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Original Article

Adoption of Drought-Resilience Agricultural Technologies among Smallholder Farmers in Luwero District, Central Uganda

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ABSTRACT

This study investigated the adoption of Drought-Resilient Agricultural Technologies (DRAT) among smallholder farmers in Luwero district. The objectives of the study were to assess the level of adoption of DRAT, identify factors influencing adoption, evaluate the importance of farmer groups and social networks and examine the impact of DRAT on socio-economic outcomes, and explore challenges to adoption and potential mitigation strategies. Both qualitative and quantitative data were collected through a survey to gather quantitative and qualitative data from 311 households. The findings revealed that 63% of households had adopted at least one form of DRAT, with agroforestry and conservation agriculture being the most common practices. The adoption of DRAT was significantly influenced by access to agricultural information (Chi2 = 92.17, P < 0.001), land tenure systems (Chi2 = 9.99, P = 0.036), and farm size (Chi2 = 9.99, P = 0.033). The education level of the household head has a marginal influence (67.9% adoption among those with no formal education, Chi2 = 7.92, p = 0.094). Participation in farmer groups and social networks significantly enhanced knowledge and access to resources, with 70% of respondents acknowledging the importance of such groups. The impact of DRAT on socio-economic outcomes was substantial, with 95.38% of households experiencing a significant increase in crop yields, 91% reporting an increase in household income, and 94% noting improved food security. However, challenges such as a lack of access to credit and insufficient knowledge and training were significant barriers to adoption. In conclusion, the study highlighted the positive impact of DRAT on agricultural productivity and household resilience. Recommendations include enhancing access to agricultural information, improving infrastructure, and providing financial support to farmers. Future research should focus on the long-term impacts of DRAT, strategies to overcome cultural resistance, and the role of government policies in promoting sustainable agricultural practices.

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INTRODUCTION

Droughts and extended dry periods are common in Uganda's semi-arid zones (Barasa *et al,* 2013). Overall, dryness episodes have been on the increase, resulting in crop failures, human and animal mortalities, amongst others (Akwango *et al*., 2017). Smallholder farmers are among the most vulnerable to livelihood systems due to their social and economic sensitivity (Lindoso *et al.,* 2014). Droughts are chiefly responsible for food and nutritional insecurity in multiple regions of Uganda (Nabikolo *et al*., 2012; Sabiiti *et al.,* 2018). Water stress threatens sustainable farm production, with research demonstrating that agrarian communities can circumvent the related restraints through constructing socio-ecological resilience (Eslamian & Eslamian, 2017; Maleksaeidi *et al*., 2017). This can be achieved through development, adoption, evaluation and learning from adaptation technologies required to lessen drought risk for better production and livelihoods of small-scale farming communities (Teixeira *et al*., 2013; Bhargava & Sawant, 2013).

Drought resilience technologies refer to the application of technology in order to lessen the vulnerability, or improve the resilience, of a natural or human system to the impacts of climate change" (UNFCCC, 2005). Rainwater harvesting (RWH) is one of the technologies that holds considerable potential for advancing rainwater-use efficiency and sustaining farming (Biazin et al., 2012). Furthermore, agroforestry (in home and forest gardens) has been employed to adapt to drought because of its dynamic, ecological and natural resource management benefits (Nguyen et al., 2013; Atangana et al., 2014). Such technologies can easily be supported and broadly adopted to better food security and incomes of the poor due to the associated equity, acceptability and productivity benefits in local dryland agriculture (Kahinda & Taigbenu, 2011).

In East Africa, small-scale farmers have largely used short-term crops, drought-resistant crops, irrigation, and tree planting to adapt to realised and potential adverse impacts of drought (Komba & Muchapondwa, 2012; Ogwang *et al*., 2012; Nyaga *et al*., 2015; Mfitumukiza *et al*.,2017). Yet, cultural factors and perceptions shape how people adopt interventions, and their motivation to respond to drought (Adger *et al*., 2013). Option selection from available drought adaptation technology by farmers has been associated with performance measures such as efficiency, effectiveness, and equity (Gorantiwar & Smout, 2005; Mendicino *et al*., 2008). Other considerations are technology constraints, such as finance, which affect farmers' access to an adequate supply of quality inputs (Mdemu *et al*., 2017). Moreover, use of drought adaptation technologies like expansion of small-scale irrigation faces various challenges including land tenure issues, lack of access to appropriate

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technology, credit services, research support, poor irrigation water management, poor extension systems, and the overdependence on national governments, Non-Governmental Organizations and donors for support which is usually not consistent (Barbier & Tesfaw, 2013; Nakawuka *et al.,* 2017). Understanding prevailing opportunities that can facilitate the improvement of access to and use of appropriate drought adaptation technology is important for the adoption and upscaling of such efforts.

It is distinct that small-scale farmers embrace a variety of drought-adapting rainwater collecting, agroforestry and irrigation technology. Nonetheless, there is scarce evaluation-based information, especially on farmers' perceived performance of such technology intervention outcomes. Yet, perceptions and attitudes are important in deciding the processes and actions aimed at dealing with drought, including for technologies and strategies (Knowler & Bradshaw, 2007). In addition, location-specific information on the constraints and opportunities prevalent in the use of drought-adapting technology (rainwater collecting, agroforestry and irrigation) does not explicitly exist. Only single drought-adapting technologies have been researched by most scholars, with very limited comparison basis across available options (Gorantiwar & Smout, 2005; Rodrigues *et al*., 2009). Such information is significant in guiding farmers and those involved in supporting them to manage drought risk, to either deal with such perceptions or support interventions that are likely to be adopted.

Despite efforts to enhance agricultural productivity in Uganda, smallholder farmers in the Luwero district continue to grapple with the adverse effects of drought on crop yields (FAO, 2019). Introducing drought-resilient agricultural technologies presents a promising solution to mitigate these challenges (Birhanu et al., 2020). However, the extent of adoption of these technologies by smallholder farmers remains uncertain within the specific context of Luwero district and thus the gist of the study. The overall objective for this study was “To assess the extent of adoption of drought resilient agricultural technologies among smallholder farmers in central Uganda, Luweero district.

Specifically, the study sought to; i) determine the current level of adoption of drought resilient agricultural technologies among small holder farmers, ii) investigate the social cultural factors influencing the adoption of drought-resilient agricultural technologies among smallholder farmers, and iii) evaluate the impact of drought-resilient agricultural technologies on seasonal household incomes among smallholder farmers in Luwero district cattle corridor.

METHODOLOGY

Study Area

The district (Luweero) lies north of Kampala, between latitude 20 north of the Equator and East between 320 and 330. The total area of Luwero district is approximately 2577.49 square kilometres. It is bordered by Mukono and Wakiso Districts in the South, Nakaseke in the West, Nakasongola in the North and in the East is Kayunga District (Luweero District Local government, 2018).

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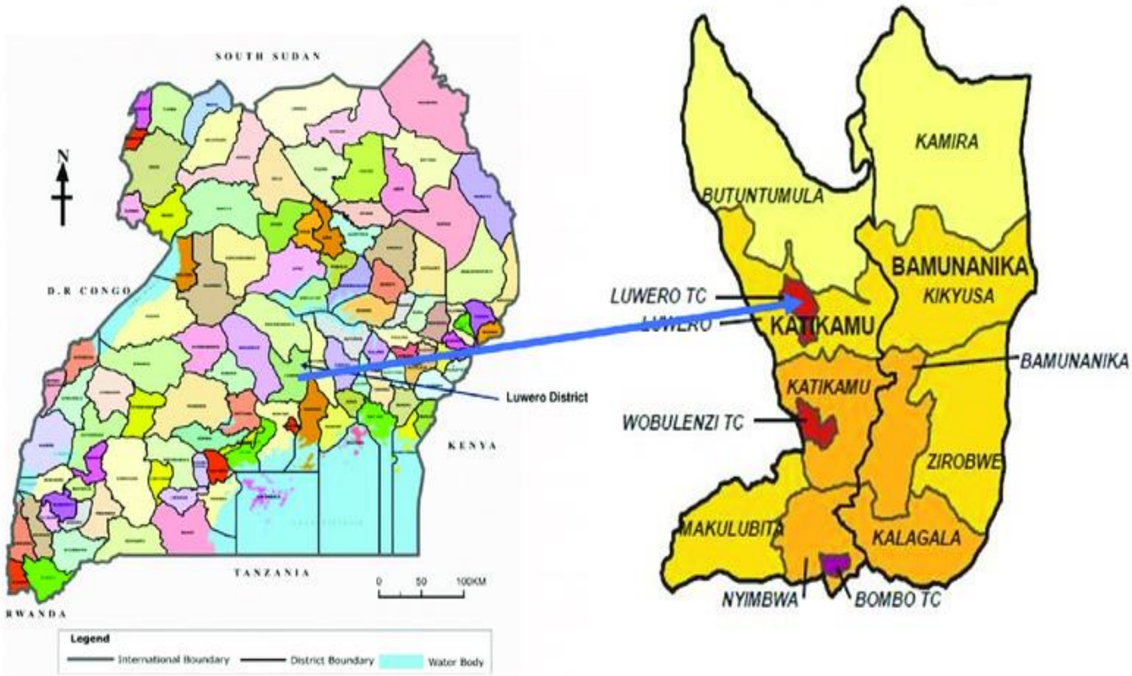
Figure 1: Luweero District Geographical Location



Topography

The present topography is a result of a number of ancient denudation processes of the rock systems, leaving a series of old erosion levels throughout the district. In terms of altitude, most of the district ranges between 1,219 and 1,524 meters above sea level. The landscape is generally made up of elevated and dissected plateaus consisting of a series of flat-topped hills and intervening valleys (Luwero district local government, 2018).

Climate and Temperature

Rainfall is well distributed throughout the year, with an annual average of 1,300mm. The mean annual maximum temperature falls between 27.5ºC and 30ºC, whereas the mean annual minimum temperature is between 15 °C and 17.5 °C (Luwero district local government, 2018)

Vegetation and Soils

Three-quarters of the district is covered with savannah. The soils are generally red sandy loam. The southern part of the district is relatively fertile and can support all kinds of crops. In the northern areas (Kamira and Butuntumula, and parts of Kikyusa Sub-counties), some parts developed from sandy loam soils, and fertility is low.

Land Use

In drier areas, cattle farming is the dominant occupation. A wide range of food crops is grown in the district, as well as cash crops. The district is predominantly rural, where farming is the main occupation, especially among women. In the northern area, there is mainly cassava, sweet potatoes, maize and bananas. In the southern and central areas, there are bananas, potatoes, cassava, beans, groundnuts, horticulture crops (like tomatoes, cabbages and greens), and upland rice as food crops. Cash crops for the southern and central region are coffee, bananas, and the horticultural crops, mainly water melons, passion fruits, tomatoes, cabbages and vegetables, whereas pineapple growing is predominant in most parts of the northern parts of the district (Luweero District Local government, 2018).

Research Design

The study was anchored on the descriptive research design, which seeks to define the characteristics and evidence of the phenomena being studied in their natural state (Bryman,

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2018). Unlike studies that solely describe the entities being examined, descriptive research even goes ahead to summarise data and helps to establish relationships between various study variables, which facilitates the analysis of correlations and regressions (Mugenda & Mugenda, 2013). Quantitative data were numerical and consequent statistics that explained the relationship and moderation outcomes between variables.

Study Population

The 2014 Population Census final results rank Luwero's population at 456,958, with the population projection at 650,000 by mid-2015 (NPHC Report, 2014). The study population consisted of small-scale holder farmers in Luweero district. This involved both farmers who have adopted drought-resilient technologies and those who have not adopted such technologies. The study intended to consider farmers who have not adopted these technologies as the control group of the study, as their production level was used as a baseline for the performance of the different drought-resilient technologies.

Sample Size Determination

There are numerous books that demonstrate how to calculate the sample size for a study based on a population, including Cochran (1977), Mark (2005), and Singh and Chaudhury (1985). Finding a sufficient sample size to estimate results for the entire population with high accuracy is the main goal. Put another way, one must extrapolate conclusions or generalise about the population from the sample data. The population's metrics, such as the mean and standard deviation, or other characteristics, like the percentage of an attribute present in the population, are related to the inference that needs to be made (Gauhati University Mathematics Association, 2012).

The representative sample size was determined using the Cochran formula:

$$N = Z^2 \times P(1 - P)/e^2$$

Where n is the sample size, Z - the z-score corresponding to the desired confidence level (1.96 for a 95% level of confidence), e - the desired margin of error.

The above parameters yield,

$N = 1.96^2 * 0.5(1-0.5)/0.05^2$

The study targeted to sample of 180 smallholder farmers from Luweero. This sample is representative enough to limit the skewness of the results. This sample was increased to 311 respondents due to accessibility and concentration of respondents in the enumeration area and to increase statistical power.

Sampling Framework

Purposive Sampling

The study employed purposive sampling in selecting the district agricultural officer and community leaders due to the believed form of vital information regarding the assessment of drought resilience technologies and their impact on crop yields within Luweero District.

Simple Random Sampling

Simple Random sampling was used in selecting respondents from the target population of farmers in the district. Smallholder farmers in the district were randomly selected to provide an equal chance selection. In that way, every member had an equal chance of being selected.

Data Source and Collection Methods

Structured survey questionnaires were administered to a larger sample of smallholder farmers within Luweero District. The survey questionnaires included both closed and open-ended questions, allowing for both quantitative and qualitative data collection. Survey questions focused on specific aspects of different drought resilience technologies and their impact on crop yields. The quantitative data gathered from the survey enabled statistical analysis, identifying patterns and correlations related to the study outcomes. The questionnaires were administered to farmers with the help of the Kobo Toolbox tool (https://ee.kobotoolbox.org/x/otPv6s4I), where real-time data were collected by field teams. This

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was very efficient since it reduced on time for data collection and cleaning is minimal.

Data Analysis

Data collected was cleaned for completeness and the statistical package of SPSS version 26 was used to draw insights from the data. Analysing the data result involves probing it to depict the relationships, patterns and trends that exist within. The dataset was coded and imported into SPSS, where descriptive statistics were analysed to investigate occurrences or frequencies, associations and differences from the information gathered.

RESULTS

The researcher conducted data collection from Luwero district in Kalagala and Kikyusa sub-counties. At the end of the data collection period, the researcher managed to retrieve 311 of the distributed questionnaires, resulting in a response rate of 98.7%. This response rate significantly surpassed the 50% threshold recommended for quantitative studies, as suggested by Amin (2004) and thus went ahead with data analysis.

Baseline Characteristics

The majority of respondents, 153 (52%), were from Kalagala sub-county, and Kikyusa had 143 (48%). Kyampogola parish had the highest representation with 30%, indicating a significant participation from this parish. This was followed by Degeya (27%) and Lunyolya (24%). The low representation from Kiziba (18%) was due to fewer farmers in the agricultural activities studied. These findings suggest that the agricultural practices and challenges observed are most relevant to Kyampogola and Degeya parishes.

Male-headed households (56%) slightly outnumber female-headed households (44%), which could reflect broader societal norms and roles in agricultural activities within the region. This gender distribution highlights the need for gender-sensitive interventions in agricultural programs. The largest age group among respondents was those above 50 years (35%), followed by 41-50 years (24%). This indicates that older farmers are more prevalent in this study, possibly due to their greater experience and investment in farming. Younger age groups are less represented, which could suggest challenges in youth engagement in agriculture. Most household heads have primary education (55%), while very few have tertiary education (2%) or university education (1%). This reflects the limited access to higher education among the farming population and suggests that agricultural training and extension services need to be tailored to individuals with basic educational backgrounds.

A significant majority of respondents have more than 10 years of farming experience (63%). This highlights a population with substantial practical knowledge and experience, which can be valuable for adopting new technologies and practices. However, the presence of less experienced farmers (16% with less than 5 years) indicates a need for ongoing support and training. Bananas (204) and maize (203) are the most grown crops, indicating their importance in the region's agricultural practices. The low numbers for cowpeas, fruits, and vegetables suggest these are less prevalent, potentially due to climatic or market conditions favouring staple crops like bananas and maize. Poultry (46%) and goats (29%) are the most common livestock, reflecting their ease of management and lower resource requirements compared to larger livestock like cattle (12%). This livestock distribution underscores the need for targeted veterinary and extension services to support small-scale livestock farming.

Freehold land tenure (54%) was predominant, suggesting secure land ownership among respondents. The significant proportion of leasehold (24%) and Mailo land (20%) indicates diverse land ownership systems, each with its implications for agricultural investment and sustainability. Nearly half of the respondents (47%) have been using the technology for more than 5 years, suggesting a reasonable level of familiarity and potential effectiveness. However, the significant portion (38%) with 1 year or less experience indicates ongoing adoption and the need for continued support and training. Fellow

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farmers (41%) are the primary source of agricultural information, highlighting their critical role in disseminating knowledge. Radio/ TV shows (31%) also play a significant role, indicating their effectiveness in farmer education. The low use of agricultural shows (0.6%) and internet/social media (2%) suggests limited access or preference for these sources. Most respondents (56%) have an income of less than UGX 500,000, indicating low economic status and limited financial resources for agricultural investment. The small percentage (1%) with more than UGX 5,000,000 highlights the disparity in income levels and the need for financial support mechanisms to enhance agricultural productivity.

Table 1: Baseline Characteristics

Variable	Category	Frequency	Percentage
Sub-county	Kalagala	153	52%
	Kikyusa	143	48%
Parish	Degeya	80	27%
	Kiziba	54	18%
	Kyampogola	89	30%
	Runyolya	72	24%
Gender of household head	Female	137	44%
	Male	173	56%
Age group	20 years and below	10	3%
	21-30	61	20%
	31-40	58	19%
	41-50	74	24%
	Above 50 years	108	35%
The highest education level of the household head	No formal education	61	20%
	Primary	170	55%
	Secondary	69	22%
	Tertiary	6	2%
	University	3	1%
Farming Experience in years	5-10yrs	66	21%
	Less than 5 yrs	49	16%
	More than 10 years	196	63%
Major crops grown on the farm.	Cowpeas	18	3%
	Sorghum	1	0.2%
	Maize	203	33%
	Banana	204	33%
	Cassava	138	22%
	Fruits	22	4%
	Vegetables	30	5%
Major livestock in the household	Cattle	28	12%
	Goats	67	29%
	Sheep	8	3%
	piggery	24	10%
	poultry	107	46%
The land tenure system used	Customary	5	2%
	Freehold	165	53%
	Leasehold	74	24%

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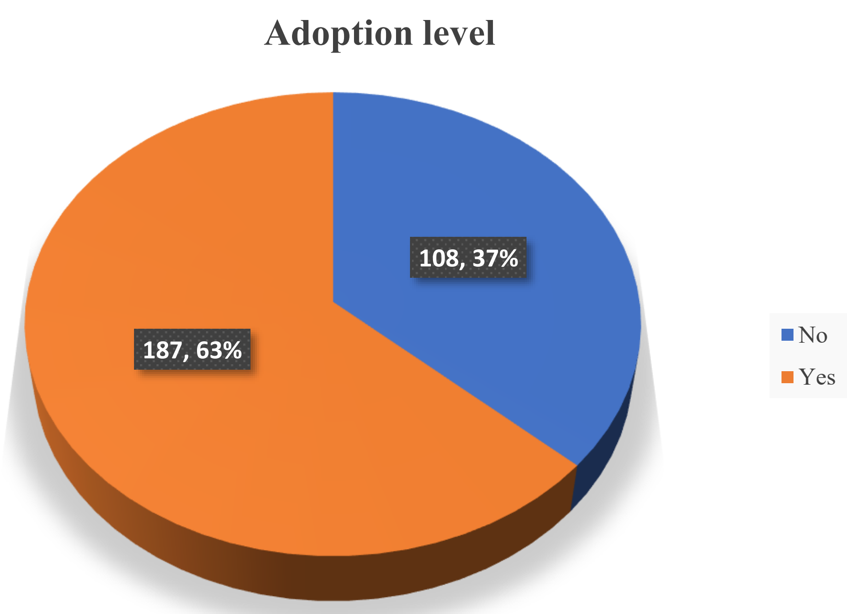
Variable	Category	Frequency	Percentage
	Mailo land	62	20%
	Public	0	0%
Experience in years of using this technology	1 year and less	117	38%
	2-5years	48	15%
	More than 5years	146	47%
	Neutral	33	18%
	Unimportant	20	11%
	Very important	126	70%
Main sources of information on agricultural technologies	Extension officers	77	25%
	Fellow farmers	128	41%
	Agricultural shows/fairs	2	0.6%
	Radio/TV programs	96	31%
	Internet/social media	6	2%
Economic harvest per season	2,000,001-5,000,000	5	2%
	500,001-2,000,000	130	42%
	Less than UGX. 500,000	173	56%
	More than 5,000,000	3	1%
	Total	311	100%

Level of adoption of Drought Resilient Agricultural Technologies

A significant majority (63.39%) of households had adopted drought-resilient technologies, demonstrating a strong awareness and proactive approach towards mitigating the effects of drought on agricultural productivity. Up to 36.61% of households that did not use these technologies may face greater vulnerability to drought impacts, highlighting the need for increased outreach and support to encourage wider adoption.

Figure 1: Adoption Level



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Agroforestry (34%) and conservation agriculture (31%) were the most adopted drought-resilient technologies, indicating their perceived effectiveness and feasibility for local farmers. Early/timely planting (21%) also played a crucial role in managing drought risk. However, the lower adoption rates of irrigation (9%) and rainwater harvesting (4%) suggest potential barriers such as cost, infrastructure, or knowledge gaps. The minimal use of other technologies (1%) highlighted a reliance on a few key strategies, underscoring the need to diversify and promote a broader range of drought resilience practices.

Figure 2: Drought-tolerant Technologies Adopted

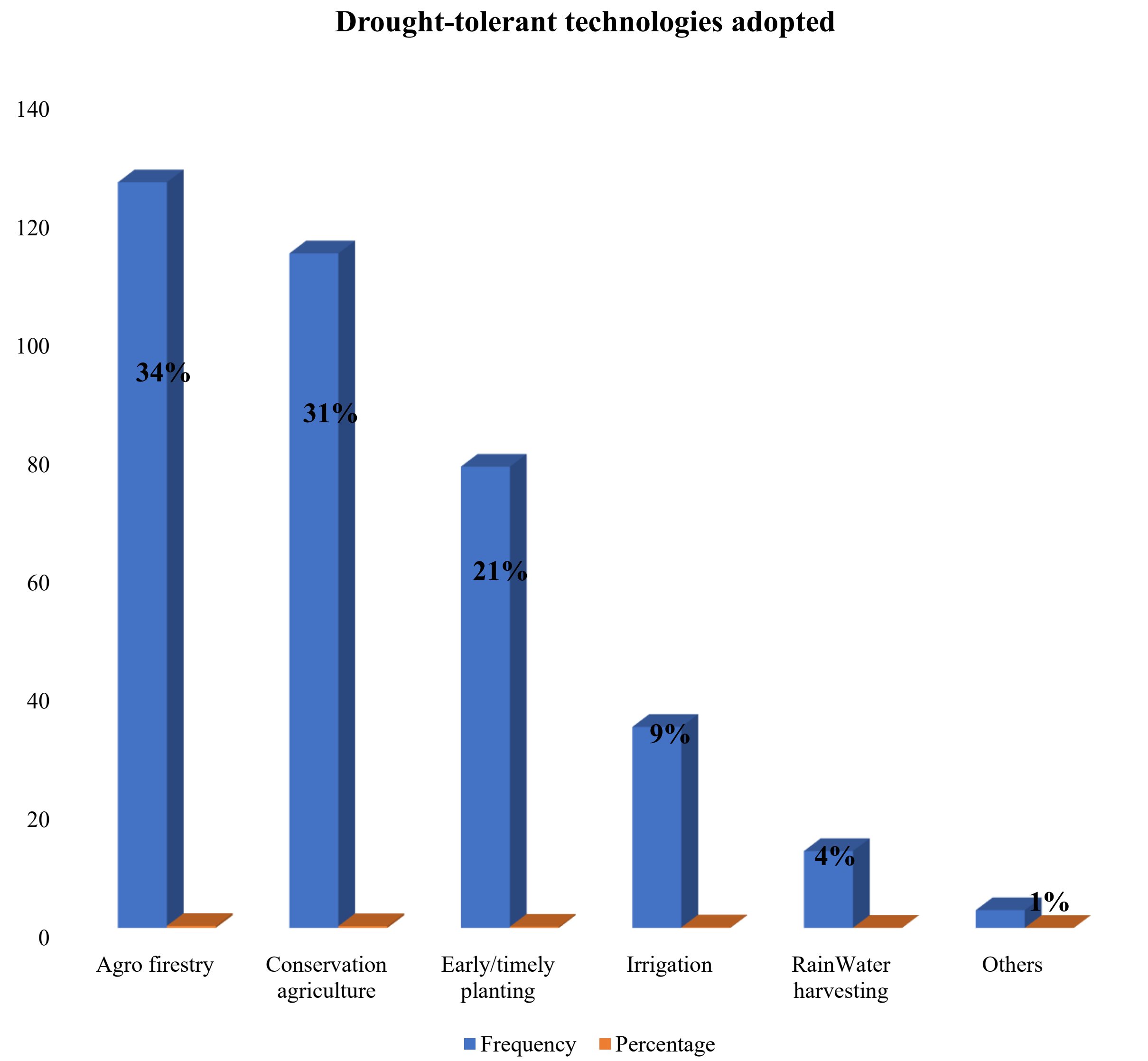

Table 2: Social-cultural Factors Influencing the Adoption of DRAT

VARIABLE	CATEGORY	Adopted DRAT No	Adopted DRAT Yes
Sub-county **Pearson Chi2 = 7.58 Prob = 0.487**	Kalagala	59 (40.1%)	88 (59.9%)
	Kikyusa	48 (36.1%)	85 (63.9%)
Parish	Degeya	31 (39.2%)	48 (60.8%)
	Kiziba	12 (25.5%)	35 (74.5%)
	Kyampogola	36 (41.9%)	50 (58.1%)

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VARIABLE		Adopted DRAT	
	CATEGORY	No	Yes
Pearson Chi2 = 10.26 Prob = 0.253	Runyolya	28 (41.8%)	39 (58.2%)
Gender of household head	Female	52 (40.3%)	77 (59.7%)
Pearson Chi2 = 1.52 Prob = 0.217	Male	55 (33.3%)	110 (66.7%)
	20 or less	3 (33.3%)	6 (66.7%)
	21-30	24 (39.3%)	37 (60.7%)
Age of household head	31-40	17 (32.7%)	35 (67.3%)
	41-50	22 (32.8%)	45 (67.2%)
Pearson Chi2 = 0.31 Prob = 0.843	51 and above	42 (39.6%)	64 (60.4%)
	No formal education	18 (32.1%)	38 (67.9%)
The highest education level of the household head	Primary	69 (42.9%)	92 (57.1%)
	Secondary	19 (28.7%)	48 (71.6%)
	Tertiary	1 (16.7%)	5 (83.3%)
Pearson Chi2 = 7.92 Prob = 0.094	University	0 (0.00%)	3 (100.0%)
	5-10 members	48 (35.6%)	87 (64.4%)
Household size	Less than 5	51 (41.1%)	73 (58.9%)
Pearson Chi2 = 2.43 Prob = 0.341	More than 10	7 (26.9%)	19 (73.1%)
Farm size (Total land being utilised)	0-3 acres	53 (40.5%)	79 (59.85%)
	3.1-6acres	50 (35.97%)	89 (64.03%)
Pearson Chi2 = 3.85 Prob = 0.033	6.1-10 acres	3 (16.67%)	15 (83.33%)
	Customary	2 (40.0%)	3 (60.0%)
	Freehold	46 (30.1%)	107 (69.9%)
The land tenure system used	Leasehold	35 (50.0%)	35 (50.0%)
	Mailo land	25 (40.3%)	37 (59.7%)
Pearson Chi2 = 9.99 Prob = 0.036	Public	0 (0.0%)	0 (0.00%)
	5-10yrs	23 (35.9%)	41 (64.1%)
Farming experience in years	Less than 5	20 (45.5%)	24 (54.5%)
Pearson Chi2 = 1.77 Prob = 0.412	More than 10 years	65 (34.8%)	122 (65.2%)
Access to agricultural information related to drought-resilient technologies	No	92 (63.9%)	52 (36.1%)
Pearson Chi2 = 92.17 Prob = 0.001	Yes	15 (10.0%)	135 (90.0%)
Membership in any agricultural social group	No	98 (37.5%)	163 (62.5%)
Pearson Chi2 = 0.90 Prob = 0.344	Yes	7 (28.0%)	18 (72.0%)

Factors Influencing the Adoption of DRAT

From table 2 above, Kiziba and Degeya parishes had the highest DRAT adoption rates with 74.5% and 60.8% respectively. The insignificant Chi2 result (p = 0.253) implies that parish-level initiatives and support systems did not play a crucial role in adoption. Higher adoption in some parishes could be due to better access to information and more effective agricultural programs. The Land tenure system significantly affected ART adoption (p = 0.036), whereby most people use the freehold system. Households with tertiary and university education levels showed higher adoption rates (83.33% and 100%, respectively). This implies that higher education equips household heads with better knowledge and understanding of the benefits of ART, leading to increased adoption.

Farm size significantly influenced ART adoption (p = 0.033). Households with larger farms (6.1-10

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acres) have higher adoption rates (83.33%), likely due to better economic capacity and a greater need to sustain larger operations through resilient technologies. Access to agricultural information is highly significant in influencing ART adoption (p = 0.000). Households with access to information show a 90% adoption rate, highlighting the critical role of information dissemination in promoting sustainable agricultural practices.

Overall, the findings indicate that land tenure systems and access to information are key factors influencing ART adoption, while age, gender, household size, farming experience, and social group membership have less impact. This suggests that targeted interventions in education and information dissemination could significantly enhance the adoption of resilient agricultural technologies.

Table 3: The Importance of Farmer Group/Association/Cooperative

Variable	Category	Frequency	Percent
Do you belong to any farmer group/association/cooperative?	No	276	92%
	Yes	25	8%
	Total	301	100%
How important is access to information in your decision to adopt new agricultural technologies?	Neutral	33	18%
	Unimportant	20	11%
	Very important	126	70%

Only 8% of respondents belong to a farmer group, association, or cooperative, while the remaining 92% do not. This low membership rate suggested that most farmers may lack the social and structural support provided by such groups. Belonging to farmer groups can significantly impact access to resources, information, and financial support, which are crucial for adopting new agricultural technologies. A significant majority of respondents (70%) considered access to information as "Very important" for adopting new agricultural technologies, with only 18% being neutral and 11% finding it unimportant. This underscores the critical role that information plays in influencing farmers' decisions to adopt innovative and resilient agricultural practices. Access to reliable and relevant information enables farmers to make informed choices, reduce uncertainties, and improve their farming outcomes.

Table 4: Influence of Social Networks on Adoption of Drought-Resilient Techs

Likert scale Statement	Strongly disagree	disagree	Neutral	Agree	Strongly Agree
Participation in farmer groups enhances my knowledge about drought-tolerant technologies	4%	4.%	8%	21%	63%
Cooperatives provide financial support for adopting new agricultural technologies	25%	21%	13%	42%	0%
Social networks facilitate the sharing of experiences and best practices related to drought-tolerant farming	8%	4%	21%	25%	42%
Group membership increases my access to drought-tolerant seeds and other inputs	4%	22%	13%	44%	17%
Being part of social networks boosts my confidence in adopting new agricultural innovations	4%	4%	17%	33%	42%

From Table 4 above, 84% agreed that participation in farmer groups enhances their knowledge about drought-tolerant technologies. This unanimity indicates a strong belief in the value of farmer groups as effective platforms for knowledge sharing. Such groups can disseminate practical

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information and innovative practices that help farmers adapt to climate challenges, fostering a more informed and resilient farming community. Also, 42% of respondents agreed that cooperatives provide financial support for adopting new agricultural technologies. This highlights the crucial role that cooperatives play in offering the financial resources necessary for implementing advanced farming methods. Access to financial support can significantly lower the barriers to technology adoption, allowing farmers to invest in tools and techniques that enhance productivity and sustainability.

Sixty seven percent of respondents agreed that social networks facilitate the sharing of experiences and best practices related to drought-tolerant farming, while 12% disagreed. This suggests that while a majority find social networks beneficial for exchanging valuable insights and practical knowledge, a notable minority do not perceive the same benefits. The mixed response may be due to variations in the effectiveness of different social networks or personal experiences with them. Respondents are evenly split on whether group membership increases access to drought-tolerant seeds and other inputs, with 61% agreeing and 26% disagreeing. This division indicates that while some farmers experience enhanced access to vital resources through group memberships, others did not perceive any significant advantage. This discrepancy could be due to differences in the resources available within various groups or the level of engagement and support provided by these groups.

75% of the respondents agreed that being part of social networks boosts their confidence in adopting new agricultural innovations. This consensus underscores the psychological and emotional support that social networks provide, which can be crucial for farmers who are hesitant to try new practices. The collective experience and encouragement from peers in social networks can enhance farmers' willingness to embrace innovative solutions, thereby promoting broader adoption of drought-resilient technologies.

Overall, the findings indicate that education, farm size, land tenure, and access to information are key factors influencing ART adoption, while age, gender, household size, farming experience, and social group membership have less impact. This suggests that targeted interventions in education and information dissemination could significantly enhance the adoption of resilient agricultural technologies. Farmer groups, associations, and cooperatives are recognised as important for knowledge sharing, financial support, and confidence-building, but actual membership and participation rates are low. This indicates a need for initiatives to increase farmer engagement in these social networks to enhance the adoption of drought-resilient technologies. Also, the findings demonstrate a strong positive perception of social networks and cooperatives in enhancing knowledge, providing financial support, and boosting confidence in adopting new agricultural technologies. However, the mixed views on the facilitation of experience sharing and access to inputs indicate areas where social networks and farmer groups could improve their effectiveness.

Table 5: Impact of DRAT on Households' Socioeconomic Status, Incomes and Livelihoods

		Frequency	Percentage
How has the adoption of drought-tolerant technologies affected your crop yields	No change	8	4.1
	Significantly decreased	1	0.51
	Significantly increased	186	95.38
	Total	195	100

Most respondents (95.4%) reported that the adoption of drought-tolerant technologies has significantly increased their crop yields. This indicates a substantial positive impact of these technologies on agricultural productivity. The minimal percentages reporting no change or a decrease in yields suggest that the technologies are highly effective in enhancing crop performance

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under drought conditions. Improved yields are crucial for food security and economic stability in farming households.

Table 6: Perceived Impact of the Adoption of Drought-Resilient Technologies

Impact of DRAT	Disagree	Agree	Not sure	Strongly Agree	Strongly disagree	Grand Total
My household income has increased	2%	31%	7%	60%	0%	100%
My household food security has improved	3%	34%	4%	59%	0%	100%
The overall resilience of my farm to drought has increased	1%	44%	7%	48%	0%	100%
The count of labour requirements on my farm has decreased	7%	30%	30%	54%	1%	100%
My overall quality of life has improved.	0.6%	39%	6%	54%	1%	100%

A combined 91% of respondents agree or strongly agree that their household income has increased due to the adoption of drought-tolerant technologies, with 2% of the respondents disagreeing. This substantial majority indicates that higher crop yields likely translate into greater marketable surplus, thus boosting household income. The 7% who are not sure might need more time to observe significant income changes or could benefit from additional support in marketing their increased yields. A significant majority (93%) agree or strongly agree that their household food security has improved, with 3% respondents disagreeing. This shows that increased crop yields are directly contributing to better food availability and stability within households. Improved food security is a key benefit of adopting drought-tolerant technologies, as it ensures that families have a reliable food supply despite adverse weather conditions.

Ninety-two percent of respondents agree or strongly agree that their farm's resilience to drought has increased, indicating that these technologies are effectively mitigating the impacts of drought. The 7% who are not sure may need more time or experience to fully assess the impact on their farm's resilience. Enhanced resilience is critical for long-term sustainability and reduces vulnerability to climate variability. The responses regarding labour requirements are more mixed, with 84% agreeing or strongly agreeing that labour requirements have decreased, while 8% disagree or strongly disagree, and 30% are not sure. This variability may depend on the specific technologies adopted, as some might be more labour-intensive initially but save labour in the long run. Further education and demonstration on labour-saving practices could help in this area. Ninety-three percent of respondents agree or strongly agree that their overall quality of life has improved, indicating a positive correlation between the adoption of drought-tolerant technologies and overall well-being. Improved income, food security, and resilience contribute to a better quality of life, reinforcing the value of these technologies in enhancing household livelihoods.

These findings collectively underscore the significant positive impact of drought-tolerant technologies on crop yields, household incomes, food security, and overall quality of life, with some areas for improvement in labour efficiency.

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Table 7: Challenges to the Adoption of DRAT and Perceived Mitigation Ways

Challenges	Agree	Not sure	Strongly Agree	Strongly disagree
Lack of access to credit/financial resources	18%	0%	82%	0%
Insufficient knowledge and training	31%	3%	65%	0%
Limited access to drought-tolerant seeds	27%	2%	71%	0%
Inadequate government support	22%	2%	75%	0%
Poor infrastructure (e.g., roads, irrigation systems)	28%	1%	70%	1%
High initial costs of technology adoption	26%	2%	71%	0%
Lack of access to markets	22%	2%	75%	0%
Cultural resistance to change	27%	8%	65%	0%

Challenges

All respondents strongly agree that a lack of access to credit and financial resources is a major challenge to adopting DRAT. This overwhelming consensus indicates that financial barriers are the most significant hindrance for farmers wanting to implement drought-resilient technologies. The high initial costs associated with adopting new technologies and practices likely require financial support, which is not readily available to many farmers. The combination of 65% strongly agreeing and 31% agreeing highlights that insufficient knowledge and training are critical barriers to adopting DRAT. This suggests that many farmers lack the necessary skills and understanding of how to effectively use drought-resilient technologies. Providing education and training could significantly improve adoption rates.

With 71% strongly agreeing and 27% agreeing, limited access to drought-tolerant seeds is another major challenge. This indicates that despite the availability of technologies, farmers struggle to obtain the necessary seeds to implement these strategies effectively. Improving the supply chain and distribution of such seeds is essential for broader adoption. The agreement of 97% on inadequate government support as a challenge suggests that governmental policies and programs are insufficient to encourage widespread adoption of DRAT. Enhanced government initiatives and support could play a pivotal role in overcoming this barrier.

Seventy percent strongly agree and 28% agree that poor infrastructure is a significant challenge, indicating that without proper roads, irrigation systems, and other necessary infrastructure, the adoption of drought-resilient technologies is hindered. Investments in infrastructure are crucial to facilitate access to markets and resources needed for these technologies. Seventy-one percent strongly agree and 26% agree that high initial costs are a significant barrier, reinforcing the need for financial support and subsidies to make these technologies accessible to farmers. The high upfront costs can be a major deterrent despite the long-term benefits of adoption. A significant number, 97% agree that lack of access to markets is a challenge, which indicates that even if farmers can produce drought-resistant crops, they face difficulties in selling their produce. Improving market access through better infrastructure and market linkages is essential for the adoption of DRAT.

The mixed responses (92% agreeing and 8% not sure) indicate that cultural resistance to change is a challenge for some but not all farmers. This suggests that while some farmers may be hesitant to adopt new technologies due to traditional practices, others are more open to change. Tailored awareness and education campaigns can help address cultural barriers.

DISCUSSION OF THE STUDY FINDINGS

Baseline Characteristics

The demographic characteristics of the respondents, such as Land tenure system used, education level, and farm size, play a crucial role

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in the adoption of DRAT. Older farmers, those with higher levels of education, and those with larger farm sizes are more likely to adopt these technologies. This is in line with the findings of Bryan *et al*. (2009), who found that socioeconomic characteristics significantly impact the adoption of agricultural technologies. Older and more educated farmers tend to have better access to information and resources, making them more capable of adopting innovative practices.

Level of Adoption of Drought-Resilient Agricultural Technologies

The study revealed that a significant majority of households (63.39%) adopted drought-resilient technologies (DRAT), indicating a substantial level of awareness and proactive measures among farmers in the study area. This finding aligns with the research by Tesfaye *et al*. (2014), who observed similar trends in other drought-prone areas where farmers adopt DRAT to mitigate the adverse effects of climate variability. The high adoption rate is also consistent with Asfaw et al. (2016), who noted that farmers are increasingly adopting DRAT to improve crop productivity and ensure household food security in the face of unpredictable weather patterns.

The study found that agroforestry (34%), conservation agriculture (31%), and early/timely planting (21%) were the most adopted DRAT among the respondents. Agroforestry, which integrates trees into agricultural landscapes, enhances biodiversity and improves soil fertility and water retention, thus making farms more resilient to drought. Mbow *et al*. (2014) highlight the importance of agroforestry in enhancing resilience to climate change, as it provides multiple benefits, including improved soil structure and microclimate regulation.

Conservation agriculture, which includes practices such as minimal soil disturbance, crop rotation, and maintaining soil cover, was adopted by 31% of the respondents. These practices are known to improve soil moisture retention and reduce erosion, which are critical in drought-prone areas. Kassam *et al*. (2009) emphasise that conservation agriculture can significantly enhance water use efficiency and soil health. Early planting, adopted by 21% of respondents, is crucial for optimising water use efficiency, ensuring crops can mature before the most severe dry periods. Studies by Cooper *et al*. (2008) and Rockström *et al*. (2010) support the benefits of timely planting in managing water resources efficiently.

Factors Influencing the Adoption of DRAT

The study identified several key factors influencing the adoption of DRAT, including access to agricultural information (Chi2 = 92.17, Prob = 0.0001), land tenure systems (Chi2 = 9.99, Prob = 0.0405), and farm size (Chi2 = 3.85, Prob = 0.02781). Access to agricultural information was found to be the most significant factor, with farmers who have better access to information being more likely to adopt DRAT. This finding is consistent with the research by Feder *et al.* (1985), which highlighted the critical role of information in technology adoption. Farmers who are well-informed about the benefits and methods of DRAT are more likely to adopt these practices.

Land tenure systems also significantly influence adoption rates, with farmers who have secure land tenure being more likely to invest in long-term improvements such as DRAT. This supports the findings of Sanginga *et al*. (2007), who noted that secure land tenure provides farmers with the confidence to invest in sustainable agricultural practices. Larger farm sizes were also associated with higher adoption rates of DRAT, likely due to better resource availability and the ability to experiment with new practices. This finding aligns with previous research by Sanginga *et al*. (2007) and Feder *et al*. (1985), which highlighted the importance of farm size in the adoption of agricultural innovations.

The Importance of Farmer Groups/Associations/Cooperatives

The study indicated that only 8% of respondents belonged to a farmer group or cooperative, yet 70% rated access to information as very important in their decision to adopt new agricultural

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technologies. This finding underscores the critical role of social networks and farmer groups in disseminating agricultural information and fostering collective action. Meinzen-Dick *et al*. (2004) emphasised that social networks and farmer groups can facilitate access to resources, knowledge, and support systems necessary for adopting new technologies. The low membership rate suggests a need to strengthen these groups to enhance their effectiveness in promoting DRAT.

Participation in farmer groups and cooperatives not only provides access to information but also financial support and resources. Pretty (2003) and Place *et al*. (2004) noted that farmer groups can offer collective bargaining power, access to credit, and technical assistance, which are crucial for adopting DRAT. The study's findings highlight the potential benefits of strengthening farmer groups and cooperatives to improve the dissemination of information and support for adopting drought-resilient practices.

Influence of Social Networks in the Adoption of Drought-Resilient Technologies

The study found that social networks significantly enhance knowledge (75% agree), financial support (50% agree), and confidence in adopting new agricultural innovations (75% agree). These findings align with the research by Bandiera and Rasul (2006), who found that social networks play a critical role in the diffusion of agricultural technologies. Interpersonal communication within social networks helps farmers learn from each other's experiences, reducing the risks associated with adopting new practices. This peer influence is crucial in building confidence and trust in DRAT. Furthermore, Rogers (2003) emphasised that social networks facilitate the sharing of experiences and best practices, making it easier for farmers to adopt new technologies. The study's findings indicate that being part of social networks not only provides access to information and resources but also boosts farmers' confidence in adopting new agricultural innovations. This highlights the importance of leveraging social networks to promote the adoption of DRAT and improve resilience to climate change.

Impact of DRAT on Households' Socioeconomic Status, Incomes, and Livelihoods

The adoption of DRAT significantly increased crop yields (95.38%), household income (88%), and food security (94%). These findings are consistent with Nhemachena and Hassan (2007), who found that adopting climate-resilient practices enhances agricultural productivity and livelihoods. Improved crop yields translate into higher household incomes, enabling farmers to invest in other aspects of their livelihoods and improving their overall quality of life. This increased resilience to climate variability is critical for long-term sustainability in agriculture. Thornton *et al*. (2006) also highlighted that improved agricultural practices can significantly boost household resilience and economic well-being. The study's findings indicate that the adoption of DRAT not only enhances agricultural productivity but also improves food security and household resilience to drought. This underscores the importance of promoting these technologies to improve the socioeconomic status of farming communities and mitigate the impacts of climate change.

Challenges to the Adoption of DRAT and Perceived Mitigation Ways

The study identified several key challenges to the adoption of DRAT, including lack of access to credit (94% agree), insufficient knowledge and training (94% agree), and poor infrastructure (75% agree). These challenges are consistent with the findings of Deressa *et al*. (2009), who highlighted financial constraints and inadequate infrastructure as significant barriers to technology adoption. Lack of access to credit limits farmers' ability to invest in new technologies, while insufficient knowledge and training hinder their ability to effectively implement DRAT. Smit and Skinner (2002) noted that insufficient training and awareness are major obstacles to adopting climate-resilient agricultural practices. The study's findings underscore the need for targeted interventions to address these challenges. Providing farmers with education and training, improving access to credit, and investing in

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infrastructure development are critical strategies for enhancing the adoption of DRAT. These interventions can help overcome the barriers to adoption and promote sustainable agricultural practices. Providing education and training (25%), raising awareness (46%), and improving infrastructure (13%) were perceived as critical strategies for encouraging DRAT adoption. These findings are consistent with the recommendations by the Intergovernmental Panel on Climate Change (IPCC, 2007), which emphasises the importance of capacity-building, awareness campaigns, and infrastructure development to enhance adaptive capacity in agriculture. Educating farmers about the benefits of DRAT and providing them with the necessary skills and knowledge are essential for promoting adoption. Raising awareness about drought-resilient technologies and improving agricultural infrastructure are also critical strategies for encouraging adoption. Investing in better roads, irrigation systems, and market access can significantly enhance farmers' ability to adopt and benefit from DRAT. The study's findings highlight the importance of a multi-faceted approach to promoting the adoption of DRAT, addressing both the technical and socioeconomic barriers to adoption.

CONCLUSION

The study concludes that the adoption of DRAT is influenced by various factors, including socioeconomic characteristics, access to information, land tenure systems and the education level of the household head.

Farmer groups and social networks play a critical role in facilitating adoption. However, significant challenges such as financial constraints, inadequate knowledge, and poor infrastructure hinder widespread adoption.

The study highlighted the positive impact of DRAT on agricultural productivity, household resilience and income.

RECOMMENDATIONS

Based on the findings, it is evident that socio-cultural factors such as Land tenure, education level, and farm size significantly influence the adoption of drought-resilient agricultural technologies (DRAT). Therefore, it is recommended that extension services and training programs be tailored to address these demographic factors. Older farmers and those with lower education levels should be specifically targeted with simplified and practical training sessions. Additionally, policies should be developed to support larger farms in adopting DRAT through subsidies and incentives, ensuring they have the resources necessary to implement these technologies effectively.

Given the high adoption rates of agroforestry, conservation agriculture, and early planting, efforts should be intensified to promote these practices further. Extension services should focus on demonstrating the benefits of these technologies through model farms and farmer field schools. Additionally, the government and non-governmental organisations should provide subsidies and financial incentives for inputs required for agroforestry and conservation agriculture, such as tree seedlings and soil cover materials. Enhancing access to timely and accurate weather information will also support early planting decisions, further improving adoption rates.

The study highlights the importance of access to agricultural information, secure land tenure, and farm size in the adoption of DRAT. Therefore, it is recommended to establish robust information dissemination systems, such as mobile platforms, radio programs, and community meetings, to ensure farmers have continuous access to up-to-date agricultural information.

Policies that secure land tenure should be enforced to provide farmers with the confidence to invest in long-term DRAT practices. Furthermore, initiatives to support smallholder farmers through grants and technical assistance should be prioritised to ensure they are not left behind in the adoption of these critical technologies.

The low membership rate in farmer groups and cooperatives indicates a need to strengthen these institutions. It is recommended that government

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and development agencies invest in forming and supporting farmer groups by providing training on group dynamics, leadership, and the benefits of collective action. Facilitating access to credit and markets through these groups can also encourage more farmers to join. Creating platforms for knowledge sharing and networking among farmer groups will enhance their effectiveness in promoting DRAT and other sustainable agricultural practices. Social networks significantly enhance the adoption of DRAT by facilitating knowledge sharing and boosting confidence among farmers.

It is recommended that agricultural extension services leverage existing social networks to disseminate information about DRAT. Organising regular community meetings and farmer-to-farmer exchange visits can provide opportunities for farmers to share their experiences and best practices. Encouraging the formation of informal farmer networks and support groups can also enhance peer learning and collective problem-solving, thereby increasing the overall adoption of DRAT. The significant positive impact of DRAT on crop yields, household income, and food security underscores the need for broader promotion of these technologies. It is recommended to implement comprehensive support programs that include financial assistance, provision of high-quality seeds, and access to markets to ensure farmers can fully benefit from DRAT.

Strengthening linkages between farmers and agricultural research institutions can also ensure continuous improvement and adaptation of DRAT to local conditions.

Monitoring and evaluation frameworks should be established to track the socioeconomic impacts of DRAT and adjust interventions as necessary to maximise benefits.

Addressing the identified challenges to DRAT adoption, such as lack of access to credit, insufficient knowledge, and poor infrastructure, requires a multifaceted approach. It is recommended that financial institutions develop tailored credit products for smallholder farmers to facilitate the adoption of DRAT. Comprehensive training programs should be rolled out to equip farmers with the necessary knowledge and skills. Infrastructure development, particularly improving roads and irrigation systems, should be prioritised to support the effective implementation of DRAT.

Policymakers should also focus on creating an enabling environment through supportive policies and incentives that address the high initial costs and market access issues faced by farmers.

Future research should focus on the long-term impacts of DRAT, strategies to overcome cultural resistance and the role of government policies in promoting sustainable agricultural practices.

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