Allocation to Paddy Farms in Tyegelo Village

Source: Fieldwork (2025)

The findings revealed that traditional irrigation increased rice yields to more than 50 sacks per acre. This practice served as a key strategy to address rainfall scarcity, and delivered high yields. As a result, some farmers across the studied villages have completely abandoned rain-fed crop dependency and invested fully in traditional irrigation to withstand droughts. Overall, due to extended dry spells and shorter rainy seasons, much of the farmers' focus has shifted toward traditional irrigation.

Photo 2b shows extensive paddy farms utilizing traditional irrigation. Farmers dug irrigation channels from a large main channel—itself diverted from the river—to direct water through streams to paddy, vegetable, and maize farms. During an in-depth interview in Tyegelo village, an elderly farmer clarified that traditional irrigation is highly effective because, even without rainfall, farmers can divert water from River Ndurumo, which collects water from other districts, a fact previously unknown. Traditional irrigation helps farmers cope with droughts, as rainfall has declined and rain-fed agriculture has become increasingly difficult. For many farmers, traditional irrigation represents the best resilience strategy. The only challenge arises when the nearby eastern districts—such as Mbulu and Mkalama—receive little rainfall, which in turn leaves farmers in the study area unable to access sufficient river water.

These findings align with resilience theory, which posits that when drought causes crop losses, communities test and adopt innovations by adjusting water management practices, sustaining productivity, and reorganizing in response to drought; and undertake this based on local ecological knowledge and social institutions. This is corroborated by several studies. Aseyehegn et al. (2012) argue that irrigation is the best adaptation strategy in water-scarce areas; while Silas (2017) found that irrigation increased crop yields in Kilosa District. Also, Pius (2023) reported that smallholder farmers in Arumeru District practiced traditional irrigation to reduce drought severity; like Gosbert et al. (2022) who found that irrigation enhanced crop yields in the semi-arid areas of Chamwino. Collectively, these findings imply that traditional irrigation sustains food production regardless of drought conditions. However, Mkonda and He (2022) highlight socio-economic barriers, particularly gaps in water access and infrastructure during the growing season, that limit the adoption and success of irrigation as a resilience strategy in Kongwa District, Dodoma Region.

4.5 Cover Cropping

Farmers used cover cropping as one of their resilience strategies to provide shade and restore soil moisture, which thereby helped them to withstand the impacts of droughts. Interviews with smallholder farmers revealed that 90.4% of the respondents used the cover-cropping strategy (Table 4). Further, the results show that 37.3% of the farmers in the studied villages used pumpkins as a cover crop; with Kidaru leading in the use of this strategy by 33.5%.

Table 4: Response to Practices of Cover Crops

Cover crops	Kidaru	Tyegelo	Tulya	Total (%)
Pumpkins	12.2	11	14.1	37.3
Sweet potatoes	8.6	10.2	3.4	22.2
Groundnuts	6.2	2.4	6.5	15.1
Cowpeas	6.5	6.8	2.5	15.8
Total (%)	**33.5**	**30.4**	**26.5**	**90.4**

Source: Fieldwork (2025).

Table 4 shows that cover cropping was widely used across the studied villages. In fact, the majority were using this strategy to enhance soil moisture retention, soil structure and increasing infiltration thereby stabilizing agroecosystem productivity to withstand drought impacts. Moreover, during field observation cover cropping was observed to include cowpeas, sweet potatoes, and pumpkins.

Photo 3 shows sweet potatoes, one of the cover crops observed in Tyegelo village. Most farmers employed cover cropping to mitigate drought impacts, as it reduces direct soil heating and evaporation, thereby preserving soil moisture. Farmers argued that cover crops helped protect against adverse drought effects by retaining soil moisture during dry spells, thereon allowing plants to flourish until rainfall returns. In the studied villages, farmers grow pumpkins, cucumbers, and yams; and use the roots, fruits, and leaves for both food and cash income. This indicates that farmers respond to drought through cover cropping for multiple purposes, including food production. Thus, cover crops serve not only to conserve soil moisture during droughts, but also as sources of revenue and sustenance.

Photo 3: Sweet Potatoes as Cover Crops in Tyegelo Village
Source: Fieldwork (2025).

These findings align with the resilience theory, which posits that effective drought adaptation strategies must integrate ecological benefits—such as improved soil health and water retention—with social drivers, including low adoption costs. This result supports Harvey et al. (2018), who reported that smallholder farmers in Central America use cover cropping to restore soil moisture and enhance yields. Similarly, Mal et al. (2018) found that smallholder farmers in Mali employ cover cropping to mitigate drought impacts. In contrast, Shilomboleni et al. (2024) caution that cover cropping is not a standalone drought strategy, as its effectiveness depends on specific soil, rainfall, and agro-ecological conditions, and it may underperform in certain drought prone areas.

4.6 Intercropping

Intercropping, which is the growing of different crops in the same area, was practiced by 84.0% of the respondents across the studied villages (Figure 5). Some farmers systematically arranged two different crops in the same plot to ensure sufficient yields during climate shocks, such as droughts.

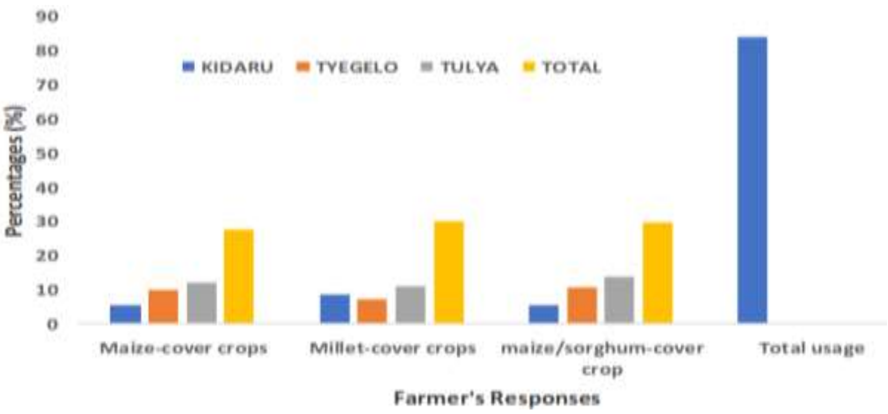

Figure 5: Farmers' Response to Intercropping Practices
Source: Fieldwork (2025).

Specifically, 29.6% of the farmers intercropped maize or sorghum with cover crops to reduce rapid soil moisture loss. Farmers also used intercropping to provide shade and increase moisture storage during droughts.

During FGDs in Tulya village, farmers clarified that intercropping serves a dual purpose: not only does it help withstand drought impacts by restoring soil moisture, but it also addresses agricultural land scarcity driven by population growth. Consequently, beyond providing shade for moisture restoration, farmers mix crops due to the small size of their farm holdings. One FGD participant stated:

> *Intercropping is our inborn strategy that even our grandparents practised with success. Nevertheless, for us, intercropping is used not only to withstand drought impacts by restoring soil moisture, but also to address the scarcity of agricultural land due to a growing population that demands more land. Intercropping serves farmers with small pieces of farms because they can integrate more than one crop in one farm* ***(FGD with a 52-years-old female farmer in Tulya Village, February 2025).***

This finding also aligns with Sawe (2019), who found that intercropping not only helps farmers adapt to climate shocks, but also increases crop yields. The field observations found intercropping as shown in **Photo 4**.

Photo 4: Intercropping Practised in Kidaru Village
Source: Fieldwork (2025).

This result implies that farmers adopted intercropping to cultivate multiple crops on a single farm; a practice that would have otherwise required separate plots and to ensure that if one crop fails, another may flourish. This finding aligns with the resilience theory, which posits that diversified farming systems provide greater benefits than conventional monocultures. Similarly, Zang et al. (2019) reported that farmers intercropped due to small farm sizes to avoid total crop failure. Pius (2023) found that smallholder farmers in Arumeru District used intercropping to recover from extreme events such as droughts. Likewise, Sawe (2019) reported that farmers in Manyoni District intercropped to withstand climate change impacts and mitigate the risk of a single crop failure.

5. Conclusion and Recommendations

This paper has examined resilience strategies that positively influenced crop yields among smallholder farmers in the semi-arid areas of Iramba District. Complementarities among diverse adaptation strategies are crucial in such environments, as a single intervention may be insufficient to withstand drought impacts. We conclude that smallholder farmers in the studied villages were resilient to droughts because they employed integrated strategies aligned with the resilience theory. Farmers combined multiple drought resilience measures–including the adoption of drought tolerant crops (e.g., millet and sorghum) alongside improved varieties; and the implementation of water and soil management techniques, such as cover cropping, intercropping, and traditional irrigation–to adapt to drought impacts. This suite of physical interventions helped retain soil moisture, improve soil health, and ultimately increase crop yields; thereby supporting the theory's emphasis on practical and material adjustments. Key adaptation strategies also included adjusting planting dates based on local climate knowledge and diversifying crop types. This risk-spreading approach ensured that the failure of any single crop did not lead to total food loss.

The findings strongly support the social dimension of the resilience theory, confirming that adaptive behaviours and a portfolio of options are essential for managing climate uncertainty. Accordingly, we recommend wider adoption of effective drought adaptation strategies through collaborative efforts among farmers, government institutions (e.g., agricultural extension services and meteorological authorities), and NGOs. Such partnerships are critical for implementing resilience strategies to mitigate drought impacts on crop production. For instance, the TMA could provide early, context-specific information to guide planting date decisions, which is a key strategy for sustaining crop production under drought conditions. Furthermore, policymakers and decision-makers should integrate drought mitigation strategies into broader agricultural policies to better support smallholder farmers in coping with drought impacts.

Competing interests
The authors declare that there are no conflicts of interest for the research, authorship, and/or publication of this article.

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