

Analyzing Climate Smart Agriculture Practices' Adoption Drivers in Refugee Hosting Districts of Uganda. A Case of Yumbe District

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DOI: <https://doi.org/10.51244/IJRSI.2026.1303000083>

Received: 13 March 2026; Accepted: 18 March 2026; Published: 01 April 2026

ABSTRACT

Climate change and environmental degradation pose significant threats to food security, particularly in refugee-affected regions of Uganda. This study examined the adoption of Climate Smart Agriculture (CSA) practices among households in Bidibidi refugee settlement and Romogi Sub-County, Yumbe District. The objectives were to identify commonly applied CSA practices, analyze socio-economic and institutional drivers of adoption. A cross-sectional household survey was conducted with 375 respondents selected through multistage sampling. Data were collected using structured interviews and analyzed with descriptive statistics and binary logistic regression.

Results indicated that the most widely adopted CSA practices were planting climate-adapted crop varieties (94.7%), adjusting planting dates (82.4%), and establishing kitchen gardens (79.2%). Intercropping and soil and water conservation were moderately practiced, while agroforestry (23.5%) and irrigation (68.3%) were least adopted. Adoption drivers varied across practices: land ownership, household income, education, and access to extension services were significant for crop varieties and agroforestry; land tenure, household leadership, and schooling influenced planting dates; irrigation adoption was shaped by water access, household size, and group membership. Structural factors such as secure land tenure and resource availability consistently emerged as critical determinants, while demographic variables like gender and marital status showed limited influence. The study concludes that CSA adoption in refugee and host communities is highly context-specific, with resource constraints limiting uptake of capital-intensive practices. Strengthening land tenure security, expanding water infrastructure, and enhancing participatory extension services are essential to scale CSA adoption. These interventions will improve household food security, build resilience to climate shocks, and contribute to sustainable livelihoods in Uganda's refugee-affected regions.

Keywords- Climate Smart Agriculture, adoption drivers, refugee settlement, food security, Uganda

INTRODUCTION

Agriculture remains central to global food security, livelihoods, and economic development. However, climate change, land degradation, and population growth continue to undermine agricultural productivity and sustainability worldwide. Climate Smart Agriculture (CSA) has emerged as a comprehensive approach that seeks to sustainably increase productivity, enhance resilience (adaptation), and reduce or remove greenhouse gas emissions (mitigation) (FAO, 2013). By integrating these three pillars: productivity, adaptation, and mitigation, CSA contributes directly to the achievement of the Sustainable Development Goals (SDGs), particularly SDG 1 (No Poverty), SDG 2 (Zero Hunger), and SDG 13 (Climate Action) (FAO, 2015). Addressing these global concerns requires solutions that are context-specific yet scalable across local, national, regional, and international levels.

Globally, agriculture remains a significant contributor to greenhouse gas emissions, and without action, this trend will persist (Skoet & Lipper, 2016). Evidence suggests that adopting climate-smart practices, such as nitrogen-efficient and heat-tolerant crop varieties, zero-tillage, and integrated soil fertility management, could reduce emissions by 10–15% while simultaneously boosting food production to meet the demands of a growing population (Buis, 2019; Tian et al., 2016a). Widespread uptake of nitrogen-efficient farming methods alone could reduce the number of people at risk of undernourishment by over 100 million by 2030 (FAO, 2016). Yet,

achieving CSA in ways that align with broader SDGs remains complex, requiring evidence-based strategies, institutional support, and effective risk-sharing mechanisms (Newell et al., 2019; Williams et al., 2015). Importantly, CSA is not a “one-size-fits-all” solution; its effectiveness depends on careful assessment of local needs and conditions (Chandra et al., 2018).

In Africa, climate change is one of the greatest obstacles to achieving food security. Rising temperatures, erratic rainfall, and recurrent droughts exacerbate malnutrition and food insecurity (Haque et al., 2017). Recognizing this threat, African countries have committed to promoting CSA-oriented projects to ensure sustainable resource use and food production for future generations (Williams et al., 2015). However, progress has been slow, and environmental degradation continues to worsen. According to FAO (2020), while global forest cover has remained relatively stable at 30–31% between 2010 and 2020, Africa has experienced significant forest loss. In Uganda, tree cover declined from 15.6% to 11.7% during the same period, driven by agricultural expansion, charcoal burning, and refugee influxes (FAO, 2020; Twongyirwe et al., 2019).

Uganda presents a unique case in the African context. The country hosts one of the largest refugee populations globally, with Bidibidi settlement in Yumbe District ranking as the second largest refugee settlement worldwide after Kutupalong in Bangladesh (UNHCR, 2016). The influx of South Sudanese refugees in 2016 placed immense pressure on land resources, increasing demand for settlement and agricultural land. This has exacerbated environmental degradation and contributed to unpredictable weather patterns in the region. In response, humanitarian organizations and government extension services have promoted CSA practices such as climate-adapted crop varieties, irrigation technologies, kitchen gardening, intercropping, soil and water conservation, and agroforestry (Eriksen et al., 2019). These interventions aim to mitigate climate risks while enhancing food security for both refugees and host communities.

Despite the importance of CSA practices, there remains limited empirical evidence on their adoption and effectiveness in Uganda, particularly within refugee settlement contexts. Few studies have critically examined the extent of uptake and the socio-economic drivers influencing adoption. This gap is especially pronounced in Yumbe District, where refugee influxes have intensified land use pressures and heightened vulnerability to climate change. Addressing this knowledge gap is essential for designing context-specific interventions that strengthen resilience, improve food security, and promote sustainable livelihoods. Therefore, this study undertakes a critical analysis of CSA practices and their adoption drivers in Yumbe District, with a focus on Bidibidi settlement, to generate evidence that informs policy and practice in Uganda’s agrifood systems.

MATERIALS AND METHODS

Research design

The study adopted a cross-sectional household survey design, which is appropriate for descriptive research aimed at capturing opinions, behaviours, and socio-economic attributes of households at a single point in time. This design enabled the development of an accurate profile of households, events, and situations relevant to climate-smart agriculture (CSA) adoption.

Study area

Research was conducted in Bidibidi refugee settlement and host communities of Romogi Sub-County in Yumbe District, Uganda. The area is characterized by prolonged droughts between November and March and declining tree cover, partly accelerated by refugee influxes (UNHCR, 2016; Yumbe DDP, 2020). The study focused on CSA practices influencing the performance of field crops, fruits, and vegetables, which constitute a major component of household diets in the settlement and surrounding communities.

Study population and sampling

The target population comprised households in Bidibidi Zone 1 and Romogi Sub-County, totaling 7,460 households. A sample of 375 respondents (225 refugees, 150 nationals) was determined using Krejcie and Morgan’s (1970) formula for finite populations. A multistage sampling approach was employed: first, Bidibidi Zone 1 was purposively selected due to its significance as the initial settlement for South Sudanese refugees;

second, two parishes (Bidibidi and Kiri) were chosen; and finally, households were selected through simple random sampling using the fish-bowl technique (Haug et al., 2006).

Data collection

Both primary and secondary data were utilized. Primary data were obtained through face-to-face interviews conducted by trained enumerators, while secondary data were drawn from scholarly literature and government reports. Household demographic and socio-economic characteristics were captured, including age, sex, household size, education, income sources, land access, and ownership. CSA practices were identified through consultations with district production offices and NGOs, and verified against literature (Barnard et al., 2015; Wekesa et al., 2018; Jamil et al., 2021). Respondents were asked about adoption of seven CSA practices and the drivers influencing uptake, including socio-economic and institutional factors (Zakaria et al., 2020; Kifle et al., 2022; Sanogo et al., 2023).

Reliability and validity

Data collection tools were pre-tested among households in the study area to ensure clarity and relevance. Adjustments were made following the pretest to enhance validity. Reliability was ensured through enumerator training and standardized administration of questionnaires.

Data analysis

Data were coded and analysed using SPSS. Descriptive statistics were presented in frequency tables. Binary logistic regression was applied to identify factors influencing CSA adoption. For adoption analysis, socio-economic and institutional variables served as predictors.

Ethical considerations

Ethical clearance was obtained from Uganda Christian University and approval was granted by the Research Ethics Committee. Informed consent was sought from all respondents, and confidentiality was maintained by anonymizing household data. Unique identifiers were used to protect respondent privacy, and all secondary sources were properly acknowledged.

RESULTS

Climate smart agriculture practices applied in Yumbe district

Table1: Climate smart agriculture practices commonly practiced in Yumbe district

CSA practice	Frequency	%
Planting climate adapted crop varieties; quick maturing varieties	355	94.7
Management of planting dates to suit changed rainfall patterns	309	82.4
Planting kitchen/back yard garden	297	79.2
Intercropping	280	74.7
water and soil conservation practices; mulching, cover crops	263	70.1
Irrigation	256	68.3
Agroforestry	88	23.5

Analysis of household survey data revealed that the most widely adopted CSA practices among refugees and host communities in Bidibidi Zone 1 and Romogi Sub-County were the use of climate-adapted crop varieties (94.7%), adjustment of planting dates to align with shifting rainfall patterns (82.4%), and establishment of kitchen or backyard gardens (79.2%). Intercropping (74.7%) and soil and water conservation measures such as mulching and cover cropping (70.1%) were moderately practiced. In contrast, irrigation (68.3%) and agroforestry (23.5%) were the least adopted practices, indicating limited uptake of technologies requiring higher resource investment (Table 1).

Drivers of climate smart agriculture practices

Binary logistic regression analysis was employed to identify socio-economic and institutional factors influencing adoption of specific CSA practices. The results from binary logistic regression are presents in tables; table2, table3, and table 4.

Table2: Factors influencing uptake of climate adapted varieties, managing planting dates and kitchen gardening

	B	Sig.	Exp(B)
Dependent variable: Climate adapted crop varieties			
Household head	1.415	0.182	4.116
Full time farmer	0.083	0.098*	1.086
Household income	0.000	0.000***	1.000
Group membership	-2.236	0.003***	0.107
Dependent Variable: Managing planting dates			
Land ownership	2.352	0.000***	10.502
Marital status	-0.531	0.205	0.588
Employment status	-20.639	0.999	0.000
Acc. irrigation water	-1.117	0.001***	0.327
Household head	1.129	0.081*	3.093
Years in school	0.119	0.016**	1.126
Distance to the farm	-0.044	0.169	0.957
Dependent Variable: Kitchen gardening			
Land ownership	2.898	0.000***	18.130
Marital status	-0.573	0.170	0.564
Household size	0.032	0.311	1.033
Employment status	0.468	0.616	1.597
Source of income	-0.816	0.193	0.442
Acc. ext. services	0.432	0.438	1.540
Acc. agro-inputs	-0.942	0.063*	0.390
Acc. irrigation water	0.774	0.035**	0.461
Constant	0.220	0.819	1.246

*Significant at 10%, ** at 5%, *** at 1% level

Table2, presents the drivers responsible for uptake of climate adopted crop varieties, management of planting dates and practicing kitchen gardening. For climate-adapted crop varieties, uptake was positively associated with household income and full-time engagement in farming, while group membership showed a negative effect. Households with higher incomes were significantly more likely to adopt improved varieties, whereas those belonging to farmer groups demonstrated lower adoption rates.

In case of management of planting dates, adoption was strongly influenced by land ownership, years of schooling, and household headship. Households owning land were over ten times more likely to adjust planting dates, while education enhanced the likelihood of adoption. Conversely, access to irrigation water negatively affected adoption, suggesting reliance on irrigation reduced sensitivity to rainfall variability.

On the other hand, for the practice of Kitchen gardening, land ownership emerged as the strongest predictor, with households owning land being eighteen times more likely to establish kitchen gardens. Access to agro-inputs and irrigation water negatively influenced adoption, possibly due to resource competition or prioritization of other farming practices.

Table3 presents analysis of drivers responsible for uptake of intercropping as well as soil and water conservation CSA practices. As such, intercropping was found to be significantly associated with land ownership, marital

status, and group membership. Landowners were 3.7 times more chances of a household's odds practice intercropping compared to a household that did not own land. Married respondents and group members also showed higher adoption probabilities. Adoption of soil and water conservation was influenced by age, land ownership, and reliance on agriculture as the main source of income. Younger farmers (18–35 years) were fifteen times more likely to adopt conservation practices, while land ownership increased adoption by over forty times.

Table3: Factors influencing uptake of intercropping and water and soil conservation practices

	B	Sig.	Exp(B)
Dependent Variable: Inter-cropping			
Age		0.162	
Age(18-35)	1.322	0.098	3.740
Age(36-60)	0.871	0.270	2.391
Land ownership	3.691	0.000***	39.86
Marital status	0.843	0.060*	0.433
Household income	0.001	0.584	1.000
Group member	1.284	0.000***	0.279
Market food availability	0.882	0.386	2.399
Dependent variable: Soil & Water conservation practices			
Sex	0.501	0.130	1.661
Age		0.028**	
Age(18-35)	2.705	0.008***	14.88
Age(36-60)	2.472	0.015***	11.84
Household size	0.041	0.260	1.040
Full time farmer	-0.044	0.304	0.960
Source of income	1.450	0.045**	4.280
Land ownership	3.741	0.000***	42.41
Distance to farm	0.042	0.215	1.041
Acc. ext. services	-0.982	0.063*	0.372
Acc. agro-inputs	0.633	0.202	1.889
Employment type	-2.137	0.449	0.118
Constant	-3.156	0.010	0.043

*Significant at 10%, ** at 5%, *** at 1% level

Table4. Factors influencing uptake of agroforestry and irrigation technologies

	B	Sig.	Exp(B)
Dependent variable: Agro-forestry			
Years in school	-0.081	0.037**	0.917
Source of income	-0.470	0.340	0.621
Household income	0.000	0.095*	1.000
Land size	-0.011	0.141	0.989
Land ownership	1.982	0.000***	0.137
Acc. ext. services	1.345	0.000***	0.260
Acc. credit	0.291	0.413	1.344
Dependent Variable: Irrigation			
Household head	0.726	0.068*	2.062
Land ownership	1.731	0.000***	5.652
Acc. irrigation water	2.050	0.000***	0.128
Household size	0.072	0.056*	0.936
Source of income	0.831	0.132	2.295
Debt status	-0.499	0.115	0.608

Group member	0.731	0.052*	2.073
Constant	1.112	0.013	3.019

*Significant at 10%, ** at 5%, *** at 1% level

Table 4 presents adoption drivers responsible for adoption of agroforestry and irrigation CSA technologies. Uptake of agroforestry was positively associated with household income, land ownership, and access to extension services, but negatively influenced by years of schooling.

This suggests that households with more resources and institutional support were more likely to invest in tree-based systems. As for irrigation, adoption was significantly influenced by land ownership, household leadership, group membership, and access to irrigation water. Landowners were nearly six times more likely to practice irrigation, while group membership doubled the likelihood of adoption. Household size also showed a marginal effect, whereas debt status and income source were not significant predictors.

DISCUSSION

Climate smart agriculture practices commonly applied in Yumbe district

The findings of this study indicate that the most widely adopted CSA practices in Bidibidi settlement and Romogi Sub-County were the use of climate-adapted crop varieties, adjustment of planting dates, and establishment of kitchen gardens. These results are consistent with evidence from other regions in East Africa.

For example, Wekesa et al. (2018) reported that Kenyan farmers frequently relied on improved crop varieties and altered planting dates to cope with changing rainfall patterns, particularly legumes integrated into crop rotations. Similarly, Nakabuo et al. (2019) observed that early planting was a dominant CSA practice among farmers in Nakasongola District, Uganda, underscoring the importance of timing as a climate adaptation strategy.

Soil and water conservation practices also emerged as significant in this study, aligning with findings from Kenya where terraces, tree planting, and live barriers were commonly applied (Wekesa et al., 2018). In Uganda, Zizinga et al. (2022) demonstrated that conservation techniques such as planting basins significantly enhanced maize productivity, thereby improving household food availability. The widespread application of these practices in Bidibidi suggests that farmers recognize their role in stabilizing yields under erratic climatic conditions.

The results further corroborate Eriksen et al. (2019), who documented similar CSA practices across Uganda, and the CARE (2021) report, which highlighted kitchen gardening as a common strategy in Mbarara Municipality. Kitchen gardens provide households with diversified food sources and contribute directly to nutrition security, a finding reinforced by the high adoption rates observed in this study.

However, notable differences were identified when compared to Wekesa et al. (2018). While irrigation was ranked among the most applied CSA practices in Kenya, this study found irrigation to be among the least adopted in Bidibidi and Romogi. This divergence may be attributed to differences in resource availability, infrastructure, and institutional support.

Irrigation requires substantial investment in water access and technology, which remains limited in refugee settlements and host communities in northern Uganda. Overall, the study demonstrates that CSA practices in Bidibidi settlement and surrounding host communities are broadly consistent with regional trends, particularly in the adoption of improved crop varieties, early planting, and soil conservation.

Yet, the relatively low uptake of irrigation highlights structural barriers that constrain the adoption of resource-intensive technologies. These findings emphasize the need for targeted interventions that address land access, water availability, and input supply to enhance CSA adoption and strengthen household food security in refugee-affected areas.

Drivers that motivate farmers to apply different CSA practices

Adoption of different climate smart agriculture practices was found to be related to different drivers as discussed in this section.

Climate-adapted crop varieties

Regression analysis revealed that adoption of climate-adapted crop varieties was significantly influenced by full-time engagement in farming and group membership. Farmers dedicating themselves entirely to agriculture tend to accumulate practical experience and skills, enabling them to identify crop varieties suited to local climatic conditions. This finding aligns with Mwangi and Kariuki (2015), who emphasized that continuous participation in demonstrations and hands-on training enhances farmers' ability to evaluate new technologies and make informed adoption decisions.

However, the results diverge from other studies. Yirga and Alemu (2016) found that access to extension services was a critical driver of improved maize variety adoption, whereas extension services were not significant in this study. Similarly, Barnard et al. (2015) highlighted extension access as central to CSA uptake, suggesting that contextual differences may explain the variation. Sanogo et al. (2023) identified marital status and education level as significant drivers of improved seed adoption, but these factors were not influential in the present study. Interestingly, group membership negatively influenced adoption of climate-adapted varieties, contrasting with Sanogo et al. (2023), who reported positive effects. Income also showed mixed results: while this study found limited influence, Kifle et al. (2022) reported that higher farm income positively supported diversified crop production in Ethiopia.

Managing planting dates

Adoption of timely planting practices was positively associated with land ownership, household leadership, and education level. Landowners were more likely to plant on time since they did not face delays negotiating access with landlords. Household heads also demonstrated greater autonomy in decision-making, reducing delays compared to spouses who often required consent. Education enhanced adoption by improving literacy and awareness of seasonal changes. Conversely, households with access to irrigation technologies were less likely to prioritize timely planting, as they could rely on alternative water sources throughout the year.

These findings are consistent with Tessema et al. (2018), who noted that sharing experiences of planting dates among farmers reduces climate risks. Barnard et al. (2015) similarly observed that limited farming experience hindered CSA adoption. Krell et al. (2018) reported that Kenyan farmers adjusted planting dates within ± 20 days of rainfall onset, highlighting the role of experience in shaping adaptive decisions.

Kitchen gardening

Results indicated that kitchen gardening was strongly influenced by land ownership and access to irrigation water, while access to agro-inputs negatively affected adoption. The positive role of irrigation reflects the need for consistent water supply to sustain vegetable production year-round, as noted by Sharma et al. (2011). Households without reliable water sources found it impractical to maintain backyard gardens. Land ownership also facilitated adoption, as kitchen gardens are semi-permanent and require secure tenure to avoid rental costs or displacement.

Interestingly, this study did not find sex or education level to be significant drivers, which contrasts with Rybak et al. (2018), who reported that gender and education were important determinants of kitchen gardening adoption. This suggests that in refugee and host community contexts, structural factors such as land and water access may outweigh demographic characteristics in influencing uptake.

Intercropping

The study revealed that adoption of intercropping was significantly influenced by land ownership, marital status, and group membership. Belonging to farmer groups provided opportunities for knowledge exchange and

exposure to new techniques, making them effective platforms for technology transfer. This finding is consistent with Mwangi and Kariuki (2015), who noted that social participation enhances adoption of agricultural innovations. Marital status also played a role, as intra-household collaboration in labour-intensive tasks such as weeding facilitated uptake of intercropping.

Land ownership emerged as a critical determinant, as tenants often face restrictions from landlords regarding crop choices. For example, households renting land for seasonal crops may be discouraged from planting intercrops with longer maturity periods such as cassava and beans. This aligns with Mwangi and Kariuki (2015), who reported that land size and ownership influence technology adoption differently depending on the practice—large landholdings favour extensive technologies, while small plots encourage practices such as intercropping and greenhouse farming. However, the findings diverge from Herath and Takeya (2003), who observed that sole landowners in Sri Lanka were less likely to adopt intercropping in rubber plantations, suggesting contextual differences in land use priorities. Both studies, however, agree that group membership significantly influences adoption.

Kifle et al. (2022) identified access to credit and household income as important drivers of crop diversification and conservation agriculture, which includes intercropping. In contrast, this study did not find these factors significant, highlighting the unique socio-economic dynamics of refugee and host communities in northern Uganda.

Soil and water conservation

Adoption of soil and water conservation practices was positively influenced by age, reliance on agriculture as the main source of income, land ownership, and access to extension services. Older farmers were more likely to adopt conservation practices, likely due to accumulated experience and exposure to peer learning. This finding supports Sanogo et al. (2023), who reported that age and farming experience significantly influenced adoption of organic manure, composting, and natural regeneration. Similarly, Mwangi and Kariuki (2015) emphasized that farmers with longer experience are better positioned to evaluate the benefits of conservation practices.

Households that depended primarily on agriculture were more motivated to invest in practices that safeguard yields, while land ownership facilitated adoption by reducing uncertainty over long-term land use. Tenants, on the other hand, were less inclined to invest in resource-intensive practices whose benefits extend beyond a single season. Extension services also played a positive role by enhancing farmer knowledge and skills, consistent with the broader literature on CSA adoption. However, Kifle et al. (2022) reported that extension services sometimes had a negative effect, as communities relying on traditional knowledge resisted external recommendations. They also found income to negatively influence conservation agriculture, whereas this study did not establish a significant relationship. Gender and education were not significant drivers in this study, a finding consistent with Sanogo et al. (2023), who similarly reported limited influence of these factors on conservation practice adoption.

Agroforestry

The study established that adoption of agroforestry was significantly influenced by education level, household income, land ownership, and access to extension services. Years spent in school and exposure to extension services enhanced literacy, knowledge, and technical skills, which are essential for uptake of non-traditional practices such as agroforestry. This finding is consistent with Wambede et al. (2019), who reported that over 40% of technology adoption in Yumbe District was linked to free inputs distributed by NGOs and government through extension networks. These inputs included tree seedlings, saplings, and small ruminants, which lowered entry barriers for households and encouraged adoption.

Household income also positively influenced uptake, reflecting the long-term investment nature of agroforestry, which requires financial resources beyond seasonal cycles. Land ownership was another critical determinant, as secure tenure enabled households to commit to multi-year tree planting without fear of displacement. This agrees with Odukuniyi and Tekana (2019), who found that extension services significantly influenced agroforestry adoption, while group membership was not a major factor. Recent studies also support these findings, with Kifle et al. (2022) highlighting the role of household income and Sanogo et al. (2023) emphasizing education as key drivers of agroforestry adoption.

Irrigation

Adoption of irrigation practices was strongly associated with access to irrigation water, land ownership, household leadership, household size, and group membership. Access to water was the most critical factor, as households relied on domestic water sources or wastewater for irrigation. This finding aligns with Fausal et al. (2021) and Kifle et al. (2022), who reported that irrigation adoption is impossible without reliable water sources. Given Yumbe District's water scarcity, limited surface water availability poses a major challenge to scaling irrigation technologies.

Land ownership also significantly influenced adoption, as irrigation requires substantial capital investment that households are unlikely to make on rented or borrowed land. Household headship and larger household size positively affected uptake, reflecting decision-making authority and labor availability for labor-intensive irrigation methods such as bucket or bottle irrigation. Amadu (2022) similarly reported that family labor was a key determinant of irrigation adoption in Malawi. Group membership further enhanced uptake by providing platforms for knowledge exchange and collective input procurement, consistent with Serote et al. (2021).

Interestingly, this study did not find extension services to be a strong driver of irrigation adoption, diverging from Adroit (2008) in Ghana and Kifle et al. (2022), who emphasized extension as critical. Amadu (2022) also reported significant effects of participatory extension approaches on CSA adoption. The discrepancy may be explained by differences in extension delivery methods, suggesting that conventional approaches may be less effective in refugee and host community contexts compared to participatory models.

Overarching patterns and cross-cutting drivers

A review of the individual CSA practices highlights several overarching patterns that cut across technologies and contexts. Most notably, land ownership emerged as the single most consistent and powerful driver of adoption. Whether for managing planting dates, kitchen gardening, intercropping, soil conservation, agroforestry, or irrigation, secure tenure provided households with the confidence to invest in practices whose benefits extend beyond a single season. This underscores the structural importance of tenure security in refugee-hosting agricultural systems, where land scarcity and contested access often constrain innovation.

Another cross-cutting theme is the role of resource availability and institutional support. Access to water for irrigation, extension services, and agricultural inputs significantly shaped adoption of practices such as irrigation, agroforestry, and soil conservation. Households with reliable water sources or exposure to extension networks were better positioned to adopt resource-intensive technologies. Conversely, limited infrastructure and weak service delivery created barriers, particularly for irrigation, which remained underutilized despite its potential to stabilize production in drought-prone Yumbe District.

In contrast, demographic factors such as gender, marital status, and household headship were relatively weak predictors of adoption. While marital status influenced intercropping through shared labour, and household leadership affected planting dates and irrigation, these effects were less consistent compared to structural drivers like land and water access. Education showed moderate influence, particularly for planting dates and agroforestry, but overall demographic variables did not emerge as decisive.

Taken together, these patterns suggest that CSA adoption in refugee and host communities is shaped less by individual characteristics and more by structural forces such as land tenure, resource access, and institutional support systems. Strengthening these foundations will be critical for scaling CSA practices, enhancing food security, and building resilience in contexts where households face both climatic stress and socio-economic vulnerability.

CONCLUSIONS

This study set out to examine the adoption of Climate Smart Agriculture (CSA) practices among refugee and host communities in Bidibidi settlement and Romogi Sub-County, Yumbe District. Against the backdrop of climate change, prolonged droughts, and environmental degradation exacerbated by refugee influxes, CSA was identified as a critical pathway to enhancing food security and resilience. Using a cross-sectional household

survey of 375 respondents, supported by multistage sampling and rigorous statistical analysis, the study provided empirical evidence on the extent of CSA adoption and the socio-economic and institutional drivers influencing uptake. Findings revealed that the most widely adopted CSA practices were climate-adapted crop varieties, timely management of planting dates, and kitchen gardening, while agroforestry and irrigation were least practiced. Adoption patterns were strongly shaped by structural factors such as land ownership, household income, access to water, and extension services. Practices requiring fewer resources, such as intercropping and soil conservation, were more widely adopted, whereas resource-intensive technologies like irrigation and agroforestry faced significant barriers. These results underscore the importance of tailoring CSA interventions to local contexts, particularly in resource-constrained refugee settlements.

The analysis of adoption drivers highlighted that farming experience, education, and group membership influenced uptake differently across practices. For example, full-time farming and higher income facilitated adoption of improved crop varieties, while land ownership and education were critical for managing planting dates. Kitchen gardening was strongly linked to irrigation access and secure land tenure, while intercropping and soil conservation were shaped by household demographics, labour availability, and social participation. Agroforestry and irrigation adoption depended heavily on resource access, long-term land security, and institutional support, reflecting their multi-year investment nature. Overall, the study concludes that CSA adoption in refugee and host communities is context-specific, shaped by a complex interplay of socio-economic, institutional, and environmental factors. Strengthening land tenure security, expanding access to water and extension services, and promoting farmer group participation are essential to scaling CSA practices. Policymakers and development partners must prioritize interventions that reduce structural barriers and enhance resource availability, thereby enabling households to adopt a wider range of CSA technologies. Such efforts will not only improve household food security but also contribute to broader climate resilience and sustainable livelihoods in Uganda's refugee-affected regions.

POLICY RECOMMENDATIONS

1. **Strengthen Land Tenure Security:** Since land ownership consistently emerged as the most critical driver of CSA adoption, policies should prioritize securing land rights for both refugees and host communities. Clear tenure arrangements will encourage households to invest in long-term practices such as agroforestry and irrigation, which require multi-year commitment and resource allocation.
2. **Expand Access to Water Infrastructure:** Irrigation adoption was constrained by limited water availability in Yumbe District. Government and development partners should invest in small-scale, community-managed water systems and promote affordable micro-irrigation technologies. This will reduce reliance on rainfall and enable households to sustain kitchen gardening and other water-dependent CSA practices.
3. **Enhance Extension Services and Farmer Training:** Extension services were found to positively influence adoption of agroforestry and soil conservation practices. Policies should strengthen participatory extension approaches that combine technical training with peer learning platforms. Integrating NGOs, farmer groups, and local government extension officers will improve knowledge transfer and increase uptake of CSA technologies.
4. **Promote Inclusive Farmer Group Participation and Resource Support:** Farmer groups were shown to facilitate knowledge sharing and collective action, particularly for intercropping and irrigation. Policies should support the formation and strengthening of farmer associations, ensuring they are inclusive of women, youth, and refugees. Linking these groups to input subsidies, credit facilities, and market opportunities will enhance adoption and sustainability of CSA practices.

Further Researchdirection

Based on the study findings, one area still needs to be further investigated.

First, future studies should expand the geographical scope beyond Bidibidi settlement and Romogi Sub-County to include other refugee settlements and host communities across Uganda. This would allow comparative analysis of CSA adoption patterns in different ecological and socio-economic contexts. Such broader studies

could help determine whether the drivers identified in Yumbe District such as land ownership, water access, and extension services, are consistent across regions or unique to refugee-affected areas.

Second, longitudinal research designs are recommended to capture changes in CSA adoption over time. The cross-sectional approach used in this study provided valuable insights into current practices and drivers, but it could not assess how adoption evolves with repeated exposure to extension services, shifts in household income, or changes in climate conditions. Long-term monitoring would provide stronger evidence on the sustainability of CSA practices and their cumulative impact on household food security and resilience.

Finally, future research should integrate qualitative approaches to complement quantitative findings. In-depth interviews, focus group discussions, and participatory rural appraisals could uncover nuanced social and cultural factors influencing adoption, such as gender dynamics, intra-household decision-making, and perceptions of risk. Exploring these dimensions would enrich understanding of why certain practices, such as irrigation and agroforestry, remain underutilized despite their potential benefits. Such mixed-methods research would provide policymakers and practitioners with more comprehensive evidence to design context-specific interventions that effectively promote CSA adoption in refugee and host community settings.

Declarations

- 1. Funding:** No funding organization provided any grant to the researcher as the research utilized own resources to have this study accomplished.
- 2. Conflicts of Interest:** The author declares no conflicts of interest.
- 3. Ethics Approval:** This research was conducted upon securing Ethical clearance from Uganda National Council for High Education(NCHE)'s Research Ethics Committee (REC).
- 5. Data Availability:** Raw data is not publicly available due to ethical considerations to keep research participants anonymous. However, anonymous extracts of the data can be availed upon special written request that clearly stating the intended use of the requested data.
- 6. Study Limitations:** The study was limited in terms of geographical scope. The study was limited to Bidibidi settlement and Romogi Sub-County in Yumbe District. Findings may not fully represent CSA adoption patterns in other refugee settlements or host communities across Uganda. Secondly, the study used cross section design which is limited to data collected at a single point in time. Data were collected at a single point in time, which restricted the ability to capture changes in CSA adoption over multiple seasons or years. Longitudinal studies would provide deeper insights into sustainability and long-term impacts.

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