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Impact of climate change and extension service on rice farmers' yield in Ebonyi State, Nigeria

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Abstract. *Emmanuel OE, Nkiruka B-CG, Nnenna OM, Ojoko NIU, Chinenyenwa T-AA, Ada AB, Oluwakemi OI, Thankgod EK, Oscar OI, Nnabugwu UB, 2024. Impact of climate change and extension service on rice farmers' yield in Ebonyi State, Nigeria. Asian J Agric 8: 116-123.* The study examined the impact of climate change and extension service on rice farmers' yield in Ebonyi State, Nigeria. A total of 402 rice farmers were sampled through multi-stage sampling for questionnaire administration. Primary data collected were analyzed using mean, frequency, percentage, ordinary least square multiple regression techniques, the Local Average Treatment Effect (LATE) model, and the probit model. Socio-economic characteristics show that a greater proportion of the farmers were male (51.7%), married (84.1%), and attended secondary education (47.8%). Sources of climate change information were farmer-to-farmer (100%), telephone/mobile phone (98.5%), radio (92.5%), workshop/seminars (73.4%), and television (46.8%). Temperature (P<-0.01), rainfall (P<-0.01), evaporation rate (P<-0.01), and severe windstorm (P<-0.01) influenced rice yield negatively, while relative humidity (P<0.05) and atmospheric pressure (P<0.01) had a positive influence on rice yield. The results from the LATE model, which measures the average effect of a treatment on the treated, show a decrease in rice yields of 84.1% and 96.5%. Production constraints felt by rice farmers include high cost of input materials (100%), inadequate capital (100%), high cost of labor (99.8%), poor extension access and service (99.5%), and Fulani-herdsmen conflict (76.9%). The study recommends rice farmers implement climate-smart agriculture to mitigate climate change and access farm information and/or services from experienced farmers.

Keywords: Climate change, extension service, impact, rice farmers, yield

INTRODUCTION

In Nigeria and other countries across the world, rice (*Oryza sativa* L.) is a vital crop that plays a major role in national food security, employment creation, and revenue generation (Wudil et al. 2023). Rice farmers cultivate the crop in a range of production environments around the country. Rice is an essential and staple food across the continents of the world. Rice is believed to be consumed daily by over 3 billion people globally (Hashim et al. 2024). In various nations, including the USA, France, UK, Belgium, Bangladesh, Cambodia, Myanmar, Laos, Vietnam, Thailand, Philippines, India, Nepal, Sri Lanka, and Sub-Saharan Africa, rice accounts for 20-44% of total calories consumed (Mohidem et al. 2022). Rice is considered the most popular staple meal consumed by Nigerians and contributes to the country's food economy. With the growing population in Nigeria, more rice needs to be produced to meet demand. Average rice yields per unit area in the country are low and range between 2.0 and 3.0 tons/ha. Currently, only 57% out of the 6.7 million metric tons of rice consumed in Nigeria annually is locally produced, leading to a deficit of 3 million metric tons. Globally, weather variations and abnormal changes in climate are affecting rice farmers' yield, income, and livelihood sustenance (Ansari et al. 2023). According to the literature, rice production in Nigeria is being affected by climate change, leading to economic losses (Mukhopadhyay and Das 2023). Still, the extent of the incidence of climate change in Ebonyi State is unknown, which seems to justify the study. Nigeria's imports of cereals, especially rice, increased sharply in 2023 to about 190 percent of total imports from the previous five-year average (FAO 2023). The above increase in rice imports has resulted tremendously in reduced local rice production and land yield. It has led to farmers' impoverishment, low income, hunger, malnutrition, and overall food insecurity in Africa's most populous nation (Akano et al. 2023; FAO 2023). Each year, extreme weather conditions, including droughts, floods, temperature spikes, wind, rain, pressure, and relative humidity, have a significant detrimental effect on rice production and result in significant financial losses (Kumar et al. 2022). For instance, the rising temperatures cause weeds, insects, diseases, and pests to increase in rice fields, and decrease in rice crop output. Elevated temperatures additionally result in decreased evapotranspiration, hence lowering moisture levels and impeding rice growth and development (Ren et al. 2023). Once more, changes in precipitation patterns increase the likelihood of rice crop failure in the short term and long term (Zhang et al. 2023). Furthermore, increases in rainfall cause flooding of lowland rice fields, hence affecting root and shoot development in rice plants. Increased evaporation rates reduce soil moisture levels and water infiltration and cause land dryness, leading to stunted rice growth. Extension service is an integral component of crop production as farmers rely on it to receive farm information during each cropping season. The application of the insights, knowledge, and experience gained from the extension service is very important in crop production (Jamil et al. 2023). An extension service provides hands-on practical farm knowledge and information needed by the farmers to make informed decisions concerning their farming operations. Extension agents disseminate agricultural information and innovative ideas capable of transforming the farming business. However, these objectives are farfetched owing to the dearth of extension services in Nigeria. Extension services are no longer practicable in Ebonyi State due to the scarcity of extension agents, low-spirited available ones, and the unconcerned attitude of the government in revitalizing extension services to assist the rural farmers (Osuji et al. 2023). These issues of concern created a huge gap in knowledge and necessitated the motivation for the study in the State. Hence, the research identified the sources of climate change information among rice farmers, analyzed the impacts of climate change variables on rice yield, examined the impact of extension service on rice yield, identified determinants of rice farmers' yield, and ascertained the production constraints faced by rice farmers.

MATERIALS AND METHODS

The study was conducted in Ebonyi State, Nigeria. The State has a large agricultural land mass and is known for its intensive rice production (*Abakaliki rice*). The State has 13 local government areas (LGAs) (Abakaliki, Izzi, Ezza-North, Afikpo-South, Ohaukwu, Ebonyi, Oniocha, Ishielu, Ezza-South, Ikwo, Afikpo-North, Ohaozara and Ivo) with an estimated population of 3,242,500 (NPC 2022). The land expanse measures 5,533 km^2 and has a *Latitude* of 6°10' 40.7028"E and a Longitude of 7°57' 33.4296" N. Multi-stage sampling technique was used in selecting the rice farmers. At first, 5 LGAs, namely (Ikwo, Izzi, Ivo, Ezza-North, and Ezza-South) mainly known for their intensive rice cultivation, were selected from the 13 LGAs, and from the 5 selected LGAs, 3 communities each were selected, making a total of 15 communities. Subsequently, 5 villages were randomly selected from the 15 communities to sum up 75 villages. The registered rice farmers were 1,275, out of which 6 rice farmers were randomly selected from the 75 villages to sum up 450 farmers. This research was conducted using primary information collected through a structured questionnaire prepared to capture the study objectives. From the outcome, a total of 402 rice farmers provided useful information out of the 450 rice farmers sampled. Descriptive statistics analyzed the socio-economic characteristics of the rice farmers, sources of climate change information among rice farmers, and production constraints faced by rice farmers. Multiple regression analyzed the impacts of climate change variables on rice yield. The local average treatment effect (LATE) model analyzed the impact of extension service on rice yield, while the probit model analyzed the determinants of rice farmers' yield in the State. This statistical model is used based on its econometric application and suitability in analyzing the study objectives without many errors.

The model for multiple regression is stated as follows;
$Y = f(X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8) + e$
Where:
Y: Rice yield (Kg per hectare of land cultivated)
X_1: Temperature (Increased :1, Otherwise 0)
X_2: Rainfall (Increased :1, Otherwise 0)
X_3: Number of rainy days (Increased :1, Otherwise 0)
X_4: Evaporation rate (Increased :1, Otherwise 0)
X_5: Sunshine hours (Increased :1, Otherwise 0)
X_6: Relative humidity (Increased :1, Otherwise 0)
X_7: Atmospheric pressure (Increased :1, Otherwise 0)
X_8: Severe windstorm (Increased :1, Otherwise 0)
e: error term

The probit model was stated as follows;
$Y = f(X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8, X_9, X_{10}, X_{11}) + e$
Where
Y: Rice yield (Kg per hectare of land cultivated)
X_1: Age of farmer (Years)
X_2: Gender (Male 1, 0 Female)
X_3: Marital status (married 1, 0 Single)
X_4: Level of education (No. of years spent in school)
X_5: Household size (No. of persons)
X_6: Occupation (Farming 1, 0 otherwise)
X_7: Farm size (Ha)
X_8: Extension contact (No. of visits)
X_9: Cooperative membership (Belong 1, 0 otherwise)
X_{10}: Participation in workshop/training (No. of times)
X_{11}: Farming experience (No. of years)
e: error term

The local average treatment effect (LATE) model was expressed as follows;

$$E\left(y_1 - \frac{y_0}{d_1} = 1\right) = LATE = \frac{cov(y,z)}{cov\,(d,z)}$$

$$= \frac{E\left(\frac{y}{z}=1\right) - E\left(\frac{y}{z}=0\right)}{E\left(\frac{d}{z}=1\right) - E\left(\frac{d}{z}=0\right)}$$

$$= \frac{E(y_i*(z-E(z_i)}{E(d_i*(z-E(z_i)}$$

$$= \left(\frac{\sum_{i=1}^{n} y_i z_i}{\sum_{i=1}^{n} z_i} - \frac{\sum_{i=1}^{n} y_i(1-z_i)}{\sum_{i=1}^{n}(1-z_i)}\right) X \left(\frac{\sum_{i=1}^{n} d_i z_i}{\sum_{i=1}^{n} z_i} - \frac{\sum_{i=1}^{n} d_i(1-z_i)}{\sum_{i=1}^{n}(1-z_i)}\right)$$

Specifying LATE model components,

$$ATE = \frac{1}{n}\sum_{i=1}^{n} i \frac{(d_i - p(X_i)y_i}{p\,(X_i)(1-p(X_i)}$$

$$ATE1 = \frac{1}{n1}\sum_{i=1}^{n} i \frac{(d_i - p(X_i)y_i}{(1-p)(X_i)}$$

$$ATE0 = \frac{1}{1-n1}\sum_{i=1}^{n} i \frac{(d_i - p(X_i)y_i}{p(X_i)}$$

Where:

Eyi: Refers to the sub-population of ith farmers

Ezi: Refers to the sub-population of ith farmers

Cov (y, d, z): Covariates

z (yi, zi): Binary variables

p(xi): Isolated weighing covariate

ATE: Average treatment effect

ATE1: Average treatment effect of farmers that accessed extension service

ATE0: Average treatment effect of farmers that did not access extension service

RESULTS AND DISCUSSION

Socio-economic characteristics of the rice farmers

The socio-economic characteristics of the rice farmers are presented in Table 1. The result shows that a greater proportion of the rice farmers were between the age group of 51-60 years, with a mean age of 56 years. This implies that the farmers have accumulated practical farming experience and are physically energetic in rice cultivation. This further indicates that the rice farmers were physically strong enough to withstand inherent farm production challenges (FAO 2023). The majority of the rice farmers (51.7%) were male, while the remaining were female (48.3%). This implies that the male rice farmers dominated rice cultivation in the area, probably due to their commitment to providing for their families (Jones et al. 2023). About 84% of the farmers were married as against the singles, at 5.2%. This indicates that rice cultivation in the area was mostly practiced by married farmers (Sadiq et al. 2022). About 48% of rice farmers attended secondary education, implying that they were relatively educated and could comprehend farm production principles to improve yield. Household size shows that the majority of the farmers, at 52.5%, had household sizes between 5-8 persons with a mean household size of 7 persons. This implies that the household size is large enough and could be efficiently utilized in rice production (Khan et al. 2022). About 47.3% of the rice farmers had farm sizes between 1.1-2.0 hectares with a mean of 1.7 hectares. This implies that the rice farmers cultivated on small pieces of land probably due to existing land tenure systems and land fragmentation in the area (Dröge et al. 2022). Extension contacts show that the majority of the farmers,74.9%, do not have access to extension services, while a total percentage of 25.1% accessed extension contacts. This implies that less than 30% of the farmers received extension services. This could be due to the paucity of extension personnel during the cropping season in 2023 (Jamil et al. 2023). Information received from extension services empowers farmers to improve land yield and productivity. The majority of rice farmers, 83.8%, belong to cooperative societies as against 16.2% who do not belong to any cooperatives. This indicates that these groups of farmers accessed vital information relating to crop production and other essential input materials, which ordinarily would have been difficult to access individually (Sadiq et al. 2022). 51.0% of rice farmers used family labor as against hired labor 35.1%, signifying the importance of family labor over hired laborers.

Table 1. Socio-economic characteristics of the rice farmers

Variables	Frequency	Percentage
Age		
21-30	19	4.7
31-40	130	32.3
41-50	107	26.6
51-60	146	36.3
Mean	56	SD=1.05
Sex		
Male	208	51.7
Female	194	48.3
Marital status		
Single	21	5.2
Married	338	84.1
Divorced	04	0.9
Widowed	39	9.7
Level of education		
Primary	162	40.3
Secondary	192	47.8
Tertiary	26	6.5
Nonformal	22	5.5
Household size		
1-4	175	43.5
5-8	211	52.5
9-12	14	3.5
13-16	02	0.5
Mean	6.6	SD=0.09
Farm Size		
0.1-1.0	154	38.3
1.1-2.0	190	47.3
2.1-3.0	27	6.7
3.1 & above	31	7.7
Mean	1.7	SD=0.72
Extension contacts		
1-2	69	17.2
3-4	32	7.9
None	301	74.9
Mean	1.2	SD=0.02
Cooperative membership		
Yes	337	83.8
No	65	16.2
Farming Experience		
1-10	37	9.2
11-20	61	15.2
21-30	297	73.9
31-40	07	1.7
Mean	26	SD=1.43
Source of labor used		
Family	205	51.0
Hired	141	35.1
Both	56	14.0

Table 2. Source of climate change and extension service information among rice farmers

Sources	*Frequency	Percentage
Farmer-to-farmer	402	100
Telephone/Mobile phone	396	98.5
Radio	372	92.5
Cooperative societies	308	76.6
Workshop/Seminars	295	73.4
Govt. ADP Offices	224	55.7
Television	188	46.8
Research Institutes	182	45.3
NGOs	59	14.7
Newspapers	46	11.4
Extension agents	43	10.6
Meteorological centers	38	9.5
Internet	21	5.2

Note: *Multiple responses

Source of climate change information among rice farmers

The source of climate change information among rice farmers is presented in Table 2. The result depicts that all the rice farmers accessed climate change and farm information via fellow farmers. This implies the transference of farm information, innovation, skills, and farm knowledge from one farmer to another. This process aids in better understanding and knowledge acquisition among farmers. Farmers generally learn faster from fellow farmers (Adeleke et al. 2024). The use of telephone/mobile phones was indicated by 98.5% of farmers. This implies that farmers accessed climate change and farm information through telephone/mobile phones. Telephone/mobile phones enhance the easy communication and transmission of climate change information and extension services (Jones et al. 2023).

Nowadays, farmers have access to telephone/mobile phones, which makes it easier to access necessary information regarding their farming business. Radio was indicated by 92.5% of rice farmers; this implies that farmers accessed climate change information and extension services via the radio. Over time, radio has proven to be an important source of communication and transmission of information among rural farmers. Nowadays, information on climate change and extension services is relayed via the radio system (Ren et al. 2023). Radio gives a wider and broader coverage of information to a wider audience, even in the most isolated or remote places, making it a potent means of communication (Jones et al. 2023). Cooperative societies were indicated by 76.6% of the farmers. This implies that the rice farmers sourced climate change information and extension services via the various cooperatives they belong. Cooperative societies aid the dissemination of farm information and the exchange of ideas and knowledge among rural farmers, and this improves crop production (Osuji et al. 2023). About 73% attended workshops/seminars; this implies that these groups of farmers accessed climate change information via attending agricultural workshops/seminars. Participation in workshops/seminars exposes farmers to new knowledge in farming and changes in climate (Waaswa et al. 2024). Research Institutes and Government ADP offices were indicated by 45.3% and 55.7% of the farmers, respectively. These two agencies are tasked with the responsibility of providing information relating to farm and climate services to rural farmers (Waaswa et al. 2024). About 46.8% of the farmers assented to television as a means of sourcing climate change information. Television is an audio-visual means of communications that assist farmers in using displayed and visible information. NGOs (Non-governmental organizations) recorded 14.7% of rice farmers, indicating that farmers obtained information on climate through non-governmental organizations involved in agriculture. About 11.4% of the farmers obtained climate information through newspapers. This implies that these small groups of farmers read information relating to climate change via newspapers. Extension agents were indicated by 24.6% of the farmers; this implies that the farmers sourced climate change information via available extension agents. Extension agents are reputed agents of communication and dissemination of agricultural and farm-related information that aid farmers in their farming operations (Jamil et al. 2023). Extension agents communicate climate information and render extension services to rural farmers to improve farm yield and output.9.5% of the rice farmers accessed climate change information through meteorological centers. Internet services recorded about 5.2% of the farmers; this implies that these farmers accessed vital information on climate change via the internet. Internets provide information relating to climate change on a global scale and wider coverage (Ngigi and Muange 2022). Nowadays, all manner of information can be sourced through the internet at a click.

Impacts of climate change variables on farmers' rice yield

The impacts of climate change variables on the rice yield of farmers per hectare of land cultivated are presented in Table 3. The result of the ordinary least square of multiple regression shows that the double-log functional form produced the lead estimates by way of the highest F-ratio, R2, and variable significance. The F-ratio shows the goodness of fit of the model, while the R2 value explains the variation in the dependent variable. Temperature was negative and significant at 1% level, implying that an increase in temperature will lead to a decrease in rice yield. The ideal temperature range for rice plants is typically between 25 and 35°C; however, temperatures over this range have a negative impact on all phenological stages of rice production, as well as lowering grain yield and production. Elevated temperatures lower the pace of rice germination, which results in water loss and hinders photosynthesis (Zhang et al. 2023). In addition, it causes the death of rice seedlings and impairs the growth of surviving seeds, thereby lowering rice output and land yield. Rainfall was negative and significant at a 1% level, implying that an increase in rainfall intensity negatively affects rice yield. This means a unit increase in rainfall by 1% will lead to a corresponding decrease of 0.6789% in rice yield. An increase in precipitation has an adverse impact on the phases of rice flowering. It destroys the reproductive cells, which lowers rice yield (Akano et al. 2023) as a result of persistently high rainfall, rice fields flooding, increasing rice pests and disease infestation, and complete crop failure.

Table 3. Impacts of climate change variables on rice yield

Variable	Linear	Semi-log	Double-log	Exponential
Constant	-0.8942	-0.8324	-0.7310	-0.9522
	(-2.014)**	(-1.408)	(-1.070)	(-1.192)
Temperature (X_1)	-0.9235	-0.8210	-0.4562	-0.5321
	(-0.011)	(-2.301)**	(-3.412)***	(-1.992)*
Rainfall (X_2)	-0.6344	-0.5415	-0.6789	-0.8325
	(-1.532)*	(-1.091)	(-4.410)***	(-1.203)
Number of rainy days (X_3)	-0.7489	-0.7122	-0.6002	-0.6423
	(-1.193)	(-4.251)***	(-1.302)	(-2.308)**
Evaporation rate (X_4)	-0.6391	-0.8325	-0.6382	-0.7124
	(-0.011)	(-3.602)***	(-5.401)***	(-1.224)
Sunshine hours (X_5)	0.9833	0.9232	0.5473	0.9002
	(2.360)**	(1.091)	(4.772)	(4.202)***
Relative humidity (X_6)	0.7783	0.9314	0.9933	0.6418
	(1.003)	(1.816)	(2.107)**	(1.099)
Atmospheric pressure (X_7)	0.8990	5.6661	10.5631	2.6662
	(1.6762)*	(2.7621)**	(4.7720)***	(1.0347)
Severe windstorm (X_8)	-0.6732	-3.6733	-5.7733	-.7733
	(-0.9882)	(-1.0733)	(-1.9063)**	(-0.5633)
R^2	0.7704	0.7905	0.8501	0.7841
F- ratio	14.81***	17.30***	26.88***	10.66***

Note: Significant at ***1%, **5% and *10%

Table 4. Impact of extension service on rice yield

Parameter	LATE (WALD)	LATE (IV)	ATE (IPSW)	PSM
ATE	-0.8410	-0.9650	-10.1092	-17.8962
	(-2.189)**	(-5.660)***	(-4.389)***	
ATE 1			0.6563	
			(4.094)***	
ATE 0			-0.7099	
			(-2.001)**	

Note: Significant at ***1%, and **5%

The evaporation rate was negative and significant at the 1% level. This implies that an increase in evaporation rate will result in a corresponding decrease in rice yield, which manifests in the loss of water during the period of plant germination and growth processes (Kumar et al. 2022). Then, high evaporation rate results in loss of soil-moisture contents and soil aeration, leading to soil dryness and failure of rice seedlings to grow effectively (Adeleke et al. 2024). High evaporation rate affects plant transpiration and soil infiltrations, resulting in abnormal growth conditions in rice plants, leading to poor yield. Relative humidity was positive and significant at a 5% level, implying that an increase in relative humidity will have a positive effect on rice yield. This means that a 1% increase in relative humidity will result in a corresponding increase in rice yield by 0.9933%. In light periods, an increase in relative humidity is critical to the growth and photosynthesis of rice plants. It speeds up the emergence of new leaves, increases plant heights, leaf area, leaf blade length, and leaf sheath length, and strengthens rice plants' roots and shoots (Mukhopadhyay and Das 2023). Additionally, it enhances plant water relations and promotes soil-biophysical processes that enhance rice field performance. Atmospheric pressure was significant and positive at a 1% level, implying that an increase in atmospheric pressure will result in a corresponding increase in rice yield. The rate of germination in rice plants is sped up by atmospheric pressure, which also speeds up the growth rate of rice seeds (Ansari et al. 2023). It results in rice plants growing rapidly in their shoots with huge root development. It increased soil-water transpiration and moisture capacity due to high atmospheric pressures, causing plants to take in more water, which raises rice output. Severe windstorms were negative and significant at a 5% level, implying that an increase in severe windstorms will result in a decrease in rice yield. This further implies that a 1% increase in severe windstorms will lead to a decrease in rice yield by 5.7733%. Severe windstorms uproot planted rice plants and seedlings and cause disintegration of the root and shoot systems, resulting in poor rice germination, poor growth rate, and total crop failure. It leads to withered rice leaves and poor leaf formation, which negatively affects rice growth and yield. Severe windstorm distorts the biodiversity of rice fields, thereby exposing rice plants to adverse environmental conditions, leading to a severe drop in rice yield (FAO 2023). More so, it exposes rice plants to adverse effects of rice pests and diseases, which reduce yield.

Impact of extension service on farmers' rice yield

The impact of extension service on rice yield is presented in Table 4. The result shows that the Propensity Score Matching (PSM) and the Inverse Propensity Score Weighting (IPSW) estimates produced negative values of -17.8962 and -10.1092, respectively. The two estimates were significant at a 1% statistical level. They failed to determine the actual effect of extension service on rice yield, thus introducing a hidden bias and hence implying that non-compliance exists using both (PSM) and (IPSW)

(Xu et al. 2022a). The non-compliance here refers to the farmers who did not access extension service during the cropping season. However, this issue can be subdued by using an impact parameter known as the Local Average Treatment Effect (LATE) that identifies and accommodates the hidden biases in the face of non-compliance in establishing the true impacts of extension contacts on rice yields (Xu et al. 2022a). From the results, the LATE (WALD) and LATE (IV) estimates produced negative values of -0.8410 and -0.9650, which are highly significant at 5% and 1% statistical levels, respectively. LATE estimated either way establishes the true picture of extension contacts on rice yield of farmers in the presence of non-compliance and limitations of PSM and IPSW. The LATE results (Wald and IV values) show that the inability of the rice farmers to access extension service decreased rice yield by 84.1% and 96.5%, respectively. This explains that lack of access to extension service is a prerequisite to decreased crop production and poor income of rice farmers (Xu et al. 2022b; Adeleke et al. 2024).

Furthermore, the result shows the present-day realities of the extinction of extension services in crop production in Nigeria. Again, the ATE 1 produced a positive estimate of 0.6563 and was significant at the 1% level, implying that the use of extension service yielded a positive increase of 65.6% in rice yield. This could be attributed to the minority of rice farmers who accessed extension services during the cropping season (see Table 1). On the other hand, the estimate of ATE 0 had a negative value of 0.7099 and was significant at the 5% level, implying a significant decrease in rice yield of about 70.9%. Extension services are known to enhance farmers' knowledge and understanding of farm production principles as well as the communication of new and innovative ideas, methods, and techniques to boost farm production. However, there is a dearth of extension services in Nigeria, and its purpose in crop production is being defeated, resulting in adverse effects on crop yield (Alzahrani et al. 2023; Danjumah et al. 2024).

Determinants of rice farmers' yield

The result in Table 5 shows the determinants of rice farmers' yield. The result shows that the F-value of 11.901 was positively significant at a 1% statistical level, implying the goodness of fit of the probit model used. The R^2 value of 0.8100 shows that 81% of the total variance in the endogenous variable was explained by the socio-economic variables investigated. The age coefficient remained negative and was substantial at 1%, indicating that increasing the age of farmers decreases rice yield. This means as farmers grow in age, their yield declines (Grigorieva et al. 2023). An increase in age brings about health weakness, which is bound to affect the physical fitness of the farmers in farm operations and productivity. The gender coefficient became substantial and positive at 5%. This denotes that male rice growers recorded higher yields than the female. The education coefficient was positively substantial at 1%, showing that literate farmers had higher yields relative to uneducated ones. Education has proven to be an agent of transformation that bequeaths farmers with the right knowledge and understanding of farm production principles (Blair et al. 2023; Danjumah et al. 2024). The household size coefficient produced a significant estimate of 5% and was positive. This indicates that large households had higher yields, unlike smaller households. Large household depicts that more hands are involved in rice cultivation (Adeleke et al. 2024). The farm size coefficient was negatively substantial at 1%. This implies that the cultivation of rice in small pieces of land can be associated with low yield and poor harvest (Lamichhane et al. 2022). The coefficient of extension contact was substantially negative at 1%. This implies that poor access to extension services decreases rice yield, which further implies that farmers who do not access extension services perform poorly (Akinnagbe et al. 2024). The coefficient of participation in workshop/training was positively substantial at 1%. This implies that attendance to agricultural workshops/training improves farmers' knowledge and understanding of farm production principles, which improves yield (Ngigi and Muange 2022; Alzahrani et al. 2023). The farming experience coefficient became positively substantial at 5%, indicating that advancement in farming experience increases rice yield. This further implies that experienced farmers record better yields, unlike inexperienced ones.

Table 5. Determinants of rice farmers' yield

Variables	Coeff.	t-values	Std. Error
Constant	2.8971	1.0543	2.7479
Age (X_1)	-4.5729	-4.8820***	0.9367
Gender (Male) (X_2)	0.7423	2.7722**	7.4829
Marital status (Married) (X_3)	-0.8952	-0.0992 ns	9.0242
Level of education (Secondary) (X_4)	2.8882	4.7201***	0.6119
Household size (Average 7) (X_5)	0.6002	2.001**	0.2999
Occupation (Non-farming) (X_6)	-7.6772	-1.2733ns	6.0294
Farm size (Ha) (X_7)	-0.8589	-4.6883***	0.1832
Extension contacts (Visits) (X_8)	-12.7822	-3.0211***	4.2309
Cooperative Membership (X_9)	-0.9921	-1.3780 ns	0.7199
Participation in workshop/training (X_{10})	0.9010	3.8123***	0.2363
Farming experience (X_{11})	0.5455	2.8822**	0.1893
R^2	0.8100		
F-value	11.901***		

Note: Significant at ***1%, **5% and *10%. ns = not significant

Table 6. Production constraints faced by rice farmers

Production constraints	*Freq.	Percentage
High cost of input materials	402	100
Inadequate capital	402	100
High cost of labor	401	99.8
Poor extension access and services	400	99.5
Inadequate information on climate change	399	99.3
Fulani-herdsmen conflict	309	76.9
Pests and disease attacks	308	76.6
Inadequate farming lands	251	62.4
Migration	242	60.2
Lack of technical-know-how	203	50.5
Lack of farm incentives	121	30.1

Note: *Multiple responses

Production constraints faced by rice farmers

The production constraints faced by rice farmers are presented in Table 6. The high cost of input materials was identified by all the rice farmers (100%). This implies that the high cost of input materials such as improved rice seedlings, chemicals for pests and diseases, and fertilizers limit the large-scale cultivation of rice. Our result corresponds with Zhang et al. (2023). Inadequate capital was also identified by all the farmers involved in rice cultivation. This implies that the inability of the farmers to access capital to purchase required farm inputs impeded rice production. Capital is very essential in farm business as it propels smooth operations in agricultural activities, while the absence of it is an impediment (Ansari et al. 2023). High labor cost was identified by 99.8% of the farmers. This implies that the majority of rice growers could not afford the higher wages charged by hired laborers, and this affected rice production and yield (Mohidem et al. 2022). Poor extension access and service were indicated by 99.5% of the farmers. This indicates insufficiency in extension service delivery in the State. Extension agents are in short supply in the State, and this affects farming activities negatively (Osuji et al. 2023). The majority of the farmers, 99.3%, identified inadequate information on climate change relative to rice cultivation in the State. This implies the inability of rice growers to access climate change data early enough had a negative effect on rice yield (Akano et al. 2023). About 77% of the farmers identified Fulani-herdsmen conflicts as a very big impediment to rice production in the area. This involves the incessant clashes between farmers and Fulani herdsmen on a daily basis and the wanton destruction of rice fields and other planted crops in search of greener pastures to feed their cows (Wudil et al. 2023). Pests and disease attacks were identified by 76.6% of the farmers. This indicates the prevalence of rice pests and diseases in the State with their associated negative impacts on rice production. Inadequate farming lands were indicated by 62.4% of the farmers. This implies that the farmers cultivated small land portions arising from land fragmentation and possibly unfavorable land tenure systems (Hashim et al. 2024). Migration was identified by 60.2% of the farmers; this implies that the rice farmers suffered from labor shortages and farm manpower due to the increasing rural-urban drift of the youth in search of white-collar jobs. The table shows that a lack of technical know-how was indicated by 50.5% of the farmers; this indicates that this group of farmers lacked the technical capacity to deal with climate change, thereby suffering production challenges that affected their yield and output. About 30% identified a lack of farm incentives; this involves the inability of the farmers to access farm incentives from the government and other relevant NGOs in the State. Generally, this implies that the above constraints posed negative threats to rice production and yield in the State.

In conclusion, the findings of the study show that the rice farmers accessed information regarding climate change through mobile phones, radio, cooperative societies, internet, and research institutes. Perceived climate variables such as temperature, rainfall, evaporation, and severe windstorms impacted rice yield negatively, while relative humidity and atmospheric pressure impacted rice yield positively. The result further shows that the inability of the rice farmers to access extension services decreased rice yield significantly. The determinants of rice yield were age, education, gender, farm size, farming experience, household size, and participation in workshop/training and extension services. Factors such as the high cost of input materials, inadequate capital, high cost of labor, poor extension access and services, inadequate information on climate change, farmer-herdsmen conflicts, and pests and disease attacks were perceived production constraints faced by rice farmers. The Government, as a matter of urgency, should resuscitate extension services and empower them to attend to crop farmers in the State. Networking with veteran farmers can help rice farmers gain valuable insights and expertise. Farmers should practice climate-smart agriculture to boost productivity.

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