

Adoption of climate smart agricultural practices among agro-pastoralist in Sagante Jaldessa Ward, Marsabit County, Kenya

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ABSTRACT

Climate change poses significant threat to agricultural productivity, food security and livelihoods among Agro-pastoralist communities in Kenya's arid and semi-arid lands (ASALs). This study investigated the adoption of Climate-Smart Agriculture (CSA) practices among Agro-pastoralists in Sagante Jaldessa Ward, Marsabit County, Kenya. Specifically determining the adoption levels of crop and livestock CSA practices, assess the influence of socio-economic and environmental factors on adoption and evaluate effectiveness of different strategies promoting CSA. The study was guided by the Diffusion of Innovation Theory and the Adopter Perception Model. A mixed-methods research design was employed involving structured questionnaires administered to 381 households supplemented by focus group discussions, key informant interviews and observations. Quantitative data were analyzed using descriptive statistics, chi-square tests and logistic regression, while qualitative data provided additional insights into farmers' experiences and adoption challenges. The findings revealed varying levels of adoption across crop and livestock production systems. Improved maize and bean varieties were widely reported while the cultivation of traditional drought-tolerant crops remained comparatively low. Manure application was more common than fertilizer use, reflecting differences in affordability and access to agricultural inputs. Livestock-related practices, including supplementary feeding, fodder conservation and the use of improved breeds, were also adopted at varying levels. However, adoption was influenced by several socio-economic and environmental factors including education, gender, farm size, land tenure security, group membership, access to information, drought and deforestation. Access to essential support services was uneven with (66.4%) reported access to weather information, (25.5%) to financial services only. Stakeholders including government agencies, non-governmental organizations and research institutions contributed through training, awareness creation, financing initiatives and agricultural support programs. Nevertheless, limited resources, knowledge gaps and inadequate coordination constrained the reach and effectiveness of these interventions. The study concludes that CSA adoption among Agro-pastoralists is shaped by the interaction of socio-economic circumstances, environmental pressures, farmers' perceptions and institutional support. Although several practices are being implemented, financial constraints, limited access to extension services and unequal access to resources continue to hinder wider adoption. The study recommends strengthening farmer education and extension services, improving access to affordable credit and appropriate agricultural inputs, promoting drought-resilient crop and livestock practices and enhancing coordination among stakeholders. Interventions should be inclusive, locally appropriate and responsive to the needs of women, older farmers and less-educated households to improve agricultural resilience, food security and livelihood sustainability. Chi-square analyses indicated associations between selected demographic characteristics and reported challenges or access to interventions. Some logistic-regression estimates showed signs of model instability and are therefore interpreted cautiously. The study concludes that CSA adoption in Sagante Jaldessa Ward is shaped by cultural preferences, socio-economic realities, environmental pressures and institutional gaps. It recommends strengthening farmer education and extension and access to flexible credit and inputs, enhancing coordination and aligning interventions with local socio-cultural contexts.

Keywords: Adoption, Agro-pastoralists, Climate-Smart Agriculture (CSA), Food Security, Marsabit County

I. INTRODUCTION

Climate change is among the most pressing global challenges, with human activities having already increased global temperatures by approximately 1°C and projections indicating a rise to 1.5°C by 2052. The Intergovernmental Panel on Climate Change (IPCC, 2021). Globally, climate change reduces agricultural production by about 2% per decade and contributes to hunger affecting approximately 318 million people (Food and Agriculture Organization of the United Nation [FAO] et al, 2025). Rising temperatures, erratic rainfall, pest and disease outbreaks, prolonged droughts, sea-level rise, increasing CO₂ concentrations, and flash floods continue to adversely affect agricultural productivity worldwide (Kogo et al., 2021; FAO et al. (2025). Kenya is already experiencing these climate-related impacts through changing precipitation and temperature patterns, threatening crop production and food security in a country heavily dependent on rain-fed agriculture.

Agriculture in Sub-Saharan Africa is a major factor in the economy and one of the main sources of livelihoods,

especially via smallholder farming. Yet the region depends on rain-fed agriculture and is therefore very vulnerable to the effects of climate change; warmer temperatures and extreme weather events such as droughts, floods and heatwaves are expected to become more frequent and intense, with forecasts indicating a 30 per cent drop in agricultural productivity by 2050 (Trisos et al., 2022). The social and economic consequences are severe, involving a reduction in agricultural income, an increase in food insecurity, and difficulties in meeting the Sustainable Development Goals (Thornton & Lipper, 2014).

The increase in greenhouse gas emissions has accelerated global warming, altered rainfall patterns, and intensified extreme events such as droughts, floods, and wildfires (Andati et al., 2022). In response, Climate-Smart Agriculture has been developed around three pillars: increasing productivity, building resilience and adaptation, and mitigating greenhouse gas emissions (Van Wijk et al., 2020; Mengistie & Ray, 2026). CSA contributes to food security, enhances resilience to climate variability, and supports carbon sequestration (Akuja & Kandagor, 2024). Furthermore, adapting CSA practices, diversifying crop selection, and improving water management have been identified as critical strategies for enhancing agricultural resilience and productivity under changing climatic conditions (Mose et al., 2025). The Kenya Climate-Smart Agriculture Strategy is among such policies; it spans the period 2017 to 2026 and brings CSA practices in line with Sustainable Development Goal 2.4 while promoting the resilience and sustainability of agriculture. Yet, due to insecure land tenure and the high cost of technologies its wide-scale adoption is being hindered, even though supportive policies are in place (Njuguna et al., 2019).

This initiative is also guided by Vision 2030 and the Agricultural Sector Development Strategy (ASDS 2010 & 2015). Despite these efforts, CSA adoption remains limited, particularly in Kenya's arid and semi-arid lands (ASALs), where communities face recurrent climate shocks (Njuguna et al., 2019). Climate-Smart Agriculture encompasses a range of practices including crop diversification, drought-resistant crop varieties, weather-based Agro-advisories, crop rotation, intercropping, conservation agriculture, and livestock adaptation. Successful adoption depends on effective dissemination of agricultural information and farmers' ability to interpret climate variability in decision-making (Ndung'u et al., 2023).

Marsabit County, located in northern Kenya, is particularly vulnerable to recurrent droughts, flash floods, dust storms, and pest infestations that threaten traditional Agro-pastoral livelihoods (MoALF, 2017; Chufe, 2019). In response to these challenges, some communities have adopted maladaptive practices such as overgrazing and charcoal burning, which further exacerbate environmental degradation (Boru & Koske, 2014). Climate-smart interventions such as rotational grazing, drought-tolerant crops, and rainwater harvesting provide viable pathways toward sustainable livelihoods and improved resilience in the fragile ASAL ecosystem (Gudere et al., 2022). Consequently, climate-smart livestock and crop technologies have become critical for improving food production and strengthening resilience against climate-induced uncertainties in Marsabit County. The findings are useful for local farmers since they show which practices government bodies and development partners could promote and expand throughout the county. The study also adds to the scientific knowledge and to the policy debates concerning the enhancement of agricultural resilience within Agro-pastoralist communities.

1.1 Statement of the Problem

Climate change being experienced globally has negatively affected agricultural production. The agriculture sector has greatly contributed to the Kenyan economy through food production. To address the effects of climate change on agricultural production, developing countries must significantly transform their agricultural systems through the adoption of climate-smart agriculture practices (Ogisi & Begho, 2023). FAO (2018) has described climate-smart agriculture as an integrated approach to managing agriculture that aims to sustainably increase agricultural productivity and incomes while reducing greenhouse gas emissions and building resilience to climate change. Climate-smart agriculture includes a combination of already existing practices such as soil conservation, water harvesting, organic agriculture, and agroforestry (Kifle et al., 2022).

However, agriculture in Kenya is almost entirely rain-fed hence being most vulnerable to global climate change risks and impacts. The changing climatic conditions have led to drastic reduction in agricultural production on which most of the Kenyan population relies on for their survival. The low adaptive capacity among the small holder farmers also contributes to the increased climate change and vulnerability in the country. In this respect, application of CSA practices is vital in reducing the interlinked problems of food security and climate change.

Agro-pastoralists in Marsabit's Saku Sub-County face extreme climate vulnerability, with 93.7% identifying drought as the primary threat to their livelihoods (Gudere et al., 2022). In response, the Kenya Climate-Smart Agriculture Project (KCSAP) and the Centre for Research and Development in Drylands (CRDD) rolled out training and extension services to promote Climate-Smart Agriculture (CSA) in the region. Despite these institutional efforts, a significant implementation gap exists even though the County government and development partners in Marsabit county continue to encourage uptake of CSA practices, but there is considerable evidence on factors constraining use of CSA to enhance food production and general crop performance. The study therefore sought to investigate the factors influencing adoption of Climate-Smart Agricultural (CSA) practices among the Agro-pastoralists in Sagante Jaldesa ward, Marsabit County.

1.2 Research Objective

Determining Crop and Livestock Adoption levels Among Agro-pastoralist in Sagante Jaldessa ward, Marsabit County

II. LITERATURE REVIEW

2.1 Theoretical Review

2.1.1 Diffusion of Innovations (DOI) Theory

The adoption of Climate-Smart Agriculture (CSA) practices among Agro-pastoralists in Sagante Jaldessa Ward, Marsabit County, is explained by two complementary perspectives: Rogers' (2003) Diffusion of Innovations (DOI) Theory and the adoption perspective of Prager and Posthumus (2010). DOI Theory explains how innovations spread within a social system, while the adoption perspective highlights how farmers' socio-economic characteristics, resources, institutional support and environmental conditions influence their willingness and ability to adopt particular practices. Together, these perspectives provide a theoretical basis for understanding why CSA adoption varies across crop and livestock practices.

Rogers (2003) theory identifies five innovation attributes that influence adoption: relative advantage, compatibility, complexity, trialability and observability. These attributes help explain differences in the uptake of practices such as improved crop varieties, crop diversification, rainwater harvesting, manure application, supplementary livestock feeding and fodder conservation. Practices perceived as beneficial, affordable, compatible with existing livelihood systems and easy to implement are more likely to be adopted than those requiring substantial financial investment, technical knowledge or labour. The theory also views adoption as a process involving knowledge, persuasion, decision, implementation and confirmation. Therefore, awareness of a CSA practice does not necessarily mean that a farmer has adopted or continues to use it.

Prager and Posthumus (2010) complement this explanation by emphasizing that adoption decisions are shaped by the interaction of personal, socio-cultural, economic, institutional and environmental factors. In Agro-pastoral communities, farmers' choices are influenced not only by the perceived benefits of a practice but also by resource availability, access to information and extension services, cultural preferences and compatibility with existing crop and livestock production systems. Farmers may consequently adopt some CSA practices while rejecting or delaying others because of financial constraints, limited knowledge, labour demands or uncertainty about expected benefits.

The theoretical framework therefore conceptualizes CSA adoption as a selective, context-dependent and potentially incremental process rather than a binary decision to adopt or not adopt. This distinction is particularly important for Agro-pastoral communities because CSA comprises multiple practices that may be adopted independently, simultaneously or sequentially. A household can therefore be classified as an adopter of one CSA practice while remaining a non-adopter of another. The study objective consequently benefits from disaggregating adoption into specific crop and livestock practices rather than treating CSA adoption as a single aggregate outcome.

The framework also provides a basis for interpreting adoption intensity and uneven uptake. A high adoption rate of one practice does not necessarily imply comprehensive adoption of CSA. Instead, it may indicate that the particular practice possesses characteristics that make it more attractive or accessible within the local farming system. Conversely, low adoption of a practice should not automatically be interpreted as resistance to climate adaptation; it may reflect high financial requirements, limited information, inadequate institutional support, labour requirements, cultural incompatibility or uncertainty regarding expected benefits. This theoretical interpretation is consistent with contemporary CSA literature, which increasingly recognizes adoption as multidimensional and shaped by interactions among socio-demographic, psychological, technological, environmental, systemic and policy factors (Gemtou et al., 2024).

The theoretical implication is therefore that differences in adoption levels across crop and livestock practices provide empirical evidence of how innovation characteristics and farmer-context interactions influence the diffusion of CSA within an Agro-pastoral social system. The framework supports the interpretation of adoption not merely as the presence or absence of a technology, but as the outcome of a process in which farmers assess, experiment with, implement and potentially continue or discontinue practices according to their perceived benefits, compatibility, feasibility and contextual circumstances. This provides a theoretically grounded explanation for the uneven adoption patterns observed among Agro-pastoralists in Sagante Jaldessa Ward.

2.2 Empirical Review

Empirical studies indicate that the adoption of Climate-Smart Agriculture (CSA) practices among smallholder farmers and Agro-pastoralists varies considerably across practices, production systems and geographical contexts. CSA encompasses a range of practices intended to improve agricultural productivity, strengthen resilience to climate change and, where possible, reduce greenhouse-gas emissions. Research by Ogisi & Begho (2023) and Finizola e Silva et al. (2024) demonstrates that adoption is influenced by farmers' education, farming experience, farm size, access to information, financial resources and institutional support. Similarly, Agyekum et al. (2024) found that farmers adopt

different CSA practices at varying rates depending on their costs, labour requirements, technical demands and compatibility with existing livelihood systems. These findings emphasize the importance of assessing adoption at the level of individual practices rather than treating CSA adoption as a uniform household decision.

Evidence from the study indicates that adoption of improved crop varieties was significantly associated with age ($\chi^2 = 11.45$, $p = 0.022$) and education ($\chi^2 = 11.14$, $p = 0.049$), with younger farmers aged 26–41 years and those with formal education more likely to adopt improved maize and bean varieties. However, adoption of traditional drought-tolerant crops, including sorghum, millet, and teff, remained low despite their potential to withstand climatic variability. Qualitative findings attributed this to food preferences, labour requirements and market considerations. These results suggest that farmers' decisions depend not only on the climate resilience of a practice but also on its perceived economic benefits and suitability to household livelihood priorities. The findings also identify low adoption of water-harvesting technologies, partly because of technical and maintenance challenges. Competing uses of crop residues for livestock feeding may limit their use for mulching and soil improvement. In livestock production, supplementary feeding and fodder conservation were among the more commonly reported practices, at 23.9% ($n = 91$) and 23.4% ($n = 89$), respectively. Local breed retention for climate tolerance (6.3%) and rangeland reseeding (3.4%) was less common, suggesting that practices requiring additional resources, technical capacity or community coordination may be more difficult to implement.

Overall, the empirical evidence indicates that CSA adoption in Sagante Jaldessa Ward is selective and context-dependent. Farmers' decisions reflect the interaction of education, age, economic resources, cultural preferences, labour requirements, technical feasibility and access to institutional support. The study contributes to the existing literature by examining crop and livestock practices within the same Agro-pastoral livelihood system and highlighting the need for targeted extension services, practical training and support for practices that remain less widely adopted. These findings provide an empirical basis for assessing the factors influencing CSA adoption among Agro-pastoralists in the study area.

The same pattern is evident in soil and water management practices. The thesis reports that the adoption of water-harvesting technologies remained low despite promotion efforts, with technical and maintenance challenges identified as important constraints. This finding corresponds with evidence cited in Gebru et al. (2021), which indicates that water-harvesting structures in arid and semi-arid environments may underperform where technical capacity and maintenance systems are inadequate. Similarly, Castellanos-Navarrete et al. (2015) demonstrated the importance of manure application and residue retention for nutrient cycling in Kenyan smallholder systems, while the thesis notes that competing uses for crop residues can reduce their availability for soil-management purposes. Karwani et al. (2024) further reported that mulching adoption can be constrained in mixed farming systems because crop residues are also required for livestock feeding.

The crop findings therefore suggest that CSA adoption in Agro-pastoral systems should be understood as a selective process. Practices that require relatively limited additional resources or are easily incorporated into existing production systems may be adopted more readily than practices requiring substantial labour, investment, technical knowledge or changes in established livelihood practices. This interpretation is supported by the broader African evidence, which identifies resource constraints, inadequate labour, limited information and the diversity of farming systems as important challenges to CSA uptake (Deku et al., 2022).

Livestock production represents an equally important but comparatively less documented dimension of CSA adoption. This is particularly significant in Agro-pastoral communities because livestock provide food, income, savings and livelihood security and therefore constitute a central component of household resilience to climatic shocks. Recent evidence on climate-smart livestock systems identifies practices such as climate-resilient fodder production, improved rangeland management, livestock insurance, supplementary feeding and early-warning systems as important adaptation options. However, adoption remains uneven because of differences in resource requirements, institutional support and access to information.

The Sagante Jaldessa study therefore contributes to the empirical literature by examining CSA adoption within an integrated Agro-pastoral livelihood system and by disaggregating adoption into crop and livestock practices. The study's geographical focus is also significant because Sagante Jaldessa lies within an arid and semi-arid environment where Agro-pastoralism is the predominant livelihood and is exposed to recurrent drought and environmental degradation. The evidence generated by the study can consequently help distinguish between CSA practices that have achieved relatively broad uptake and those that remain marginal despite their potential contribution to climate resilience.

Overall, the empirical literature demonstrates that CSA adoption is neither uniform nor automatic. Adoption varies by practice, production system and local context, with farmers tending to adopt practices that are compatible with their livelihood systems, technically feasible, economically manageable and perceived to provide tangible benefits. The evidence from Sagante Jaldessa is consistent with this broader pattern: improved crop varieties show stronger uptake among particular farmer groups, while drought-tolerant traditional crops, some water-harvesting technologies and other resource-intensive practices remain less widely adopted. The literature therefore supports the need for practice-specific assessment of CSA adoption among Agro-pastoralists and provides a strong empirical basis for Objective of the study.

III. METHODOLOGY

3.1 Study Area

The study focused on the Sagante Jaldessa wards in the Saku Sub-County of Marsabit County. This area is situated at latitude of 2.3167ON and a longitude of 37.9667OE. It is located next to the Marsabit Forest and Marsabit town, spans an area of 70,961.2 square kilometers in the upper eastern part of Kenya, and shares borders with Ethiopia, as well as with the counties of Wajir, Isiolo, Samburu and Turkana.

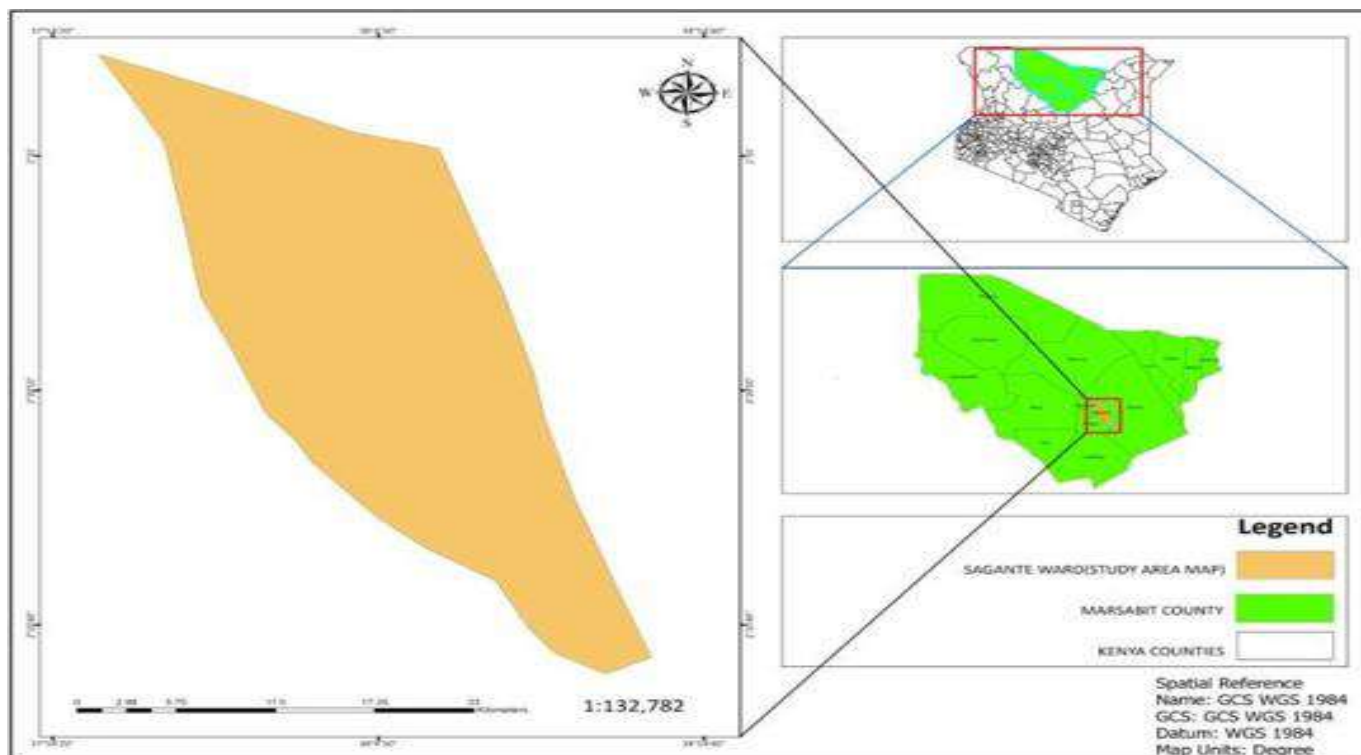


Figure 1
A map of a study Area

3.2 Research Design

The study employed a descriptive cross-sectional research design within a mixed-methods approach. The mixed-methods approach integrated both quantitative and qualitative techniques to comprehensively examine the adoption of Climate-Smart Agriculture (CSA) practices among Agro-pastoralists in Sagante Jaldessa Ward, Marsabit County. The cross-sectional design enabled the researcher to collect data from the study population at a particular point in time and establish the prevailing patterns of CSA adoption, while the mixed-methods approach facilitated the integration of numerical evidence with qualitative explanations of farmers' experiences, perceptions and challenges. The unit of analysis was the Agro-pastoral household, since decisions concerning crop production, livestock management and adoption of CSA practices are predominantly made at household level. The quantitative component involved the administration of structured household questionnaires to generate data on the levels of CSA adoption and examine relationships between socio-economic, environmental and institutional factors and CSA uptake. The qualitative component consisted of focus group discussions (FGDs) and key informant interviews (KIIs) involving relevant stakeholders, including county officials and extension agents. These qualitative approaches provided detailed information on farmers' perceptions, experiences, barriers and the institutional context surrounding CSA adoption.

3.3 Target Population

The study population was drawn from Agro-pastoralist households in Sagante Jaldessa Ward, Saku Sub-County, Marsabit County. The thesis identifies a total population of 56,900 households across the five locations forming the sampling frame. For purposes of the study, however, the 8,022 households engaged in Agro-pastoral activities in Sagante Jaldessa constituted the sampling population from which the household sample was drawn. The study targeted household heads or their representatives who had practiced mixed farming in the ward for at least 12 continuous months. This criterion ensured that respondents had sufficient experience of the local agricultural and climatic conditions and had the opportunity to interact with CSA interventions implemented within the study area.

3.4 Sampling techniques and sample size

The study employed a multi-stage sampling approach. First, Sagante Jaldessa Ward was purposively selected from the four wards of Saku Sub-County because of its Agro-pastoral characteristics, vulnerability to climate-related risks and its involvement in CSA interventions, including the Kenya Climate-Smart Agriculture Project (KCSAP). The wards were divided into clusters based on the administrative locations or villages, namely Qilta, Sagante, Dirib Gombo, Manyatta Jillo and Jaldessa. Cluster sampling enabled the researcher to capture respondents from different geographical and ecological areas within the study ward and thereby reduce the possibility of geographical bias.

The sample size used was 8,022 Agro-pastoralist households in Sagante Jaldessa Ward as the population from which the household sample was determined. The sample size was calculated using Yamane's (1967) formula at a 5% margin of error. The resulting sample consisted of 381 households.

The formula used was:

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

Where:

n = required sample size;

N = total target population; and

e = allowable margin of error.

Using $N = 8,022$ and $e = 0.05$, the study obtained a sample size of approximately 381 households. The 381 households were then distributed proportionately across the five locations according to their respective population sizes using Probability Proportional to Size (PPS). This ensured that locations with larger populations contributed more respondents while smaller locations remained adequately represented

3.5 Data Collection Methods

The study employed a mixed-methods approach to data collection, using several complementary instruments to obtain both quantitative and qualitative information. The main data collection methods were household surveys, key informant interviews, focus group discussions and direct observation.

3.6 Methods of Data Analysis

The collected quantitative data were first checked, coded, cleaned and organized before analysis. The data-cleaning process involved checking for inconsistencies, removing unusable records and outliers, clarifying ambiguous responses and resolving contradictions in closely related questions. A consistent coding scheme was subsequently developed to facilitate data entry and analysis using the Statistical Package for the Social Sciences (SPSS), Version 25.

3.7 Ethical Considerations

Concerning the ethical issues of research, the researcher, maintained confidentiality at all times. Only certain authorized people conducting the survey knew the identity of the participants. The researcher accepted individual responsibility for the conduct of the research and, as far as foreseeable the consequences of the research. The researcher obtained informed consent from the subjects used in the study and ensured that all respondents participated voluntarily. The researcher prepared a sample informed consent form, to be filled and signed by those respondents who would have voluntarily agreed to participate in the research. The researcher was open and honest in that she did not manipulate the respondents or offer bribes in a monetary form. The researcher fully explained to the respondents what the research was all about so that the respondents could make an informed decision on whether to participate in the research or not. The researcher sought a clearance letter from the Directorate of post graduate studies of Masinde Muliro University of Science and Technology (MMUST) to facilitate a clearance letter from the Ethical and Review Board (ERB) and a research permit from the National Commission for Science, Technology & Innovation (NACOSTI). The researcher recruited Research Assistants with diploma and above and at least two years of experience in data collection and who were able to speak local language for ease of translation. They were university graduates, who had done some courses on Research Methods. They had undergone training in data collection and research ethics before going into the field.

IV. FINDINGS & DISCUSSION

4.1 Demographic of respondent

The age distribution of respondents provided insight into farmers' experience and their potential for long-term adoption of climate-smart agriculture (CSA) practices, while gender offered insights into decision-making dynamics within households.

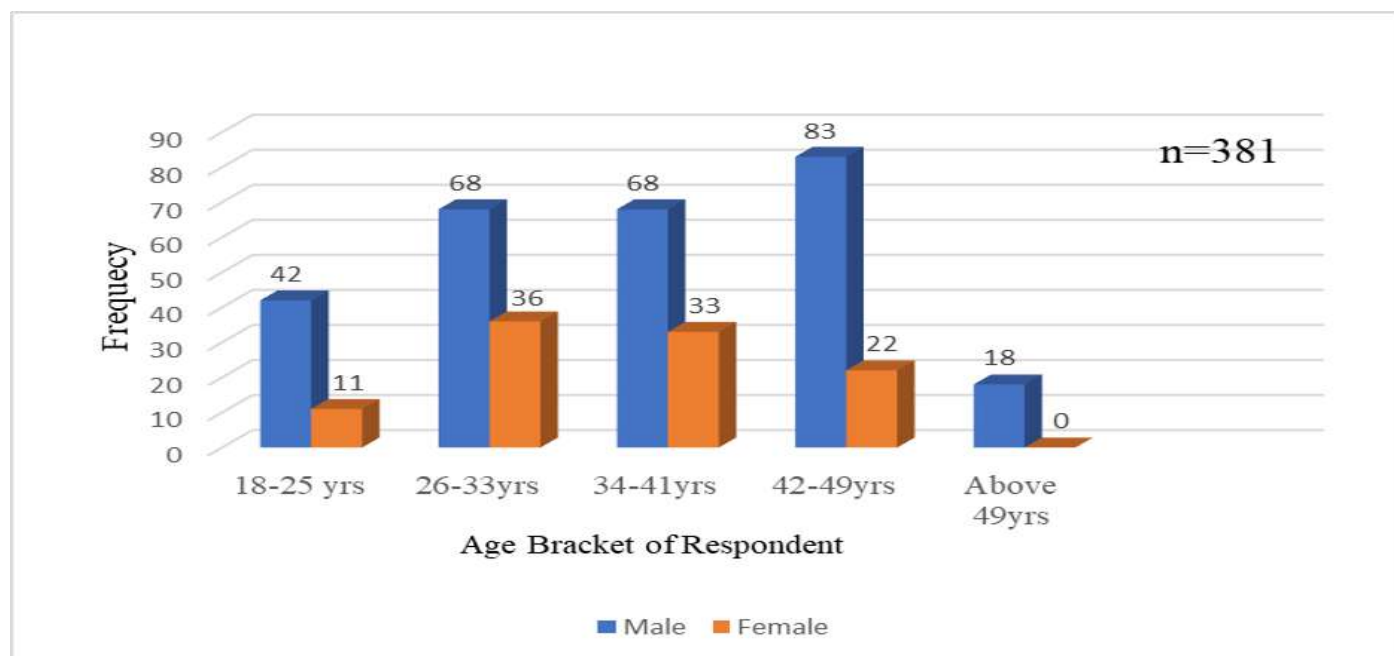


Figure 2

Respondents' Distribution by Age and Gender

From Figure 4 above, the age distribution of respondents is important in understanding the socio-economic characteristics that may influence the adoption of Climate-Smart Agriculture (CSA) practices. According to the findings of the study, respondents aged 42–49 years constituted the largest group, at 27.6% (105) followed by those aged 26–33 years at 27.3% (104) and 34–41 years at 26.5% (101). Respondents aged 18–25 years accounted for 13.9% (53), while those above 49 years represented 4.7% (18). These findings indicate that most respondents were within the 26–49-year age range, showing the experiences of farmers in their economically active years. Age may influence CSA adoption through differences in farming experience, openness to new technologies, access to resources and willingness to invest in agricultural practices. Younger farmers may be more receptive to new technologies, although this study did not directly measure technology receptiveness, while older farmers draw on accumulated farming experience when making agricultural decisions. In relation to the reviewed literature, the findings highlight age as an important socio-economic variable to consider when examining CSA adoption. The study should establish whether age was statistically associated with the adoption of specific crop or in Sagante Jaldessa Ward.

Table 1 below, the study assessed marital and educational status of the household heads because these demographic characteristics may influence household decision-making, access to information, and the ability to adopt climate-smart agricultural practices shows that most respondents were married (76.6%, n=292), while 23.4% (n=89) were single. Regarding education, 66.4% (n=253) had formal education, while 33.6% (n=128) had non-formal education. These socio-economic characteristics show an influence on the adoption of Climate-Smart Agriculture (CSA) practices by shaping household labour, decision-making and farmers' ability to understand and apply agricultural information.

The findings relate to reviewed literature, including Musafiri et al. (2022), KNBS (2019), Mthethwa et al. (2022), and Agbenyo et al. (2022), which the thesis cites in discussing socio-economic factors and CSA adoption. The results highlight the need for practical demonstrations, local-language communication, and accessible farmer training to support adoption of crop and livestock CSA practices, regardless of formal education level. However, marital status and education alone do not prove higher adoption. Education level determines how farmers are able to cope with adaptations and mitigate challenges through climate-smart agricultural practices. Education may influence farmers' understanding and adoption of CSA practices.

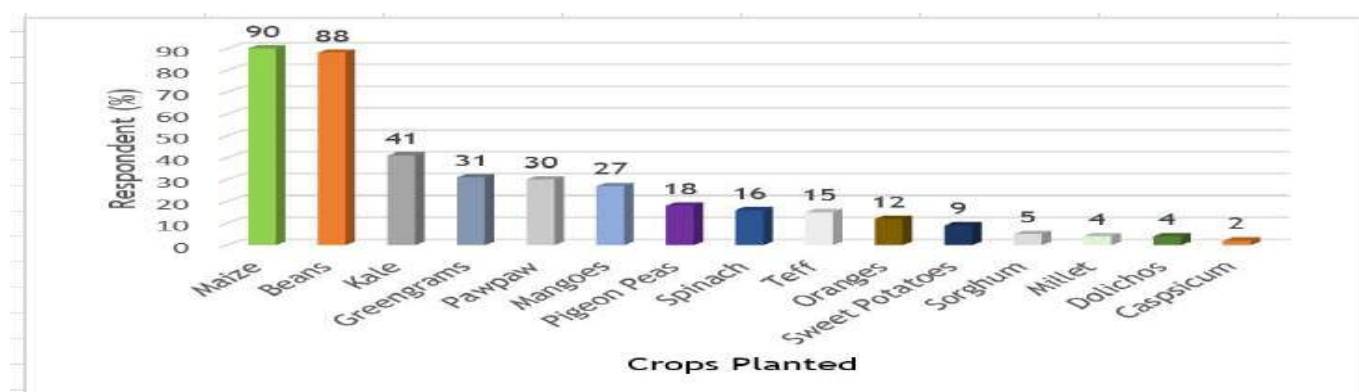
Table 1*Marital and Education status of respondents*

Variable	Description	Frequency (n)	Percentage %
Marital status	Single	89	23.4
	Married	292	76.6
Level of Education	Formal	253	66.4
	Non formal	128	33.6

4.1.1 Crops grown by Agro-pastoralist in Sagante Jaldesa

The findings on crops grown by Agro-pastoralists in Sagante Jaldessa Ward indicate that 90% and 88% of respondents grew improved maize and bean varieties, 14.1% grew traditional drought-tolerant crops such as sorghum, millet and teff, while 50.9% practiced crop rotation. These findings relate to the dependent variable in the conceptual framework, which is the adoption of Climate-Smart Agriculture (CSA) practices. The independent variables including education, farm size, access to extension services, agricultural information, training, credit and environmental conditions which influenced farmers' ability to adopt these practices.

The findings can be discussed alongside Musafiri et al. (2022) and Maina et al. (2020), cited in the thesis, regarding socio-economic factors influencing CSA adoption. The relatively high reported use of improved crop varieties and crop rotation suggests that some farmers are applying practices that may support adaptation to variable climatic conditions. However, the lower reported use of traditional drought-tolerant crops indicates potential scope for promoting locally suitable crops. Studies by Snelder et al. (2018) and Gebru et al. (2021), also cited in the thesis, provide relevant context for discussing water management and climate adaptation, while Deku et al. (2022) highlights resource, labour and information barriers that may constrain adoption. Overall, the findings suggest that CSA uptake may depend on the interaction of farmers' socio-economic circumstances, institutional support and environmental conditions. Field observations further indicated that sorghum and millet occupied considerably smaller land areas than maize. The dominance of maize and beans, despite their susceptibility to moisture stress, reflects a limited transition toward climate-resilient cropping systems and exposes farmers to increased risk of crop failure during prolonged dry periods. Discussions with Key informant interviews revealed that the continued preference for maize is largely driven by household consumption needs and market demand, while key informants identified limited access to improved seed as a major barrier to the adoption of drought-tolerant crops.

**Figure 3***Summary details crops grown by pastoralists*

4.1.2 Livestock reared by Agro-pastoralist in Sagante Jaldesa

From Table 2 below, the study found that cattle (80.1%, n=329) and goats (70.3%, n=289) were the most commonly reared animals in the area. These were followed by sheep (36.5%, n=150), donkeys (27%, n=111), and camels (24.8%, n=102), which were the least kept. According to focus group discussions held in Sagante Jaldessa Ward, donkeys were mainly used for transportation and ploughing. Although camels are often described as the “hope” in the face of climate change challenges due to their ability to withstand harsh climatic conditions (Watson *et al.*, 2016), their adoption remained relatively low, with only 24.8% of respondents reporting ownership. The findings on livestock reared by Agro-pastoralists in Sagante Jaldessa Ward indicate that livestock production is an important component of local livelihoods. These findings relate to the dependent variable, which is the adoption of Climate-Smart Agriculture (CSA) practices, particularly livestock-related practices such as supplementary feeding, fodder conservation, improved livestock breeds and rangeland management. Independent variables, including education, farm size, access to extension services, training, credit and environmental conditions may influence farmers' ability to adopt these practices.

The findings can be discussed in relation to the reviewed literature cited in the thesis, including Musafiri et al.

(2022), Gebru et al. (2021) and Deku et al. (2022), which provide context for examining socio-economic and environmental factors affecting CSA adoption. In the drought-prone environment of Marsabit County, livestock management practices that strengthen feed availability and improve resilience to changing climatic conditions are particularly relevant. Access to agricultural information, extension services and financial support may help Agro-pastoralists implement these practices.

Table 2

Livestock Reared

Livestock Category	Frequency(n)	Percentage (%)
Cattle	329	80.1
Goats	289	70.3
Sheep	150	36.5
Donkey	111	27
Camel	102	24.8

4.1.3 Different livestock management CSA practices in Sagante Jaldessa

From Figure 5 below, the findings indicate that Agro-pastoralists in Sagante Jaldessa Ward adopted various livestock management practices to sustain production under drought and climate variability. These practices included supplementary feeding, fodder conservation and storage, improved livestock breeds, the introduction of local breeds, grassland management, rangeland reseeding and destocking. According to the study, supplementary feeding was reported by 23.9%, fodder conservation and storage at 23.4% of respondents destocking by 19.4%, improved livestock breeds by 13.1%, grassland management by 10.5%, introduction of local breeds by 6.3%, and rangeland reseeding by 3.4%. These practices relate to the dependent variable, which is the adoption of Climate-Smart Agriculture (CSA) practices, while independent variables such as education, age, gender, and farm size, access to extension services, training, credit and agricultural information may influence farmers' adoption decisions.

The findings can be discussed in relation to the literature reviewed in the thesis, including Musafiri et al. (2022), Gebru et al. (2021) and Deku et al. (2022), which provide context for understanding the socio-economic, institutional and environmental factors associated with CSA adoption. Fodder conservation and supplementary feeding may help farmers manage seasonal feed shortages, while improved livestock breeds and sustainable grassland management may support livestock productivity and resilience. However, the comparatively low reported adoption of rangeland reseeding and local breed introduction suggests that these practices may require greater technical support, awareness and access to resources. Extension services, practical demonstrations and community-based livestock management initiatives could therefore help Agro-pastoralists strengthen their capacity to respond to drought and changing climatic conditions.

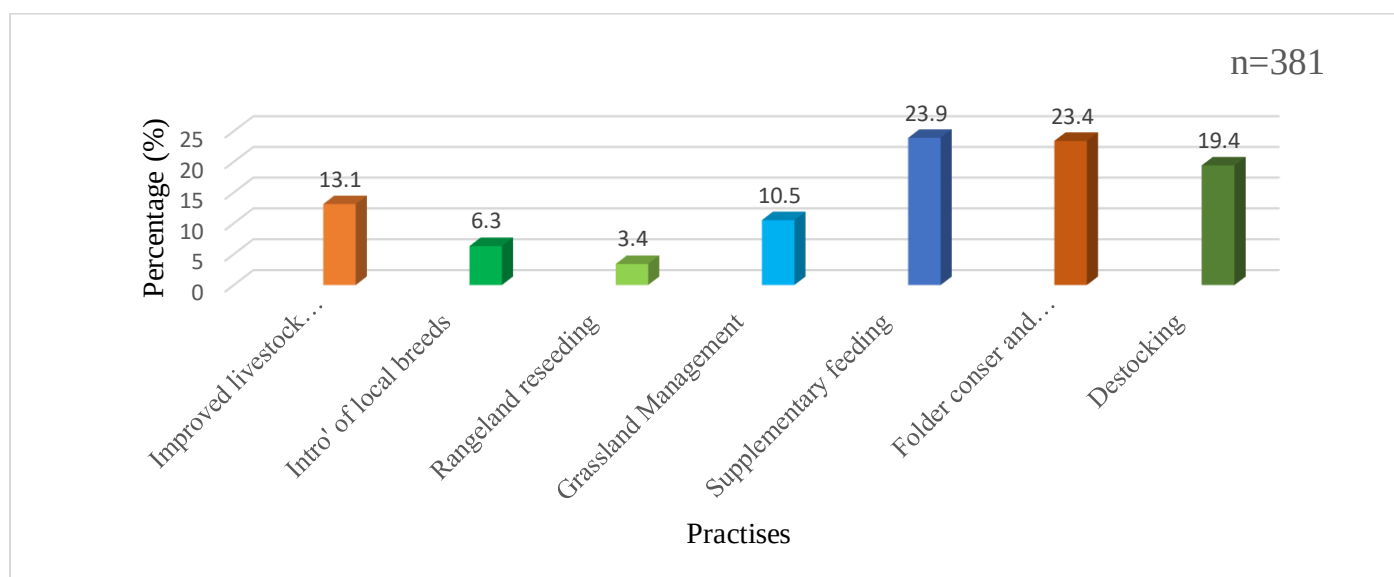


Figure 4

Different livestock management CSA practices adopted by the Agro-pastoralists

4.2 Sources of CSA Practices among Agro-Pastoralist in Sagante Jaldessa ward, Marsabit County.

4.2.1 Water and water use management

Water is a precious resource, especially in arid regions. Using it wisely is a clever way to tackle climate challenges while enhancing food security—this approach can help extend growing seasons even in times of drought.

Water harvesting technologies are a great solution to address scarcity, and numerous studies back this up (Geburu et al., 2021; Wekesa et al., 2021; Snelder et al., 2018).

Soil Fertility Management: After years of farming the same plots, concerns start to arise. Many households about 66.9% apply manure, but the use of artificial fertilizers is quite low at just 8.9%, mainly due to their cost and limited literacy. Agroforestry practices are adopted by 31.5% of farmers, but the uptake is sluggish; many trees are cut down without much effort to plant new ones. Windstorms, which agroforestry could help mitigate, highlight the need for greater awareness in this area.

Livestock Management Strategies: When it comes to livestock, strategies vary, with 27.1% of farmers rearing improved breeds and 7.1% sticking to local breeds. However, the adoption of these improved breeds is low due to concerns about their climate resilience. Discussion groups have pointed out that camels are excellent milk producers during droughts, yet not many Agro-pastoralists choose to keep them, despite their hardiness (Watson et al., 2016). Pasture management practices include conserving and storing fodder (48.6%), supplementary feeding (43.6%), managing grasslands (18.4%), and minimal reseeding of rangelands (4.5%). Farmers often supplement poor pastures with root tubers, acacia, and forest leaves. The low rates of reseeding have led to land degradation and desertification, which in turn has increased conflicts over resources. Percentages shown in Figure 7 represent aggregated adoption rates within each CSA category and are derived from the combined frequencies of individual practices presented in Table 3.

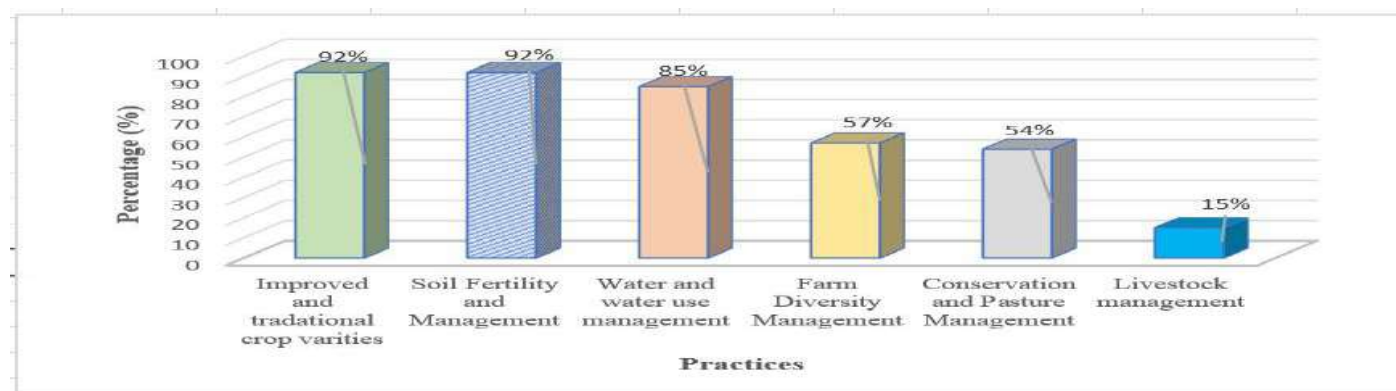


Figure 5

Agricultural practices in different categories

4.2.2 Climate-Smart Agricultural Practices Among Agro-Pastoralist in Sagante Jaldesa Ward.

Climate-smart agricultural practices can be categorized into six groups, as detailed in Table 3. Research indicates that 90.3% of farmers are using a mix of both improved and traditional crop varieties. Improved varieties include maize and beans, while traditional crops like teff, sorghum, and millet are less commonly used, with only 15.2% opting for them.

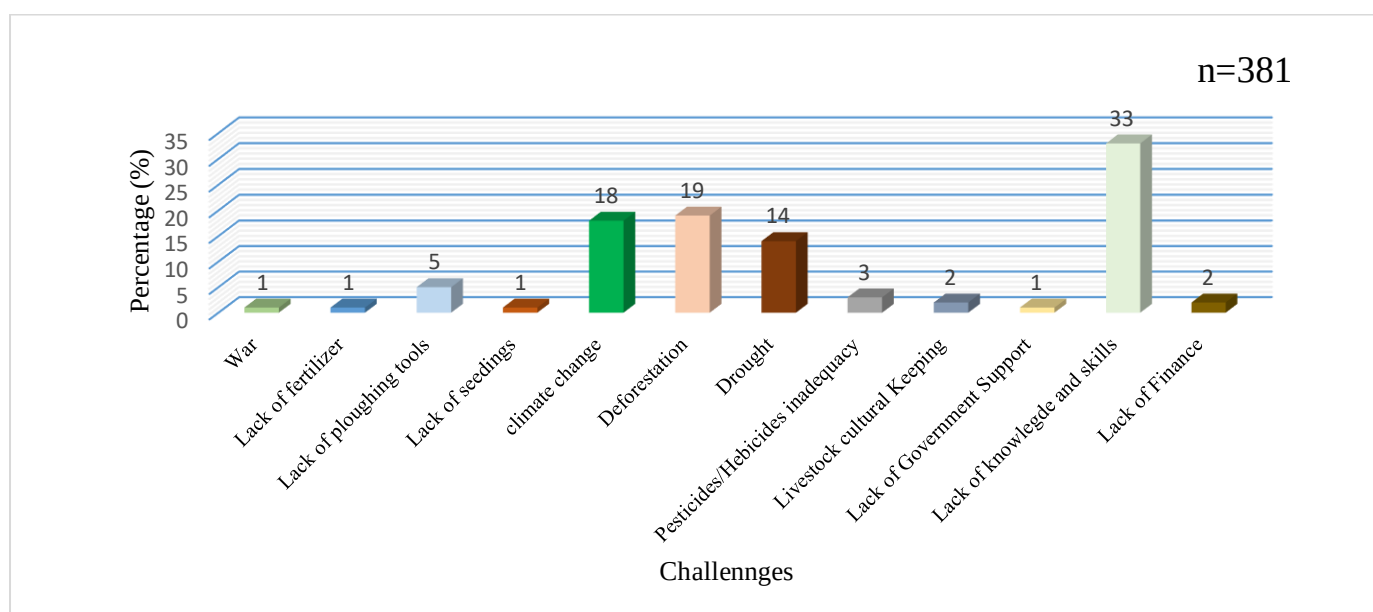
Maize and beans were classified as improved, while teff, sorghum, and millet were traditional, with only 15.2% practicing traditional cropping. Teff, though climate-smart and water-efficient, was labor-intensive and mainly grown in Sagante Jaldesa ward, promoted by KCSAP through community groups. Crop rotation and intercropping were key strategies for farm diversity, practiced at 54.9% and 35.7%, respectively, improving soil fertility. Efficient water uses practices included rainwater harvesting (29.1%), water catchment pans (11.3%), irrigation (16.5%), and cultivation of water-efficient crops (35.9%), notably Sukuma wiki in kitchen gardens. Mulching was practiced by 13.1% to retain soil moisture. Soil fertility management relied heavily on manure application (66.9%), while artificial fertilizer use was low (8.9%) due to cost and literacy barriers. Agroforestry adoption stood at 31.5%, but tree cutting and low replacement efforts were common, despite its potential to mitigate windstorms. Crop retaining residues at 30.7% and fertilizer application only at 8.9%.

The findings relate to the dependent variable, which is the adoption of CSA practices and the independent variables in the study's conceptual framework, including education, age, gender, farm size, land tenure, access to information, extension services, training, credit and environmental conditions. These factors may influence farmers' capacity to adopt particular practices. The pattern is consistent with study by Geburu et al. (2021), Wekesa et al. (2021), and Snelder et al. (2018) provide relevant context for water harvesting and water-management practices in dryland environments. Castellanos-Navarrete et al. (2015) discusses the role of manure and crop residues in soil nutrient management, while Watson et al. (2016) highlights the relevance of livestock suited to harsh climatic conditions. The wider adoption of crop and soil-management practices, compared with the lower reported uptake of livestock management, reinforces the need to assess each CSA practice separately rather than assume that farmers adopt all practices equally.

Table 3*Summary details on Climate Smart Agricultural practices*

Crop CSA Practices	Frequency (n)	Percentage (%)
Improved and Traditional crop variety		
Traditional	58	15.2
Improved	344	90.3
Managing diversity on farm		
Crop Rotation	209	54.9
Intercropping	136	35.7
Water and water use management		
Water tank rainwater harvesting	111	29.1
Water pans rainwater harvesting	43	11.3
Irrigation	63	16.5
Water efficient crops	137	35.9
Mulching	50	13.1
Soil fertility Management		
Fertilizer Application	34	8.9
Agroforestry	120	31.5
Crop Retaining Residues	117	30.7
Manure Application	255	66.9

Challenges of CSA Adoption: Figure 8 below reveals that lack of knowledge and skills/limited access to information (33%) emerges as the most significant challenge. 68% of the farmers' access information through radio and 45% through peer learning. Thus, from the findings, Deforestation was cited at 19%. Being the highest impact, Climate change (18%) and drought (14%) proved the environmental reality of Marsabit County as an arid and semi-arid land where water scarcity is a major hindrance. Participants of the FGDs that practices such as nomadism and crop diversification have been impacted by climate variability. The lack of ploughing tools (5%) and pesticides/herbicides inadequacy (3%) represent material input barriers that affect a smaller but still significant proportion of farmers. Other constraints that farmers identified are cultural beliefs of livestock keeping (2%), lack of finances (2%), war at (1%), lack of seedlings (1%), and lack of government support (1%). The low adoption rates documented among Agro-pastoralists may reflect not merely resource constraints but also the persistence of traditional norms that prioritize livestock mobility over crop diversification.

**Figure 6***Challenges hindering adoption of CSA practices in Sagante Jaldessa Ward*

4.2.3 Chi Square Summary Analysis on Adoption of Climate Smart Agriculture

The Chi-square analysis revealed that demographic characteristics significantly influenced several CSA-related interventions and challenges. Age showed significant associations with seedling distribution ($\chi^2 = 11.45$, $p = 0.022$) and training opportunities ($\chi^2 = 10.01$, $p = 0.040$), suggesting that participation in agricultural support programmes varies across age groups. This finding supports the descriptive results which showed that most respondents were within the economically active age categories and is consistent with Musafiri et al. (2022), who reported that age influences exposure to agricultural innovations. Marital status was significantly associated with fertilizer distribution ($\chi^2 = 15.71$, $p = 0.001$), indicating that household structure may influence access to agricultural inputs. Education level was strongly associated with lack of knowledge as a constraint to CSA adoption ($\chi^2 = 30.764$, $p < 0.001$), reinforcing the descriptive findings which showed a high proportion of respondents had non-formal education. This suggests that educational attainment remains an important factor in understanding and applying climate-smart agricultural technologies.

Gender was significantly associated with perceptions of drought challenges ($\chi^2 = 22.405$, $p < 0.001$). This finding implies that climate-related risks may affect male and female farmers differently and highlights the importance of gender-responsive CSA programming. Cultural beliefs were also significantly associated with age ($\chi^2 = 21.853$, $p < 0.001$), suggesting that older and younger farmers may differ in their acceptance of certain agricultural innovations. Overall, the findings confirm that demographic characteristics influence access to interventions and experiences related to CSA adoption, supporting the conceptual framework which identifies socio-economic factors as important determinants of adoption behavior.

Table 4

Summary of Chi-square analysis on CSA adoption

CSA Practice / Policy	Demographic Factor	Chi-Square Value	Significance (p-value)	Interpretation
Seedling Distribution	Age	11.45	0.022	Significant association
Training	Age	10.01	0.04	Significant association
Fertilizer Distribution	Marital Status	15.71	0.001	Strong association
Drought Challenge	Gender	22.405	0.000	Highly significant
Lack of Knowledge	Education	30.764	0.000	Highly significant
Cultural Beliefs	Age	21.853	0.000	Highly significant

V. CONCLUSION & RECOMMENDATIONS

5.1 Conclusion

The study concludes that the adoption of Climate-Smart Agriculture (CSA) practices among Agro-pastoralists in Sagante Jaldessa Ward is moderate but uneven, with adoption varying considerably across crop and livestock practices. Farmers demonstrated relatively high adoption of improved crop varieties, particularly improved maize (90%) and bean (88%) varieties were widely adopted, whereas traditional drought-tolerant crops were reported by only 15.2% of respondents. Crop rotation was also relatively common (54.9%), whereas practices such as rainwater harvesting, irrigation, mulching, agroforestry and fertilizer application recorded comparatively lower levels of adoption.

For livestock, the findings show continued dependence on cattle (80.1%) and goats (70.3%), despite the vulnerability of cattle to drought conditions. Livestock CSA practices such as supplementary feeding (23.9%) and fodder conservation and storage (23.4%) were more commonly adopted than rangeland reseeding (3.4%) and retention of climate-tolerant local breeds (6.3%). The findings therefore demonstrate that Agro-pastoralists tend to adopt practices that are familiar, accessible and immediately useful during periods of climate stress, while practices requiring greater financial investment, technical knowledge, or changes in traditional production systems remain less adopted.

5.2 Recommendations

The study recommends that government agencies, development partners, agricultural extension officers, research institutions and other stakeholders should strengthen the promotion and implementation of Climate-Smart Agriculture (CSA) practices among Agro-pastoralists in Sagante Jaldessa Ward by improving access to climate-resilient crop and livestock technologies, extension services, climate and weather information, agricultural inputs and financial support. CSA interventions should be designed to reflect the local socio-cultural practices, resource constraints and risk perceptions of Agro-pastoral households, while emphasizing practical training, farmer demonstrations and locally appropriate technologies. Strengthened coordination among stakeholders, together with regular monitoring of CSA programmes, is also recommended to enhance adoption and sustainability of climate-smart practices and improve the resilience of Agro-pastoral households to climate change.

Declaration of Interest

The authors declare that they do not have any known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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