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THE IMPACTS OF CLIMATE CHANGE ON VEGETABLE PRODUCTION IN EBONYI STATE, NIGERIA

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Abstract

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The impacts of climate change on vegetable production in Ebonyi State, Nigeria, were investigated. With the use of questionnaire, 286 vegetable producers were chosen using multi-stage sampling. Primary sources were used for data collection. Data obtained were analyzed using descriptive statistics, probit, beta and multiple regression methods. The study reveals that the vegetable growers were female (62.6%), married (75.9%), and in their prime age (47%). With greater mean outputs and a higher percentage of vegetable producers, fluted pumpkin (6943.63 kg), green pepper (6011.20 kg), garden egg (5976.52 kg), and okra (5874.53 kg) dominated vegetable cultivation. The outputs of vegetables were favorably influenced by age ($P< 0.05$), farm size ($P< 0.01$), and education ($P< 0.01$). Some of the adaptation measures utilized by vegetable producers were planting improved vegetable seeds (99.7%), modifying planting and harvesting dates (98.6%), and effective staking methods (100%). Age ($P< 0.01$), education ($P< 0.01$), household size ($P< 0.01$), farming experience ($P< 0.05$), and extension contacts ($P< 0.01$) served as important predictors of climate change adaptation. Vegetable production was negatively impacted by temperature, precipitation, and relative humidity, while sunshine fared well with vegetable yield. The study concludes that climate change poses negative impacts on vegetable production and advised vegetable producers to practice climate smart agriculture to mitigate climate change impacts on vegetable crops.

Key words: adaptation, determinants, socioeconomic features, fluted pumpkin.

Introduction

Vegetables are important in nutrition of humans because they are rich in dietary fiber, vitamins, minerals, and in short supply of fat and carbohydrates (Gaire, Dahal, 2021). Vegetables are becoming more important due to nutrient deficiency in other food consumptions. It is reputed as a promising economic sector that can help developing countries minimize rural unemployment and poverty and plays a key role in agricultural diversification programs (Osuji et al., 2022a). According to statistics, China has been the world's top producer of vegetables, accompanied by India, the United States, Turkey, Iran, and Egypt (FAO, 2021). Vegetable industrialization will promote large-scale crop production and a wider range of rural entrepreneurship. Variations in climate are rapidly affecting vegetable output and the financial gains of vegetable growers. In Nigeria, vegetable production has been impaired by severe droughts, high temperature, delayed and irregular precipitation, floods, increased wind, and other varying climate changes that are common in Nigeria and many African countries (Abram et al., 2020). These climate changes have a serious impact on food and vegetable production in Nigeria and around the globe. Climate change remains a serious issue affecting the agricultural sector in Nigeria due to its predisposition mostly temperature and rainfall variations. Changes in climate is a significant obstacle for food output and vegetable crops for instance, high temperature reduces crop yields while increasing the spread of weeds and insects, and changes in precipitation patterns increase the chances of immediate crop failure and extended output losses (Abubakar et al., 2020). In addition, severe rainfall and harsh temperatures exacerbate agricultural production, leading to low yields and occasionally failure of crops (Igberi et al., 2022a). The production of vegetables is mostly dependent on rain-fed farming and a good climate, both of which are undergoing global climate change. No doubt, the output and yield of vegetables in Nigeria have been declining annually despite its intensive cultivation due to instances of climate change and other variable weather condition (FAO, 2022). In Ebonyi State in particular, vegetable farmers are experiencing severe losses from pre-to-post-harvest field caused by climate change in both the immediate and extended periods. Vegetable production in the state is declining rapidly resulting in output loss, reduced income, and lower contribution of vegetable crops to gross domestic product in the state (Osuji et al., 2022b). Empirical records show that the vegetable market in Nigeria is projected to grow by 13.53% (2024-2028), resulting in a market volume of USD 45.02 billion in 2028 (FAO, 2023). Thus, this estimation was projected across the 36 states in Nigeria including Ebonyi State. However, this projection cannot be achieved if climate change continues to negatively influence vegetable production across the states. However, numerous studies (Dominic et al., 2017; Asfew et al., 2022; Rathod et al., 2018; Onyeneke et al., 2024) have examined the impacts of climate change on crop production in Nigeria. Other studies (Boansi, 2017; Igberi et al., 2022b; Kumari et al., 2018; Gershon et al., 2020) were direct and specific on the crops (cassava, yam, and cocoyam) impacted by climate change as well as cereal crops (rice, maize, wheat, and sorghum) (Gairhe, Adhikari, 2018; Mariem et al., 2020; Rettie et al., 2022; Wang et al., 2018; Emenekwe et al., 2022). Interestingly, no study has addressed the impact of climate change on vegetable crops in Ebonyi State, Nigeria, using varieties of vegetable crops (see Table 2). This created a huge gap in knowledge and drives the motivation for the study. Furthermore, the study examined up to five climate variables affecting vegetable crops, against previous studies that captured only temperature and rainfall.

Material and methods

Study area

The study was conducted in Ebonyi State, Nigeria. The state is located in southeast zone and has a large agricultural land mass with the majority of the populace being farmers. The total land area is about 5,533 km^2 with latitude: 6°10′ 40.7028″ and longitude: 7°57′33.4296″. The State has 13 local government areas (LGAs) with an estimated population of 3,242,500 people. The temperature in the state is 25°C, while the rainfall is between 1200 and 1500 mm. Between November and March, there are two seasons: the dry and the rainy. Rainforest-dominated vegetation in the area sustains the farming of cereals, root and tuber crops, fruits, and vegetables.

Sampling techniques

Multi-stage sampling technique was used in selecting the respondents. In the first phase, four LGAs were picked at random from each of the agricultural zones of the State (Ebonyi North, Ebonyi South, and Ebonyi Central) to make 12 LGAs. The second phase involved the random selection of four autonomous communities from the selected LGAs, making a total of 48 communities. The third phase had three villages picked at random from the communities to make 144 villages. In the final and last phase, 5 vegetable farmers were picked at random to make 720 farmers. A questionnaire was used to collect the primary data from the 720 sampled farmers. The data collection was guided by the researchers to ensure total compliance of information needed. From the outcome, a total of 402 vegetable farmers provided useful information for data analysis.

Methods of data analysis and model specification

Data analyses were carried out using descriptive statistics, beta regression model, probit model, and multiple regression technique.

The beta regression model is expressed as follows:

$$F(y; p, q) = \frac{\Gamma(p+q)}{\Gamma(p)\Gamma(q)} y^{p-1}(1-y)^{q-1},\ 0 < y < 1\,, \qquad (1)$$

where *p* and *q* are unidentified parametric quantities. Where*p*, *q*> 0, *y* is the dependent variable and is the gamma function.

Transforming parametric quantity (*p*, *q*) to those of the mean *μ* and precision φ, by settingand φ = *p* +*q*, we now have

$$F(y; \mu, \varphi) = \frac{\Gamma\varphi}{\Gamma(\mu,\varphi)\Gamma(1-\mu)\varphi} y^{\mu\varphi-1}(1-y)^{(1-\mu)\varphi-1},\ 0 < y < 1, \qquad (2)$$

where 0 <*μ*< 1 andφ> 0. The random variable *y*'s mean and variance were calculated as *E* (*y*) = and Var (*y*) = (1-*y*) / (1 + y). The precision parameter is denoted by the symbol φ, indicating that the higher the *y*'s mean, the smaller the *y* variance. The dispersion parameter is denoted by the symbol -1, since *y*'s variance depends on *y*'s mean. The beta regression model is a parameterization model and is thus inherently heteroskedastic in nature. Assuming a Var (*y*) = (1-y) / (1 + y), we now have

$$\mathrm{Var}\,(y_i) = \frac{\mu i\,(1-\mu i)}{1+\varphi} = \frac{g^{-1}\left(X_1^T\beta\right)\{1-g^{-1}\left(X_1^T\beta\right)\}}{1+\varphi}\,. \qquad (3)$$

Let $y_{1 \ldots\ldots\ldots\ldots} y_n$ be stochastic sample distribution such that y_{1-} β (μ_i φ), i =1, …n. Thus, the beta regression model is stated

$$g\,(\mu_i) = X_i^T\,\beta + r_i = \acute{\eta}_i\,, \qquad (4)$$

where β = (β1,……βk)T is a *k* by 1 vector of unidentified regression parameters (*k*; *n*), where Xi = (xi1,…………xik). *T* is a vector made up of *k* regressors, independent variables, or covariates, and i is a linear predictor for the ith observation, i.e., i = 1xi1 + kxik. Typically, xi1 = 1, with n being the sample size and accommodating intercept for all i. Here, g (.): (0, 1) – i.e. the linear predictor and the response variable are connected by a link function called IR. Consequently, beta regression logit link function is written as

$$g\,(\mu) = \log \mu \,/\, (1-\mu) \qquad (5)$$

Thus, an estimation of beta regression model's log likelihood is written as

$$L_i\,(\mu_{i,}\,\varphi) = \log \Gamma'\,(\varphi) - \log \Gamma'\,(\mu_i\varphi) - \log \Gamma'\,(1-\mu_i)\,\varphi\} + (\mu_i\,\varphi - 1) \log y_i + \{1-\mu_i)\,\varphi - 1\} \log\,(1-y_i) \qquad (6)$$

Note that $\mu_i = g^{-1} X \frac{T}{1} \beta$ is a function of β, the vector of regression parameters, thus

$$ADAP_{ti} = g(\mu_i) = X_i^T\beta + r_i = \acute{\eta}_i , \quad (7)$$

$$ADAP_{ti} = f(b_o + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6X_6 + b_7X_7 + b_8X_8 + b_9X_9 + b_{10}X_{10})_{+} ri, \quad (8)$$

$$ADAP_{ti} = \text{Adaptation Index} = \frac{M}{N} , \quad (9)$$

where $ADAP_{ti}$= Adaptation index (adaptation measures/practices engaged by vegetable farmers), M = Specific number of adaptation measures/practices engaged by ith vegetable growers, N = Total number of adaptation measures/practices exposed to vegetable growers, B = Vector with undetermined coefficients, r_i = which is thought to be independently distributed with a mean of 0 and a constant variance, X_i = Independent variable vector Which include? X_1 = Farmer age (Years), X_2 = Schooling (No. of years spent in school), X_3 = Size of household (No. of persons), X_4 = Capital access (Naira), X_5 = Experience in farming (No. of years), X_6 = Size of farm (Hectare), X_7 = Seeking for early information on climate change (Yes, 1, No; 0), X_8 = Participation in climate change expository workshops (No. of times), X_9 = Labor supply (Man days), X_{10} = Contacts with extension agents (No. of visits), ri = Error term.

The dependent and independent variables were estimated using the maximum likelihood (ML) of beta regression model.

Multiple regression using ordinary least squares is expressed as

$$Y = f(X_{1,} X_{2,} X_{3,} X_{4,} X_{5,} X_{6,} X_{7,} X_{8,} X_9)_{+} ei \quad (10)$$

where Y = Output of vegetable crops (Kg), X_1 = Age (Years), X_2 = Sex (Male 1, Female 0), X_3 = Size of Household (No. of persons), X_4 = Size of Farm (Ha), X_5 = Schooling (No. of years spent in school), X_6 = Experience in farming (No. of years), X_7 = Input price (Naira), X_8 = Membership in cooperative (Member 1, Otherwise 0), X_9 = Contacts with extension agents (No. of visits), ei = Error term.

Probit model is shown as follows

$$Y = f(X_{1,} X_{2,} X_{3,} X_{4,} X_{5,})_{+} ei, \quad (11)$$

where Y= Perceived output of vegetable crops (Increased =1, Otherwise = 0), X_1= Temperature , X_2 = Rainfall , X_3 = Sunshine hours , X_4 = Relative humidity , X_5= Evaporation rate , ei = Error term.

Table 1. Socio-economic features of vegetable growers.

Socio-economic factors	Frequency	Percent
Gender		
Male	107	37.4
Female	179	62.6
Age		
21-30	6	2.1
31-40	126	44.1
41-50	144	50.3
51-60	10	3.5
Mean age	47	
Marital status		
Single	26	9.1
Married	217	75.9
Separated/Divorced	14	4.9
Widow/Widower	29	10.1
Schooling		
Primary	101	35.3
Secondary	135	47.2
University	12	4.2
None	38	13.3
Field experience		
1-10	99	34.6
11-20	112	39.2
21-30	73	25.5
31-40	2	0.7
41-50	-	-
Mean farming experience	19	
Household size		
1-4	92	32.2
5-9	194	67.8
10-14 Mean household size	- 7	-
Extension contacts		
Contacted	98	34.3
Otherwise	188	65.7
Cooperative membership		
Belong	222	77.6
Otherwise	64	22.4
Farm size		
0.1-1.0	70	24.5
1.1-2.0	203	70.9
2.1-3.0	13	4.5
Mean farm size	1.8	

Results

Socioeconomic features of vegetable growers

In Table 1, the primary socioeconomic traits of vegetable growers are displayed using frequency and percentages. The results showed that vegetable growers were more of female, married, had secondary education, had experience in vegetable farming, belonged to cooperative unions, and had poor extension contacts with a mean age of 47 years, household size of 7 persons and farm size of 1.8 ha which is less than 2 ha. These socioeconomic traits of vegetable growers influenced vegetable production in the area.

Descriptive statistics of different vegetable production outputs

Table 2 displays the descriptive statistics of the various vegetable production outputs using mean output, standard deviation, min-

Table 2. Descriptive statistics of different vegetable production outputs.

Vegetable	No. of Growers F	%	Mean Output	Standard Deviation	Minimum Output	Maximum Output
Green pepper	285	99.7	6011.20	67.6453	6004.65	7200.54
Water leaf	200	69.9	4454.84	45.6474	4344.66	5111.74
Onion	88	30.8	2327.92	43.5353	2284.97	3000.84
Tomato	211	73.8	3343.83	54.6764	3254.84	4550.00
Okazi leaf	67	23.4	4532.82	65.4392	4502.84	5022.53
Scent leaf	102	35.7	3453.53	66.4599	3412.93	4344.83
Amaranthus	99	34.6	2321.73	76.7755	2002.53	3000.64
Spinach (Green leaf)	246	86.0	4432.81	53.7353	4011.64	5053.74
Bitter leaf	280	97.9	5645.54	64.6353	5242.73	6032.93
Cucumber	189	66.1	4543.34	32.5422	4000.73	4700.64
Okra	278	97.2	5874.53	84.7454	5000.74	6113.74
Mushrooms	107	37.4	1222.54	56.5343	1200.65	1900.87
Eggplant leaf	171	59.8	2323.57	634.433	2011.74	3000.84
Garden egg	281	98.3	5976.52	43.8432	5203.63	6002.63
Watermelon	282	98.6	4863.93	53.8432	4035.84	5000.74
Fluted pumpkin	286	100	8943.63	69.5433	5673.94	7000.64
Cabbage	192	67.1	4343.75	84.7464	4000.84	4900.74
Lettuce	154	53.8	2345.43	65.6454	2300.63	2983.84
Uziza leaf	109	38.1	3983.93	48.7454	3213.84	4003.81
Carrot	170	59.4	2453.32	47.5454	2002.63	2788.99

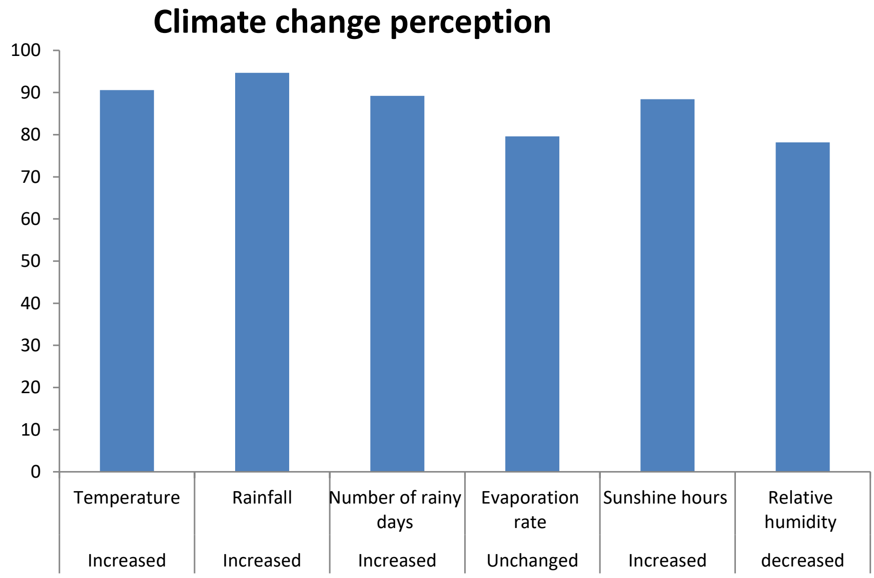

Fig. 1. Perception of climate change among vegetable growers.

imum and maximum outputs. The results showed that the vegetable growers cultivated different varieties of vegetables ranging from Green pepper, Water leaf, Onion, Tomato, Okazi leaf, Scent leaf,Amaranthus, Spinach (Green leaf), Bitter leaf, Cucumber, Okra, Mushrooms, Egg plant leaf, Watermelon, Fluted pumpkin, Cabbage, Lettuce, Uziza leaf and Carrot with different mean outputs,standard deviation, minimum and maximum outputs. These vegetables produced provided the vegetable growers with both food and income for family upkeep.

Perception of climate change among vegetable growers

The perception of climate change among vegetable growers is shown in Figure 1. From the figure, the vegetable growers observed different variations in the climate variables investigated. The results showed that temperature, rainfall, number of rainy days and sunshine increasedwhile evaporation remained unchanged with a decrease in relative humidity. Variations in climate variables have been a serious challenge for vegetable production.

Perceived impact of climate change on vegetable production

In Table 3, the probit regression model produced the perceived impact of climate change on vegetable production. The results showed that climate variables such as temperature, rainfall, and relative humidity were negative and significant at both 1 and 5%statistical levels. Sunshine hour had a positive sign and was significant at both 1% statistical level. On the other hand, the evaporation rate was negative and showed no significance. The R^2 value of 0.961 indicated that 96.1% of the entire variance in the output of vegetable crops was explained by the climate variables investigated. The *F*-value of 18.61being significant at 1% level showed that the model fitted perfectly.

Effects of socioeconomic factors on vegetable production

The socioeconomic factors that impact vegetable production are shown in Table 4. The double-log function was selected as the principal equation providing best fit due to its high value of coefficient of multiple determinations (R^2), higher number of relevant significant variables, and high *F*-value. About 80% of variability in the endogenous variable was explained by socioeconomic elements studied according to (R^2) result of 0.800. The *F*-value of 34.13 explained the model's fitness. Socioeconomic factors such as age, gender, household size, farm size, education, and farming experience were important significant variables that influenced vegetable production in the area. They often play peculiar roles in vegetable farming.

Adaptation measures adopted by vegetable growers in the face of climate change

Table 5 shows adaptation measures adopted by vegetable growers in the face of climate change and this was expressed using descriptive statistics. The various adaptation measures include: planting improved and different vegetable crop varieties, insur-

Table 3. Perceived impact of climate change on vegetable production.

Variables	Coefficient	T-values	Std. Error
X_1	-0.801	-4.103***	0.195
X_2	-0.911	-4.820***	0.189
X_3	0.558	3.901***	0.143
X_4	-0.900	-2.003**	0.449
X_5	-0.818	-0.029	28.21
R^2	0.961		
F-value	18.61		
Constant	3.706	4.030***	0.175

Table 4. Effects of socioeconomic factors on vegetable production.

Variable	Linear	Semi-log	Double-log	Exponential
Constant	45.565 (1.104)	3.2352 (4.201)***	32.0402 (2.322)**	5.4022 (2.721)**
Age (X_1)	4.2351 (3.424)***	3.0251 (1.512)*	6303.1 (2.437)**	1.3271 (0.349)
Gender (X_2)	-524.333 (-1.403)	-6.4039 (-0.941)	-542.31 (-3.360)***	-4.4775 (-1.477)
Household size (X_3)	313.312 (1.211)	4.2066 (0.111)	3365.0 (3.739)***	4.1355 (1.007)
Farm size (X_4)	3001.10 (4.339)***	4.2345 (2.419)**	6244.32 (4.603)***	4.0025 (4.024)***
Education (X_5)	340.356 (1.020)	4.9320 (1.223)	5029.9 (3.211)***	1.5219 (2.934)***
Experience (X_6)	522.202 (1.132)	0.6515 (4.104)***	3442.1 (2.360)**	4.5502 (1.030)
Input price (X_7)	612.06 (1.539)*	2.4291 (1.315)	270.212 (0.331)	2.4405 (1.445)
Membership in cooperative (X_8)	4013.1 (1.121)	4.2546 (1.304)	3.4652 (1.043)	4.2218 (2.039)**
Extension contact (X_9) R^2	68.195 (1.321) 0.889	14.333 (1.373) 0.608	2.6542 (1.410) 0.800	6.4401 (1.331) 0.701
F- ratio	12.07***	17.18***	34.13***	23.41***

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

Table 5. Adaptation measures adopted by vegetable growers in face of climate change.

Adaptation Actions	*Frequency	Percentage
Planting improved and different vegetable crop varieties	285	99.7
Insurance policy	67	23.4
Diversification of livelihood	267	93.4
Water & soil conservation techniques	281	98.3
Adjusting planting and harvesting dates	282	98.6
Application of Irrigation	41	14.3
Climate information and forecasts	201	70.3
Nursery planting	245	85.7
Correct application of fertilizer	283	99.0
Efficient and effective use of pesticide	205	71.7
Prompt and regular weeding	209	73.1
Access to loans, grants and subsidies	123	43.0
Reliance on government inputs and materials	188	65.7
Reliance on government extension agents	194	67.8
Appropriate and efficient mulching	202	70.6
Appropriate and efficient staking	286	100
Crop rotation system	141	49.3
Use of efficient tillage system	203	71.0
Attendance of climate change trainings/forums/discussions	178	62.3
Efficient drainage and erosion control measures	199	69.5

Table 6. Determinants of vegetable growers' adaptation to climate change.

Variables	Parameters	Coefficients	Z-values	Std. Error
Constant	b_o	10.985	4.689**	2.342
Age of farmer	b_1	-4.875	-3.789***	1.286
Education	b_2	10.567	4.945***	2.136
Household size	b_3	0.684	4.430***	0.154
Access to capital	b_4	0.789	2.500**	0.315
Farming experience	b_5	9.385	2.602**	3.606
Farm size	b_6	6.849	1.032	6.635
Seeking of early information on climate change	b_7	8.478	2.702**	3.137
Participation in climate change expository workshops	b_8	9.878	1.099	8.987
Labour supply	b_9	0.687	1.333	0.515
Extension contacts	b_{10}	0.590	4.402***	0.134
Log likelihood		194.3***		
Pseudo (R^2)		0.879		
N		286		

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

ance policy, diversification of livelihood, water and soil conservation techniques, adjusting planting and harvesting dates, application of irrigation, climate information and forecasts, nursery planting, correct application of fertilizer, efficient and effective use of pesticide, prompt and regular weeding, access to loans, grants and subsidies, reliance on government inputs and materials, reliance on government extension agents, appropriate and efficient mulching, appropriate and efficient staking, crop rotation system, use of efficient tillage system, attendance of climate change trainings/forums/discussions, and efficient drainage and erosion control measures. These practices were deployed in mitigating climate change impacts on vegetable farming.

Determinants of vegetable growers' adaptation to climate change

The adaptation determinants of vegetable growers to climate change are shown in Table 6. The beta regression model's fitness was informed by the pseudo (R^2) value of 0.879, which also accounted for 87% heterogeneity in factors responsible for vegetable growers' adaptation to climate change. The log probability value of 194.3 was significant at 1% level indicating a high likelihood value and implies the suitability of the model used in evaluating the determinants of vegetable growers' adaptation to climate change. Results showed that the age of farmer, education, household size, access to capital, farming experience, seeking of early information on climate change and extension contacts were important and major significant variables responsible for vegetable growers' adaptation to climate change. These variables influenced the vegetable growers' decisions in adjusting to climate change.

Discussion

According to Table 1, about 63% of the vegetable growers were women. This suggests that there were more female vegetable growers than the male (Malhi et al., 2021). The majority of vegetable growers were between the ages of 41 and 50. This suggests that the vegetable growers were in their prime age. Majority of the vegetable growers, 76% were married, and this implies that vegetable cultivation was dominated by married growers (Leisner, 2020). The majority of vegetable growers had at least a secondary education, which suggests that they were relatively educated to comprehend fundamental production principles. The majority of vegetable growers had an average of 19 years in farming experience, which suggests that the vegetable growers were experienced in vegetable production (Osuji et al., 2021). The average household size among vegetable growers was seven people, suggesting more workforces utilized in vegetable production. About 66% of vegetable growers had no contact with extension agents, probably due to the shortage of extension agents or the farmers not being present during extension visits (Pushparani et al., 2017). Majority of the vegetable growers, 78% belonged to cooperatives and this helps in accessing improved planting materials such as improved seedlings, agro-chemicals, etc. The mean farm size was 1.8 ha, suggesting that vegetable growers cultivated on small portions of lands (Onyemuwa et al., 2017).

Table 2 shows that 100% of the farmers produced fluted pumpkin with an average of 8943.63 kg. This implies the domineering nature of fluted pumpkin among other vegetables in the state. More than 90% of the vegetable growers cultivated green paper, bitter leaf, okra, garden egg, and watermelon with an average of 21860.52 kg per cropping season. This implies a higher production output and increased income for the vegetable growers (Osuji et al., 2022a). Less than 40% cultivated uziza leaf, mushrooms, amaranthus, scent leaf, and onion with an output of 13309.65 kg, which indicates improved financial returns (Amao, Egbetokun, 2018). Tomato, lettuce, water leaf, and cucumber with a total output of 14687.44 kg were cultivated by 263.6% of the vegetable growers. Consequently, carrot, eggplant leaves, spinach, okazi leaves, and cabbage gave a total mean output of 18086.27 kg and were cultivated by over 290% of the vegetable growers. It is interesting to note that fluted pumpkin, green pepper, garden egg, and okra dominated vegetable cultivation in the state with higher mean output and higher percentage of vegetable growers. The popularity of these veggies may be due to their high demand and nutrient composition in the area. Vegetables are a significant source of food component, which is rich in nutrition and vital for body growth and development (Thomas, Nigam, 2018).

According to Figure 1, almost 91% of the vegetable growers felt that the temperature was rising. Thus, a rise in temperature has a negative impact on many aspects of vegetable production. An increase in temperature alters vegetable output and yield leading to poor economic and meager monetary returns (Akinbola, 2021). About 95% of the vegetable growers perceived an increase in rainfall patterns. An increase in rainfall destroys planted vegetable crops via heavy downpours initiating uncontrollable flooding of vegetable farmlands (Akanni-John et al., 2020). It causes the multiplication of vegetable pests and diseases resulting in low yield. 89.2% of vegetable growers reported frequent occurrence of rainy days. A rise in rainy days hampers vegetable production by causing farmlands to be destroyed by water erosion and other flooding threats. It could cause the wearing-off of topsoil and nutrient contents of vegetable farmlands, leading to poor yield and output (Aune et al., 2017). About 80% of the vegetable growers perceived the evaporation rate to be unchanged; this implies that evaporation rate neither increased nor decreased. About 88.4% of the vegetable growers perceived an increase in sunshine hours. An increase in sunshine hours has multiple positive effects on vegetable production. It aids the photosynthetic activities of plants and other microbial activities of the soil leading to improved yield and output. It further enhances root and shoot penetration thereby allowing overall plant growth and development (Bisbis et al., 2018). About 78.2% of the vegetable growers perceived a decrease in relative humidity. Reduced relative humidity causes the drying of vegetable leaves, roots, and shoots. It distorts soil and water aerations and further impoverishes the soil leading to poor harvest and poor financial returns.

In Table 3, temperature was substantial and negative at 1%, indicating that a rise in temperature reduces vegetable yield by breeds of different insect pests that eat up vegetable leaves, shoots, and roots (Fu et al., 2015; Kukal et al., 2018). Again, an increase in temperature lead to the hotness of the soil surface, thereby suffocating planted vegetable seeds. Rainfall was unfavorable and substantial at 1%, depicting that a rise in rainfall intensity reduces vegetable yield through soil-erosion of planted vegetable seeds. An increase in rainfall initiates flooding and water logging of farmland, thereby promoting vegetable crop failure, low yield, and reduction in market prices (Kifle, 2021). Sunshine hours were beneficial and statistically substantial at 1%, suggesting that a rise in sunshine hours results in a rise in vegetable production due to the vegetable plants' visible signs of photosynthetic activity. Sunlight hours boost agricultural yield and help to establish strong vegetative roots and shoots of planted vegetable crops, and promote soil anaerobic and microbial activities which ensure better performance of planted vegetables (Kondinya et al., 2014). A 1% up-shift in low relative humidity will cause a 90% fall in vegetable yield, according to estimates of relative humidity, which was unfavorable and substantial at 5%. Low relative humidity limits soil-moisture infiltration in vegetable fields, particularly in dry seasons, causing drier, harder soils that result in crop failure, stunted plant development, and low market value for vegetable crops (Prasad et al., 2020). Low relative humidity also causes dryness of the vegetable leaves and leaf deformation and discolorations, thereby resulting in plant casualties.

According to Table 4, the age coefficient was substantial and beneficial at 5%, which suggests that as vegetable farmers advance in age, so does the quality of their yields. Age is regarded as a significant determining variable that may improve or negatively impact agricultural performance (Osuji et al., 2021). Gender was significant and negative at 1%, suggesting that female farmers predominated in the state's vegetable farming. This may be the case given that more female farmers are engaged in vegetable farming in the state (see Table 1). The impact of household size was 1% beneficial and substantial; indicating that any increase in the number of households among vegetable farmers will raise output. Larger households promote more family labor, work efficiency, and higher household engagement in agricultural activities (Adriana et al., 2020). Farm size was significant at 1% and favorable, indicating that any expansion in the size of vegetable growers' farms will correspond to an increment in yield of vegetables. Large farm sizes promote and facilitate increased production of agricultural crops. Education was 1% significant and favorable, suggesting that 1% more education among farmers will result in 1% more improvement in vegetable output. Education helps people learn more and have a better grasp of farming and agricultural techniques (Dong et al., 2018). The 5% level of positive and substantial farming experience suggests that any improvement in the producers' level of farming experience will translate into an increase in vegetable yield. Farmers learn more via experience and exposure to farm operations.

In Table 5, it showed that the vegetable farmers employed a variety of adaptation measures to lessen climate change impacts. It was found that 99.7% of vegetable growers planted improved and diverse vegetable crop varieties, 93.4% used livelihood diversification strategies, 98.3% used water and soil conservation techniques, 98.6% adjusted planting and harvesting dates, 99% applied fertilizer appropriately, and 100% staked vegetables properly and effectively. Planting improved and different vegetable crop varieties enhances yield performance and optimal output of vegetable crops. Improved vegetable varieties are result-output oriented and resistant to vegetable insects, pests, and diseases which devalue vegetable produce (Gruda et al., 2021). Livelihood diversification enables vegetable growers to diversify to other means of livelihood outside vegetable cultivation. Soil and water conservation techniques enhance vegetable crop production leading to profitable economic returns (Oriangi et al., 2020). Adjusting planting and harvesting dates aid vegetable growers to overcome and mitigate climate change excesses. It assists vegetable growers to properly prepare, plan, and coordinate their vegetable production without climatic hitches. Appropriate application of fertilizer aids maximum output and yield performance of vegetable crops. It increases the nutrient content of the soil and mineral composition. Appropriate and efficient staking of vegetable plants improves vegetative growth and provides support for vegetable plants. Also noted on the table were the percentages of vegetable growers who planted in nurseries (85.7%), relied on weather reports and predictions (70.3%), and used pesticides effectively (73.1%), efficient and timely weeding (71.7%), appropriate and effective mulching (70.6%), and adoption of an effective tillage technique (71.0%). Planting in a nursery shields young vegetable seedlings from the direct harm that climate change and other bad weather conditions can cause. It improves the plant quality and nutrient contents of vegetable produce (Ayyogari et al., 2014). Efficient and effective use of pesticides helps vegetable growers to control incessant pests' attacks on planted vegetables which degrade their economic returns. Prompt and regular weeding ensures proper and adequate growth of the planted vegetable crops without suffocation from unwanted weeds. It ensures proper soil aerations and ventilations at all times. Appropriate and efficient mulching supports the roots, shoots, and overall plant growth leading to optimal yield and overall performance of the vegetable plants. Use of an efficient tillage system enhances soil and land conservation and ensures overall protection and sustenance of the vegetative layers of the soil, especially the topsoil (Amao, Egbetokun, 2018). Again, the vegetable growers (65.7%), relied on government inputs and materials, 67.8%, reliance on government extension agents, 62.3%, attendance of climate change trainings/forums/discussions, and 69.5%, efficient drainage and erosion control measures. Reliance on government inputs and materials aids indigent vegetable growers to procure improved planting vegetable materials and other planting inputs at little or no cost. Reliance on government extension agents provides vegetable growers with the requisite practical and on-hand knowledge on different climate adaptation actions and techniques (Onyeneke et al., 2024). Attendance of climate change training/forums/discussions offers vegetable growers opportunities to be educated and enlightened on climate change diversity and mitigation strategies. Effective drainage and erosion management strategies aid in preserving the soil's surface and guard against soil erosion, denudation, and general devastation of vegetable farmlands. Consequently, some of the vegetable growers 23.4%, engaged in insurance policy, 14.3%, irrigation drive, 43.0%, access to loans, grants, and subsidies, and 49.3%, crop rotation system. Insurance policy protects the vegetable growers from possible natural hazards such as fire incidence, flood, erosion menace, and other negative eventualities which might affect the vegetable growers (Gershon, Mbajekwe, 2020). Irrigation supplies the required water needed for plant growth and development especially during dry season. Access to loans, grants, and subsidies assist poor vegetable growers in cushioning the high cost or inflated prices of planting materials and other valuable inputs. Crop rotation system improves the fertility of the soil and enhances maximum vegetable growth and quantum output.

In Table 6, age is implied as a substantial adaptation variable due to the fact that the age coefficient turned negative and was substantial at 1% level. This indicates that as farmers get older, their propensity for adaptation declines, and they become more conservative and non-receptive to new agricultural innovations (FAO, 2023). The coefficient of education was beneficial and important at 1%, suggesting that the level of education attained by the vegetable growers greatly influences their adaptation tendencies and behaviors. Educated farmers adapt to climate change more than uneducated ones. At 1% level, a positive and substantial correlation between household sizes was found. This implies that the likelihood of vegetable growers adapting to climate change favorably increases with household size. Some adaptation activities, like staking vegetables, weeding, mulching, etc. are labor-intensive and need additional hands to complete quickly (Guta et al., 2020). The coefficient of access to capital was found to be substantial and beneficial at 5%. This suggests that increased accessibility to capital strengthens the propensity of vegetable growers to adapt to climate change. Experience in farming was beneficial and favorable at 5%, which indicates that it is easy for experienced vegetable growers to adapt to climate change without persuasion. The coefficient of seeking preliminary data on climate change was favorable and statistically substantial at 5%, which suggests that vegetable producers who sought out early information on climate change were better equipped to adjust to the shift in climate change than those who did not (FAO, 2022). Positive and meaningful result for the coefficient of extension contact was seen at the 1% level. As a result, vegetable producers have a greater chance of adapting quickly to climate change resulting from extension visits.

Conclusion

Assessing the adverse effects of changing climate on vegetable output in Ebonyi State, Nigeria, was investigated. The findings revealed that the vegetable farmers were in their prime age, married, relatively educated, and experienced. Varieties of vegetable crops were cultivated with fluted pumpkin, green pepper, garden egg, and okra dominating the vegetable cultivation with a higher mean output and higher percent of vegetable growers. Production of vegetable crops was impacted by age, education, farm size, and extension contacts. The vegetable farmers noticed significant increases in temperature, rainfall, number of wet days, and sunlight. Decreases in relative humidity and evaporation rates were also noticed. Planting improved and different vegetable crop varieties, insurance policies, livelihood diversifications, and conservation strategies were some of the adaptation measures applicable to vegetable growers. Consequently, age, education, farm size, farming experience, and extension contacts were important adaptation determinants of vegetable farmers to climate change. Climate change variables including temperature, precipitation, and relative humidity have a detrimental influence on the growth of vegetable crops, while sunshine had a positive impact on vegetable production. The study recommends vegetable growers to practice climate smart vegetable production to mitigate adverse consequences of climate change on vegetable production. Accessing climate change information before cultivation of vegetables was also advised. Governments were also tasked to assist vegetable crop growers with the provision of adequate planting materials and deployment of adequate extension agents to educate and assist vegetable growers.

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