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RESEARCH ARTICLE

Rice farmers' adoption of climate-smart agricultural technologies and its effects on yield and income: empirical insights from Ghana

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Abstract

Rice stands as a popular staple in Ghana, crucial to both sustenance and livelihoods for many. However, the nexus of climate change and other factors has inflicted a decline in rice yields. The study was undertaken to investigate rice farmers' perceptions and adoption of Climate-Smart Agricultural (CSA) technologies in Ghana. Using a cross-sectional survey, 319 rice farmers in the Central Region were selected through the multistage sampling method. Descriptive and inferential statistics were used to analyze the data. The results indicate that rice farmers have a positive perception of CSA technologies, associating them with increased income and improved production. Key CSA technologies commonly used by rice farmers were planting improved varieties, proper fertilizer usage, and nursery management. The determinants of CSA adoption were farming experience, farm size, extension access, secondary occupation, and farmer group membership. Education, farming experience, household size, farmer group membership, and the use of integrated pest management significantly affect income. Gender, household size, farm size, secondary occupation, and crop diversification emerged as the determinants of rice yield. However, their adoption is hindered by the high cost of agricultural inputs and land insufficiency. The government should strengthen weather monitoring systems and provide easy access to accurate and up-to-date weather forecasts for farmers. There should be increased investment in agricultural extension services to educate farmers on the use of climate-smart technologies. This study enriches global climate change literature through empirical grounding, local contextualization, and practical insights, fostering climate-smart agriculture adoption among rice farmers.

Keywords: Adopter perception theory; Climate change; Conservation Agriculture; Drought; Economic constraint theory.

1. Introduction

Recently, the concern about climate change has been regarded as a factor in food production. Changes in the weather are referred to as climate change can be detected by variations in the compositions of the atmosphere that last for decades or longer, typically (Intergovernmental Panel on Climate Change (IPCC), 2014). Agriculture is impacted by climate change, notably because it results in lower precipitation and higher temperatures, both of which have a detrimental impact on agricultural productivity (Kolleh and Jones, 2018). Crop productivity and the kinds of crops that can be cultivated in particular locations can be affected by the influence of climate change on agricultural inputs including the quantity of plant's exposure to solar radiation for development, how often pests are present and for irrigation (Yakubu *et al.*, 2021). Rice is a significant food crop in Sub-Saharan

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Africa because it serves as an important source of calories in meals for the region's occupants (Macauley and Ramadjita, 2015). External forces, including temperature and precipitation, influence agricultural output and have a substantial influence on the production of rice (Onyegbula and Oladeji, 2017). Consequently, Ghanaian farmers employ various cultivation systems including rice grown using irrigation, rain-fed lowland, and rain-fed upland. Due to years of severe drought, the nation's rice growing has decreased (Kolleh and Jones, 2018). As rice is extremely susceptible to soil, environmental, and climatic factors, rice production is expected to plummet from 2020 to 2080 due to the anticipated rise in temperature and fall in precipitation, as predicted by Kolleh and Jones (2018). The severity of weather conditions will determine the output of rice production (Kolleh and Jones, 2018; Onyeneke, 2021). The consequences of climatic change comprise a prolonged dry season, higher temperatures, an unpredictable pattern and distribution of rainfall, a late start to rain, and an early end to the rain, which have negatively impacted the production of rice over time.

To lessen the implications of climate change on agriculture, the promotion of climate-smart technology in the form of climate-smart farming has been advanced (Zakaria *et al.*, 2020). Diverse agricultural smart technologies, practices, or strategies, including irrigation, planting enhanced varieties, water and soil safeguarding techniques, reliance on climatic data and predictions, proper use of fertilizer, insurance, and effective and efficient usage of pesticides, among others, have been introduced to rice growers to alleviate and reduce the incidence of climatic change effects in growing it (Onyeneke, 2021; Kolleh and Jones, 2018). To educate and enhance farmers' abilities, GIZ and the Ministry of Food and Agriculture (MoFA) are collaborating in various regions to impart knowledge of composting, usage of dryness-resistant crops, collecting water, growing trees, and access to data on the atmosphere (Anuga and Gordon, 2016). Climate-smart agriculture (CSA) prioritizes the creation of robust food manufacturing processes that can ensure food as well as financial stability in response to growing climatic change and unpredictability (Lipper *et al.*, 2014). CSA's general strategies include location-specific innovative services, methods, and tools (International Center for Tropical Agriculture (CIAT), 2014). Palanisami *et al.* (2009) opined that despite the potential benefits of climate-smart agricultural technologies, farmers' adoption rate is relatively low. This is due to certain farmer traits such as the ecological surroundings of a specific place, and traits of new techniques (Olive and David, 2021). Furthermore, regardless of the growth of these agricultural smart technologies, Ghana has paid little to no attention to how rice farmers perceive these climate-smart technologies, and virtually no research has been done in the research areas to look into how rice farmers see climate-smart technologies. To decide what kinds of strategies or technologies and management styles they have to embrace in their effort to decrease the negative effects brought by the changes in climate, it is essential to comprehend growers' views of climate change, particularly climate smart technology among rice growers (Mairura *et al.*, 2021). Converting rice farmers' impressions of climate-smart technologies into speedy, effective activities is also necessary to deal with climate change concerns (Onyeneke, 2021).

Supported by the adopter perception theory, economic constraint theory and diffusion-innovation theory, researchers believe it offers some explanation for the adoption of CSA technologies by rice growers. According to the adopter perception theory, the use of agricultural technology depends on people's perception of its advantages (Senyolo *et al.*, 2018). The economic constraint theory contends that although patterns of adoption are asymmetrically distributed among farmers, people aim to maximise their profit or utility (Ngwira *et al.*, 2014). The diffusion-innovation theory emphasises knowledge, information, and communication as contributors to social or personal disparities (Rogers, 2003). Numerous research on climate change all over the world has been conducted. In terms of perceptions and adoption, Fosu-Mensah *et al.*, (2012) carried out a study on the views and responses of farmers to climate change in Sekyedumase, Ghana. The findings revealed that while 92% of the participants thought that temperatures had risen, only 87% were convinced that there had been a decline in rainfall. Despite widespread awareness of climate challenges in the farming community, only 44.4% of farmers have adapted their practices to mitigate the effects of rising temperatures and 40.6% of declining precipitation. Abid *et al.* (2015) found in their investigation of farmers' attitudes and responses to climate change, that there was a widespread apprehension of climate change and an adaptation of farming practices accordingly. Debela *et al.* (2018) investigated the views of smallholders in the Borana region of southern Ethiopia on climate change and its effects, focusing on pastoral and agro-pastoral systems. The results indicated that most respondents viewed climate change as detrimental to agriculture and a significant threat to their economic and personal well-being. Gadédjisso-Tossou (2015) carried out a study in Togo's Maritime, Plateau, and Savannah Regions to gain an understanding of growers' perspectives on climate change and fluctuations. The outcomes of the research revealed that the farmers noticed a rise in warmth and a drop in rainfall. These observations, particularly about temperature, correlated with the climatic data trend analysis in the research area. Adeoti *et al.*, (2016) performed a study in Kwara State to explore the opinions, susceptibility, and actions of farmers towards climate change. The research utilized descriptive statistics and the MNL (Mixed Logit Model) method.

Several other factors, including technology, wealth, skills, information, infrastructure, equity and institutions, shape individual adjustments to the ramifications of climate change. By using Heckman probit and MNL models, Ng'ang'a *et al* (2016) conducted a study on how rural Ethiopians in the Lake Tana Sub-basin perceive and respond to climate change. It was discovered that variables like marital status, farm size, access to climate change knowledge, and income generation level were statistically and significantly connected to farmers' opinions of climate change. Gadédjisso-Tossou (2015) found that characteristics including education level, agricultural experience, exposure to extension personnel, financing availability and exposure to climate information enhanced farmers' capacity to adapt to climate change and unpredictability. Ng'ang'a *et al.* (2016) indicated that factors such as education, age, financial standing, access to agricultural extension personnel, and proximity to medical facilities significantly influence their adaptation to climate change. Adeoti *et al.* (2016) revealed that a household head's educational background, farming expertise, land ownership, and fluctuations in temperature and rainfall greatly impacted farmers' adaptation decisions.

In terms of the constraints and benefits, De Pinto *et al.* (2020) highlighted the global potential benefits of Conservation Agriculture (CA) practices, including efficient agricultural practices aimed at improving crop yields including integrated soil fertility management, no-tillage, adjusted drying and wetting techniques, and enhanced application of nitrogen. Furthermore, CSA technology can considerably reduce the amount of labour that is required by women in farming (Khatri-Chhetri *et al.*, 2019). Lan *et al.* (2018) showed a significant range of farm earnings with CSA practices across different scales, emphasizing that comparable methods can yield varying financial output based on the specific context. The creation of extension services, agricultural policy, and geographically suitable interventions is facilitated by an understanding of the limitations and local knowledge of CSA practices (Aryal *et al.*, 2018). Findings from Kenya demonstrate that domestically motivated adaption rewards also reduce the cost of implementation (Chaudhury *et al.*, 2016). It was discovered that the linkages between information about farming and land management methods amongst growers and government authorities are not explicitly characterised in the recent CSA literature, despite the significance of domestic know-how in developing viable climate-smart solutions. Many of the climate change adaption strategies are only available to farmers with spare land resources or investment capital, and if this is not taken into account, potential action may harm disadvantaged farmers (Clay and King, 2019).

Climate change poses a significant threat to agricultural productivity, particularly impacting rice cultivation in Ghana. Ghanaian farmers, especially those cultivating rice, face multiple challenges due to climate change, including prolonged dry seasons, higher temperatures, unpredictable rainfall patterns, and severe weather conditions. To address these challenges, various CSA technologies have been introduced, encompassing irrigation, planting improved varieties, water and soil conservation, reliance on climatic data, and efficient use of fertilizers and pesticides. However, understanding how rice farmers perceive and adopt these technologies is crucial for effective implementation. Although there is extensive global research on perceptions and adaptations to climate change as discussed previously, little attention has been paid to how rice farmers in Ghana perceive and adopt CSA technologies. The study aims to fill this research gap by investigating the perceptions and adoption of CSA technologies among rice farmers in the Assin Central, North, and South Districts of the Central Region. Specifically, the study sought to: (i) determine the CSA technologies currently utilized by rice growers; (ii) examine the perceptions of rice farmers regarding the use of CSA technologies; (iii) identify the influencing factors affecting rice growers' yield, income, and adoption of CSA technologies; and (iv) determine the constraints faced by rice farmers in the use of CSA technologies. By addressing these objectives, the study aims to provide valuable insights into the challenges and opportunities associated with the adoption of CSA technologies among rice farmers in the Central Region of Ghana. The findings contribute to the development of targeted strategies and policies to enhance the adoption of climate-smart farming practices, ensuring the sustainability and resilience of rice production in the face of climate change.

2. Materials and Methods

The Assin North District is situated in the north of the Ashanti Region. It is surrounded by the Adansi South District to the north, the Assin Foso Municipal to the south, the Birim South District in the Eastern Region to the east, and the Twifo Atti-Morkwa District to the west. It encompasses a total area of 750 square kilometres and is comprised of 260 communities, including the capital of Assin Breku, as well as Assin Akonfudi, Assin Praso, and Assin Kushea. The Assin Central district's capital city is Assin Fosu, which is situated on the northwest side of the Central Region. Assin South has Nsuaem-Kyekyewere serving as its administrative centre, it is situated in the Central Region's northwest. The total land area of the district is 1100, 89650 square kilometres. The Assin South District, situated at longitude 10 2" W and latitude 50 30" N, is the biggest in the Central Region. According to the 2021 Census, the district has 105,995 people, with a breakdown of 52,083 men and 53,912 women. (GSS, 2021).

Research Design serves as the blueprint of research. The study utilized a cross-sectional survey strategy. In utilizing the cross-sectional survey design, the quantitative research approach was adopted. In a quantitative study, numerical data are gathered to make generalizations about a situation. The research included all rice farmers in the Assin North, Assin South and Assin Central Districts. There are a total of 1,156 rice farmers in the three selected districts. In selecting the sample, Yamane's formula was used. Thus, $n = \frac{N}{1+N(0.05^2)}$. Where; n is the sample size being determined, (0.05) is the 5% error margin, and N is the target populace (1,156). Therefore, the study covered a sample size of 319 rice farmers. The multi-stage sampling method was used to choose the sampled units for this investigation. The first stage of the sampling process involved purposefully selecting three districts in the Central Region. These districts were chosen purposively because they are the primary rice-producing districts in the Central Region (Rice production increases in Central Region - MoFA | Ghana News Agency). In the second stage, four communities were randomly selected from each of the three districts using a simple random sampling method. Subsequently, respondents were randomly chosen from each community using proportion-to-size sampling. A structured questionnaire was employed to gather data for this study. Three research assistants were engaged to assist with the data collection. To adequately achieve the objectives of this study, the researcher relied on primary data. Data collection took place between April and June 2022. Statistical Package for Social Sciences (SPSS) version 20 was used to analyze the data after it had been cleaned and checked for consistency.

Descriptive statistics were used to determine the climate-smart technologies being used or adopted by rice farmers in the study area. "Use" in this study was measured by a three-point Likert scale: 1= Never; 2= Sometimes; 3= Always. An adoption index (mean) was calculated for each respondent and used as the basis for the dependent variable used in the Ordinary Least Squares (OLS). A three-point Likert scale was employed to measure rice farmers' perceptions of the adoption of climate-smart technology. In using this scale, the respondents were asked to rate their perceptions; where 3 means Agree; 2 means Neutral; and 1 means Disagree. The factors influencing rice farmers' adoption of climate-smart rice production technologies were analyzed using the OLS regression model. OLS is a method used to estimate the parameters of a linear regression model. The OLS finds the line of best fit that minimizes the difference between the actual values of the dependent variable and the predicted values from the linear model. This is done by calculating the residuals, which are the differences between the observed values and the predicted values, and then finding the values of β that minimize the sum of the squared residuals. The resulting model can be used to predict the value of the dependent variable based on the values of the independent variables. The OLS equation can be written mathematically as:

$$Y = \beta_0 + \beta_1 X_1 + ... + \beta_n X_n$$

Where Y represents the dependent variable, Xs are independent variables, and β represents coefficients for each predictor variable. The yield was calculated as yield per acre (productivity) while the income of rice farmers was measured using net income from their rice farm only. Kendall's Coefficient of Concordance was used to assess the constraints rice farmers face in using climate-smart technologies. The formula is:

$$W = \frac{12(\sum D^2)}{m^2(N)(N^2-1)};$$

where D = R-A

$$A = \frac{\sum R}{n}$$

3. Results and discussion

3.1. Socioeconomic Characteristics of Rice Farmers

Table 1 describes the socioeconomic characteristics of the farmers. The results show that the majority (54%) of the rice farmers in the study area were males. The dominance of males in rice production is expected as has been reported by Appiah and Guodaar (2022). According to the study, the majority of the farmers (89%) belonged to farmer groups. Farmer groups are crucial distribution points for information and technology to farmers. For example, Debela *et al.* (2018) opine that farmers' cooperatives enhanced the income and productivity of smallholder farmers. Table 1 also shows that 57% of the rice farmers were farm owners while 43% were either caretakers, leased farmers or sharecroppers. The majority (90%) of the farmers had access to extension services. Despite the high percentage of group membership, 94% of farmers lacked access to financing. This is not surprising considering that the majority of farmer groups in Ghana are created for specific projects and commercial objectives, rather than with credit as their primary emphasis. In the particular example of rice farmers, organizations are set up to facilitate the government's discounted input supply through agro-input dealers.

Respondents' average number of years of formal education was 6 years. This implies that almost all the farmers can receive, comprehend and utilise information to make informed decisions about the use of CSA technologies for rice production. Table 1 also reveals that a respondent has, on average, been involved in rice farming for 10 years. The average number of people in a farmer's household was 5. The respondents' average annual production was 22 bags of rice per acre. Overall, respondents profit from their work in rice cultivation on average by GH 9586 every year.

Table 1. Socioeconomic Characteristics of Rice Farmers

Socioeconomic characteristics	Frequency	Percent (%)
Sex		
Female	147	46.10
Male	172	53.90
Land tenure		
Others (lease, caretaker, sharecropping)	138	43.30
Own land	181	56.70
Access to credit		
No	299	93.70
Yes	20	6.30
Access to extension		
No	31	9.70
Yes	288	90.30
Secondary occupation		
No	141	44.20
Yes	178	55.80
Membership in farmer group		
No	36	11.30
Yes	283	88.70
Continuous Variable	Mean	Std. Dev.
Years of education	6.42	4.15
Yield per acre	22.93	12.44
Farming experience (years)	9.50	6.52
Farm size (acre)	2.97	2.03
Household size	5.43	2.81
Income (GHC)	9585.54	20910.79

Source: *Field Survey,2022*

3.2. Perception of Rice Farmers on the Use of CSA Technologies

Farmers' perception of CSA technologies is important for their adoption. Respondents were asked about their perception of the use of CSA technologies over the last 5 years. Table 2 presents rice farmers' perceptions of CSA technologies in the study area. From the results, the statements with the highest mean were "CSA technologies seem to be practised by other farmers" and "CSA technologies have increased my income" (Mean= 2.77). This was followed by

"CSA technologies have improved my production" and "CSA technologies have improved my soil fertility and moisture" (Mean=2.76). This implies that farmers have experienced a substantial increase in their yield and subsequently in their income. Thus, rice farmers attributed improved soil fertility, increased yields and income to the adoption of CSA technologies. The results agree with Murage *et al.* (2015) who posit that farmers perceive CSA technologies to increase (cereal) production. Earlier studies (Agegnehu and Amede, 2017; Mwaura *et al.*, 2021) have also reported the positive influence of CSA technologies such as integrated pest management on soil fertility which in turn increases land productivity and income of farmers in the long run. The statement with the least mean was "It is very cheap to use these technologies" (Mean=1.94). This implies that despite the numerous benefits of the technologies perceived by the rice farmers, they were indecisive on the cost associated with it. This might be ascribed to the fact that most rice growers lack access to loans. The overall mean of 2.56 indicates that rice farmers agree with all the perception statements. This suggests that they have a favourable opinion of CSA technologies hence the likelihood that will adopt them. This implies that CSA technologies must be encouraged among farmers, as it has the likelihood to improve crop production, soil fertility and in turn, farmers' income.

Table 2. Perception of Rice Farmers on The Use of CSA Technologies

Statement	Agree (3)		Neutral (2)		Disagree (1)		Mean	SD
	freq.	%	freq.	%	freq.	%		
CSA technologies are consistent with my beliefs and experience	150	50.34	71	23.83	77	25.84	2.16	0.87
CSA technologies are easy to practice	156	52.35	107	35.91	35	11.74	2.38	0.68
CSA technologies are much better than traditional methods	216	72.48	52	17.45	30	10.07	2.65	0.65
It is very cheap to use these technologies	111	37.25	78	26.17	109	36.58	1.94	0.87
CSA technologies give particular status to others	200	67.11	74	24.83	24	8.05	2.62	0.62
CSA technologies seem to be practised by other farmers	233	78.19	58	19.46	7	2.35	2.77	0.47
CSA technologies have increased my income	225	75.50	59	19.80	14	4.70	2.77	0.51
CSA technologies reduce the potential risk of crop loss	234	78.52	50	16.78	14	4.70	2.73	0.54
CSA technologies have improved my production	237	79.53	48	16.11	13	4.36	2.76	0.52
CSA technologies have improved my soil fertility and moisture	232	77.85	57	19.13	9	3.02	2.76	0.49
Overall mean							2.56	

Source: *Field Survey, 2022*

3.3. CSA Technologies Used by Rice Farmers

The substantial threat put forward by climate change to the world food supply is well recognized. The effect of climate change on rural development and agriculture in Africa is pronounced, as the agricultural sector plays a vibrant role in driving economic growth in the region (Kangogo et al., 2021). As a result, steps like the deployment of CSA technologies have become necessary. Table 3 presents the frequency at which rice growers use CSA technologies. Among the CSA technologies, the results show that "planting improved rice varieties" and "proper usage of fertilizers"

(Mean=2.77 and SD=0.48) were always used by the rice farmers. This shows that farmers are concerned about how climate change may affect their ability to produce rice, which is why they need to plant improved varieties and use fertilizer to counteract the negative effects it will have on their yields. The next technology farmers always use is "Nursery management" (Mean=2.73 and SD=0.56). This might be explained by the high mortality rate of rice seedlings brought on by adverse weather. To make up for their yields, farmers must replace dead plants. Hence the need for a nursery. This was followed by "Efficient and effective use of pesticides" (Mean= 2.68 and SD=0.56) and "Adjusting planting and harvesting time" (Mean=2.62 and SD=0.60). Rice farmers sometimes practice crop diversification (Mean= 2.46 and SD=0.64) as a way of combating the consequence of climate change. However, these farmers never irrigated their rice farms. (Mean= 1.18 and SD=0.39). Farmers completely rely on rainfall because irrigation is expensive and labour-intensive.

The overall mean of 2.26 indicates that farmers sometimes adopt CSA techniques on their rice farms. The findings are in line with Nyang'au *et al.* (2021), who found that farmers commonly used CSA technologies like crop diversification and altered cropping and harvesting schedules. Maya *et al.* (2019) reported that the chief adaptation strategy of rice growers was rice variety switching, changing planting dates, use of different crop varieties and conversion of rice paddy to fish production. Ejembi *et al.,* (2018) reported that improved rice varieties, pesticide and fertilizer application, and disease and pest control were some of the technologies introduced to rice farmers in Nigeria. CSA technology being used by farmers suggests a possible doubling of agricultural output since they can improve crop yield by threefold (Kangogo *et al.*, 2021).

Table 3. CSA Technologies Used by Rice Farmers

CSA technologies	Never (1)		Sometimes (2)		Always (3)		Mean	SD.
	freq.	%	freq.	%	freq.	%		
Planting improved rice varieties	8	2.68	57	19.13	233	78.19	2.77	0.48
Insurance	240	80.54	37	12.42	21	7.05	1.12	0.33
Crop diversification	25	8.39	122	40.94	151	50.67	2.46	0.64
Livelihood diversification	18	6.04	116	38.93	164	55.03	2.52	0.60
Bund construction	92	30.87	89	29.87	117	39.26	2.14	0.84
Rice straw for mulching	20	6.71	144	48.32	134	44.97	2.42	0.61
Adjusting harvesting planting and time	19	6.38	82	27.52	197	66.11	2.62	0.60
Reliance on climate forecast and information	67	22.48	67	22.48	164	55.03	2.37	0.81
Irrigation	196	65.77	48	16.11	54	18.12	1.18	0.39
Nursery management	8	2.68	71	23.83	219	73.49	2.73	0.50
Proper usage of fertilizer	8	2.69	57	19.19	232	78.11	2.77	0.48
Efficient and effective use of pesticides	15	5.03	72	24.16	211	70.81	2.68	0.56
Use of integrated pest management	165	55.37	79	26.51	54	18.12	1.59	0.76
Overall							2.26	

Source: *Field Survey, 2022*

According to Issahaku and Abdulai (2020), farmers who adopt CSA practices, such as proper crop selection, and soil and water management, experience increased agricultural income and reduced crop production risk. Wekesa *et al.* (2018) argued that utilizing a combination of

CSA technologies by a household leads to that household being food secure. Similarly, Murage *et al.* (2015) found that CSA adoption boosted cereal crop production. Inferentially, most of the rice farmers use CSA technology indicating the possibility of an increase in rice output in the study area and increased food security for farm households.

3.4. Factors Influencing Rice Farmers' Adoption of CSA Technologies

The OLS models' final findings, which pinpoint the elements influencing rice farmers' adoption of CSA technology, are shown in Table 4. In the model, the explanatory variables explained 23% of the total variation in the explained variable (adoption of CSA technologies). The model is significant because the value of the F-statistic is statistically significant at 1%. At 10%, the farming experience coefficient is statistically significant and positive. The positive sign exhibited by the coefficient of farming experience indicates that when farming experience increases by 1 year, the adoption of CSA technologies is anticipated to increase. Furthermore, a percentage change in farming experience will result in a 10% increase in the adoption of CSA technologies. The favourable impact is anticipated because more seasoned farmers may benefit from developing stronger skills and having access to cutting-edge information regarding improved methods. Due to their managerial skills, conviction, and knowledge of potential climate change effects, farmers with extensive farming experience may adopt CSA technologies. The result also suggests that information and experiences accumulated through time while working in an environment of uncertainty creation may aid in evaluating the technologies and so influence the choice to adopt them. The finding is supported by Abubakar *et al.* (2019) who stated that farming experience influences technology adoption.

The factor of farm size is positive and significant at 10%. The positive sign exhibited by the coefficient of farm size indicates that when farm size surges by 1 acre, adoption of CSA technologies is expected to increase. Furthermore, a percentage change in farm size will result in a 20% increase in the adoption of CSA technologies. This propounds that a farmer who has access to more farmland for the production of rice is more likely to experiment with and eventually embrace CSA methods. It's also feasible that large-scale farmers might need more technical assistance to streamline their tasks and increase productivity. This outcome is consistent with Abubakar *et al.* (2019), Ejembi *et al*. (2018), and Sisay *et al.* (2023). They stated that farm size significantly and favourably influences the choice to adopt improved production practices as a climate change and variability adaptation option. Farmers who own farmlands are more likely than those who are caretakers and sharecroppers to adopt CSA technologies. Thus, landowners are 90% more likely to espouse CSA technologies than sharecroppers, caretakers and those who acquire lands through a lease. Due to the possibility of eviction, tenants who do not own their land, as is typically the case with land rents, will be unable to benefit from future technology-induced benefits (Zeng *et al.*, 2018).

Farmers who have extension access are 25% more likely to adopt CSA technologies than their counterparts who do not have extension access. Farmers who have extension access are in a better position to adopt CSA technologies than those with no contact with extension. So, it might suggest that if the number of extension contacts is increased, farmers will be more inclined to employ CSA technology for rice cultivation. This is because farmers are introduced to new knowledge, which lowers the information imbalance that characterizes a new technology and increases their awareness of it as well as their willingness to test it out at a higher risk. Extension officers serve as a channel of transfer of agricultural technologies. Furthermore, they encourage and help farmers to practice agricultural technologies which leads to increased production and income (Danso-Abbeam *et al.*, 2018). Contact with extension officers can therefore help the rice growers in the study area to use and maintain the CSA technologies which in turn, may result in increased rice production. The result agrees with Abubakar *et al.* (2019) who reported that extension access significantly influences technology adoption. Farmer-to-farmer extension, according to Maya *et al.* (2019), has a considerable influence on rice farmers' adaption techniques. A farmer who has a secondary occupation is 90% less likely to adopt CSA technologies. This implies that growers who are involved in other activities apart from farm farming are probably not to espouse CSA technologies. Finally, farmers who are members of farmer groups are likely to adopt CSA technologies. Thus, being a part of a farmer organization boosts the probability of espousing CSA technologies by 111%. This finding is consistent with Djibo and Maman (2019) who reported that membership in an agricultural cooperative was a significant determinant of improved seeds in Niger.

Table 4. Socioeconomic Factors Influencing Rice Farmers' Adoption of CSA Technologies

Variables	Coefficients	Std. Error	t-Statistic	Prob.
(Constant)	2.02	0.10	19.58	0.00
Sex	-0.04	0.03	-1.23	0.22
Age	-0.00	0.00	-1.02	0.31
Household size	-0.01	0.01	-1.5	0.15
Access to extension	0.25***	0.06	4.31	0.00
Years of formal education	-0.01	0.00	-1.25	0.21
Farming experience	0.01*	0.00	1.87	0.06
Farm size	0.02*	0.01	1.91	0.06
Land tenure	0.09***	0.03	2.54	0.01
Access to credit	0.02	0.07	0.25	0.81
Secondary occupation	-0.09*	0.03	-2.58	0.01
Membership in farmer group	1.11*	0.06	1.82	0.07
R Squared	0.23	Adjusted R Square		0.20
F-Statistics	8.35	Prob (F-Statistics)		0.00

Source: *Authors' Construct, 2022* *Note: *10%, **5%, ***1%*

3.5. Determinants of CSA Technologies Adoption and Socioeconomic Factors on Rice Farmers' Income

An econometric OLS technique was used to investigate how the adoption of CSA technologies affected income. Table 5 displays the outcomes of the OLS model. The value of R2 in the OLS regression findings is 0.23, or 23%, and the Adjusted R2 is 0.15, or 15%. This suggests that the independent variables account for around 23% of the overall variation in income. The model's overall goodness is shown to be significant by the estimated F-statistic, which has a value of 2.88 and a p-value of 0.00. Consequently, the null hypothesis was disproved. The coefficient of years of formal education (negative), farming experience (positive), farmer group (positive) and use of IPM (negative) were significant at a 5% probability level while the coefficient of household size (positive) and irrigation (negative) was significant at 5%.

The coefficient of years of formal education indicates that additional years in school will decrease rice farmers' income by GHC 253.47. It's possible that the education obtained is not high quality and applicable to farmers' demands with regard to their activities involved in the production of rice, or that the educated farmers may be devoting their time and energy to other activities as a result of which there is a decline in yield and a corresponding decrease in revenue. The results contradict those of Aidoo-Mensah (2018) who found a substantial positive relationship between education and income. Whereas, the coefficient value of farming experience shows that an additional year in rice farming will increase rice farmers' income by GHC 157.89. The result is consistent with Aidoo-Mensah (2018). They noted a positive and significant influence of farming experience on income. Moreover, the coefficient of household size indicates that an additional member of a household will lead to a decrease in rice farmers' income by GHC 264.18. The finding disagrees with that of Chune (2022) who reported that household size significantly influenced farmers' income. Additionally, the coefficient value of the farmer group shows membership in a farmer group will increase rice farmers' income by GHC 2956.81. By increasing income, cooperatives significantly contribute to the sustainable development of homes and farms. Rice farmers may therefore boost their productivity when farm household income rises by using new or enhancing existing technologies and getting the right and necessary production inputs (Ankrah Twumasi *et al.*, 2021). The results are in line with those of Ankrah Twumasi *et al.* (2021), who found that joining a cooperative might boost farmers' income by 63.29% (i.e., both farm and household income). The irrigation coefficient value shows that irrigation of rice farms will decrease rice farmers' income by GHC 1998.01. Finally, the coefficient of use of integrated pest management indicates the use of IPM will decrease farmers' income by GHC 1313.75.

Table 5. Influence of CSA Technologies Adoption and Socioeconomic Factors on Income

Variables	Coefficients	Std. Error	t-Statistic	Prob.
(Constant)	12957.24	4317.61	3.00	0.00
Sex	704.83	735.36	0.96	0.34
Age	-0.83	24.70	-0.03	0.97
Years of formal education	-253.47**	108.14	-2.34	0.02
Household size	-264.18*	140.23	-1.88	0.06
Farming experience	156.89**	61.02	2.57	0.01
Access to extension	685.41	1372.09	0.50	0.62
Farm size	145.71	229.09	0.64	0.53
Land tenure	-365.79	709.86	-0.52	0.61
Access to credit	-753.15	1710.27	-0.44	0.66
Secondary occupation	-214.67	707.03	-0.30	0.76
Membership in farmer group	2956.81**	1468.83	2.01	0.05
Planting improved rice varieties	-495.91	946.88	-0.52	0.60
Planting different crops (Crop Diversification)	58.96	708.98	0.08	0.93
Insurance	1530.47	1427.36	1.07	0.29
Irrigation	-1998.01*	1186.32	-1.68	0.09
Livelihood Diversification	-912.59	739.31	-1.23	0.22
Bund Construction	1003.63	688.00	1.46	0.15
Using rice straw for mulching	-100.56	804.38	-0.13	0.90
Adjusting planting and harvesting time	-355.07	731.01	-0.49	0.63
Proper application of fertilizer	-135.15	914.68	-0.15	0.88
Reliance on climate forecast and information	-365.47	628.53	-0.58	0.56
Nursery Establishment	-565.45	896.70	-0.63	0.53
Efficient and Effective use of pesticides	238.55	798.30	0.30	0.77
Use of Integrated Pest Management	-1313.75**	586.27	-2.24	0.03
R Squared	0.23	Adjusted R Square		0.15
F-Statistics	2.88	Prob (F-Statistics)		0.00

Source: *Authors' Construct, 2022* *Note: *10%, **5%, ***1%*

3.6. Determinants of CSA Technologies Adoption and Socioeconomic Factors on Yield

The Ordinary Least Square approach was used to investigate how CSA technology adoption affected yield. Table 6 presents the findings of the regression analysis. According to the outcome of the OLS regression, R2 is 0.23, or 23%, and Adjusted R2 is 0.14, or 14%. This suggests that explanatory variables account for around 23% of the entire change in yield. The F-statistic was calculated with a value of 2.75 and a probability value of 0.00, indicating that the model's overall goodness is substantial.

The results revealed that the coefficient of sex was highly significant at a 5% significance level, which showed that there is a positive association between sex and yield. This implies that male rice farmers are 400% more likely to increase their yield compared to female rice growers. Thus, male rice growers are more likely than female rice to increase their yields. This finding is accurate because men are more likely to increase their yields than women since they are better able to handle the demanding tasks involved in producing rice. Males typically occupy the majority of leadership positions in the home along with decision-making duties. They choose the sort of crop to be farmed each season as well as the combination of inputs, marketing, and labour allocation for the farm, among other things. Also, men farmers have easier access than female farmers to crop types, adoption techniques, farm training, market information and workshops.

Table 6. Influence CSA Technologies Adoption and Socioeconomic Factors on Yield

Variables	Coefficients	Std. Error	t-Statistic	Prob.
(Constant)	26.71	10.67	2.50	0.01
Sex	4.00**	1.82	2.20	0.03
Age	0.01	0.06	0.09	0.93
Farming experience	0.02	0.15	0.11	0.92
Years of formal education	-0.04	0.27	-0.14	0.89
Household size	0.60*	0.35	1.73	0.08
Farm size	1.08*	0.57	1.91	0.06
Land tenure	1.31	1.75	0.75	0.46
Access to credit	1.23	4.23	0.29	0.77
Access to extension	3.00	3.39	0.88	0.38
Secondary occupation	5.16***	1.75	2.96	0.00
Membership in farmer group	-3.67	3.63	-1.01	0.31
Planting improved rice varieties	1.30	2.34	0.56	0.58
Insurance	-5.51	3.53	-1.56	0.12
Planting different crops (Crop Diversification)	-5.01***	1.75	-2.86	0.01
Livelihood Diversification	-0.43	1.83	-0.24	0.81
Bund Construction	1.60	1.70	0.94	0.35
Using rice straw for mulching	-1.22	1.99	-0.61	0.54
Adjusting planting and harvesting time	-0.14	1.81	-0.08	0.94
Irrigation	2.34	2.93	0.80	0.43
Reliance on climate information and forecasts	1.22	1.55	0.80	0.43
Nursery Establishment	-0.13	2.22	-0.06	0.95
Proper application of fertilizer	-3.68	2.26	-1.63	0.11
Efficient and Effective use of pesticides	1.26	1.97	0.64	0.52
Use of Integrated Pest Management	1.27	1.45	0.88	0.38
R Squared	0.23	Adjusted R Square		0.14
F-Statistics	2.75	Prob (F-Statistics)		0.00

Source: *Authors' Construct, 2022* *Note: *10%, **5%, ***1%*

As a result, they produce more food on the farm than women do. The result is supported by Musaba and Mukwalikuli (2019) and David *et al.* (2022) who reported that sex had a significant influence on rice output. The results further revealed that the coefficient of household size is also significant at 10%, which indicates that a strong and positive relationship exists between yield and household.

This suggests that an increase in household size by 1 will lead to a 60% surge in yield. Production of rice requires a lot of labour. Among the activities that need heavy effort for cultivating rice are harvesting, weeding, planting, and land preparation. Because many subsistence farmers in Africa rely on family labour, families with a significant number of household members were able to supply labour on their farms, which led to an increase in farm yield. Moreover, rice is one of the major essential foods that several Ghanaians rely on. Families with big numbers of household members would require extra food compared to their peers with few individuals. Farming provides the bulk of the food. As a result, the need for food would force large families to invest extensively in production to support the size of their enormous families. In the long term, this enhances yield. Farm size had a significant influence on yield. A 1-acre rise in farm size will result in a 108% in yield. This demonstrates a direct correlation between growing farm size and rising productivity. The results obtained by Chau and Ahamed (2022), David *et al.* (2022), Musaba and Mukwalikuli (2019) and Kulyakwave *et al.* (2019) indicate that land area is a primary determinant of rice yield. Farmers who have secondary occupations are 516% more likely to increase yield than those who do not engage in secondary occupations. This implies having a secondary occupation could increase rice yields. The findings contradict that of Musaba and Mukwalikuli (2019) who stated that participation in off-farm income-generating activities reduces rice yield. The coefficient of planting different crops is significant and negative at 1%. This shows that farmers who cultivate different crops are 501% less likely to increase their yields. Thus, farmers who cultivate other crops reduce the time for rice cultivation which leads to a reduced yield.

3.7. Constraints Faced by Rice Farmers in the Use of CSA Technologies

While the benefits of the use of CSA technologies to farmers are proven (Appiah and Guodaar, 2022; Nyang'au *et al.*, 2021), some challenges hinder farmers from using or practising them. Table 7 presents constraints to farmers' use of CSA technologies. The results revealed that there was 49% concurrence among the farmers on the ranking of CSA technologies challenges encountered. This implies that respondents were of different opinions regarding their ranking of the challenges. The coefficient of concordance (W) was significant at 1%. The study shows that lack of access to credit, lack of access to timely weather information and high cost of labour were ranked as a high challenge. The findings are corroborated by Partey *et al*. (2018), Loko *et al.* (2022) and Denkyirah *et al.* (2017) discovered that the adoption of CSA technologies is hindered by a lack of clear comprehension of the idea, insufficient supporting policies, and difficulties in securing financing and inadequate labour. Lack of information about the technology, lack of access to water resources and limited access to agricultural extension officers were ranked as a moderate challenge. Access to extension officers helps farmers to use or adopt agricultural technologies through the demonstration of the technology to the farmers. Extension officers assist farmers in understanding the complicated uncertainties about agricultural technologies. Furthermore, extension officers help farmers sustain the use of agricultural technologies even after the adoption of the technologies (Danso-Abbeam *et al.,* 2018). Therefore, lack or limited access to extension officers by the rice farmers might lead to the farmers not sustaining the use of the adopted technologies. However, the high cost of farm input, land insufficiency and illiteracy of farmers as a low challenge was ranked a low challenge for the farmers. According to Mponela *et al.* (2016), the high cost of inputs and labour may prevent farmers from using CSA technologies. Senyolo *et al.* (2018) opined that the high cost of initial investment and high input cost have a negative influence on farmers' adoption of CSA technologies. The result of the study implies that although the majority of the farmers perceived CSA technologies to be beneficial, their use of the technologies is hindered by several factors.

Table 7. Constraints to the Use of CSA Technologies

Constraints	Mean	Rank
Lack of access to credit facilities	4.11	1
Lack of access to timely weather information	4.18	2
High cost of labour	4.24	3
Lack of information about the technology	4.71	4
Limited access to agricultural extension officers	4.72	5
Lack of access to water resources	5.30	6
High cost of farm input	5.78	7
Land insufficiency	5.86	8
Illiteracy of farmers	6.11	9

Source: *Field Survey, 2022*

4. Conclusion and recommendations

Rice farmers generally have a positive perception of CSA technologies, with improved rice varieties and proper fertilizer usage being the most widely adopted practices. Several factors influence the adoption of CSA technologies, including farming experience, farm size, ownership of farmland, access to extension services, secondary occupation, and membership in farmer groups. Factors such as farming experience, household size, and membership in farmer groups positively influence income, while sex, household size, farm size, secondary occupation, and planting different crops affect yield. In adopting CSA technologies rice farmers face constraints such as lack of access to credit, timely weather information, and high labour costs.

Recognizing that climate change is negatively affecting rice production, the government should prioritize the promotion of CSA technologies. This should include increased research and development to create improved rice varieties that are more resilient to changing climate conditions. Moreover, the government should provide support and incentives for farmers to adopt these improved varieties and other climate-smart practices like water and soil conservation techniques, efficient fertilizer use, and integrated pest management (IPM). Moreover, there should be increased investment in agricultural extension services to educate farmers on the use of climate-smart technologies. This would entail training more extension officers and conducting farmer workshops to disseminate knowledge about the latest agricultural practices.

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All authors contributed to this research

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The authors disclosed no conflict of interest.

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