

Determinants of the Adoption of Multiple Climate Smart Agricultural Practices Among Refugee Farmers in Uganda

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Abstract

Refugee farmers in Uganda face compounded challenges due to climate change and resource constraints. These make the adoption of climate-smart agriculture urgent and difficult. To establish the level of adoption rates of various CSAPS and the determinants of the adoption of multiple climate-smart agricultural practices among this population, 202 refugee maize farmers in Madi-Okollo were surveyed using structured questionnaires, and the data were analysed using descriptive statistics and multivariate probit regression. Results showed that hybrid seeds were the most widely adopted practice (51%), followed by crop rotation (42%) and cover cropping (30%), while irrigation and mulching lagged with 5% and 9%, respectively. Socioeconomic factors, especially household size and farm size, along with institutional factors such as credit access, market information, and extension services, were significant determinants of the adoption. Demographic factors like age, gender, and education did not significantly influence the adoption of CSAPS. The findings suggest that adoption levels of CSAPS are varied, and the efforts to promote CSAPS among refugees should focus on expanding tailored training, strengthening extension services, and improving access to credit and market information. These steps could enhance agricultural resilience and livelihoods in refugee communities.

Keywords: Climate Smart Agricultural Practices; Socioeconomic factors; institutional factors; Multivariate Probit Models.

Introduction

The increase in greenhouse gas emissions has significantly impacted climate change, posing threats to agricultural productivity, human health, and environmental sustainability (Ali, 2021). This impact trickles down to food security and poverty, due to a decline in agricultural output. These effects are most experienced in regions where traditional agricultural practices are utilized. In Uganda, agricultural output is projected to decline from 29.4% to 11.2 % by 2090, contingent on emission scenarios (Chemura et al., 2025). Such traditional agricultural practices often struggle with limited productivity, environmental degradation, water resource depletion, and socio-political challenges (Murtaza et al., 2021). Thus, embracing CSAPS presents a promising solution. CSAPS are practices that focus on crop diversity preservation, conservation tillage, and efficient resource management, which are vital in maximizing economic, social, and environmental agricultural benefits (Kumar et al., 2020). CSAPS significantly enhance crop

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yields, increase farmers' incomes, and improve food security, benefiting smallholder farmers in particular (Saadu et al., [2024](#); Chemura et al., [2025](#)). However, the levels of adoption of various CSAPS remain sub-optimal (Wasswa et al., [2024](#)).

In Uganda and Africa, agriculture is an important sector which plays a crucial role in economic advancement (USAID, [2020](#)). The sector is a major source of food for households, provides raw materials for industries, and generates income alleviating poverty for over 63% of households (USAID, 2020; UBOS, 2024). Despite its importance, the sector is affected by climate change due to its reliance on rain-fed systems, threatening yields and food security (Oriangi et al., [2020](#)). The sector underperforms by about 40% in food crop production, largely due to limited adoption of modern farming techniques, erratic weather patterns, minimal use of high-yield seed varieties, and fertilizer usage (IGC, [2017](#)). The promotion of CSAPS such as the use of fertilizers, improved seeds, irrigation, pest management, inter-cropping, and crop rotation is necessary (GIZ, [2020](#)). This is because these strategies enhance farmers' resilience to climate change, conserve the environment, and increase productivity (GIZ, [2020](#)). However, their adoption, particularly in Uganda, remain low (Ehiakpor et al., [2021](#); Namulene & Alum, [2023](#)). Uganda is the fifth-largest host of refugees globally, and the largest host in Africa, hosting 1.9 million of the 36.8 million refugees, many of whom live in protracted situations (UNHCR, [2025](#); Kamugasha et al., [2024](#)). This number continues to rise due to ongoing civil strife in neighbouring countries. Rising numbers and the persistent funding gaps have affected refugee livelihoods. For instance, UNHCR received only 17% of the needed funding for 2025 (Ajuna, [2025](#)). In Uganda, food rations provided by the WFP to refugees are among the lowest in Africa (WFP, [2025](#)). Due to the shortage of funds, WFP reduced its coverage from 1.6 million individuals to 662,000, including new arrivals. By 2025, the number of refugees who no longer receive assistance was 18 times higher than in 2023, negatively affecting the food consumption of refugee households by 20% (WFP, [2025](#)). Kamugasha et al. ([2024](#)) found that food insecurity and economic vulnerability are dire among refugees in protracted situations, where over 80% lack adequate food, and more than half face severe food insecurity.

Thus, prioritizing resilience by promoting alternative livelihoods like agriculture, which directly impact food availability and income access at the household level, is key. It is a fundamental livelihood source for most refugees, with over 73% of refugee households involved and 57% citing it as their primary source of both wage earnings and crop and livestock sales (World Bank, [2019](#); Muhangi et al., [2022](#); Kamugasha et al., [2024](#), Uganda Comprehensive Refugee Response Plan 2024/2025). However, the potential of agriculture as a sustainable livelihood for refugees is significantly hindered by climate change, along with challenges like small land sizes, limited access to modern farming technologies, land constraints, inadequate extension services, quality inputs and credit facilities, declining soil fertility, unsustainable resource use, and environmental degradation (Mukhaye, [2023](#)). The Comprehensive Refugee Response Framework (CRRF), in line with the Global Compact on Refugees (GCR), promotes self-reliance, supporting refugees with land and agricultural resources to foster CSAP adoption (Uganda Refugee Act [2006](#), Betts et al., [2021](#)). Records from the Office of the Prime Minister (OPM) show that around 53 organizations are involved in supporting agricultural production, with at least 34 implementing initiatives incorporating CSAPs, providing innovative solutions to increase productivity on small plots, improve resilience to climate change, and lessen agriculture's environmental impacts in refugee-hosting districts (OPM, [2024](#); UNHCR, [2024](#)). For refugees with limited land access, CSAPs can introduce methods to maximize yields on restricted acreage. Techniques such as

agroforestry, intercropping, and the use of drought-resistant crops enhance small parcel productivity, enabling refugees to achieve higher outputs without needing extensive land.

Despite extensive support from development partners in promoting CSAPs, adoption rates remain low. For example, only 22% of refugees access improved seeds, despite them being freely distributed by development partners (UNDP, 2018). Additionally, pesticide usage is a mere 4%, while fertilizer and irrigation utilization are below 1% (Pace et al., 2023). The World Bank (2019) attributes low agricultural productivity among refugees to minimal adoption of improved inputs like pesticides and fertilizers, with potential serious implications for hunger and poverty among these communities if not addressed. Addressing these adoption issues is crucial to ensure sustainable agricultural development, enhance food security, and improve refugee households' livelihoods in Uganda. Therefore, this paper examines the level of adoption of CSAPS and their determinants among refugee farmers in Uganda, which is important in ensuring sustainable agricultural development as climate change remains a threat in this unique context. Different studies have linked the adoption of CSAPs to demographic, socioeconomic, and institutional factors (Saadu et al., 2024; Wasswa et al., 2024; Mbanasor et al., 2024; Manono et al., 2025). Unlike host communities or countries, refugees face unique challenges such as resource scarcity, restricted movement, and dependence on aid, which alter the influence of these factors on the adoption of CSAPS. This study seeks to fill this gap by establishing the level of adoption of the CSAPS and how the demographic, socio-economic, and institutional factors determine the adoption of Multiple CSAPS. The following objectives guided the study:

1. To establish the level of adoption of CSAPS among refugee farmers in Uganda;
2. To evaluate the demographic factors that influence the adoption of multiple CSAPS among refugee farmers in Uganda;
3. To establish the socio-economic factors that influence the adoption of multiple CSAPS among refugee farmers in Uganda; and
4. To establish the institutional factors that influence the adoption of multiple CSAPS among refugee farmers in Uganda.

Theoretical background.

The study is anchored on the expected maximum utility theory (Schoemaker, 1982). According to the theory, an individual's decision to adopt a given technology depends on whether the perceived benefits of that technology outweigh those of available alternatives (Ojo et al., 2023). In theory, the selection of adaptation strategies is influenced by farmers' anticipated utility from adapting to climate change and their socioeconomic circumstances (Schoemaker, 1982; Deresa et al., 2009; Ali, 2021). Implying a farmer will adopt a CSAP if the anticipated utility from adoption exceeds the utility of not adopting any strategy or that of previously utilized strategies (Kule et al., 2025). This utility-based decision-making framework provides insight into how farmers prioritize different adaptation strategies. In the context of this study, a refugee farmer is expected to adopt the promoted CSAP, like the use of hybrid seeds, crop rotation, cover cropping, mulching, irrigation, and judicious use of pesticides, if the perceived benefit from their adoption, such as increased yield or profitability exceeds that of other alternative practices. Based on the theory, a k th farmer maximizes utility U by taking up n th CSAP, which X_n predictor variables can influence. Thus, the farmer will adopt n th CSAP if $Y^*_{in} = U_{in}^* - U_o > 0$, indicating that the farmer obtains the benefits of adopting n th CSAP.

Climate Smart Agricultural Practices (CSAPS)

The adverse effect of climate change on food security and agricultural productivity has drawn interest among non-governmental organizations and research institutions to develop and promote climate-smart technologies and practices for farmers across the globe (Zakaria et al., [2020](#)). These initiatives are aimed at enhancing agricultural productivity, improving resilience, and reducing greenhouse gas emissions (Kifle et al., [2022](#)). These Climate Smart Agricultural Practices (CSAPS) provide strategies that help to transform and reorient agricultural systems towards sustainable development, ensuring food security and environmental preservation (Kassa & Abdi, [2022](#)). Different agricultural techniques, such as crop rotation, cover cropping, mulching, and terracing, are designed to establish resilient food production systems that support food and income security (Manono et al., [2025](#)). Improved or hybrid seed varieties are engineered to endure diverse climatic conditions, resist diseases, mature more rapidly, and yield more abundantly (Bist et al., [2025](#)). These seeds boost crop yields and farmer incomes, contributing positively to rural livelihoods. In Uganda, enhanced varieties include drought-resistant maize and rice, disease-resistant beans, and improved soybean and cassava, with certain varieties offering pest resistance. High-yielding, pest- and drought-resistant varieties of sorghum, sweet potatoes, plantains, and iron-rich beans are promoted among refugee populations (GIZ, [2020](#)). The adoption of these advanced seeds enhances resilience against pests and diseases and significantly reduces the time required for crop maturation (Midamba et al., [2024](#); Mnu kwa, [2025](#)). Saadu et al. ([2024](#)) and Alemayehu et al. ([2024](#)) found that adoption of improved seeds was at 45.88% and 50 %, respectively.

Crop rotation involves planting different crops sequentially in the same area to maintain soil health and reduce pest build-up (Al- Musawi, [2025](#)). By alternating crops such as cereals and legumes, crop rotation reduces the risk of complete crop failures, enhancing resilience to shifting climatic conditions (GIZ, [2020](#)). This practice improves soil structure, increases organic matter content, interrupts pest and weed life cycles, and enhances the soil's water and nutrient retention capacity (Pahraj, [2025](#)). Studies by Wacal et al. ([2024](#)) reported 72.4% adoption rate of crop rotation as a CSAP, much lower than 100% reported by Alemayehu et al. ([2024](#)). Implying differences in adoption rates of similar practices across varied geographic contexts. Planting grasses or legumes as cover crops alongside or between primary crops protects and enhances soil conditions (Sui et al., [2025](#)). Cover crops, particularly legumes, fix atmospheric nitrogen, improving soil fertility, preventing erosion, retaining moisture, and controlling weed growth (Quintarelli et al., [2022](#)). They also enhance soil structure by reducing nutrient depletion, erosion, and compaction (Çerçioğlu, [2025](#)). In Uganda, the implementation of cover crops such as velvet bean, jack bean, sun hemp, and pigeon pea are actively encouraged (GIZ, [2020](#)).

Mulching is an essential CSAP as it maintains soil moisture levels, boosts fertility, and reduces erosion (Mugisha et al., [2025](#)). It involves applying materials like leaves, straw, or plastic over the soil to conserve moisture, suppress weed growth, and enhance soil fertility (Masasi et al., [2025](#)). Furthermore, mulching aids in soil and water conservation during dry periods and increases organic content, thereby improving soil fertility (Mugisha et al., [2025](#); Masasi et al., [2025](#); El-Beltagi et al., [2022](#)). Pesticides consist of substances or combinations designed to minimise, eliminate, or mitigate the effects of various pests (Dong et al., [2023](#)). These chemicals manage a broad range of pests, including insects, weeds, fungi, and rodents, which can adversely affect crops, stored goods, and the health of humans and animals (Ahmad et al., [2024](#)). Employing pesticides reduces pest and disease accumulation in crops (Oirdi et al., [2024](#)). The use of

pesticides enhances food production, increases farmer profits, and aids in disease prevention (Dentzman et al., [2025](#)). Similarly, irrigation plays a crucial role in maintaining consistent soil moisture levels, particularly during dry spells, ensuring continuous crop growth and productivity. From the above literature, adoption levels of different CSAPS are varied.

Determinants of Climate Smart Agricultural Practices

The adoption of Climate Smart Agricultural Practices (CSAPs) is influenced by various factors based on literature. They are broadly categorized into demographic, socioeconomic, and institutional factors (Mogaka et al., [2021](#); Negera et al., [2022](#)). Each of these influence the adoption levels of various CSAPS in different ways.

Demographic Factors and the Adoption of Multiple CSAPS

Demographic elements such as age, gender, and education significantly impact the adoption of CSAPS. Research by Makate et al. ([2018](#)) shows a positive correlation between age and the adoption of CSAP. They argue that older farmers leverage their experience to anticipate climate change. Saadu et al. ([2024](#)), on the other hand, found a negative relationship between age and CSAP adoption in Nigeria, attributing resistance to change among older farmers to well-established routines and high-risk aversion. Education level is also crucial; educated farmers are more aware of modern, climate-smart practices, unlike those relying on traditional methods (Mashi et al., [2022](#); Tesema et al., [2018](#)). Gender plays a pivotal role, too, as male-headed households typically have more resources like land, facilitating CSAP adoption, whereas women-led households face financial constraints (Murray et al., [2016](#); Manono et al., [2025](#)).

H1: There is a relationship between demographic factors and the adoption of Climate-smart Agricultural Practices.

Socioeconomic Factors and the Adoption of Multiple CSAPS

Socioeconomic factors such as family size, household income, and farm size significantly influence CSAP adoption. Large families provide labor that can help increase farm productivity and generate additional income for CSAP implementation (Tadesse and Ahmad, [2023](#); Mogaka et al., [2021](#)). Smaller families, reliant on costly hired labor, find it challenging to adopt CSAPS (Ehiakpor et al., [2021](#)). Additionally, household income allows households to invest earnings into CSAP adoption, and larger farm sizes correlate positively with improved practices (Wasswa et al., [2024](#)).

H2: There is a relationship between socio-economic factors and the adoption of multiple CSAPS.

Institutional Factors and the Adoption of Multiple CSAPS

Institutional determinants, like market access, credit availability, and extension services, are critical for CSAP adoption. Membership in farmer associations enhances access to resources and knowledge necessary to adopt CSAPS (Saadu et al., [2024](#)). Farmers' participation in climate change trainings is also vital for influenced by extension support and involvement in farmer organizations (Zakaria et al., [2020](#)). Strengthening cooperative societies, enhancing credit access, and targeted training programs increase the adoption of CSAPS (Mbanasor et al., [2024](#)). Thus, the following hypothesis is tested to establish the relationship between institutional factors and the adoption of multiple CSAPS among refugee farmers in Uganda.

H3: There is a relationship between institutional factors and the adoption of multiple CSAPS.

Many studies have measured CSAP adoption as an index (Wordofa et al., [2021](#); Negera et al., [2022](#); Kifle et al., [2022](#)). This hinders a deeper understanding of the determinants associated with each CSAP. Secondly, scholarly efforts have extensively explored the determinants of the adoption of Multiple CSAPs in non-refugee contexts (Kule et al., [2025](#); Mugisha et al., 2025; Mnukwa et al., [2025](#)). However, studies on the same in refugee situations are scarce, which warrants the current study given the uniqueness of the context.

Research Methods and Design

The study used a cross-sectional survey design employing a quantitative approach. This allows for data to be collected and analyzed in numerical form at one point in time (Ntsoane et al., 20250). This design helps to establish associations between certain variables of interest and an outcome variable at one point in time without the need for long-term follow-up (Rana et al., [2021](#); Wang and Cheng, [2020](#)). This design is found to be appropriate for the current study to evaluate how demographic, socio-economic, and institutional factors determine the adoption of multiple CSAPS. The population of refugee maize farmers remains unknown due to a lack of records in West Nile. The study purposively focuses on maize farmers because maize is one of the key staple crops of the refugees in the region, which is grown by most of the refugee farmers (UBOS, [2016](#)). Further, it is critical for food security and income in Uganda as households produce it for both household consumption and sale (Osewe et al., [2023](#)). Thus, the study employed Cochran's formula (Cochran, [1963](#)) for sample size determination for an infinite population. Using 95% confidence level, the estimated proportion of farmers who adopted multiple sustainable agricultural practices is assumed to be 0.5 since we did not know the variability, so we chose the maximum variability, and of those who did not adopt is $1-0.5=0.5$, and the margin of error is $e=0.05$. We use the formula $no=Z^2pq/e^2 = 1.96^2*0.5*0.5/0.05^2= 0.9604 /0.0025=384.16$. Small sample correction $=n=no/1+(no-1)/N$. We assumed the number of refugee maize farmers in Madi-Okollo is based on records of Palm Corps, a non-governmental organization, 1100. $N=384.16/1+(384.16-1)/1100=384.16/1.35=285$. A total of 285 questionnaires were sent out, of which 202 were returned. This represented 71% response rate, which is sufficient (Goyder, [1985](#)).

Multi stage sampling approach is used for the study. First, purposive sampling was employed to select refugee hosting district and the refugee settlement where the study is to be conducted. The choice of the purposive sampling technique is based on Memon et al. ([2025](#)), who state that the sampling technique is commonly used because it enables specific targeting of people meeting the criteria for the study. Consequently, the Madi-Okollo district and Rhino Camp refugee settlement from West Nile were chosen for the study. This is because the settlement is known for having poor soils and receiving erratic rainfall (Kamugasha *et al.*, [2024](#)). Further, the settlement is one of the oldest that has received more support for the agricultural sector, as well as in the promotion of CSAPS for enhanced productivity. Cluster sampling is employed to select the respondents. The settlements are clustered into zones from which maize farmers were selected using simple random sampling.

A structured questionnaire was utilized to collect data. Questions were carefully crafted based on the review of existing literature on the variables considered in the study. Enumerators were carefully chosen, trained in data collection procedures, and on the important ethical considerations. Clearance was obtained from the Office of the Prime Minister's Desk Office and

the United Nations High Commission for Refugees' sub-office in Arua City. The team conducted a pilot survey of 25 randomly selected refugee maize farmers. This was aimed at ensuring the questions are clear, reliable, and aligned with the research objectives. Based on the pilot, identified gaps were revised, and the questions refined. The refined questionnaire was then deployed in the Kobo tool, which the enumerators used to collect the data from the sampled farmers.

Data analysis in this study utilized a blend of descriptive statistics and econometric modelling to examine the adoption rates and the determinants of adoption of the individual CSAPS. Using STATA 18, descriptive statistics on the rate of adoption of each CSAP considered in this study, and the determinants of the adoption of specific CSAPS were modelled using multivariate Probit regression analysis. The Multivariate probit model is a statistical approach used for modelling situations where there are multiple interrelated binary or ordinal outcomes (Chib & Greenberg, 1998). It is particularly suitable for studying the adoption of climate-smart agricultural practices due to its ability to handle multiple interrelated binary outcomes. By accurately representing the complexities and simultaneous nature of these adoption decisions, the Multivariate Probit Model provides valuable insights into the factors influencing farmers' choices and the interactions between different climate-smart strategies. In theory, the selection of adaptation strategies is influenced by farmers' anticipated utility from adapting to climate change and their socioeconomic circumstances (Schoemaker, 1982; Deresa et al., 2009; Ali, 2021). A farmer will adopt a CSAP if the anticipated utility from adoption exceeds the utility of not adopting any strategy. This utility-based decision-making framework provides insight into how farmers prioritize different adaptation strategies.

Descriptive statistics using frequency and percentages were used to establish the adoption rate of the individual CSAPS. While the Multivariate Probit regression analysis was used to establish the effect of the various factors on the adoption of multiple CSAPs in the study, given by the equation; $R_{ij} = X'_{ij} \delta_j + \tau_{ij}$. X_{ij} denotes the vector of exogenous predictors that could influence farmers' adoption of a particular farming practice, δ are the regression coefficients, and τ_{ij} stands for the error term. The following variables were considered as the exogenous predictors of the adoption of specific CSAP in the study: Several scholars including Kule et al. 2025; Mnutwa et al., 2025 and Midamba et al. 2024 have measured the factors influencing adoption as follows; Demographic factors- gender 1=male,0=female, age in yrs, education in years of farming experience in yrs), socioeconomic factors- household size measured in numbers, farm size in acres, household income in Ugx, off farm income in Ugx, assets in Ugx and institutional factors- access to credit 1=yes, 0=no, access to market information 1=yes,0=no, access to extension services 1=yes,0=no

Results and Discussion

The rate of adoption of various CSAPS

The table below shows the results of the adoption rates of the six (6) most commonly promoted CSAPS among refugee farmers in Uganda. The results in [Table 1](#) show the adoption rates of climate-smart agricultural practices (CSAPS) among maize farmers within refugee communities. The adoption of hybrid seeds stands as the most prominent agricultural practice, with an impressive adoption rate of 51%. This figure surpasses the 45.88% and 50% adoption rates

reported by Saadu et al. (2024) and Alemayehu et al. (2024), respectively. This significant percentage underscores a marked preference for hybrid seeds, indicative of their capacity to significantly enhance agricultural productivity. The elevated adoption rates can be attributed to the superior yield potential of hybrid seeds compared to traditional varieties, which is particularly advantageous in resource-constrained settings such as those encountered by refugee farmers. Furthermore, the adoption of hybrid seeds among refugees is likely facilitated by the concerted efforts of development actors who establish vital connections between refugee farmers and agro-input dealers. This institutional support is crucial in surmounting supply chain barriers, thereby enhancing accessibility to high-quality seeds. The collaboration effectively addresses challenges related to the availability and affordability of hybrid seeds, promoting their wider dissemination within the refugee farming community.

In contrast, crop rotation exhibits a notable application rate of 42%, indicating a recognition among farmers of the value of crop diversity in preserving soil health and fertility. However, this rate remains lower compared to adoption levels in non-refugee contexts, as reported by Alemayehu et al. (2024) and Saadu et al. (2024), who observed adoption rates of 50% and 100%, respectively. Additionally, Wacal et al. (2024) reported a 72.4% adoption rate for crop rotation among non-refugee sesame farmers in northern Uganda, further emphasizing the gap in adoption within refugee communities. Cover crops are employed by 30% of respondents, reflecting an increasing awareness of their benefits, such as soil erosion prevention, improved nutrient management, and enhanced biodiversity. This rate, however, remains below the 45% usage of cover crops observed by Saadu et al. (2024). Meanwhile, pesticides are utilized by 24% of respondents, indicating a substantial reliance on chemical means for pest management. While this highlights ongoing challenges related to pest pressures on crop health and yield, it also suggests an opportunity for the development of alternative pest management strategies that align with ecological sustainability goals. Mulching, with an adoption rate of 9%, is notably less common despite its acknowledged benefits in moisture retention, soil temperature regulation, and weed suppression. The low adoption rate may be attributable to the additional labor or material costs associated with mulching, underscoring a need for enhanced education and support to encourage its wider use.

Finally, irrigation, utilized by only 5% of respondents, reflects the limited prevalence of this resource-intensive practice. This low percentage likely stems from constraints such as water availability or a prevailing emphasis on rain-fed agriculture. The findings reveal potential areas for innovation in sustainable irrigation techniques that optimize water consumption while maintaining crop productivity.

Table 1: Adoption Rate of Specific CSAPS

CSAPS	Frequency (F)	Percentages (%)
Use of hybrid seeds	104	51
Use of irrigation	10	5
Crop rotation	84	42
Use of cover crops	60	30
Use of mulching	19	9
Use of pesticides	48	24

Test for multicollinearity

Multicollinearity among the independent variables was tested using the Variance Inflation Factors (VIFs). From the [Table 2](#) above, the VIF values indicate the absence of multicollinearity. This is because the minimum values are not less than one, and the maximum is less than 10 (De Jongh et al., 2015).

Table 2. Multicollinearity test.

Independent variables	VIF	1/VIF
Age group	2.50	0.40
Education	2.32	0.43
Household size	2.18	0.46
Years of experience	2.01	0.50
Gender	1.98	0.51
Farm size	1.81	0.55
Off-farm income	1.69	0.59
Household income	1.53	0.65
Credit access	1.34	0.75
Farmer field school membership	1.25	0.8
Access to extension services	1.19	0.84
Access to market information	1.13	0.89
Mean VIF	1.74	

VIF: Variance Inflation Factor

Test for correlation between the binary dependent variables

Several techniques can be used to establish the determinants of the adoption of agricultural technologies. These are dependent on whether there exist complementarities between the technologies considered in the study. Legesse et al. (2024) propose that the correlations among the binary dependent variables in the study should be established before proceeding with any given estimation method. Therefore, correlation analysis was undertaken to assess whether there were any significant relationships among the various CSAPS (CSAP1=HYBRID SEEDS, CSAP2=IRRIGATION USE, CSAP3=CROP ROTATION, CSAP4=USE OF COVER CROP, CSAP5=MULCHING, CSAP6=USE OF PESTICIDES) considered in the study, as detailed in [Table 3](#). [Table 3](#) indicates that there are some significant correlations among the CSAPS considered in this study. Hybrid seeds and irrigation use have a significant positive relationship

($p < 0.001$). Hybrid seeds and the use of pesticides have a significant positive correlation ($p < 0.05$). Irrigation and Mulching have a significant positive relationship ($p < 0.05$). Further, the use of cover crops has a significant negative correlation with the use of pesticides ($p < 0.05$). The significant association among CSAPS justifies the use of MVP in the analysis (Legesse et al., 2024).

Table 3: Test for correlation between the binary dependent variables (CSAPS)

CSAPS	CSAP1	CSAP2	CSAP3	CSAP4	CSAP5	CSAP6
CSAP1	1					
CSAP2	0.147***	1				
CSAP3	0.20	0.23	1			
CSAP4	0.051	-0.14	0.30	1		
CSAP5	0.042	0.056**	0.051	0.026	1	
CSAP6	0.27**	0.168	0.019	0.015**	0.068	1

Note. *** and ** denote statistical significance at the 1% and 5% levels, respectively.

Determinants of the adoption of climate-smart agricultural practices (CSAPS)

Several demographics, socioeconomic, and institutional factors were regressed on the specific CSAPS to ascertain the significant predictors of the adoption of these CSAPS (CSAP1=HYBRID SEEDS, CSAP2=IRRIGATION USE, CSAP3=CROP ROTATION, CSAP4=USE OF COVER CROP, CSAP5=MULCHING, CSAP6=USE OF PESTICIDES) as shown in Table 4. Table 4 presents information on the goodness of fit of the Probit model, the various demographic, socioeconomic, and institutional factors influencing the adoption of specific CSAPS. The Likelihood Ratio (LR) Chi-squared statistic, with a value of 59.00 and 11 degrees of freedom, tests whether all model coefficients are zero. This indicates a strong model fit, showing significant correlations between predictors and the dependent variable. The Pseudo R-squared value of 49.1% suggests that 49.1% of the variance in the dependent variable is explained by the predictors. Although generally lower in probit models, this value still denotes a satisfactory fit. The log-likelihood ratio is -11.3, and less negative values typically represent better model fit. The Prob>Chi2 value of 0.002 implies statistical significance, confirming meaningful predictor-outcome associations. Overall, the model aligns well with the data, indicating key associations between certain predictors and the adoption of agricultural practices. This understanding aids policymakers, educators, and agricultural stakeholders in enhancing productivity and sustainability.

The analysis using the Multivariate Probit model highlights significant findings regarding the determinants of Climate-Smart Agricultural Practices (CSAP) adoption, aligning with the broader literature on socioeconomic and institutional influences. The absence of significant demographic factors in determining CSAP adoption is noteworthy, diverging from studies by Saadu et al. (2024), Makate et al. (2018), and others. This contradiction may suggest that demographic influences take a backseat to more pressing economic and institutional factors for these communities. Socio-economic aspects, such as household and farm size, had a marked impact on the adoption of various CSAPs, corroborating studies like Wasswa et al. (2024) and Ehiakpor et al. (2021). Larger farms have more resources for diverse agricultural methods, while smaller household sizes might face fewer economic constraints, indicating a nuanced relationship between these variables and agricultural decisions.

Institutional factors, specifically credit access, market information, and extension support, were pivotal in promoting CSAP adoption, as supported by Zakaria et al. (2020) and Mbanasor et al.

(2024). Credit availability and market insights are critical, providing farmers with the means and motivation to pursue innovative techniques. Financial access allows for investing in new technologies, while market information guides farmers toward profitable practices. The results of this study illustrate several key determinants affecting the adoption of various Climate-Smart Agricultural Practices (CSAPs), highlighting both expected outcomes and areas of divergence from previous literature. Household size emerged as a significant factor influencing the adoption of cover crops, with a negative coefficient (-0.338, $p = 0.015$). This suggests that larger households might have constraints, such as labor availability or resource allocation, which hinder the adoption of cover crops. This finding aligns with the works of Mugisha et al. (2025) and Zakaria et al. (2020), corroborating the assumption that household dynamics influence adoption decisions. Conversely, farm size exhibited a positive impact (0.227, $p = 0.050$) on the adoption of cover crops. Larger farms are likely to have more resources and a greater capacity to experiment with or embrace new practices such as cover cropping. This could be due to economies of scale, where larger farms can spread the cost of adoption over a more extensive area, thereby reducing per-unit costs.

Extension support stands out as a robust promoter of cover crop adoption (0.716, $p = 0.012$). Extension services provide farmers with critical information, technical assistance, and encouragement, fostering an environment conducive to the uptake of sustainable practices. The significant role of extension support is further confirmed by the existing literature. The analysis also highlights the importance of access to credit and market opportunities in motivating the use of hybrid seeds. Credit access (0.459, $p = 0.0523$) and market access (0.406, $p = 0.096$) reveal significant positive impacts on adoption rates. These elements are crucial as they provide farmers with the necessary financial resources and market incentives to invest in hybrid seeds, which typically involve higher costs but promise increased yields. The insights align well with the notion that financial and market conditions are pivotal in agricultural decision-making processes. Interestingly, the study found that irrigation, crop rotation, and mulching did not show significant determinants within the study parameters. These findings challenge earlier studies, such as those by Alemayehu et al. (2024) and Mugisha et al. (2025), which identified various determinants like credit availability, education level, and extension services as influential. This discrepancy suggests that there might be other unexplored factors or regional differences that merit further investigation. The use of pesticides, another crucial CSAP, is shown to be significantly affected by household size (-0.393, $p = 0.009$) and access to extension services (0.798, $p = 0.024$). These results support Zakaria et al. (2020) and emphasize the complex interrelationships between household demographics, external support, and agricultural practice adoption.

Table 4: Results of the Multivariate Probit model on the Determinants of adoption of specific CSAPS.

Variables	CSAP1	CSAP2	CSAP3	CSAP4	CSAP5	CSAP6
	0.158	-0.125	-0.168	-0.118	0.101	-0.366
Sex	(0.525)	(0.593)	(0.484)	(0.635)	(0.753)	(0.251)
	-0.048	-0.064	-0.060	0.253	0.049	0.016
Age group	(0.574)	(0.424)	(0.461)	(0.104)	(0.653)	(0.891)
	0.447	0.027	-0.011	-0.309	0.362	0.446
Education level	(0.113)	(0.870)	(0.947)	(0.118)	(0.194)	(0.253)
Years of experience	-0.009	-0.113	-0.031	-0.239	-0.159	-0.244
	(0.949)	(0.386)	(0.818)	(0.290)	(0.321)	(0.1340)
	0.064	0.142	-0.039	-0.338**	0.132	-0.393***
Household size	(0.617)	(0.240)	(0.753)	(0.015)	(0.422)	(0.009)
	0.203	-0.014	0.400	0.277**	-0.265	0.120
Farm size	(0.154)	(0.916)	(0.103)	(0.050)	(0.163)	(0.484)
Household income(log)	0.176	-0.008	0.056	-0.054	-0.001	0.093
	(0.1080)	(0.931)	(0.569)	(0.613)	(0.993)	(0.449)
Off-farm income(log)	0.099	0.026	0.095	-0.055	0.054	0.065
	(0.325)	(0.782)	(0.326)	(0.622)	(0.671)	(0.598)
	0.459*	-0.312	-0.211	0.039	-0.269	-0.496
Credit access	(0.0523)	(0.188)	(0.396)	(0.876)	(0.430)	(0.149)
Farmer field school membership	-0.023	-0.399	0.391	-0.025	0.091	0.501
	(0.920)	(0.165)	(0.187)	(0.920)	(0.767)	(0.294)
Access to extension services	-0.082	0.341	-0.454	0.716**	0.191	0.798**
	(0.713)	(0.107)	(0.138)	(0.012)	(0.513)	(0.024)
Access to market information	0.4058*	-0.059	0.212	-0.074	0.189	0.478
	(0.096)	(0.796)	(0.376)	(0.775)	(0.566)	(0.206)
	-1.814	0.246	-1.172	0.184	-2.248	-1.653
cons	(0.005)	(0.687)	(0.075)	(0.788)	(0.007)	(0.057)

LR Chi2 (11) = 59.00, Pseudo R2 = 0.491%, Log-likelihood ratio=- 11.3, Prob>Chi2 =0.002, N=202. *, **, and *** represent the statistical significance at 10, 5, and 1%, respectively, and standard errors in parentheses.

Policy, Practical Theoretical Implications

The analysis underscores the critical role of institutional factors, specifically credit access, market information, and extension services, as well as Socio-economic factors like household size and farm size, in the adoption of Climate-Smart Agricultural Practices (CSAPS). Governments and non-governmental organizations should focus on implementing targeted support systems that ensure well-coordinated institutional support across actors, while implementing targeted interventions for varying household and farm sizes. Policies should be designed to account for the varying household and farm sizes. For instance, for larger farms, policies could focus on facilitating access to resources and technologies that enable the expansion of climate-smart practices for larger farms. Incentives such as subsidies or grants can alleviate financial constraints, and help smaller farms to adopt CSAPS like cover crops and integrated pest management. Future research could employ a qualitative approach to delve deeper into the aspects where certain

CSAPS, like crop rotation, mulching, and irrigation, did not have significant determinants. provide a nuanced understanding, paving the way for tailored interventions. Further, conducting comparative studies across various regions is crucial for understanding the adoption and determinants of these CSAPs. Exploring how these factors affect the adoption of CSAPs among refugee populations across different regions can offer clear guidance for future studies. Further, conducting a multi-disciplinary approach to the study may uncover many useful insights.

Conclusion

In conclusion, the adoption levels of the different promoted CSAPS vary among the refugee population. Most of them are much lower than rates found in non-refugee contexts. Whereas demographic factors have had no significant influence on the adoption of CSAPS in this context, socio-economic and institutional factors significantly influenced the level of adoption. The influence varies across the various CSAPS. The varying effects highlight the need for tailored initiatives. Policymakers and stakeholders should focus on customizing strategies that account for regional, cultural, and individual differences. While the study effectively captures many dynamics, it identifies a gap in determinants for practices like irrigation and mulching, suggesting areas for further investigation into aspects such as water availability and cultural influences. Therefore, prioritising the strengthening of institutional support, particularly in credit access, information dissemination, and varying strategies tailored to varying farm sizes. The insights from this study offer a guiding framework for governments, NGOs, and researchers to enhance the adoption of CSPAS through focused adaptive policy interventions, ultimately improving the adoption rates of CSAPS in refugee communities.

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