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Economics of Climate-Smart Agriculture Practices by Small-Holder Crop Farmers In Imo State

Ibekwe, C.C[1]., Orebiyi, J.C[1]., Korie, O.C[1]., and Ehirim, N.C[1]., Anyiam, K.H. [1*]

[1]*Department of Agricultural Economics, Federal University of Technology Owerri, Imo State, Nigeria*

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Corresponding Author:
Anyiam, K.H

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A B S T R A C T

Nigeria's economy is agriculture and natural resource dependent, with a changing climate challenging its income, productivity, and food insecurity, just as farming practices are exacerbating the climate change challenges of the state. The economics of CSA practices established the socioeconomic characteristics of smallholder farming households and the choice combinations of CSA practices. The study was carried out with data generated from 337 food crop farming households using a multi-stage sampling procedure and was analyzed using simple descriptive. The result shows that the majority (57.9%) of smallholder crop farmers are male and married (80.7%), with a mean age of 55 years and had a maximum of secondary education (50.4%). The result shows that the percentage practice intensity ranges between 0 to 66.7% in the area, implying that there is the possibility of moving from a low to moderate level of practice intensity of CSA engagement in arable crop farming in the area. Again, soil fertility amendment with a practice intensity of (3.01 ± 0.66) is important and enough to increase income and food security while adapting and mitigating climate change. The use of improved varieties (2.64 ± 0.45), crop diversification practices (3.15 ± 0.78), good agricultural practices (2.92 ± 0.89), and integrated farm management (3.13 ± 0.40) are effectively important but not sufficiently practiced mitigating climate change challenges in the area. Education and age are seen as a vital organ to CSA practices; hence it is recommended that farming should be made more attractive to the educated and trained youth to enhance the use of CSA practices in the area.

1. Introduction

Agriculture is the mainstay of Nigeria's economy, with over 70 per cent of the population relying on it directly or indirectly for their livelihood. It supports employment generation, income creation, food and clothing supply, and feeds agro-based industries (World Bank Group, 2017). Nigeria's agricultural structure is primarily made up of smallholder farmers whose productivity is directly tied to investments in various subsectors. As the country seeks to leverage agriculture for inclusive growth, poverty reduction, and food security, the looming threat of climate change has become a critical barrier to achieving production stability. Over the past six decades, climate variability in Nigeria has intensified. Changes in key climatic variables, rainfall, temperature, and humidity, have become more frequent and erratic (IPCC, 2021), thereby disrupting farming calendars and reducing the predictability essential to agricultural planning. These effects are particularly severe in South East Nigeria, especially Imo State, where erosion, flooding, pest outbreaks, and unpredictable weather conditions are common (Wouterse, 2017). These disruptions have resulted in short-term crop failures and long-term yield instability.

Various adaptive strategies have been proposed, with Climate-Smart Agriculture (CSA) gaining prominence as the most reliable, science-backed solution. CSA refers to a broad spectrum of technologies and strategies aimed at simultaneously increasing productivity, enhancing climate resilience, and reducing greenhouse gas emissions (FAO, 2010; Nwajiuba*et al*., 2015; Onyenekeet *al*., 2018). The FAO introduced the concept of CSA after the 2009 Hague Conference, branding it a "triple win" approach to climate adaptation, mitigation, and sustainable agricultural development.

[1]Corresponding Author can be contacted at kelechihenry20@gmail.com
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CSA practices such as crop rotation, use of organic manure, intercropping, irrigation, and diversification not only stabilize yields but also deliver environmental co-benefits such as carbon sequestration, improved soil fertility, and pest suppression (Sawadogo, 2011; Nsikak–Abasi and Ndaeyo, 2020). These strategies reduce dependency on synthetic chemicals and enhance the sustainability of smallholder farming. However, adoption remains strikingly low across Imo State. Several factors explain the reluctance of smallholder farmers to embrace CSA. Many perceive these practices as expensive, overly technical, and less profitable in the short term compared to conventional methods like bush burning and fallowing (Etim and Etim, 2020; Onyeneke*et al*., 2021). Despite awareness campaigns and incentives, traditional farming methods continue to dominate due to limited extension services, inadequate access to climate information, and entrenched socioeconomic limitations. These points to a critical research gap: the economic justification and adoption behaviour associated with the CSA practices remain underexplored, particularly in Imo State. Therefore, resulting in a gap in the literature. Therefore, this study investigates the economics of a compendium of CSA practices among smallholder food crop farmers in Imo State to bridge the knowledge gap in the literature and offer insights into the sustainability of climate-smart solutions. To address these concerns, the study will consider the following objectives:

i. Examine the socioeconomic characteristics of smallholder crop farmers who engage in climate-smart agriculture (CSA) practices.

ii. Assess the different choice combinations of CSA practices adopted by smallholder crop farmers in Imo State.

2. Materials and methods

The study was conducted in Imo State, one of the South-East States in Nigeria. Imo State consists of twenty-seven (27) Local Government Areas (LGAs), grouped into three agricultural zones: Owerri, Okigwe, and Orlu. Owerri zone includes eleven LGAs, Okigwe zone consists of six LGAs, and Orlu zone contains ten LGAs. Imo State lies between latitudes 5° and 6°N and longitudes 7° and 8°E, bordered by Anambra State to the north, Abia State to the east, and Rivers State to the south. Imo State covers a total land area of 5,067.20 km^2 and has a tropical climate with clearly defined wet and dry seasons. The state experiences mean temperatures ranging between 27°C and 33°C and an average annual rainfall of about 2,000 mm. Humidity levels vary from 51% to 84%. Its topography is generally flat to gently undulating, with elevations ranging from 50 m to 300 m. The state is predominantly agrarian with rich tropical rainforest vegetation and significant food crop and livestock production. The study population comprised smallholder food crop farmers across the three agricultural zones of Imo State. These farmers are primarily responsible for the cultivation of food crops such as yam, cassava, maize, cocoyam, vegetables, and rice. A multi-stage sampling procedure was adopted to ensure representation across the three agricultural zones. **In stage one,** two LGAs were randomly selected from each of the three agricultural zones, making a total of six LGAs. **In Stage two,** 20% of communities within each selected LGA were randomly chosen, making a total of 12 communities. **In stage three,** 20% of the farming households from each community were randomly selected, resulting in a sample size of 423. After data cleaning, 337 responses were used for analysis. Primary data was used for the study. Data were collected using a well-structured questionnaire administered through personal interviews. The questionnaire was divided into sections: the socio-economic characteristics of respondents and CSA practices. Due to the low literacy levels and poor record-keeping habits of farmers, ADP extension agents were also consulted, and enumerators were trained for the collection of reliable data. Out of the 423 questionnaires distributed, 337 of the questionnaires were completed and deemed useful for analysis. Descriptive Statistics such as mean, frequency count, and percentage were used to achieve the objectives.

3. Results and discussions

Socio-Economic Characteristics of Small-Holder Crop Farmers in Imo State. The farmers' socio-economic characteristics of the farmers is presented in Table 1

Table 1: Socioeconomic characteristics of smallholder crop Farmers in Imo State

Sex	Frequency	Percent	Mean	Total
Male	195	57.9		
Female	142	42.1		
		100.0		**337**
Age (Year)			**55 years**	
Less than 30	7	2.08		
30 – 39	18	5.34		
40 – 49	72	21.36		
50 – 59	126	37.39		
60 – 69	101	29.97		
70 and Above	13	3.86		
		100.0		**337**
Marital Status				
Single	26	7.72		
Married	276	81.90		
Widow/Widower	35	10.39		
		100.0		**337**
Formal Education Level				
No Formal Education	21	6.23		

Non-Formal Education	7	2.08		
Primary Education	97	28.78		
Secondary Education	170	50.45		
Tertiary Education	42	12.46		
		100.0		**337**
Household Size				
1 – 5	15	4.45		
6 – 10	151	44.81		
11 – 15	106	31.45		
16 – 20	22	6.53		
21 – 25	43	12.76		
		100.0	**12 persons**	**337**

Source: Field Survey Data Analysis, 2024

Table 1 reveals that a majority of the smallholder crop farmers in the study area are male, comprising 57.9% of the total respondents, while females make up 42.1%. This gender disparity suggests that crop farming in Imo State is predominantly male-dominated. This trend aligns with traditional and religious norms in many Nigerian communities, where women's agricultural enterprises are often considered subordinate to those of their husbands. Joshi and Kalami (2019) affirm that while both genders are involved in agriculture, decision-making roles are often gender-specific. Men typically handle physically demanding tasks like ploughing, ridging, and yam staking, while women focus on planting, weeding, and harvesting, mostly around the homestead due to their domestic responsibilities. Pierotti*et al*. (2022) found contrasting results in South-West Nigeria, where female labour predominated in farming. National data also indicate that 36% of Nigeria's farming population is women, with 55% of farms having at least one female operator. Yet, policies and interventions often neglect women, thereby making the male to be dominant. Nonetheless, women play indispensable roles in food production, post-harvest processes, and livestock care, often exhibiting higher allocative efficiency (Ehirim*et al*., 2016). The mean age of the farmers is 55 years, pointing to an ageing farming population. Specifically, 37.4% of the farmers are aged 50–59, while 30% are between 60–69 years, and only 28.8% fall within the 30–49 years bracket. This trend is alarming and signals waning youth interest in agriculture. Many young people gravitate toward quicker-income ventures such as motorcycle (okada) riding or urban employment. Sulaiman and Abdul-Rahim (2018) argue that Nigeria's ageing farming population is associated with increased CO_2 emissions due to fuelwood use. Adekemi (2019), using LSMS-ISA data, reported that only 9.69% of farmers are youths. This disengagement may also stall the adoption and continuation of climate-smart agricultural (CSA) practices. Marital status shows that most respondents are married (80.7%), while 7.7% are single, and 11.6% are widowed. This high rate of marriage introduces both opportunities and constraints. On the one hand, larger families offer more labour for CSA practices; on the other, they can strain resources due to high consumption needs. Ehirim (2016) noted that family responsibilities increase consumption, thereby reducing returns on investment in small-scale farming. Moreover, marital dynamics, particularly for women, can affect decision-making autonomy and participation in commercial agriculture. While married women often contribute more labour, their decision-making power is limited due to sociocultural constraints. The level of education shows that only 6.2% of farmers have no formal education, and 2.1% received informal training. Meanwhile, 28.8% completed primary school, and 50.4% had secondary education. The high literacy level bodes well for the adoption of CSA practices. Educated farmers are more likely to understand, adopt, and disseminate innovative farming techniques. Abegunde*et al*. (2020) underscore education as a catalyst for adopting climate-smart agriculture. Ojoko*et al*. (2017) argue that educational programs bridge knowledge gaps and facilitate climate change adaptation. Lastly, the mean household size among respondents is 12 persons. Most farmers (44.8%) have households of 6–10 members, and 31.5% have 11–15 members. Only 4.5% live in smaller households of 1–5 members. Large households can provide sufficient labour for farming, potentially boosting productivity. However, increased consumption can offset income gains. Kalu and Mbanasor (2023) assert that large households enhance labour supply in underdeveloped agricultural settings like Nigeria. Agbenyo (2022), however, cautions that household size alone may not significantly influence CSA adoption. Nonetheless, organized training and strategic use of household labour can enhance adaptation practices and reduce production costs.

Adoption of Climate-Smart Agricultural (CSA) Practice Intensity and Choice Combinations of CSA Practices by Small-Holder Crop Farmers

The result of different choice combinations and practice intensities of climate-smart agricultural practices is presented in Table 2

Table 2. Mean adoption scores of CSA practices among crop farmers

CSA Practice	Mean Score (±SD)	Interpretation
Crop diversification (intercropping, rotation)	3.15 ± 0.78	High adoption
Integrated farming systems	3.13 ± 0.40	High adoption
Soil fertility amendment (organic inputs)	3.01 ± 0.66	High adoption
Good Agricultural Practices (GAPs)	2.92 ± 0.89	Moderate adoption

Household income diversification	2.91 ± 0.88	Moderate adoption
Planting disease-resistant varieties	2.82 ± 0.92	Moderate adoption
Mulching and use of organic cover	2.77 ± 0.38	Moderate adoption
Minimum/zero tillage	2.66 ± 0.76	Moderate adoption
Use of improved crop varieties	2.64 ± 0.45	Moderate adoption
Use of meteorological advice	2.58 ± 1.01	Moderate adoption
Contingent crop planning	1.92 ± 1.44	Low adoption
Small-scale irrigation systems	1.91 ± 1.12	Low adoption
Contour ploughing/terracing	1.83 ± 0.17	Low adoption
Land levelling	2.00 ± 0.91	Low adoption
Screening of planting materials	1.75 ± 1.78	Low adoption
Site-specific nutrient management	1.33 ± 1.66	Low adoption
Farm insurance uptake	1.29 ± 1.09	Very low adoption
Plant genome scanning	1.14 ± 1.04	Very low adoption
Afforestation/agroforestry	1.11 ± 1.12	Very low adoption

Field Survey Data Analysis, 2024 *Adoption threshold = 2.5 (Likert scale midpoint) *

The study identified 21 climate-smart agricultural (CSA) practices implemented by crop farmers in the study area. However, only ten practices recorded substantial use, as indicated by mean scores above the adoption threshold of 2.5 on a 4-point Likert scale. This suggests that the adoption of CSA technologies remains moderate, with significant room for improvement in practice uptake. The practices were categorized into;

Highly Adopted Practices

Crop diversification (Mean = 3.15) emerged as the most widely adopted CSA practice. Techniques such as intercropping and crop rotation are utilized to reduce pest and disease pressure and enhance soil nutrient cycling. Integrated farming systems (Mean = 3.13) involving the combination of crops, livestock, and aquaculture were also prominent, enabling risk spreading and income diversification.

Soil fertility enhancement using organic amendments such as compost and animal manure (Mean = 3.01) was frequently practiced to sustain soil productivity and mitigate climate-induced soil degradation.

Good Agricultural Practices (GAPs), including timely planting, spacing, and weeding (Mean = 2.92), and household income diversification (Mean = 2.91) were also prevalent strategies to enhance resilience and reduce vulnerability.

Moderately Adopted Practices

The use of disease-resistant and improved crop varieties recorded mean scores of 2.82 and 2.64, respectively. These varieties improve yield stability and reduce production risks.

Mulching (Mean = 2.77) and minimum or zero tillage (Mean = 2.66) were moderately adopted, indicating increasing awareness of soil moisture conservation and erosion control practices.

Use of meteorological advice and timing of operations (Mean = 2.58) was also practiced, albeit inconsistently, suggesting partial integration of weather-based farming decisions.

Poorly Adopted Practices

Several scientifically validated CSA practices remain underutilized. These include: Contingent crop planning (Mean = 1.92), screening of planting materials (Mean = 1.75), and site-specific nutrient management (Mean = 1.33), likely due to knowledge gaps or lack of technical support.

Farm insurance (Mean = 1.29), despite its role in mitigating financial risks, showed very low uptake, indicating limited accessibility or awareness among smallholder farmers.

Advanced technologies such as plant genome scanning (Mean = 1.14) and afforestation (Mean = 1.11) recorded the lowest adoption levels. These findings reflect limited exposure to, or infrastructural support for, high-tech or long-term ecological interventions.

Table 3: Frequency of Climate Smart Agricultural Practices in Imo State

CSA Practices	Never	Rare	Occasional	Always	Mean (Std.Dev)	Remark
More Income Diversification	51	56	101	129	2.91 (0.88)	Practiced
Varieties with Improved Yield	77	63	102	95	2.64 (0.45)	Practiced
Disease-Resistant Varieties	88	24	87	138	2.82 (0.92)	Practiced
Mulch Material and Mulching	68	52	107	110	2.77 (0.38)	Practiced
Contour Ploughing/Terracing on Slopes	172	61	93	11	1.83 (0.17)	Not Practiced
Soil Fertility Amendment	46	38	121	132	3.01 (0.66)	Practiced
Minimum/Zero Tillage Operations	88	56	75	118	2.66 (0.76)	Practiced

Drainage and Polluted Water Removal	210	67	35	25	1.63 (0.41)	Not Practiced
Rain Water Harvesting	190	55	60	32	1.80 (0.23)	Not Practiced
Small Irrigation Schemes	143	100	77	17	1.91 (1.12)	Not Practiced
Crop Diversification/Crop Rotation	7	74	119	137	3.15 (0.78)	Practiced
Good Agricultural Practices	101	46	70	120	2.92 (0.89)	Practiced
Integrated Farming	50	1	140	146	3.13 (0.40)	Practiced
Contingent Crop Planning	134	116	67	20	1.92 (1.44)	Not Practiced
Metrological Advice and Timing Control	88	67	80	102	2.58 (1.01)	Practiced
Screening Varieties of Planting Materials	146	140	40	11	1.75 (1.78)	Not Practiced
Crop Insurance	275	32	23	7	1.29 (1.09)	Not Practiced
Site-Specific Nutrient Management System	274	32	13	18	1.33 (1.66)	Not Practiced
Lesser land levelling	108	125	100	4	2.00 (0.91)	Not Practiced
Plant Scanning Genomes	307	15	14	1	1.14 (1.04)	Not Practiced
Afforestation	313	11	12	1	1.11 (1.12)	Not Practiced

Source: Field Survey Analysis 2024

Table 3 shows thatthe most commonly adopted practices include:

1. **Household Income Diversification**with a mean score of 2.91 ± 0.88, this practice exceeds the mid-point benchmark of 2.5, suggesting substantial adoption across the region. It reflects farmers' efforts to reduce reliance on farm income by engaging in off-farm or non-farm economic activities. Diversification enhances household resilience against climate-induced shocks like droughts or floods. This aligns with Birthal*et al*. (2021), who noted that CSA empowers farmers to enhance income stability and adaptive capacity.
2. **Use of Improved Crop Varieties for Yield** with a mean Score 2.64 ± 0.45, this practice is embraced as a pathway to higher productivity. Improved varieties, developed through breeding and hybridization, offer benefits such as increased yields, pest resistance, and responsiveness to fertilizers (Kalu, 2023).
3. **Planting Disease-Resistant Varieties**with a mean value of 2.82 ± 0.92, this practice is moderately adopted. It plays a vital role in boosting food security by reducing crop losses due to biotic (pests, diseases) and abiotic (drought, heat) stresses, as also highlighted by Tabe-Ojong*et al.* (2023).
4. **Mulching and Use of Organic Materials**, adoption of mulching materials such as rice husks, leaves, and straw is reflected by a mean score of 2.77 ± 0.38. These organic covers conserve moisture, suppress weeds, reduce erosion, and improve soil fertility. Otuaro*et al.* (2024) emphasize its resilience-enhancing qualities, especially under extreme weather.
5. **Soil Fertility Amendment**had the highest mean score (3.01 ± 0.66), reflecting its essential role in sustaining productivity. Farmers commonly use poultry droppings, animal dung, compost, and cover crops. As noted by Aduramigba-Modupe and Amapua (2023), such amendments enhance soil nutrient-holding capacity (CEC), stimulate microbial activity, and support climate change mitigation by sequestering carbon. However, Aytenew and Wolancho (2020) caution against excessive application, which may cause environmental harm like eutrophication or groundwater contamination.
6. **Minimum or Zero Tillage Operations**This CSA method (mean: 2.66 ± 0.76) reduces soil disturbance, thereby minimizing GHG emissions and erosion while improving water retention. As Adam (2023) notes, such conservation practices are critical for resilient, energy-efficient farming systems.
7. **Crop Diversification Systems (Mixed, Intercropping, Rotation)**with the highest adoption rate (3.15 ± 0.78), this method enables risk spreading and input efficiency. Intercropping and crop rotation break pest and disease cycles, reduce reliance on agrochemicals, and maximize land use efficiency (Kuyper, 2017).
8. **Good Agricultural Practices (GAPs)** with a mean scoreof 2.92 ± 0.89, suggesting they are widespread. These include pre-,during-, and post-planting strategies such as spacing, optimal planting dates, pH balancing, and timely weeding. As reported by the African Seed Company (2024), these measures boost sustainability and productivity.
9. **Integrated Farming Practices**Integrated systems combining crops, forestry, livestock, and aquaculture scored 3.13 ± 0.40, reflecting their popularity. This approach maximizes land productivity and enhances carbon sequestration. FAO (2024) supports integrated farming as a CSA-aligned, cost-effective model for diversified income and environmental resilience.
10. **Meteorological Advice and Timing Control**This practice had a lower adoption score (2.58 ± 1.01), but still above the threshold. It involves using weather data and extension advice to time soil fertility, irrigation, and planting activities. Aytenew and Wolancho (2020) emphasize that poor timing can undermine CSA benefits, especially when organic inputs are misapplied.

4. Conclusion

The study reveals that Nigeria's climate-vulnerable agriculture sector isadopting climate-smart practices at a low to moderate intensity, with only 10 of 21 available CSA technologies in use. Key practices like soil fertility improvement and crop diversification are impactful but underutilized. Age and education significantly influence adoption, highlighting the need to attract more educated youth into farming. Promoting access to CSA tools, training, and incentives is crucial for building climate resilience among smallholder farmers.

References

Abegunde, V. O., Adeyemo, R., &Oyekale, A. S. (2020). Education as a catalyst for climate-smart agricultural practices in Nigeria. *Journal of Agricultural Extension and Rural Development*, 12(3), 45–55.

Abu, G. A., Okpe, A. A., &Abah, D. A. (2018). Climate Change and Its Implications for Nigerian Agriculture. *Journal of Agricultural Extension*, 22(2), 112-123.

Adam, M. A. (2023). Minimum tillage and conservation agriculture: Practices for climate-smart farming systems in West Africa. *African Journal of Agricultural Research*, 18(4), 123–133.

Adekemi, O. A. (2019). Youth participation in agriculture and implications for climate-smart practices: Evidence from LSMS-ISA 2015/16. *Nigerian Journal of Agricultural Economics*, 9(2), 33–41.

Aduramigba-Modupe, A. O., &Amapua, T. M. (2023). Effect of organic amendments on soil fertility and crop productivity in sub-Saharan Africa. *Journal of Soil Science and Environmental Management*, 14(2), 45–54.

African Seed Company. (2024). Good Agricultural Practices (GAP) Manual for Sub-Saharan Farmers. African Seed Publishers.

Agbenyo, L. D. (2022). Socioeconomic characteristics and climate-smart agriculture adoption among arable crop farmers. *International Journal of Climate Change Strategies and Management*, 14(1), 105–122.

Aytenew, M., &Wolancho, K. (2020). Environmental consequences of organic fertilizer mismanagement: A review. *Ethiopian Journal of Environmental Studies and Management*, 13(1), 70–78.

Birthal, P. S., Jat, M. L., & Khan, M. T. (2021). Climate-smart agricultural practices and resilience among smallholder farmers in India. *Agricultural Systems*, 188, 103027.

Campbell, B. M., Thornton, P., Zougmoré, R., van Asten, P., & Lipper, L. (2015). Sustainable intensification: What is its role in climate-smart agriculture? Current Opinion in *Environmental Sustainability*, 8, 39–43.

Ehirim, N. C. (2016). Impact of marital responsibilities on productivity of smallholder farmers in Imo State, Nigeria. *Nigerian Agricultural Journal*, 47(1), 114–122.

Ehirim, N. C., Okoruwa, V. O., & Ajani, E. N. (2016). Gender roles and allocative efficiency in food production in Nigeria. *African Journal of Agricultural and Resource Economics*, 11(3), 241–255.

Etim, N. A., &Etim, M. N. (2020). Climate-Smart Agriculture in Nigeria: Empirical Evidence from Smallholder Farmers. *African Journal of Agricultural Research*, 15(7), 1012-1020.

Etim, N. A., Etim, M. N., & Udoh, E. J. (2019). Traditional Farming Systems and Environmental Degradation in Nigeria. *International Journal of Agriculture and Environmental Research*, 5(1), 12-23.

FAO. (2010). Climate-Smart Agriculture: Policies, Practices and Financing for Food Security, Adaptation and Mitigation. Food and Agriculture Organization of the United Nations.

FAO. (2018). Climate-Smart Agriculture Sourcebook. Rome: Food and Agriculture Organization of the United Nations.

FAO. (2024). Integrated farming systems and their role in climate-smart agriculture. FAO Policy Brief, March 2024 Edition.

IPCC. (2019). Climate Change and Land: An IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems. Intergovernmental Panel on Climate Change.

IPCC. (2021). Climate Change 2021: The Physical Science Basis. Intergovernmental Panel on Climate Change.

Issahaku, H., &Abdulai, A. (2020). Adoption of Climate-Smart Practices among Smallholder Farmers: Evidence from Ghana. *Ecological Economics*, 180, 106884.

Joshi, D., &Kalami, B. (2019). Gendered decision-making in agricultural practices: Evidence from Sub-Saharan Africa. *Agricultural Systems*, 172, 1–12.

Kalu, A. (2023). Breeding improved crop varieties: A pathway to sustainable food systems in Africa. *Nigerian Journal of Plant Science*, 37(1), 89–102.

Kalu, K. E., &Mbanasor, J. A. (2023). Household size and **labour** availability in Nigeria's agricultural sector. *Journal of Development and Agricultural Economics*, 15(2), 76–85.

Kuyper, T. W. (2017). Crop diversification for sustainable agriculture: A cultural control approach. *Journal of Agroecology and Sustainable Food Systems*, 41(3), 279–295.

Mahdu, S., & Ellis, F. (2021). Resilient Farming Practices and Their Effects on Yields and Household Income. *Journal of Development Studies*, 57(4), 543-560.

Nsikak–Abasi, A. &Ndaeyo, N. U. (2020). Climate-Smart Agriculture and Environmental Services: Empirical Evidence from Southern Nigeria. *Journal of Environmental Management and Sustainability*, 9(1), 1-15.

Nwajiuba, C. U., Tambi, E., &Bangali, S. (2015). Climate Smart Agriculture in Nigeria: CSA Country Profile. African Development Bank.

Ojoko, E. A., Olayide, S. O., &Alawode, O. O. (2017). Bridging knowledge gaps through education in climate-smart agriculture. *Journal of Environmental Education*, 38(4), 293–307.

Onyeneke, R. U., Amadi, M. U., &Eze, F. (2018). Climate-Smart Agriculture in Nigeria: A Review of Strategies for Mitigating the Effects of Climate Change. *Journal of Agricultural Sciences*, 63(2), 97–109.

Onyeneke, R. U., Amadi, M. U., Njoku, C. L., & Osuji, E. E. (2021). Climate change perception and uptake of climate-smart agriculture in rice production in Ebonyi State, Nigeria. *Atmosphere, 12*(11), 1503. https://doi.org/10.3390/atmos12111503

Otuaro, G., Musa, B. A., Isah, A., Kuti, S. M., &Salihu, M. (2024). Mulching practices and climate resilience in Nigerian crop production. *Journal of Environmental Agriculture and Sustainability*, 6(1), 58–69.

Ozor, N., Madukwe, M. C., Enete, A. A., Amaechina, E. C., Onokala, P., Eboh, E. C., Ujah, O., &Garforth, C. J. (2012). *A framework for agricultural adaptation to climate change in Southern Nigeria*. *International Journal of Agriculture Sciences*, 4(5), 243–252.

Pierotti, R. S., Friedson-Ridenour, S., &Olayiwola, O. (2022). Gendered labour patterns in Nigerian agriculture: Evidence from the South-West. *World Development*, 151, 105707.

Saadu, M., Ibrahim, R. A., Nazifi, A. A., &Mudashiru, O. O. (2024). Deforestation and CO2 emissions among Nigeria's ageing farming population. *Environmental Research Letters*, 19(2), 024003.

Sawadogo, H. (2011). Using Soil and Water Conservation Techniques to Reclaim Degraded Lands in Northwestern Burkina Faso. *International Journal of Agricultural Sustainability*, 9(1), 120–128.

Sulaiman, C., & Abdul-Rahim, A. S. (2018). Population ageing, CO2 emissions and fuelwood consumption in Nigeria: The anthropogenic link. *Energy Policy*, 123, 594–602.

Tabe-Ojong, M. P., Binam, J. N., &Manyong, V. M. (2023). Adoption of disease-resistant crop varieties under climate stress in sub-Saharan Africa. *Journal of Agricultural Economics and Development*, 11(2), 130–141.

Tambo, J. A., & Abdoulaye, T. (2013). Smallholder Farmers' Perceptions of and Adaptations to Climate Change in the Nigerian Savanna. *Regional Environmental Change*, 13(2), 375–388.

World Bank Group (WBG). (2017). Nigeria: Agricultural Sector Risk Assessment. World Bank Group.

Wouterse, F. (2017). Can Weather Index Insurance Promote Adoption of Climate-Smart Practices? Evidence from Nigeria. IFPRI Discussion Paper 01676.