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Climate smart agriculture? Adaptation strategies of traditional agriculture to climate change in sub-Saharan Africa

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Introduction: Sub-Saharan Africa faces increasingly unpredictable and extreme weather patterns due to climate change, posing significant threats to food security and rural livelihoods. Traditional agriculture, deeply rooted in the region's history and culture, is particularly vulnerable to these changes. This study investigates the adaptation strategies of traditional agricultural farmers to climate change using southeast Nigeria as a microcosm of the broader challenges facing sub-Saharan Africa.

Methods: Multistage sampling procedure was used to select 75 farmer group leaders in the study region. Cross-sectional data were collected through semi-structured interview schedules and focus group discussions. Data were analyzed using descriptive statistics and principal component analysis using Varimax rotated matrix.

Results: Findings showed that farmers rely on face-to-face discussions with neighbors (76.0%), fellow farmers (66.7%), and radio (54.7%) as their primary sources of information on climate change. Results showed that traditional adaptation practices such as use of organic manure ($\bar{x} = 3.89$), traditional organic composting ($\bar{x} = 3.80$), afforestation ($\bar{x} = 3.71$), agroforestry ($\bar{x} = 3.61$) were the topmost traditional agricultural practices use to cushion the effect of climate change. Conserving the overall soil health, soil moisture retention, reducing CO_2 emissions and maintaining crop productivity were the major reasons for using the traditional approaches. Climate-induced drought and high cost of accessing weather information ($\bar{x} = 1.93$), and inadequate funding ($\bar{x} = 1.92$), among others were the key constraints to adaptation.

Discussion: Results showed that farmers prioritize agronomic manipulation and integrated research approaches as key strategies to adapting traditional agriculture to climate anomalies. Although farmers used their indigenous practices, continuous learning and improvement through capacity-building workshops and progress monitoring are essential for effective climate change adaptation. Policymakers should invest in promoting indigenous knowledge, provide access to credit for climate-resilient infrastructure, promote climate-smart agricultural practices and foster collaborative research as the cornerstone for sustainable rural development.

KEYWORDS

traditional practices, adaptation, climate-smart agriculture, resilience, indigenous knowledge, sub-Saharan Africa

1 Introduction

Sub-Saharan Africa, a vast and diverse region characterized by its rich cultural heritage and ecological variety, has long been recognized as a crucial battleground in the fight against climate change and its devastating consequences (Thompson et al., 2010). The region is particularly vulnerable to climate change, with multiple biophysical, political, and socioeconomic stresses interacting to affect rural communities, where agriculture is a major lifeline. Studies consistently predict decreased crop productivity, land degradation, high market prices, and negative impacts on livelihoods, exacerbating food insecurity in the region (Emediegwu et al., 2022; Oyelami et al., 2023). Climate change is intensifying food insecurity across sub-Saharan Africa, and leading to changes in yield and area growth, higher food prices, reduced calorie availability, and growing childhood malnutrition (Ringler et al., 2010). Salgado Baptista et al. (2022) projected the crop yield, especially in key staples, in the region to decline by 5–17% by 2050 due to rising temperatures and rainfall volatility. Successive weather shocks, such as droughts and floods, significantly raise food insecurity, particularly in countries where agricultural productivity is already below the global average (Salgado Baptista et al., 2022). With a predominantly agrarian economy dominated by stallholder farmers and a heavy reliance on traditional agricultural practices rooted in centuries of local knowledge and practices, the nations of sub-Saharan Africa are acutely vulnerable to the adverse impacts of a changing climate.

Nigeria, as the most populous country in Africa, serves as a microcosm of the broader challenges and opportunities facing sub-Saharan Africa. It plays a pivotal role in the region's agricultural landscape and is emblematic of the broader climate adaptation issues faced by many nations in sub-Saharan Africa. Nigeria is estimated to contribute 14% of Africa's agriculture GDP, making it one of the top three African countries with the highest GDP contribution from agriculture (Oyaniran and Omomia, 2018). Between January and March 2021, agriculture contributed to 22.35% of Nigeria's GDP, with over 140 million Nigerians engaged in the sector mainly at a subsistence level. On formal level, more than 36% (above 28.9 million) of Nigeria's labor force was employed in agriculture, with over 80% of the agricultural workforce being smallholder farmers (FAO, 2019; Mayong et al., 2021; International Trade Administration, 2023). Nigeria possesses an abundance of arable land and a favorable climate to produce various crops, including maize, cassava, guinea corn, yam, beans, millet, and rice (FAO, 2019). However, despite its significant contribution to the economy, Nigeria's agricultural sector faces formidable challenges such as climate change and climate-induced socio-economic stressors. These challenges have stifled agricultural productivity, affecting the sector's contribution to the country's GDP and leading to increased food imports due to population growth (FAO, 2019).

The impacts of climate change in Nigeria are characterized by increasing climate variability, leading to more intense and untimely rainfall, land degradation, flash floods, landslides, and gully erosion (Ghosh, 2019; World Bank, 2022). By 2009, an estimated 6,000 gullies were destroying infrastructure, farmland, and real estate across rural and urban Nigeria, causing fear and despair among the population (World Bank, 2022). The climate change-induced losses and unsustainable use of resources have elevated themselves to a real development challenge in Nigeria, particularly along the coastal states in the south and the northern frontline states, thwarting the age-old rhythms of traditional agriculture which are rooted in centuries of local knowledge and practices.

The negative impacts of climate change on Nigeria's agriculture have been observed predominantly in the northern, northeastern, southwestern and southeast regions, which experience extreme weather conditions (Tajudeen et al., 2022; World Bank, 2022). The loss of life and property due to sudden, unpredictable, and uncontrollable floods is a nightmare for many Nigerians, destroying crops, farms, lands, and houses. The agricultural sector, which is the country's economic mainstay, is also grappling with lower crop yields, food insecurity, deepening poverty, forced displacement, labor inefficiency due to high temperatures and conflicts due to drought, flooding, sea level rise, erosion, and rapid decline in earth's limiting resources (Brouziyne et al., 2018; Obaji et al., 2022; United Nations Development Programme, 2023). In 2022 alone, climate-induced pests and diseases insurgence caused crop losses of up to 80% in some areas, impacting 1.5–200,000 hectares of land, and more than 20% of crops experienced post-harvest losses in several states (Adegwu, 2022). Major crops affected included maize, rice, sorghum, millet, soybean, groundnut, cowpea, root and tubers, fruits, vegetables, and tree crops in 33 states (Adegwu, 2022; Rizzo et al., 2023). The country's tropical climate is characterized by high temperatures, humidity, and rainfall, with larger amounts of rainfall experienced in the south and southeast regions of the country. Wind patterns are influenced by Nigeria's location and topography, largely due to the Inter-Tropical Convergence Zone (ITCZ) which brings moist winds from the Atlantic Ocean during the wet season and dry winds from the Sahara Desert during the dry season (Dia et al., 2023), which influences the annual temperature. The Nigeria temperature records indicate an average increase of 1.4–1.9°C, with predictions of further increases of 2–5°C by the end of the century if no decisive action is taken (Brouziyne et al., 2018).

Nigeria is already experiencing the adverse effects of climate change, as with natural disasters are occurring more frequently and with greater intensity. These multi-dimensional adverse effects have not only hampered the ability of the agricultural sector to meet the country's food demands but have also disrupted the traditional roles of agriculture in Nigeria's economy, leading to a shift from being a net food exporter to an importer (Onyeneke et al., 2021). The cumulative agricultural imports of the country stood at N3.35 trillion between 2016 and 2019, which was four times higher than the agricultural export of N803 billion within the same period (FAO, 2019). Therefore, it is crucial to explore and implement interdisciplinary adaptation strategies that can enhance the sustainability and resilience of agri-food systems to climate anomalies.

Climate-smart agriculture (CSA) has emerged as a competent response to the challenges posed by climate change on agriculture in rural areas. It entails the integration of traditional agricultural practices with modern techniques. Traditional agriculture, rooted in indigenous knowledge, cultural beliefs, and sustainable practices, offers valuable insights into adapting agricultural systems to a changing climate (Tsado, 2019). The approach of CSA is recognized for its potential to enhance farm productivity and incomes, adaptation, and resilience to climate change in rural African context (Abegunde and Obi, 2022). CSA offers a comprehensive strategy for addressing the interconnected challenges faced by smallholder farmers in African countries, focusing on three core goals: increasing agricultural productivity, adapting and building resilience to climate change, and developing opportunities to reduce greenhouse gas emissions from agriculture (Obaji et al., 2022). Additionally, the FAO emphasizes that CSA is an approach that helps guide actions to transform agri-food systems toward green and climate-resilient practices, addressing challenges related to climate change and agriculture (FAO, 2023). However, CSA is not a one-size-fits-all approach and requires tailoring to specific climate risks faced by different farming communities, regions, and ecosystems. While CSA offers a solution to many of the secondary and tertiary problems caused by climate shocks, it is still not a familiar solution to climate adaptation and mitigation in last-mile communities. The effective utilization of CSA at grassroots is not just about understanding "how its works" but in appreciating the intricate web of cultural, economic, ecological, and technological factors that influence this adaptation tactics.

Rural communities in sub-Saharan Africa are adapting their traditional agriculture to climate change through a variety of strategies and practices. Indigenous peoples and local communities are leveraging traditional knowledge and improved crop varieties to cope with extreme weather and environmental changes caused by climate change (Swiderska, 2011). Traditional agricultural practices, which have been developed over centuries, are proving to be valuable in building resilience and adapting to the impacts of climate change (Singh and Singh, 2017). Adjustments in planting dates, crop varieties, drainage systems, using advanced technologies and land management regimes to maintain yields and soil fertility (Arbuckle et al., 2015), are crucial on-the-ground strategies used by local farmers to counter the adverse effects of climatic changes. Traditional practices, such as agroforestry, intercropping, crop rotation, cover cropping, traditional organic composting, and integrated crop-animal farming, have demonstrated the potential to improve crop productivity and mitigate climate change impacts (Tripathi et al., 2019; Mashi et al., 2022). These practices, honed over thousands of years by indigenous farmers and local communities, provide valuable adaptation strategies in the face of climate uncertainties.

Traditional agricultural practices have the potential to adapt and mitigate climate change through its unique agroecological features. They increase agrobiodiversity and resilience of agroecosystems, are low-cost, energy-efficient, and based on locally available resources (Singh and Singh, 2017). It is characterized by high productivity, biodiversity conservation, low energy inputs, and climate change mitigation (Singh and Singh, 2017). Therefore, integrating traditional knowledge into climate change policies is seen as a cost-effective, climate-smart approach and sustainable adaptation strategy to climate variability.

While there is a growing recognition of the role of traditional knowledge in adapting agriculture to climate change, the role of indigenous knowledge and adaptive practices remains largely undervalued by decision-makers. Negotiating parties in international climate talks tend to focus on intensifying production through modern agriculture, overlooking the potential of traditional knowledge in adaptation (Swiderska, 2011). The unsustainable transition from traditional agriculture to modern methods in rural communities has led to the loss of crop genetic resources and environmental sustainability challenges, exacerbating the effects of climate change. Therefore, there is an urgent need to rediscover and re-implement traditional agricultural practices while integrating them with modern approaches to enhance the socio-ecological integrity of agroecosystems (Shittu et al., 2021). Ricart et al. (2023) analyzed a portfolio of 435 articles collected from WoS and Scopus databases between 2010 and 2020, finding that farmers are in a favorable position to offer first-hand observations and provide a deeper understanding of climate change manifestation, relevance, effects, and narratives. Therefore, farmers' knowledge provides a framework for appraising and incorporating new ideas, experiences, and information into existing systems (Haradhan, 2017).

This study explored the adaptation strategies employed by farmers to mitigate the impacts of climate change on their indigenous agricultural system using southeast Nigeria as a model region for all riparian regions in sub-Saharan Africa. The specific objective of the study entails identifying the key climate change information sources by farmers; elicit the effective traditional adaptation practices farmers use to cushion the effect of climate change; examine the possible reasons for using traditional approaches to climate change adaptation, identify the constraints to adaptation, and the effective strategies to adapt and mitigate the effect of climate change. The grand objective of the study is to provide grassroots insights and recommendations for fostering sustainability and climate-resilient agri-food systems in sub-Saharan Africa.

2 Methodology

The study was carried out in Southeast Nigeria, specifically within the geographical coordinates of latitudes 04° 17′N and 07° 06′N and longitudes 05° 23′E and 09° 28′E, as described in Macmillian's 2009 report. This region covers an area spanning 29,908 square kilometers and is inhabited by ∼16,381,729 people, according to the Nigeria. National Bureau of Statistics (2007). It encompasses the territories of Abia state, Anambra state, Ebonyi state, Enugu state, and Imo state (see Figure 1). The climate of the Southeast can be broadly characterized as tropical, featuring distinct wet and dry seasons. It falls within the tropical belt, with early rainfall typically occurring in January/February and the full onset of the rainy season in March, concluding in November each year. The dry season typically lasts for 4–5 months, with the highest rainfall occurring from July to October, with a slight respite in August. On average, the region experiences an

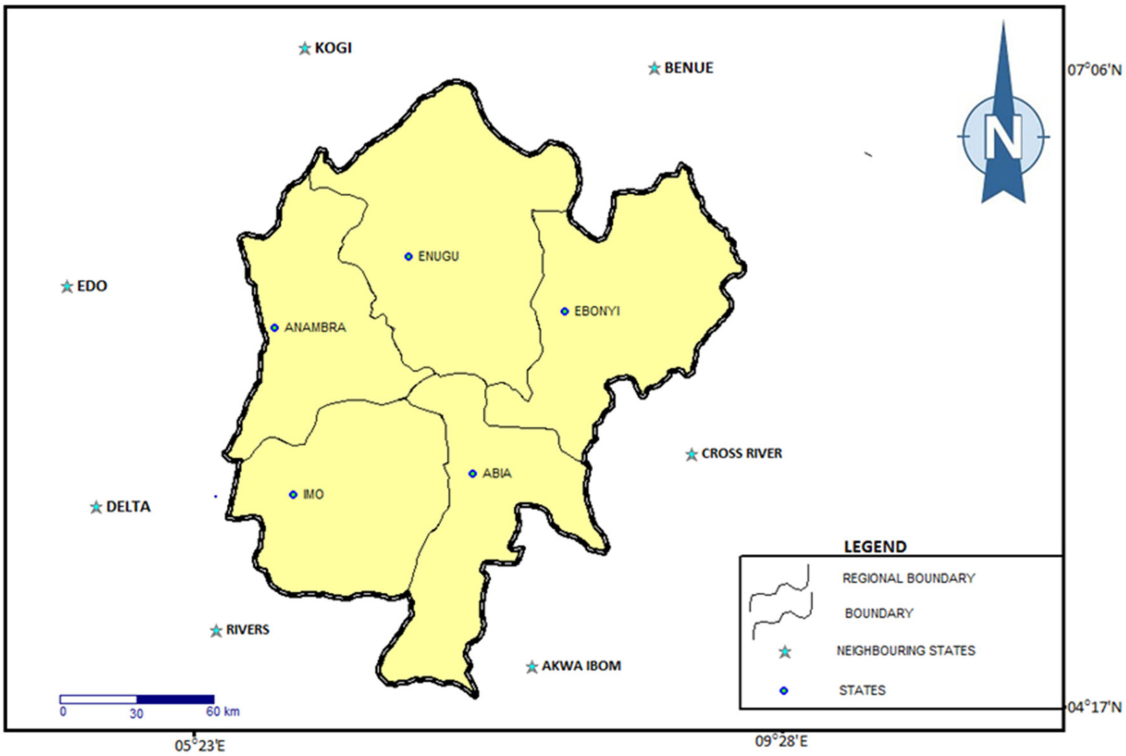

FIGURE 1
Map of southeast Nigeria. Source: Macmillian Atlas Series 2009.

annual rainfall of ~1,952 mm, and the mean daily and annual temperatures are around 28 and 27°C, respectively (Igbokwe et al., 2008). Southeast Nigeria is primarily an agricultural area, with predominantly sandy and often loose and porous soil types. The most commonly cultivated crops in this region include cassava, rice, yam, cocoyam, maize, plantain/banana, cashew, oil palm, and coconut. Additionally, the major livestock raised in the area consist of goats, sheep, and poultry. In the southeastern region, the effects of climate change are readily noticeable, manifested in increased instances of flooding, landslides, and erosion, which have resulted in the loss of lives, homes, farmlands, properties, and roads, among other adverse consequences (Agwu and Okhimamhe, 2009).

The population for the study comprised all farmers and relevant stakeholders operating in difficult-to-reach communities in the study region. Respondents were selected using a multi-stage sampling procedure. In the first stage, the five states that make up the Southeast Nigeria were selected purposefully to have good spread and depth of data and local perspectives. In the second stage, three senatorial zones were randomly selected in each state, given a total of 15 senatorial zones. In the third stage, five representative lead-farmers each were randomly selected from each of the 15 senatorial zones, given a total of 75 farmers used for the study. Data were collected using a semi-structure interview schedule and focus group discussion based on the specific objectives. The reliability of the instrument was tested using the Cronbach Alpha coefficient for internal consistency. The instrument was validated by experts in the Department of Agricultural Extension, University of Nigeria, Nsukka.

Personal data, such as age (in years), gender (male or female), marital status (single, married, divorced/separated, and widowed), education (number of years spent in school), farming experience (years), household size (number of persons currently in the household), household monthly income (naira), estimated annual earnings (naira), access to extension service (number of times in the past 1 year), membership to the social organization(s), and access to credit facilities, were collected. Sources of information on climate change were collected by asking respondents to tick "Yes" or "No" from a list of information sources. Data on the effective traditional adaptation practices used to cushion the effects of climate change were collected by providing a list of perceived traditional practices. Respondents were required to rate the effective adaptive practices on a four-point Likert-type scale of very effective (4), effective (3), a little effective (2) and not effective (1). A mean score (2.5) was obtained. Variables with a mean score ≥2.5 were regarded as effective practices. Information on possible reasons for using traditional approaches for climate change adaptation were obtained by providing a list of variables for the respondents. Respondents were asked to rank the importance of traditional practices to their climate adaptation from a list of practices on a 3-point Likert scale of very important (3), important (2) and not important (1). A mean score (2) was obtained and all the variables with mean score ≥2 were regarded as important to adaptive capacity. Data on constraints to adaptation and mitigation were collected by asking the respondents to rank their constraints on a 3-point Likert scale of major constraint (2), minor constraint (1), not a constraint (0)—with a mean score of one.

Data on the effectiveness of the strategies to mitigate the effect of climate change was measured by asking respondents to choose from a list of variables provided. Their responses were captured on a four-point Likert-type scale of very effective (4), effective (3), little effective (2), and not effective (1). A mean score (2.5) was obtained. Responses with a mean score ≥2.5 were regarded as effective. Excerpts from semi structure interviews and focus group discussions were reported in the result section of the article. Data obtained were analyzed with descriptive statistics (percentages, mean, and standard deviation) and principal component analysis using Varimax rotated factors analysis—through the IBM SPSS Statistics version 21 software.

3 Results

3.1 Socioeconomic characteristics of the farmers

According to Table 1, results reveal that 52.0% of the respondents were female, while 48.0% were male. Regarding age distribution, most respondents (28.0%) fell within the 31–40 age range. Approximately 24.0% were aged between 41 and 50, 20.0% were 60 and above, and 18.7% were 30 and below. Only 9.3% were between 51 and 60 years old. The mean age of the farmers was 46.11, suggesting the active participation of middle-aged individuals in traditional agriculture. Regarding household size, a significant proportion (72.0%) of respondents had a household size of 5–8 persons, while 12.0% had 1–4 persons, and 16.0% had 8 or more persons. The results also indicate that the mean monthly household income was ₦20,093.33.

TABLE 1 Socioeconomic characteristics of the respondents ($n = 75$).

Variables	Frequency	Percentage (%)	Mean
Sex			
Female	39	52.0	
Male	36	48.0	
Age (years)			
Below 31	14	18.7	
31–40	21	28.0	
41–50	18	24.0	46.11
51–60	7	9.3	
Above 60	15	20.0	
Household size (number of people living and eating under the same roof)			
1–4	9	12.0	
5–8	54	72.0	6.43
Above 8	12	16.0	
Farming experience (years)			
1–10	30	40.0	
11–20	10	13.3	
21–30	16	21.3	21.88
Monthly income (₦)			
1–10,000	42	56.0	
10,001–20,000	13	17.3	20,093.33
20,001–30,000	5	6.7	
Above 30,000	15	20.0	

3.2 Sources of information by farmers on climate change adaptation

The results in Table 2 indicate that most (76.0%) respondents obtain information on climate change, adaptation, and mitigation through face-to-face discussions with neighbors. This implies that community-based community approaches could be highly effective in disseminating information about climate change. Leveraging indigenous communication channels such as implementing community meetings or local discussion groups could be a strategic way to spread awareness and knowledge on climate adaptation and mitigation measures. Additionally, 66.7% of the respondents acquired information from fellow farmers. This implies that farmers probably trust and value the experiences and knowledge of their peers. Programs that engage local farmers as educators or facilitators could leverage this trust and peer influence for effective communication on climate resilience building. The reliance on radio by more than half 54.7% of respondents highlights its importance as a traditional but still relevant medium, especially in areas where digital connectivity might be limited. Radio programs focused on climate change, featuring expert advice, success stories from other farmers, and practical tips for adaptation and mitigation, could be a very effective outreach tool. Other information sources include videos (29.3%), newsletters on climate change (22.7%), internet (21.3%), television (20.0%), and among others. The variety of climate change information sources used by farmers underscores the need for a multi-channel communication strategy—since informal channels (neighbors and fellow farmers) could brood risk of misinformation or incomplete information being circulated.

3.3 Effective traditional adaptation practices farmers use to cushion the effect of climate change

In Table 3 show the traditional adaptation practices farmers use to cushion the effect of climate change. The traditional adaptation practices used include use of organic manure ($\bar{x} = 3.89$), traditional organic composting ($\bar{x} = 3.80$), afforestation ($\bar{x} = 3.71$), agroforestry ($\bar{x} = 3.61$), crop rotation ($\bar{x} = 3.40$), and mulching ($\bar{x} = 3.37$). These practices not only help in adapting to climate change but also contribute to mitigating its effects by enhancing carbon sequestration and biodiversity. For instance, the use of organic manure by the study participants is due to their accessibility, cost-effectiveness, or perceived effectiveness in improving soil health and resilience against climate variability.

TABLE 2 Source of information of farmers on climate changes ($n = 75$).

Sources	Frequency	Percentage (%)
Telephone	8	10.7
Television on climate change	15	20.0
Radio program on climate change	41	**54.7**
Extension agent	5	6.7
Fellow farmers	50	**66.7**
Journal articles on climate change	2	2.7
Books on climate change	6	8.0
Pamphlets on climate change	2	2.7
Face-to-face discussions with neighbors	57	**76.0**
Audio files	6	8.0
Videos on climate change	22	29.3
Discussion forum	3	4.0
Electronic Journal	2	2.7
Dictionary	4	5.3
Research report	9	12.0
Workshop on climate change	2	2.7
Newsletters on climate change	17	22.7

TABLE 3 Traditional adaptation practices farmers use to cushion the effect of climate change ($n = 75$).

Variables	Mean	Std. deviation
Crop rotation, e.g., cultivation of different crops sequentially on the same piece of land	**3.40**	0.805
Use of organic manure, e.g., poultry manure, to increase the soil fertility	**3.89**	0.388
Planting of cover crops, i.e., the use of plant-primarily to slow soil erosion	**3.29**	0.693
Mixed cropping practices, e.g., planting two or more crops together on the same piece of land in one crop season	**2.76**	0.867
Afforestation, i.e., sowing of seeds or planting of trees in an area that does not have trees to create a forest	**3.71**	0.712
Bush fallow practices, i.e., cultivating a piece of land for several years and left to fallow for some years to regain fertility	**3.13**	0.844
Intercropping, e.g., sowing of different species of crops on the same piece of land at the same time	**3.36**	0.799
Agroforestry, e.g., growing of trees or shrubs around crops or pasture land	**3.61**	0.884
Mulching, i.e., the use of dry leaves on the soil surface for soil and water conservation for proper plant growth	**3.37**	0.927
Irrigation practices, e.g., applying a controlled amount of water to land to assist in the production of crops	**3.29**	0.785
Shifting cultivation practices, e.g., a practice of cultivating on a piece of land for a short period, then abandoned to revert to its natural	**2.92**	0.941
Integrated crop-animal farming, i.e., the practice of mixed production that utilizes crops and animal	**3.21**	0.890
Traditional organic composting, i.e., breaking down organic materials in a large heap	**3.80**	0.493

Source: Field survey, 2022 Mean score, 2.5.

Excerpts from the focus group discussion indicate that farmers unanimously agree that ["…they use organic manure due to their accessibility, cost-effectiveness, or perceived effectiveness in improving soil health and resilience against climate variability…"]. Hence, these practices indicate a level of knowledge and adaptation to local climatic conditions.

Other traditional adaptation practices include intercropping ($\bar{x} = 3.36$), planting of cover crops and irrigation ($\bar{x} = 3.29$), integrated crop-animal farming ($\bar{x} = 3.21$), bush fallow practices ($\bar{x} = 3.13$), and among others. The use of intercropping and integrated crop-animal farming implies that indigenous people and communities prioritizes diversification as a key risk management strategy against the backdrop of climate change. Additionally, the use of irrigation, bush fallowing and covering crops indicates an awareness of and response to the need for optimal resource utilization, maintenance of soil health and sustainability, which is crucial for long-term agricultural productivity in the face of climate change.

3.4 Possible reasons for using traditional approaches to climate change adaptation

Table 4 presents the key reasons for using traditional approaches to climate change adaptation. The reasons identified include increased soil fertility ($\bar{x} = 2.95$), aeration of soil ($\bar{x} = 2.85$), reduction of soil erosion ($\bar{x} = 2.73$), increase in soil moisture ($\bar{x} = 2.03$), enhancement of soil structure and aggregation ($\bar{x} = 2.79$), promotion of mineralization of nitrogen-containing compounds in the soil through the use of leguminous crops ($\bar{x} = 2.68$), reduction of nutrient loss from the soil ($\bar{x} = 2.73$), reduction of chemical pollution in the soil ($\bar{x} = 2.33$), and enhancement of agro-biodiversity through intercropping of legumes ($\bar{x} = 2.56$). This implies that farmers are aware of the importance of soil health in sustainable farming and climate change adaptation. This reflects

TABLE 4 Possible reasons for using traditional approaches to climate change adaptation.

Variables	Mean	Std. deviation
Increased soil fertility	**2.95**	0.226
Reduces greenhouse gas emission	**2.19**	0.456
Improves aeration of the soil	**2.85**	0.356
Reduces soil erosion	**2.73**	0.445
Increases soil organic matter and crop yield	**2.89**	0.311
Increases soil microbial diversity	**2.03**	0.492
Increases soil moisture	**2.79**	0.444
Leguminous crops enhance the mineralization of N-containing compounds in the soil	**2.68**	0.549
Minimizes loss of nutrients from the soil	**2.73**	0.475
Reduces chemical pollution in the soil	**2.33**	0.502
Intercropping of legumes enhances agrobiodiversity	**2.56**	0.620

Source: Field survey, 2022 Mean score, 2.0.

a desire to maintain sustainable, eco-friendly farming practices that not only benefit the current crop but also contribute to the long-term health of the farm ecosystem. The reliance on traditional methods to deliver these benefits indicates a strong base of traditional agricultural knowledge and practices well-suited to local environmental conditions that have been passed down through generations. While these traditional practices are beneficial, there is potential for enhancing their effectiveness through the integration of scientific research and modern agricultural techniques.

3.5 Constraints to adapting traditional agriculture to climate change

Table 5 presents the constraints identified by the respondents to the use of traditional adaptation strategies. The major constraints to adaptation include climate variation leading to drought and high cost of accessing weather information ($\bar{x} = 1.93$), and inadequate funding ($\bar{x} = 1.92$). Access to micro-climate cues and finances are crucial in building local adaptation strategies. High cost of accessing reliable weather information frustrates traditional adaptive measures, making it difficult for farmers to plan and make informed climate-smart decisions effectively. It is therefore imperative to provide a more accessible, affordable, and accurate weather forecasting services tailored for farmers alongside financial assistance programs, subsidies, or microfinance solutions targeted at smallholder farmers. Participants also indicated that lack of technical knowledge and know-how ($\bar{x} = 1.89$) pose a major challenge to adapt. Mrs. Ngozika, a rural farmer from the study participant stated thus ["…I do not know the practical steps I could take to improve my farm activities in this era of climate change…"]. This implies a gap in the knowledge and skills necessary to implement effective adaptation strategies, which could probably be due to inadequate extension services or training programs. Inadequate infrastructure ($\bar{x} = 1.87$), such as roads and storage facilities, limits the ability of farmers to adapt to and mitigate

TABLE 5 Constraints to adaptation.

Variables	Mean	Std. deviation
Inadequate funds for the adaptation	**1.92**	0.273
Inadequate credit facilities	**1.79**	0.473
Inadequate access to climate information	**1.85**	0.356
Poor technical know-how knowledge	**1.89**	0.311
Lack of extension services for providing information to farmers	**1.45**	0.622
Lack of skilled laboratory in carrying out farm practice	**1.53**	0.684
Poor access to irrigation facilities	**1.55**	0.527
Vulnerability to pests and diseases	**1.83**	0.415
High cost of farm operation	**1.49**	0.705
Inaccurate agro metrological information	0.37	0.564
Poor agricultural program and service delivery	**1.69**	0.492
Inconsistent government policies	**1.56**	0.526
High cost of accessing the weather information	**1.93**	0.251
High economic losses from farm	**1.65**	0.533
Inadequate farm input supplies	**1.37**	0.514
Drought climate variation	**1.93**	0.251
Inadequate access to hybrid seeds	**1.73**	0.445
High cost of fertilizer and other inputs	**1.16**	0.616
Poor infrastructural facilities	**1.87**	0.342
Inadequate water supply for irrigation	**1.19**	0.485

Source: Field survey, 2022 Mean score, 1.0.

TABLE 6 Varimax rotated factors on constraints to adaptation.

Variables	Factor 1	Factor 2
	Technical problems	Informational problems
Lack of extension services for providing information to farmers	**0.539**	−0.008
Lack of skilled laboratory in carrying out farm practice	**0.650**	0.097
Vulnerability to pests and diseases	**0.487**	0.032
High cost of farm operation	**0.663**	0.106
Poor agricultural program and service delivery	**0.768**	0.174
Inconsistent government policies	**0.580**	−0.339
High cost of accessing the weather information	−0.040	**0.692**
High economic losses from farm	**0.500**	0.358
Drought climate variation	0.126	**0.515**

Source: Field survey, 2022, Factor loading, 0.4.

TABLE 7 Possible strategies to adopt and mitigate the effect of climate change ($n = 75$).

Strategies	Mean	Std. deviation
Use of improved or resistant crop	3.85	0.425
Afforestation	3.67	0.577
Use of cover crop	3.47	0.644
Incorporation of residues into the soil	3.23	0.894
Use of climate-smart agriculture	3.93	0.251
Weather forecasting services information	3.89	0.311
Change in the timing of farm operation	2.75	0.946
Use of organic manure	3.87	0.342
Improvement of irrigation practices for crop production	3.20	0.678
Use of water flood-tolerant crop	3.73	0.600
Increase in agricultural research and development	3.00	0.930
Availability of extension service delivery on the issues of climate	3.57	0.661
Provision of adequate mulching materials	3.40	0.854
Proper conservation of seeds	3.75	0.496
Provision of infrastructure	3.83	0.381
Use of draft-resistant crops	3.68	0.498
Proper tillage practice or operation	2.13	0.827
Provision of adequate farm input supplies	2.64	0.782

Source: Field survey, 2022 Mean score, 2.5.

the impacts of climate change. There is a need for governmental and non-governmental bodies to invest in rural infrastructure to support agricultural activities. Also, inadequate access to climate change information ($\bar{x} = 1.85$) present a formidable obstacle to rural adaptive capacities. This aligns with the high cost of accessing weather information and highlights a broader issue of information accessibility. Vulnerability to pests and diseases ($\bar{x} = 1.83$) resulting from climate change bedevils farmers adaptation efforts. Therefore, research into and promotion of climate-resilient crop varieties and integrated pest management practices are crucial for traditional agricultural systems. Other constraints faced by farmers include inadequate credit facilities ($\bar{x} = 1.79$), poor agricultural program and service delivery ($\bar{x} = 1.69$), high economic losses from farming ($\bar{x} = 1.65$), among others.

Table 6 presents the results of the factor analysis of the constraints to adaptation. The variables with a loading of 0.4 score and above were included in naming the factors. Variables that loaded in more than one factor or had loadings below 0.4 were not used. Two key factors were identified and named: a technical problem (Factor 1) and a climate information problem (Factor 2). Under the technical problem (Factor 1), the major constraints identified by farmers include poor agricultural program and service delivery (loading = 0.768), high cost of farm operations (loading = 0.663), lack of skilled laboratory facilities for farm practices (loading = 0.650), inconsistent government policies (loading = 0.580), lack of extension services for providing information to farmers (loading = 0.539), high economic losses from farming (loading = 0.500), and vulnerability to pests and diseases (loading = 0.487). In Factor 2, the climate informational problem includes the high cost of accessing weather information (loading = 0.692) and drought climate variation (loading = 0.515). The factor analysis provides a clear framework for understanding the complex array of challenges in agricultural adaptation, emphasizing the need for comprehensive, well-coordinated responses that address both immediate technical issues and longer-term climate information accessibility challenges.

3.6 Possible strategies to adapt and mitigate the effect of climate change

Table 7 presents the respondents' responses regarding adopting respective mitigation measures. The major strategies adopted by farmers include the use of organic manure ($\bar{x} = 3.87$), use of resistant crops (score $\bar{x} = 3.85$), use of drought-resistant crops ($\bar{x} = 3.68$), and use of flood-tolerant crops ($\bar{x} = 3.73$). Farmers can adopt resistant crop varieties that are better suited to withstand the

TABLE 8 Varimax rotated factors of possible strategies to adopt and mitigate the effect of climate change.

Variables	Crop	Research
Afforestation	**0.414**	0.257
Use of improved or resistant crop	**0.535**	0.062
Use of cover crop	**0.414**	0.025
Incorporation of residues into the soil	**0.738**	−0.174
Change in the timing of farm operation	**0.777**	−0.105
Use of water flood-tolerant crop	0.202	0.798
Increase in agricultural research and development	0.389	**−0.424**
Availability of extension service delivery on the issues of climate	**0.774**	0.188
Provision of adequate mulching materials	**0.674**	−0.086
Proper conservation of seeds	0.054	**0.580**
Provision of infrastructure	**0.550**	−0.175
Provision of adequate farm input supplies	0.315	**−0.437**

Source: Field survey, 2022, Factor loading, 0.4.

impacts of climate change, such as drought, extreme temperatures, and pests. Also, afforestation (planting trees; $\bar{x} = 3.67$), and use of use of cover crops ($\bar{x} = 3.47$) are important strategies to adapt and mitigate the effect of climate change. Excerpts from the focus group discussion indicate that farmers unanimously agree that ["…Planting palm, orange, and gmelina help remove climate pollutants from the atmosphere, contribute to climate change mitigation and provide additional benefits such as soil conservation and biodiversity enhancement…"]. Furthermore, the participant indicated access to reliable weather forecasting services ($\bar{x} = 3.86$) could help farmers make informed decisions and adapt their farming practices to changing climate conditions, thereby mitigating risks associated with irregular rainfall patterns. Famers also indicated that climate-smart agriculture practices ($\bar{x} = 3.93$) are important adaptation strategies. Implementing climate-smart agricultural practices, such as conservation tillage, diversified crop rotations, and rotational grazing, could effectively mitigate climate change impacts by sequestering carbon and enhancing soil health.

Other important strategies identified by the respondents include incorporation of residues into the soil ($\bar{x} = 3.23$), proper conservation of seeds ($\bar{x} = 3.75$), provision of adequate mulching materials ($\bar{x} = 3.40$), among others. These strategies align with the principles of climate-resilient agriculture, which aims to enhance the adaptive capacity of agricultural systems and reduce their vulnerability to climate change while contributing to climate change mitigation.

Table 8 shows the Varimax rotated factors of possible strategies to adopt and mitigate the effect of climate change. Variables that had loadings of 0.4 and above being included in naming the factors. Variables that loaded in more than one factor or had loadings below 0.4 were not used. Two factors were identified and named: agronomic methods (Factor 1) and research methods (Factor 2). Under the agronomic methods (Factor 1), the major strategies identified by farmers include changing the timing of farm operations (loading = 0.777), availability of extension service delivery (loading = 0.774), incorporation of residues into the soil (loading = 0.738), provision of adequate mulching materials (loading = 0.674), provision of infrastructure (loading = 0.550), use of resistant crops (loading = 0.535), and afforestation (loading = 0.414). In Factor 2, the research methods, the strategies identified are proper conservation of seeds (loading = 0.580), provision of adequate farm input supplies (loading = 0.437), and increased investment in agricultural research and development (loading = 0.424).

4 Discussion

4.1 Demographic characteristics of the farmers

The United Nations reports that households in three Sub-Saharan African countries have an average of over 6 members each. Senegal stands out with one of the largest household sizes in Africa, averaging 10.8 members (United Nations, Department of Economic and Social Affairs, Population Division, 2019). These significant household sizes in Sub-Saharan Africa contribute to a valuable pool of labor for agricultural activities. The substantial household sizes in sub-Saharan Africa serve as a valuable labor reservoir for agricultural activities. Mr. Ode, a rural farmer said […I cannot afford machineries hence I use local labor, often involving family and friends…]. Compared to other regions such as North America and Europe, sub-Saharan Africa has larger average household size of 6.9 (Galal, 2023; Pew Research Center, 2023). This aligns with the result of this study of a mean household size of 6.43 people, indicating the families are relatively large and can contribute as a source of labor for farming activities. Thereby giving room for farming household to spend their extra income on other adaptive expenses. The empirical evidence from Swaziland underscored that sub-Saharan African countries could bear the brunt of climate change in terms of increased incidence of poverty and economic decline, with potential impacts on household welfare (Sam et al., 2021). The decrease in agricultural production due to the effects of climate change is a key contributing factor to farmers' reduced income. Findings showed that farmers have relatively low-income, indicating their reliance on income generated from the sales of their agricultural produce. This aligns firmly with related studies from sub-Saharan Africa (Ayanlade et al., 2018; Steinert et al., 2018; Ogada et al., 2020; Nwonu et al., 2022), which indicated that farmers within the region rely on personal savings. Farming experience is crucial to building climate resilience in traditional farming systems. Findings show that farmers have an average farming experience of 21.88 years, this implies that farmers in sub-Saharan Africa possess considerable experience addressing climate change issues in their farming practices, including adaptation and mitigation strategies (Sani and Chalchisa, 2016). However, support from governments and other organizations is crucial to enhance farmers' adaptation capacity and improve their access to resources and information.

4.2 Sources of information by farmers on climate change adaptation

Smallholder farmers in sub-Saharan Africa heavily rely on the environment for their livelihoods, making climate change adaptation crucial for their resilience. To achieve this, timely information on climate change adaptation strategies is vital. Although, there is limited information on the trend in climate information sources in sub-Saharan Africa. However, a study on smallholder farmers' climate resilience in Malawi and Ghana suggests that the relevance of information sources on climate change resilience is place-specific, and some sources may impede resilience (Amoak et al., 2023). Findings from the present study showed that across various survey regions, the main avenues through which individuals access information about climate change prominently include radio broadcasts, interactions with fellow farmers, and in-person discussions with neighbors. This widespread pattern of information dissemination aligns with the findings of multiple studies conducted not only in Anambra, as highlighted by Nwabugwu et al. (2019) and Uzochukwu et al. (2021), but also in diverse sub-Saharan African contexts. One of the noteworthy aspects of this information-sharing framework is the pivotal role of radio as a powerful and accessible medium for effectively communicating climate-related knowledge to diverse target groups across the region. According to and Antwi-Agyei et al. (2021) radio has proven to be a versatile tool in disseminating climate change information to both rural and urban communities, bridging information gaps, and promoting awareness and understanding of climate-related challenges. Additionally, community radio stations have been recognized for their ability to reach huge audiences and disseminate location-specific weather reporting, making them an effective tool for sharing climate information (Harvey et al., 2019; Global Center on Adaptation, 2023). This underscores the significance of radio as a primary and trusted source of climate-related information in sub-Saharan Africa.

In addition to radio, the significance of peer interactions, particularly with fellow farmers and neighboring community members, emerges as a vital information source in the present study. A study on farmers' social networks and regional spillover effects in agricultural climate change mitigation emphasizes the positive influence of peer interactions on farmers' uptake of climate change adaptation measures (Kreft et al., 2023). Furthermore, a systematic review of smallholder farmers' climate change adaptation in sub-Saharan African indicated that knowledge integration and sharing within farming communities is important for adaptation to climate change (Jellason et al., 2022). This interpersonal exchange of knowledge within farming communities fosters the sharing of practical experiences, locally relevant adaptation strategies, and mitigation measures. Farmers can learn from one another's successes and challenges, making peer interactions a crucial component of climate change education and resilience-building efforts. It is important to acknowledge that while these channels are prevalent, there are variations in their prominence and effectiveness across sub-Saharan Africa's diverse regions and cultural contexts.

4.3 Effective traditional adaptation practices farmers use to cushion the effect of climate change

Traditional adaptation practices are crucial for enhancing the climate change resilience of smallholder farmers in sub-Saharan Africa. Findings show that all the tested traditional practices have high adoption rates as farmers utilize them to mitigate and adapt to climate change to minimize its effects. This aligns with the findings of the Crace (2019), which revealed that rural farmers have developed various strategies to reduce the impact of climate change, and these strategies have been tested and proven effective, reflecting farmers' perceptions and serving as effective mitigation and adaptation strategies. The increased application of organic manure by farmers serves multiple purposes, including enhancing soil fertility sustainably and increasing soil moisture content. Farmers noted that with rising temperatures and increased evapotranspiration caused by climate change, preserving moisture for crop use is crucial, making organic manure, planting of cover crops, bush fallow and mulching preferred options. They also emphasized that organic manure is cost-effective and readily available compared to inorganic fertilizers. This aligns with the findings of Quarshie et al. (2023) that traditional agricultural practitioners in sub-Saharan Africa implement on-farm adaptation options such as water management, and soil conservation techniques to combat climate change. Results showed that farmers deployed crop rotation, mixed cropping, intercropping, integrated crop-animal irrigation practices and shifting cultivation as key traditional soil and water management practices to adapt food crop production to climate change (Olumba et al., 2020; Benhin, 2021). This aligns with the findings of Naazie et al. (2023) who found that rural farmers in Ghana use crop diversification, intercropping, mixed farming and the adoption of improved crop varieties to adapt their agricultural production to climate change.

Afforestation and agroforestry are important practices for promoting sustainable land use and mitigating the effects of climate change in sub-Saharan Africa. Results from the present study showed that farmers used afforestation and agroforestry techniques as an effective adaptation strategy as opposed mitigation strategy. These offers one of the most promising technological options for reversing soil degradation, restoring tree cover, and improving agricultural productivity in Africa. Famers reported the key agroforestry practices that helped them to adapt their agricultural system to climate change to include grazing or farming under savanna trees, growing coffee or cocoa under shade trees, planting fruit trees, sowing tree seeds on fallow land to speed up the restoration of fertility, planting "living" fences, windbreaks, or woodlots, combining trees, shrubs, and field crops in multistoried cropping systems, and growing crops between rows of nitrogen-fixing trees or shrubs ("alley cropping"). On the other hand, farmers also reported their engagement in tree planting campaigns in areas where there was no forest cover previously. In sub-Saharan Africa, afforestation programs have been implemented to combat deforestation and land degradation (Chomba et al., 2020). This is an effective traditional way of increasing soil cover, sequester carbon and mitigate the effects of climate change on rural agriculture.

4.4 Possible reasons for using traditional approaches to climate change adaptation

Sub-Saharan African countries are incorporating traditional approaches to climate change adaptation due to their effectiveness and relevance to local conditions. Findings indicate that adopting traditional agricultural practices for climate change adaptation delivers multi-faceted benefits including enhancing soil quality and crop productivity by altering soil structure, promoting nutrient cycling, and reducing pests and diseases. Peoples and Baldock (2020) reported that crop rotation can increase the production of subsequent crops. Niggli et al. (2019) also stated that organic matter enhances soil resistance to drought and makes them adaptable to low and high rainfall conditions. Famers reported that improving over soil health, soil organic matter and crop yield, reducing greenhouse gas emission and enhancing resilience against climate variability are the major reasons why they use traditional approaches such as use of organic manure, traditional organic composting, afforestation and agroforestry, among others. The utilization of these techniques highlights the importance of diversifying agricultural practices to enhance climate resilience, which can serve as a model for other regions grappling with similar challenges. For instance, the successful implementation of afforestation and agroforestry initiatives in Southeast Nigeria as a means of enhancing the productivity of farming business demonstrates their potential as nature-based solutions to climate change that can be scaled up in similar agro-ecosystems. As climate change continues to pose challenges to agricultural systems across the continent, sharing and scaling up these effective practices can contribute significantly to building climate-resilient farming communities and ensuring food security for future generations in sub-Saharan Africa.

4.5 Constraints to adapting traditional agriculture to climate change

Smallholder farmers in sub-Saharan Africa face multifaceted challenges as they seek to adapt traditional agriculture to climate change. Lead farmers in the present study reported that poor agricultural extension services, pest and disease vulnerability, and inadequate dissemination of climate change information due to limited extension services are factors that hinder climate change adaptation, which corroborates the research conducted by Satishkumar et al. (2020). Studies in Nigeria and Ghana have highlighted constraints such as inadequate finance, scarcity of labor, inadequate access to climate information, and lack of access to weather information as significant barriers to farmers' efforts to adapt to climate change (Abegunde et al., 2019; Ige et al., 2021). Additionally, unpredictable weather conditions have been identified as a serious constraint to climate change adaptation strategies in Northern Ghana, affecting arable crop farmers' choice of adaptation strategies (Ige et al., 2021). On the other hand, findings showed that farmers do not have the knowledge to determine the level of accuracy of their climate information, because they never had real-time access to climate information. However, Fagariba et al. (2018) suggested that the inadequacy, inaccuracy, and inconsistency of climatic information available to farmers pose constraints in weather forecasting as an adaptation strategy to climate change. Furthermore, the high cost of accessing weather forecast information and its incompatibility with farmers' needs also hampers the adoption of weather forecasting as a reliable means of coping with the effects of climate change (Ojo et al., 2018). The result of the factor analysis resolved the constraints encountered by farmers into two components namely technical production and climate information problems. This is in tandem with the findings of Autio et al. (2021) who found that smallholder farmers in Southeast Kenya face challenges in adopting climate-smart agricultural practices due to limited access to productive resources and climate uncertainty. This is probably because formal climate adaptation strategies in sub-Saharan Africa often fail to consider the agency of smallholder farmers, leading to a disconnect between the strategies and the farmers' actual adaptation practices and needs. Addressing these constraints is crucial for the successful implementation of climate-smart agricultural practices and the resilience of agricultural systems in the region.

4.6 Possible strategies to adapt and mitigate the effect of climate change in traditional agricultural systems

Climate change poses significant challenges to traditional agricultural systems in sub-Saharan Africa. Smallholder farmers in the region have been adapting to a changing climate, but there is a need for more comprehensive strategies to mitigate its effects. Farmers in the study area indicated that the use of climate-smart agriculture, the use of resistant crop varieties, afforestation, and other identified strategies can effectively mitigate the effects of climate change. This finding aligns with the research conducted by Ali et al. (2019), who highlighted the importance of using resistant crop varieties to adapt and build resilience to the effects of climate change. Resistant crops are known to survive and complete their life cycles even in adverse environmental conditions, providing a useful adaptation strategy (Barasa et al., 2021). Similarly, Jellason et al. (2022) indicated that on-farm adaptation options, agro-ecological intensification (AEI) practices, diversification and intercropping, adoption of improved crop varieties and soil and water management practices are crucial adaptation strategies to climate change in sub-Saharan Africa dry lands. The results further demonstrate that farmers have developed and tested various strategies to reduce the effects of climate change. This highlights their proactive approach to adopting measures to mitigate climate change and their ability to innovate and adapt to the changing environment. The results from the factor analysis categorized the strategies adopted by farmers into two categories namely agronomic methods and research methods for adaptation. Farmers indicated that adjusting the timing of farm operations, availability of extension services, incorporating crop residues into the soil, provision of mulching materials, infrastructure, and adoption of resistant crops and afforestation, are vital agronomic strategies to adapt traditional agriculture to climate change. In terms of the research methods to adaptations, farmers highlight the importance of proper seed conservation, availability of adequate farm inputs, and increased investment in agricultural research and development as crucial aspects to address in enhancing the resilience of their agricultural systems to climate change.

5 Conclusion

This study provides valuable insights into the socioeconomic characteristics of farmers and their practices in adapting to climate change. The findings highlight the significant role of women in rural areas and their involvement in sustainable agriculture practices, as evidenced by a higher percentage of female respondents. The large household size and relatively low-income levels underscore the importance of agriculture as a primary source of livelihood for these farmers. Farmers have considerable experience addressing climate change issues, indicating their potential to collaborate and implement effective adaptation and mitigation strategies. However, the study also reveals the reliance on limited sources of climate change information, such as radio and fellow farmers, indicating the need for improved dissemination channels and access to diverse sources of knowledge.

The study highlights the prevalent use of climate-smart traditional agricultural practices among indigenous people, including organic manure application and mixed farming, demonstrating farmers' proactive approach to mitigating the effects of climate change. These practices enhance soil fertility and moisture retention and improve crop productivity and resilience. Nevertheless, the study identifies constraints such as poor extension services, limited access to climate information, and technical challenges that hinder effective adaptation. These constraints require enhanced support systems, policy interventions, and agricultural research and development investments. In light of the findings, promoting climate-smart agriculture, the use of resistant crop varieties, afforestation, and sustainable farming practices emerge as essential strategies to mitigate the effects of climate change. By addressing the identified constraints and building upon farmers' existing knowledge and experiences, we can enhance their resilience, improve agricultural productivity, and contribute to sustainable rural development.

5.1 Policy implications of the findings

- Strengthen extension services and diversify information sources: Governments should invest in and strengthen extension services to provide farmers with up-to-date climate change information, area-specific weather cues, agricultural best practices, and new technologies. And promote the use of diverse information sources, including indigenous channels, digital platforms and community-based knowledge sharing.
- Promote climate-smart agricultural practices: Encourage the adoption of climate-smart agricultural practices through incentives, subsidies, and training programs. Governments should support research and development in climate-resilient crop varieties and livestock breeds.
- Increase investment in agricultural research: Allocate more funding to agricultural research and innovation to develop climate-resilient technologies, improved crop varieties, and sustainable farming practices.
- Access to credit for climate-resilient infrastructure: Facilitate access to credit and financial services for farmers to invest in climate-resilient infrastructure, such as irrigation systems, drought-resistant seeds, and storage facilities.
- Supportive policies and collaborative networks: Create a conducive policy environment that encourages sustainable agricultural practices and promotes collaboration among various stakeholders, including government agencies, NGOs, and research institutions.
- Capacity-Building Workshops and Progress Monitoring: Organize capacity-building workshops and training programs for farmers, extension workers, and other stakeholders to enhance their knowledge and skills in climate adaptation and mitigation. And also implement regular progress monitoring and evaluation to assess the effectiveness of climate adaptation efforts.
- Enabling Environment for Continuous Learning and Improvement: Foster an environment that promotes continuous learning and improvement in agricultural practices. Encourage farmers to experiment with new techniques and technologies while providing them with the necessary support and resources.
- Collaboration among policymakers, researchers, and local communities: Promote collaboration and coordination among policymakers, researchers, and local communities to ensure that climate-resilient and sustainable agricultural practices are developed, disseminated, and adopted effectively.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by University of Nigeria Research Ethics Committee. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

DO: Conceptualization, Funding acquisition, Methodology, Project administration, Supervision, Writing—original draft, Writing—review & editing. RO: Conceptualization, Funding acquisition, Methodology, Software, Writing—original draft.

RU: Data curation, Formal analysis, Funding acquisition, Project administration, Writing—review & editing. UN: Conceptualization, Funding acquisition, Methodology, Writing—original draft, Writing—review & editing. CN: Conceptualization, Funding acquisition, Writing—original draft, Writing—review & editing. CU: Writing—original draft, Resources, Visualization. GO: Project administration, Resources, Writing—review & editing. EM: Writing—review & editing, Methodology, Supervision.

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