Journal of Agriculture, Food, Environment and Animal Sciences
Tarım, Gıda, Çevre ve Hayvancılık Bilimleri Dergisi
http://www.jafeas.com, ISSN: 2757-5659

J. Agric. Food, Environ. Anim. Sci. 6(1): 244-257, 2025

Assessment Climate Change Adaptation Strategies on Maize Production in Selected States, in South-West, Nigeria

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Research Article

Article History:
Received: 02 November 2024
Accepted:02 April 2025
Published online: 01 June 2025

***Keywords*:**
Climate Change
Adaptation Strategies
Assessment
Maize
Production

ABSTRACT

Nigeria agriculture is rainfed, consequently, the climate change (CC) is severe and deter food sufficiency goals. Adaptation strategies (AS) for mitigating CC is at a cost, reducing the profit. Thus, assessment of CC adaptation strategies on maize in Southwest, Nigeria was examined. A multistage sampling method was adopted using the Agricultural Development Programme (ADP) frame. Osun and Oyo states were purposely selected due to high maize production level. Seven ADP zones: (Oyo four and Osun three) were stochastically picked. A block was stochastically picked from the selected zones. Twenty-one cells were picked each. Then 240 maize farmers were selected proportionate to the cell's size. Questionnaire was used to elicit data on CC, AS, maize yield, costs and benefits of AD. Data were analyzed with descriptive statistics: Likert scale, bar chart, net benefit, net present value, internal rate of return and Ordinary least squareα 0.05. Temperature (M = 4.22±0.99), Precipitation (M= 4.01±1.22), Sunshine (M = 3.33±3.22) were the perceived climatic factors that influence maize. Ten AD were adopted with late planting (60%), farmyard manure (24%), artificial fertilizer (33%), improved maize seed (45%), and ridges (25%). Fertilizer application (p<0.001), compost manure (p<0.001) and livestock rearing on farmland before cultivation (p<0.001) positively and significantly affected maize yield. High Net-present-value and internal-rate-of-return showed the order of economic efficiency: fertilizer, compost manure and drought resistant varietywere significant AS. The study established that climate factors affect maize yield and recommended fertilizer, compost manure and drought resistant seed to increase maize yield.

To Cite : Komolafe JO, Ikotun DO, Aghedo, HO., 2025. Assessment Climate Change Adaptation Strategies on Maize Production in Selected States, in South-West, Nigeria. Agriculture, Food, Environment and Animal Sciences, 6(1): 244-257.

INTRODUCTION

Maize is a multipurpose cereal cultivated and utilized globally. It provides food and fuel for man and feed for animals (Adiaha, 2017; Komolafe and Adeoti, 2018; Mensah, et al., 2022). Maize, rice and wheat are global staples, they provide more than fifty percent of global calories intake (World Atlas, 2017). Maize is an important ingredient for flour mills, breweries, feed manufacturing and confectionaries (Adiaha, 2017; Dabija et al., 2021). Unfortunately, its production is directly and indirectly confronted with CC challenges, seemly unsurmountable because it is rainfed, therefore, farmers depend solely on climate since there are no infrastructure for irrigation (Amare and Simane, 2017; Mubiru et al., 2017). In Nigeria maize has a significant contribution to food for the populace, employment for small-scale farmers and marketers (Vučkovski and Marina, 2024).

Persistent weather of a location, for more than 30 years is climate (IPCC, 2023). The (IPCC, 2021) provided a comprehensive definition of climate change (CC), emphasizing its anthropogenic causes CC in short CC is a long-term deviation from normal weather patterns associated with precipitation, wind, humidity temperature and other climatic factors. Hansen and Stone, (2016) asserted that CC resulted from either natural change in sun activities and burning of fossil fuels and large volcanic eruptions. Scientists observed changing earth's climate by human actions of burning of fossil fuels and deforestation that lead to the emission of greenhouse gases (Abbass et al., 2022; IPCC, 2023). Mostly affected were vulnerable populations, which comprises of marginalized communities and small-scale farmers, They bear a disproportionate brunt of the changes due to overly rely on climate-sensitive sectors for survival and their limited resources which disadvantaged them to mitigate and adapt to CC. Farmers are exposed to droughts, floods, heatwaves, and pest outbreaks, which has become more frequent and intense, posing challenges for maize production(Adesina et al., 2020). Issue of CC calls for urgency due to its negative effect on economic sectors, including agriculture (Smith et al., 2022).

The impact of CC on maize is serious and multifaceted. Studies have shown that CC can result in reduced crop yields, decreased profitability, increased costs and compromised food security for farmers (Cudjoe et al., 2021; Smith et al., 2022). Studies examined the weather factors that significantly impact maize productivity, providing valuable insights into the complex relationship between weather conditions and crop yield. Okafor et al. (2017) used a modelling method to assess the impact of levels of humidity on maize yield, revealing a strong negative correlation between high humidity and crop yields. Ibrahim et al. (2019) investigated the influence of extreme weather on maize. The results highlighted the detrimental impact of precipitation and temperature on maize, leading to crop failure and reduced yields.

To mitigate this, adaptation which is the measures used to minimize vulnerability and enhance CC risk resilience is key (IPCC, 2014). Farmers adaptation to CC were changes in cropping period, soil water management, utilization of drought-resistant, agroforestry methods and using meteorological information in making decisions. Recent literature emphasizes the importance of adaptive capacity, farmers' knowledge and practices, institutional support, and policy frameworks for effectiveness in adapting to CC (Ojehomon and Fosu-Mensah, 2021; Pattison et al., 2022). In using CC adaptation in maize farmers apply safety-first model theory that suggests that farmers prioritize minimizing the risk of maize failure or significant yield reductions over maximizing potential profits (Musshoff et al., 2019). This theory expounds the importance of adaptation in mitigating climate risks and its impacts on maize. By using risk-reducing strategies, such as implementing crop diversification and investing in mitigation infrastructure with the aim to enhance the resilience of their systems, safeguard losses due to (CC). Numerous empirical studies have rigorously investigated the methods adopted by farmers to combat the problems of (CC). These studies not only furnish tangible evidence regarding the efficacy of various adaptation measures, but also illuminated the methodological approach and analytical techniques deployed to fine-tune their outcomes Nwankwo et al. (2019), examined the efficacy of methods such as altering cropping time, embracing improved seed, and implementing water management methods. These adaptive measures significantly enhanced farmers' capacity to cope with changing climatic conditions, resulting in a notable increase in farmer's productivity. The specific impacts of CC on key factors such as rainfall, humidity, temperature, wind and their subsequent implications for profitability and food security are not yet fully understood. This knowledge gap hinders the emergence of suitable adaptation methods. Furthermore, CC is contributing to the migration of labour from agriculture to other sectors due to low agricultural returns, leading to a reduced agricultural workforce and impacting productivity negatively, thereby enhancing food insecurity and hunger. Additionally, implementing CC adaptation methods, which are critical for maintaining productivity, is faced with financial, technological, and knowledge barriers. Information access and support for adaptation also remains a challenge, thus, costs and benefits of adaptation methods of farmers is critical for policy. Few works assessed the costs and benefits of embracing climate-resilient agricultural systems, one of which is (Adebayo et al., 2016). This research revealed that initial investments were necessary for implementation, but they ultimately led to improved yields, decreased crop losses, and increased long-term profitability. Okafor et al. (2017) investigated the importance of adaptation methods on farm-level profit and income. The study provided analytical insights into the economic gains associated with diverse adaptation measures. Empirical evidence from Nigeria strongly indicates that the implementation of adaptation can yield positive effects on maize productivity. Adekunle et al. (2017) evaluated the impact of soil and water conservation practices on maize yield and revealed a positive association between the adoption of these practices and improvements in maize yield.

Socioeconomic factors emerge as a serious constraint, as suggested by the empirical evidence from a study by Ojo et al. (2020) that investigated the barriers to the adoption of climate-smart practices among farmers, revealed limited access to financial resources, posed challenges in CC adaptation technologies investment.

Addressing these interconnected issues of CC in maize is vital to ensure the sustainable production, consequently, food abundance and the stability of the labour force in agriculture. Therefore, an assessment of the prevailing CC adaptation methods adopted to adapt CC effects on maize production is crucial for policy, so as to identify the cost and benefit of the strategy which is the basis of this study. This study has the following specific objectives: (1) identify the climate factors affecting maize (2) identify adaptation strategies adopted by the farmers (3) determine the effect of these strategies on yield and (4) compare the cost and benefit of using selected significant adaptation strategies between users and non-users

MATERIAL and METHOD

Sampling Procedure For Maize Farmers' Selection

The State Agricultural Development Project sampling frame was adopted for this study. A multi-stage sampling method was used. The first stage of the selection was the purposive selection of two states in southwest Nigeria due to high maize production in the states The selection followed the division into low, medium, medium to high and high maize production potential groups formulated by USAID and adopted (Olaniyan, 2015; Komolafe and Adeoti, 2018). Osun state in southwest Nigeria is grouped as medium and Oyo state as medium to high only and the two states were picked for representation of the two categories in the southwest. In stage two, random picking of a block each from the state ADP zone was carried out. Then, 3 cells were stochastically picked from the block and in the final stage random picking of maize farmers from the cells proportional to the size of each cell. A total of 240 farmers were picked and data was gathered using a structured questionnaire.

Table 1. Sampling procedure for maize farmers' selection

State	ADP zone/ estimated household	L.G.A/ADP estimated household	Village	No of questionnaire administered
Oyo State	Ibadan/Ibarapa (113,368)	Ibarapa central (10,966)	Eruwa	13
			Bamigbose	13
			Dawodu	13 Total = 39
Oyo State	Ogbomoso (90,413)	Ogo Oluwa (14,251)	Aba Oyo	13
			Alawusha	13
			Awaye	13 Total = 39
Oyo State	Oyo (91,9340	Iseyin (21,477)	AbuleOdo	16
			Aba Titun	16
			Aleshinloye	16 Total = 48
Oyo State	Saki (119,312)	Saki east (11,885)	Shaki	14
			Adaku	10
			Abaja	10 Total = 36
Osun State	Osogbo (63,421)	Ede north (1152)	Ifon osun	9
			Kajola	9 Total=27
			Abogunde	9
Osun State	Ilesa (62,132)	Oriade (1245)	Iloko	6
			Ijebu-jesa	10 Total=24
			Ilo	8
Osun State	Iwo (73,453)	Iwo (1343)	Alebiosu	9
			AfiNgba	9
			Agbede	9 Total=27
Total	seven zones	Seven LGAs	Twenty-one towns/villages	240

Source: field survey 2023

Data Analysis

Data were analyzed using the following analytical tools. Descriptive statistics- Likert scale showing mean, and standard deviation was used to achieve objective (i), bar chart was used to achieve objective (ii), Cost benefits analysis (net present value NPV) and internal rate of return (IRR) was used to achieve objective (iii). and Least squares regression was used to achieve the objective. (iv)

Analytical Technique

Ordinary Least square (OLS)

OLS was used to estimate the unknown parameters in a regression model to show the effect of AS on yield of maize. OLS was used to minimize the sum squares of the differences between the observations in the dataset and the prediction of the linear function of the dependent variables. The resulting estimator was shown by the formula of a basic OLS regression equation

$$Y_i = \alpha + \beta x_i + \varepsilon_i \quad \text{...} \quad (1)$$

In this equation,

Y_i = the dependent variable, α = a constant, β = the coefficient, x_i= the independent variable and

e_i =the error term.

OLS is computationally feasible and easily used while in econometrics tests. it rests on these assumptions. The violation of the assumptions would result in incorrect results. The assumptions are: The linear regression model is "linear in parameters," there is a random sampling of observations, the conditional mean must be zero, there is no multicollinearity, spherical errors: There is homoscedasticity, and no autocorrelation and error terms must be normally distributed.

Objective 3: $Y = \alpha + \beta x_i + \epsilon_i$ ....(2)

Y= Yield, α and β were parameters estimated, $\in_i$=the error term.

X_1 = Livestock rearing on farmland before cultivation; X_2 = Fertilizer application

X_3 = Compost manure; X_4 = Taungya farming /agroforestry; X_5 = Ridging

X_6 = Drought/hybrid resist variety; X_7 Late planting; X_8 = Early planting

X_9 = Land rotation/shifting cultivation; X_{10} = Intercropping

Cost-Benefit Analysis

Cost-benefit analysis (CBA) for selected significant AS was done using the net present values (NPV) net benefit and internal rate of returns (IRR). AS with a high NPV and high IRR implies the most economically efficient adaptation strategies. The CBA evaluates CC effect on maize and allows for the estimation of the net benefits adaptation options and assess the efficiency of AS for decision making criteria. Net present values discount the future benefits to present values, while internal rate of returns evaluates the most economic adaptation strategy. This was done using selected adaptation methods after the regression analysis.

$NB = \Sigma TB - \Sigma TC$ ………………………………………………………………… (3)

Where,
NB = net benefits
TB = total benefits
TC = total costs

For adaptations with no direct costs and benefits, the shadow pricing and opportunity costs were used for computation.

NPV = Σ (–) / ………………….............…………………………………………… (4)

Where;

B_t= Total benefits in time t,   = Total costs in time t, r = Discount rate

(1+r)$_t$= Discount factor for time t.

RESULTS and DISCUSSION

The adaptation strategy with a positive and highest NPV is the most economic and efficient. The net benefit was discounted at 5%, 10% and 15% to perform sensitivity tests. The NPV computed was based on average returns per hectare. IRR implies the discount rate at which NPV is zero. On the scale of preference, the adaptation strategy with the highest IRR is selected.

Table 2. Perceived climate factors affecting maize production

Variable	Mean	Std dev.	Rank	Remark
Temperature	4.22	0.99	1st	Very serious climate factors
Precipitation	4.01	1.22	2nd	Very serious climate factors
Sunshine	3.33	3.22	3rd	Serious climate factors
Humidity	2.42	4.42	4th	Mild climate factors
Wind	2.62	3.32	5th	Mild climate factors

Serious climate factors (mean ≥3.00), Field survey, 2023

Perceived Climate Factors Affecting Maize Production

The perceived climate factors influencing maize were captured on a 3 point Likert scale based on the perceived level: high, moderate and low. The result was presented in Table 2. A mean cut off threshold of 3.0 was used as criteria in making decisions, variables with a mean threshold of score of 3.0 were said to be a serious climate factors influencing maize yield negatively. On the other hand, variables with a mean score < 3.0 were not climate factors of serious concern to the farmers. Based on five climate factors identified, three had a mean score of 3.0. These climate factors were Temperature (M = 4.220.99), Precipitation (M= 4.011.22), Sunshine (M = 3.333.22), Humidity (M =2.424.42), and Wind (M = 2.263.32). This corroborates the work of Igene et al. (2023a) and Komolafe et al. (2024). The mean clustered around 3.00 was an indication that the challenges were serious and equally affected the majority of the respondents. The values of the standard deviations were low showing low variability of farmer's responses and indicating severity of the challenges.

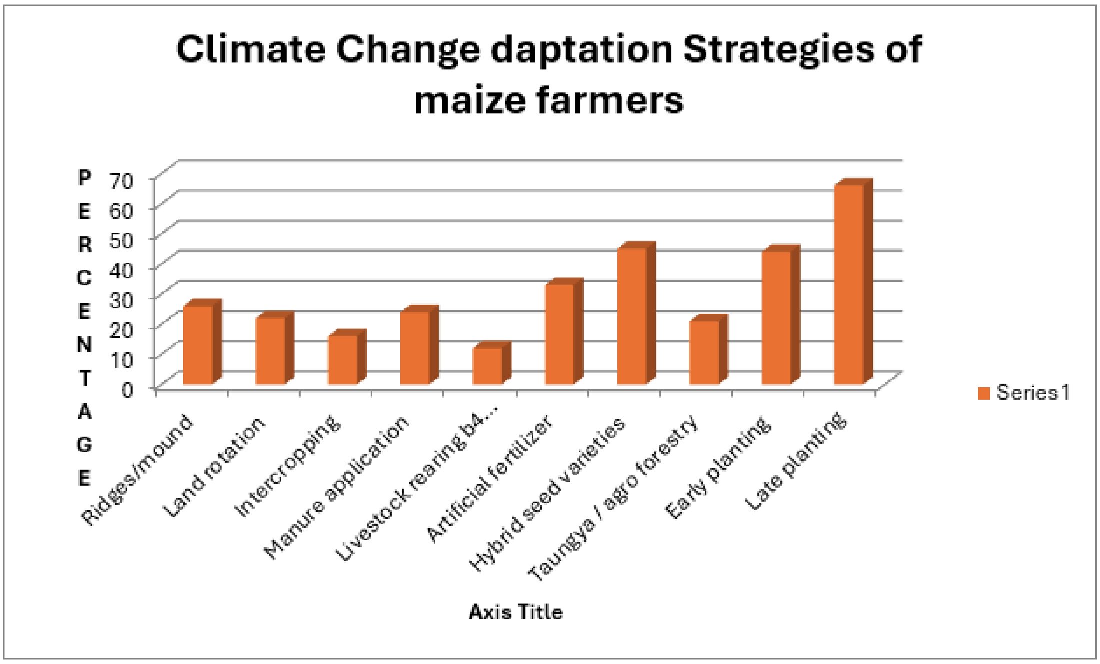

Figure 1. Adaptation strategies used by farmers

Farmers' strategies used to adapt to Climate change

The level of adaptation to the influence of CC on maize is a function of their awareness about CC Le Dang et al. (2014). The results of Figure 1 revealed maize farmers' strategies in adapting to CC**.** Ten strategies were identified (Adeagbo et al., 2021). Some of the maize farmers adopted more than one strategy. Late planting had the highest number of adopters. Sixty-six% of the farmers adopted late planting while 44% of the respondents adopted early planting. Twenty-four % of the respondents applied farmyard manure, while only 33% of the respondents applied artificial fertilizer. Forty-five % of the respondents planted improved maize seed, while others either recycle seeds from previous harvest or use traditional seeds. Twenty-six % of the respondents made ridges for planting maize and most of the respondents that made ridges intercropped (16%) maize with other crops like cassava and yam. Land rotation or shifting cultivation was adopted by 22% of the respondents. Some of these strategies. This result agrees with Igene et al. (2023b) were identified by Ojo et al. (2020) and Ifeanyi-obi et al. (2017).

Table 3. Effect of adaptation strategies on maize yield

Variable	Coefficient	P>Z
Livestock rearing on farmland before cultivation	2.101** *	0.001
Fertilizer application	0.006***	0.000
Compost manure	0.164** *	0.000
Taungya farming /agroforestry	0.020*	0.041
Ridging	0.647*	0.043
Drought(hybrid) resist variety (DRV)	0.128**	0.001
Late planting	0.005	0.600
Early planting	0.191	0.488
Land rotation/shifting cultivation	0.004	0.910
Intercropping	-0.481	0.133
R^2	0.662	
AdjR^2	0.653	

Field survey, 2023

Effect of Adaptation Strategies on Maize Yield

Ordinary least square result that revealed the effect of farmers' adaptation methods on maize yield was presented in Table 3. The R^2 =0.662 and the adjusted R^2 = 0.653 showed that the variables included in the model explained 66% of the model. The model showed fertilizer application (p <0.001), this complied with the work of Liang et al. (2018), compost manure (p <0.001) this corroborate the work of Brüssow et al. (2019) and livestock rearing on farmland before cultivation (p<0.001) positively and significantly impacted maize yield more than other adaptation methods because they were significant at 1%. They were closely followed by the use of hybrid/ drought resistant variety (p<0.01) that was also positively and significantly contributed to maize yield at 5%, the finding is in line with the work of y (Karapinar and Özertan, 2020). This implies that as the quantity of seed increases farmers tend to use local seed (Komolafe and Adeoti, 2018). Taungya farming /agroforestry (p<0.01) and ridging (p<0.01) also, positively and significantly impacted maize yield, but at 10% level of significance. This is in line with the work of (Brüssow et al., 2019) that discovered that good agronomic management with the use of drought resistant varieties, change in planting dates and good fertilization, control pest, and disease improve maize yield. Late planting, Early planting, Land rotation/shifting cultivation and intercropping were positive, but not significant

The result of the OLS therefore permits the rejection of the earlier stated null hypothesis that adaptation strategies have no significant effect on yield of maize. Since most of the variables were statistically significant at 5% cut off point, hence the alternative hypothesis is accepted.

Table 5. Compares the cost and benefit derived by users of selected significant adaptation strategies over non-users per hectare of land

Maize	TC (₦ '000)	TR (₦ '000)	NB (₦ '000)	IRR%	NPV 10%	NPV 5%	*NPV 15%*
Drought resistant variety	3990.4	4060.5	70.1	970.6	210.7	220.70	*200.8*
non-users	2560.0	2970.0	41.0	960.0	120.3	120.90	*110.8*
Compost manure users	584.07	4,465.74	3,881.74	4336.9.3	3226.7	3764.86	*3002.64*
non-users	74	3574.24	3500.24	39675.7	3422.80	3533.70	*2938.5*
Fertilizer application	425	860	43500	52630	49962	50050	*44630*
non-users of fertilizer	200	3774	3574.24	39675.7	3422.80	3533.70	*2938.5*

Comparison of the cost and benefit of farmers' adaptation strategies per hectare-users and non-users.

In table 5 compare the cot and benefit of adaptation strategies used. The net benefit, IRR and the NPV for farmers that recycled or used local seed was lower than those farmers that used improved seed variety. This corroborate (Shongwe et al., 2014; Williams et al,. 2020). Farmers that were credit constraint and ignorant / laggard decided to use recycled seeds since they cannot purchase the complementary inputs for improved seed variety. In the same vein the net benefit, IRR and the NPV for farmers that applied compost manure was higher than farmers that refused to apply manure. In addition, users of artificial fertilizers had a higher net benefit, IRR and the NPV. The implied that the use of these strategies improves the net returns of maize farmers despite the initial expense that raises the cost of production. Therefore, putting the selected strategies on the scale of preference, the order of preference would be artificial fertilizer application follow by use of Compost manure and then, the use of drought resistant variety with the highest IRR is selected by the IRR and NPV that show their economic efficiency (Shongwe et al., 2014; Williams et al., 2020).

CONCLUSION

In conclusion, the study established that climate factors affect maize yield. The study identified temperature, precipitation, and sunshine as the main elements of climatic factors that impacted maize yield. Fertilizer application, compost manuring, livestock rearing on farmland before cultivation, hybrid/ drought resistant variety, taungya farming /agro forestry and ridging were strategies that positively and significantly impacted maize yield.

Recommendation

Usage of fertilizer, compost manure and livestock rearing on farmland before cultivation and hybrid especially drought resistant maize variety increased the yield of maize. It means that to increase maize output in Nigeria adoption of these methods should be enhanced especially the use of hybrid maize that are drought resistant and compost and farmyard manure that are cheaper and environmentally friendly should be adopted using workable policies.

Farmers should be trained on taungya farming /agro forestry and be provided with modern ridging implemented by the government, nongovernmental organizations to enhance maize yield and food security.

Irrigation farming should be introduced to arguments for water shortage during drought to further improve the yield from drought resistant maize varieties.

Conflict of Interest

The authors have declared that there are no competing interests.

Authors Contribution

Concept, design and critical review, funding, and Supervision KJO, Data collection, processing and data analysis, funding by IDO, literature search, writing, and funding by AHO.

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