

IMPACT OF CLIMATE CHANGE AND ADAPTATION STRATEGIES AMONG SMALLHOLDER FARMERS IN ZARIA LOCAL GOVERNMENT AREA, KADUNA STATE, NIGERIA

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Abstract

Climate change constitutes a formidable threat to agricultural productivity and rural livelihoods across sub Saharan Africa, with smallholder farmers bearing a disproportionate share of its consequences. This study investigated the impact of climate change and the adaptation strategies employed by smallholder farmers in Zaria Local Government Area (LGA), Kaduna State, Nigeria. A quantitative research design was adopted, and structured questionnaires were administered to 384 smallholder farmers purposively selected from five wards (Dambo, Dutsen Abba, Kufena, Tukur Tukur, and Wuciciri), of which 365 copies were retrieved and analysed using descriptive statistics. Time series data on temperature and rainfall spanning 1988 to 2023 were also examined to establish long term climatic trends within the study area. The findings reveal that 40.8% of respondents reported increased temperatures and drought conditions, while 50.1% indicated reduced income and heightened food insecurity as a direct consequence of climate variability. The predominant adaptation strategies identified include changing planting dates to match rainfall patterns (48.5%), adopting drought tolerant crop varieties (40.8%), and diversifying farming activities (43.6%). However, institutional barriers such as limited access to credit, insufficient extension services, and the high cost of improved crop varieties continue to constrain effective adaptation. The study recommends strengthening agricultural extension services, expanding access to climate information systems, and promoting community based adaptation initiatives to enhance the resilience of smallholder farming systems in the region.

Keywords: Climate change; Adaptation strategies; Smallholder farmers; Resilience; Agricultural productivity; Food security; Nigeria

1. Introduction

Climate change is increasingly recognised as one of the most serious environmental challenges affecting global agricultural systems. Rising temperatures, erratic rainfall patterns, and extreme weather events continue to disrupt food production and threaten livelihoods in many developing countries (IPCC, 2021). Smallholder farmers, who constitute a significant proportion of the agricultural workforce in these regions, are disproportionately affected due to their limited resources, low adaptive capacity, and dependence on rain fed agriculture (Morton, 2007). Understanding the dynamics of climate change impacts and the adaptation strategies employed by smallholder farmers is therefore critical for ensuring their livelihoods, building resilience, and promoting sustainable agricultural practices in a changing climate.

The Intergovernmental Panel on Climate Change projects that global temperatures will continue to rise, leading to more frequent and intense heat waves, droughts, floods, and other extreme weather events (IPCC, 2021). These changes carry significant implications for agriculture and food security, particularly for smallholder farmers who rely on rain fed agriculture and have limited access to irrigation and other technologies (Rosenzweig *et al.*, 2022). Empirical evidence indicates that climate change has already reduced global agricultural productivity by approximately 21% since 1961, with the most substantial impacts concentrated in Africa and Latin America (Rosenzweig *et al.*, 2022). Yield reductions in major crops such as wheat, rice, and maize are estimated to reach as high as 30% by 2050 (Challinor *et al.*, 2014), with grave implications for food security in developing countries where agriculture serves as the primary source of livelihood and sustenance for millions.

In response to these challenges, there is a growing need for adaptation measures to enhance the resilience of agricultural systems. Adaptation strategies can be broadly categorised into farm level practices, such as changing planting dates, using drought tolerant crop varieties, and diversifying crops, as well as policy level interventions, including investment in irrigation infrastructure, provision of access to climate information services, and promotion of sustainable land management practices (Lipper *et al.*, 2014; IPCC, 2022). In Nigeria, agriculture remains a major source of livelihood for rural households, yet climatic variability has significantly impaired agricultural productivity, resulting in declining crop yields and increasing food insecurity. Against this backdrop, this study examines the socioeconomic attributes of smallholder farmers in Zaria LGA, identifies the climate change challenges they encounter, and evaluates the adaptation strategies they have

employed to mitigate these impacts.

2. Literature Review

2.1 Global and Regional Context of Climate Change

Globally, climate change is identified as the most significant threat to food security, with the IPCC reporting a marked increase in the frequency of extreme weather events (IPCC, 2023). Sub Saharan Africa is particularly vulnerable due to its heavy reliance on rain fed agriculture and limited adaptive capacity. In Nigeria, this vulnerability manifests as a southward expansion of the Sahara Desert and increasingly erratic monsoon patterns, which threaten the livelihoods of over 70% of the population engaged in smallholder farming (Ojo and Baiyegunhi, 2021). The continent's agricultural sector is uniquely exposed because a majority of its farming systems depend on seasonal rainfall rather than irrigation, making them acutely sensitive to shifts in precipitation timing and intensity.

2.2 Climate Variability in Northern Nigeria

Climate change represents perhaps the most serious threat to the fight against hunger, starvation, malnutrition, poverty, and disease across Africa (Ofoegbu, 2025). In Northern Nigeria, the Savanna ecological zone has experienced documented increases in mean annual temperatures and a significant shift in rainfall onset dates. Research indicates that the region is prone to rainfall harvesting challenges, where intense short duration storms lead to flooding, followed by prolonged dry spells (Adamu *et al.*, 2024). These fluctuations disrupt the traditional agricultural corridor spanning Saminka, Zaria, and Kano, forcing a re evaluation of traditional planting calendars that smallholder communities have relied upon for generations.

2.3 Impact on Smallholder Farmers in Zaria LGA

At the local level, Zaria LGA serves as a critical agricultural hub, yet it faces unique pressures from both climate change and rapid urbanisation. Meka (2019) notes that smallholder farmers in Zaria have observed a distinct shortening of the rainy season, which historically spanned from May to October but has become increasingly unpredictable. A study by Umar (2013) reported that climate variability accounts for nearly half of the yield fluctuations in staple crops such as millet and maize, while Meka (2019) found that the high incidence of water scarcity, reported by 91% of local farmers, has led to increased production costs and, in some cases, the abandonment of ancestral farmlands.

2.4 Local Adaptation Strategies and Constraints

Smallholder farmers in Zaria have transitioned from being passive observers to active adapters. Common local strategies include shifting to drought resistant varieties and altering

planting dates (Issa *et al.*, 2015), a pattern that aligns with findings from Edo State reported by Igene *et al.* (2023). The increased use of fadama (floodplain) irrigation and chemical fertilizers to compensate for soil nutrient leaching caused by flash floods represents another important technological adjustment. Despite these efforts, adaptation in Zaria is hindered by a lack of climate smart extension services and poor access to formal credit, with over 72% of farmers lacking the financial liquidity to invest in sustainable irrigation technology (Meka, 2019; Daikwo *et al.*, 2025). These constraints underscore the need for institutional support mechanisms that go beyond individual farm level interventions.

3. Methodology

The study adopted a quantitative research design. Primary data were collected using structured questionnaires administered to smallholder farmers across selected wards in Zaria LGA. Five wards, namely Dambo, Dutsen Abba, Kufena, Tukur Tukur, and Wuciciri, were purposively selected on account of their high concentration of smallholder farmers. Since the total population of smallholder farmers in the study area is not known, the study adopted the Israel (1992) formula to derive a statistical sample size of 384, expressed as:

$$n = Z^2 pq / e^2 \quad (1)$$

where Z is the Z score corresponding to the desired confidence level (1.96 for a 95% confidence level), p is the estimated proportion of the population possessing the attribute of interest (assumed at 0.5 where the proportion is unknown), q equals 1 minus p , and e is the margin of error (0.05). Substituting these values yields a sample size of 384. A total of 384 copies of the questionnaire were administered to respondents, of which 365 copies were retrieved and used for data analysis. Descriptive statistics, including frequency distribution and percentages, were adopted for data analysis. The main thrust of the data obtained was presented using tables and figures. Secondary data on temperature and rainfall from the Power Access Climate Data platform were analysed over the period 1988 to 2023 to establish long term climatic trends.

4. Results and Discussion

4.1 Demographic Characteristics of the Respondents

Table 1 presents the demographic characteristics of the 365 respondents categorised by gender, age, marital status, education level, and number of children. The findings reveal that male farmers constitute the majority of respondents (72.9%), a pattern that is consistent with studies documenting the dominance of male farmers in smallholder agriculture across sub Saharan Africa (Manyong *et al.*, 2015). The age distribution indicates

that the largest proportion of respondents (29.9%) falls within the 31 to 40 years bracket, followed closely by those aged 41 years and above (28.5%), suggesting that farming in the study area is primarily undertaken by individuals in their productive years.

Table 1. Socio demographic characteristics of respondents.

S/N	Variable	Characteristic	Freq.	%
1	Gender	Male	266	72.9
		Female	99	27.1
2	Age	15–20 years	65	17.8
		21–30 years	87	23.8
		31–40 years	109	29.9
		41 years and above	104	28.5
3	Marital Status	Single	118	32.3
		Married	94	25.8
		Divorced	74	20.3
		Widowed	79	21.6
4	Education	Qur'anic	98	26.9
		Primary	141	38.5
		Secondary	67	18.4
		Tertiary	59	16.2
5	No. of Children	1–5 children	86	23.6
		6–10 children	173	47.4
		Above 11	106	26.0

Source: Author's field survey, 2025

With regard to education, the majority of respondents (38.5%) attained only primary level education, while 26.9% received Qur'anic education. This low level of formal educational attainment is consistent with the observation by Omotilewa *et al.* (2016) that smallholder farmers in Nigeria tend to possess limited formal schooling, which constrains their ability to adopt new technologies and respond effectively to climate change. The relatively high proportions of divorced (20.3%) and widowed (21.6%) respondents are noteworthy and may reflect the specific social and economic conditions prevailing in the study area, characterised by elevated levels of poverty and insecurity. The finding that 47.4% of respondents have between 6 and 10 children, with an additional 26.0% reporting more than 11 children, contrasts with trends observed in Ethiopia, where family size among smallholder farmers has been declining as a result of improved access to education and family planning services (Asfaw *et al.*, 2017).

4.2 Climate Change Challenges Affecting Smallholder Farmers

Table 2 presents the farmers' perceptions of climate change, its impacts on their agricultural practices and livelihoods, and the implications for adaptation strategies. A central finding is the significant proportion of farmers (26.3%) reporting decreased temperatures and harmattan conditions, which contrasts with prevailing climate change projections for sub Saharan Africa that anticipate warming trends (Niang *et al.*, 2014). This discrepancy warrants further investigation, including analysis of localised meteorological data and long term climate trends specific to Zaria LGA. It is plausible that microclimatic variations or subjective perceptions among farmers contribute to this observation.

Table 2. Climate change related challenges affecting smallholder farmers in Zaria LGA.

S/N	Variable	Characteristic	Freq.	%
1	Climate challenges observed	Increased rainfall & flooding	42	11.5
		Decreased temp. & harmattan	96	26.3
		Increased temp. & drought	149	40.8
		No noticeable changes	78	21.4
2	Impact of rainfall changes	Delayed planting (late rains)	125	34.3
		Increased yields (more rain)	59	16.2
		No significant impact	88	24.0
		Improved water for irrigation	93	25.5
3	Impact of increased temperatures	Increased crop growth & yields	82	22.5
		Reduced yields (heat stress)	153	41.9
		No noticeable impact	66	18.1
		Increased pest & disease	64	17.5
4	Extreme weather events	No extreme events experienced	46	12.5
		Droughts but not floods	167	45.8
		Floods but not droughts	52	14.3
		Both droughts and floods	100	27.4
5	Impact on overall livelihood	Improved income & food security	24	6.6
		Reduced income & food insecurity	183	50.1
		No significant impact	86	23.6
		Increased off farm employment	72	19.7

Source: Author's field survey, 2025

Conversely, 40.8% of farmers reported increased temperatures and drought, a finding that aligns with broader regional climate trends documented by Abaje *et al.* (2016). Elevated temperatures induce heat stress in crops, diminish yields, and escalate irrigation requirements. Droughts pose a substantial threat to agricultural production, potentially leading

to crop failure, livestock losses, and heightened food insecurity, observations consistent with studies emphasising the vulnerability of Nigerian smallholder farmers to drought (Apata *et al.*, 2019). The data further reveal that changes in rainfall patterns are significantly affecting farming activities, with delayed planting due to late onset of rains (34.3%) emerging as a prevalent challenge that disrupts traditional planting calendars and potentially reduces yields (Tarhule and Lamb, 2018). While increased rainfall may enhance water availability for irrigation (25.5%), it also carries the risk of flooding and soil erosion (Odekunle *et al.*, 2020).

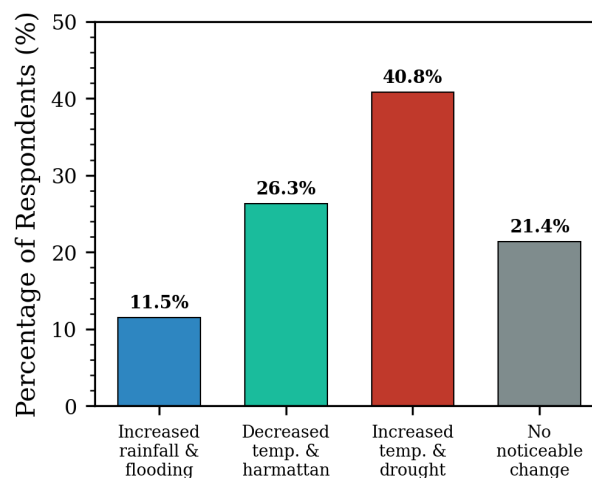


Figure 1: Distribution of climate change related challenges observed by smallholder farmers in Zaria LGA.

Increased temperatures are reported to have a detrimental impact on crop production, with 41.9% of farmers experiencing reduced yields due to heat stress (Figure 1). This underscores the urgency of adopting heat tolerant crop varieties and implementing adaptation measures to mitigate the adverse effects of rising temperatures (IPCC, 2022). Furthermore, the reported increase in pest and disease infestations (17.5%) is consistent with the understanding that climate change can create conditions favourable for the proliferation of pests and diseases, posing a significant threat to agricultural productivity (Lehmann *et al.*, 2020). The results also indicate a high prevalence of extreme weather events, with 27.4% of farmers having experienced both droughts and floods, highlighting the escalating frequency and intensity of such events and their potentially devastating consequences for smallholder farmers (Ologunorisa and Adeyemo, 2018).

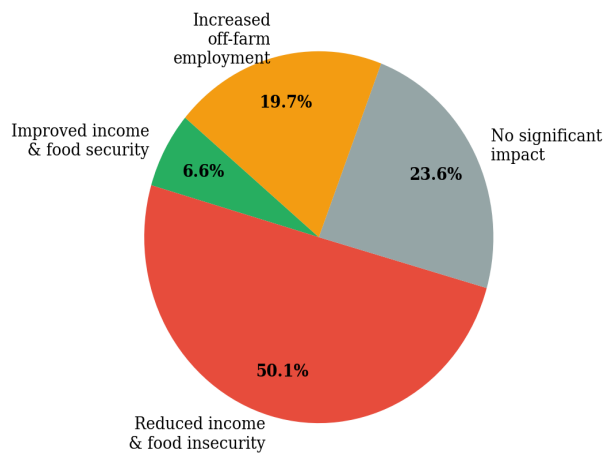


Figure 2: Impact of climate change related challenges on overall livelihoods of smallholder farmers.

The impact of these challenges on livelihoods is substantial, with 50.1% of farmers reporting reduced income and heightened food insecurity (Figure 2). This compelling evidence demonstrates that climate change poses a formidable challenge to smallholder farmers in Zaria LGA. The impacts are diverse, encompassing shifts in temperature and rainfall patterns and a surge in extreme weather events, all of which adversely affect agricultural productivity, diminish incomes, and aggravate food insecurity in a region where farming constitutes the primary economic activity.

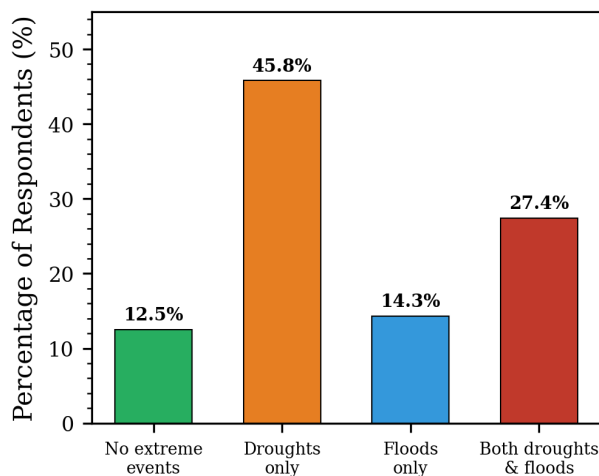


Figure 3: Experience of extreme weather events among smallholder farmers in Zaria LGA.

4.2.1 Trends of Annual Temperature in Zaria LGA (1988 to 2023)

The time series data presented in Figure 4 illustrate the variability of annual temperature in Zaria LGA from 1988 to 2023. The analysis reveals fluctuations in temperature over the

years, with a general upward trend. While the overall trend indicates a gradual increase in temperature, there are notable periods of both warming and cooling. The late 1980s and early 1990s experienced a relatively cool period, followed by a warming trend until the mid 2000s. Subsequently, temperatures fluctuated with a slight decline until the early 2020s, followed by a more pronounced drop.

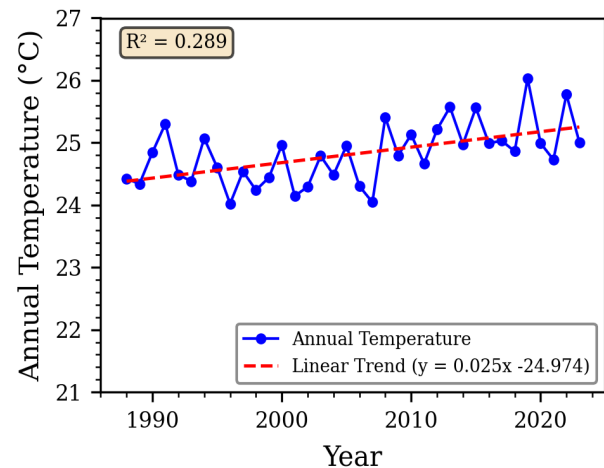


Figure 4: Trends of annual temperature in Zaria LGA from 1988 to 2023.
Source: Power Access Climate Data.

The linear trend line provides a simplified representation of the overall warming trend. The equation of the trend line and the coefficient of determination ($R^2 = 0.187$) indicate a weak positive correlation between year and temperature. This suggests that while there is a general warming trend, other factors beyond the simple passage of time contribute to the observed temperature variability. The observed warming trend aligns with broader climate change projections for sub Saharan Africa, which anticipate rising temperatures due to increasing greenhouse gas concentrations (Niang *et al.*, 2014). Studies have documented warming trends in various parts of Nigeria, including the Sudano Sahelian ecological zone where Zaria is located (Abaje *et al.*, 2016). However, the magnitude of the warming trend appears relatively small compared to some regional and global estimates, a discrepancy that could be attributed to localised factors such as land use changes, urbanisation, and microclimatic variations.

The observed temperature variability and overall warming trend have significant implications for smallholder farmers in Zaria LGA. Rising temperatures can lead to increased evapotranspiration, reduced water availability, and heat stress in crops, potentially affecting yields and agricultural productivity (IPCC, 2022). Changes in temperature can also influence the prevalence of pests and diseases, posing additional challenges for farmers (Lehmann *et al.*, 2020). The contrast between the

observed fluctuations and recent cooling trend in Zaria and the more consistent warming trends reported in some studies (Odjugo, 2010) highlights the importance of considering local climate dynamics and long term data analysis to understand the specific climate change patterns affecting this locality.

4.2.2 Variability Trends of Annual Rainfall in Zaria LGA (1988 to 2023)

The time series presented in Figure 5 depicts the variability of annual rainfall in Zaria LGA from 1988 to 2023. The analysis reveals notable fluctuations in rainfall patterns over the years, with an overall trend that deviates from typical expectations for the region. The data exhibit considerable inter annual variability, with periods of relatively high rainfall interspersed with periods of drought. A distinct peak in rainfall is observed around 2020, followed by a sharp decline.

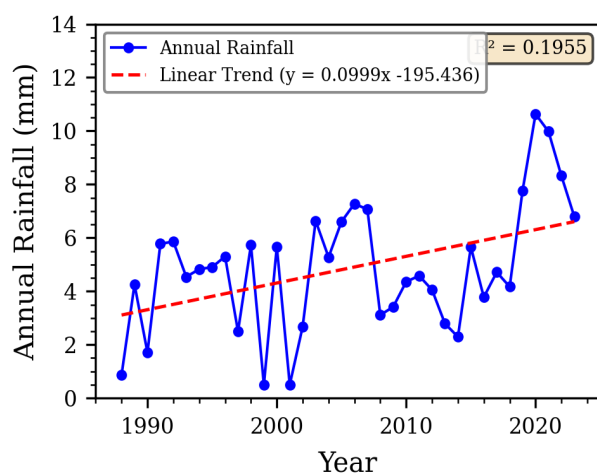


Figure 5: Variability trends of annual rainfall in Zaria LGA from 1988 to 2023. Source: Power Access Climate Data.

The linear trend line and the low coefficient of determination ($R^2 = 0.0163$) indicate a very weak positive correlation between year and rainfall. This suggests that the overall increase in rainfall over the study period is minimal and that other factors beyond the passage of time significantly influence rainfall variability. The observed trend of slight increase in rainfall in Zaria LGA contrasts with some studies reporting a decreasing trend in the Sudano Sahelian region of Nigeria (Abaje *et al.*, 2016). This discrepancy could be attributed to localised factors such as land use changes, urbanisation, and microclimatic variations. It is also possible that the time frame of analysis influences the observed trends, as different studies may use varying periods of data.

However, the high degree of inter annual variability is consistent with the general understanding of rainfall patterns in the region. Studies have highlighted the unpredictable nature of rainfall in the Sudano Sahel, with frequent droughts and floods

(Tarhule and Lamb, 2018). This variability poses significant challenges for rain fed agriculture, which is the dominant farming system in Zaria LGA. The fluctuating rainfall patterns and the occurrence of extreme events have profound implications for smallholder farmers, potentially leading to crop failure, reduced yields, and loss of income, thereby exacerbating food insecurity and poverty (Ologunorisa and Adeyemo, 2018).

4.3 Adaptation Strategies Employed by Smallholder Farmers

This study assessed the adaptation strategies employed by smallholder farmers in Zaria LGA to counter the challenges posed by climate change. Table 3 reveals a diverse range of responses, highlighting both the resourcefulness of farmers and the persistent obstacles they confront in adapting to a changing climate.

Table 3. Adaptation strategies employed by smallholder farmers in Zaria LGA.

S/N	Variable	Characteristic	Freq.	%
1	Adaptation strategy adopted	Changing planting dates	177	48.5
		Relocating to favorable area	88	24.1
		Abandoning farming	38	10.4
		None of the above	62	17.0
2	Use of drought resistant varieties	Yes, adopted	149	40.8
		Not aware of varieties	70	19.2
		Available but not accessible	89	24.4
		Available but too expensive	57	15.6
3	Diversification of farming	Yes, diversified crops	159	43.6
		Still focus on same crops	86	23.6
		Tried but unsuccessful	48	13.2
		Not interested	72	19.8
4	Soil & water conservation	Use terracing/mulching	117	32.1
		Not familiar with techniques	108	29.6
		Too labor intensive	84	23.0
		Not effective	56	15.3
5	Information sources	Extension services	78	21.4
		Fellow farmers	98	26.9
		Government programmes	62	17.0
		All of the above	127	34.8

Source: Author's field survey, 2025

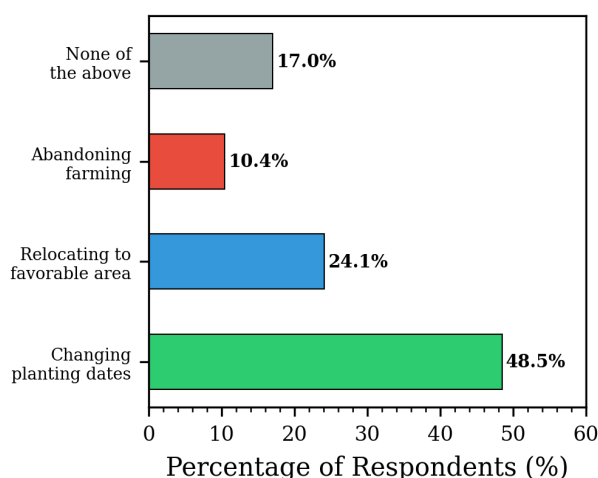


Figure 6: Primary adaptation strategies adopted by smallholder farmers in Zaria LGA.

The most prevalent adaptation strategy is adjusting planting dates to align with rainfall patterns (48.5%), as illustrated in Figure 6. This proactive approach reflects farmers' recognition of the shifting rainfall regime and their efforts to optimise planting schedules for improved yields (Tarhule and Lamb, 2018). However, the effectiveness of this strategy hinges on accurate and timely weather information, which may be limited in accessibility for some farmers. Relocating to areas with more favourable climatic conditions (24.1%) represents a more drastic measure, indicative of the severity of climate change impacts in certain localities. This strategy, however, can be constrained by land tenure systems, social networks, and access to resources in new locations (Odekunle *et al.*, 2020). The study also reveals a concerning trend of farmers abandoning agriculture altogether (10.4%), which underscores the profound impact of climate change on livelihoods and the potential for agricultural abandonment if adaptation support is not strengthened (Apata *et al.*, 2019).

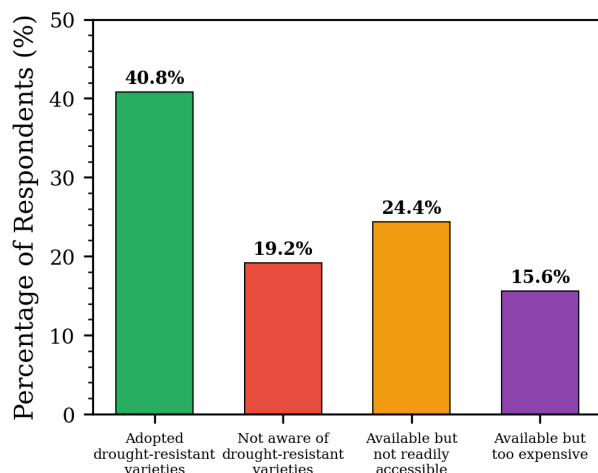


Figure 7: Adoption status of drought resistant crop varieties among smallholder farmers.

While a considerable proportion of farmers (40.8%) have adopted drought resistant crop varieties (Figure 7), access remains a significant barrier. A quarter of the respondents (24.4%) indicated that these varieties are not readily available, while 15.6% found them too expensive. This highlights the need for interventions that enhance the availability and affordability of improved crop varieties, coupled with extension services to promote their adoption (Manyong *et al.*, 2015). Crop diversification (43.6%) emerges as another key adaptation strategy, reducing reliance on single crops and mitigating risks associated with climate variability. However, a notable proportion of farmers (23.6%) persist with traditional cropping patterns, potentially due to market demand, cultural preferences, or lack of awareness regarding diversification benefits.

The adoption of soil and water conservation techniques, such as terracing and mulching (32.1%), is crucial for enhancing resilience to climate change. However, a significant proportion of farmers (29.6%) remain unfamiliar with these techniques, underscoring the importance of extension services and farmer training programmes. Labour intensity (23.0%) and perceived ineffectiveness (15.3%) are also cited as barriers, suggesting the need for context specific approaches and technologies that address these concerns.

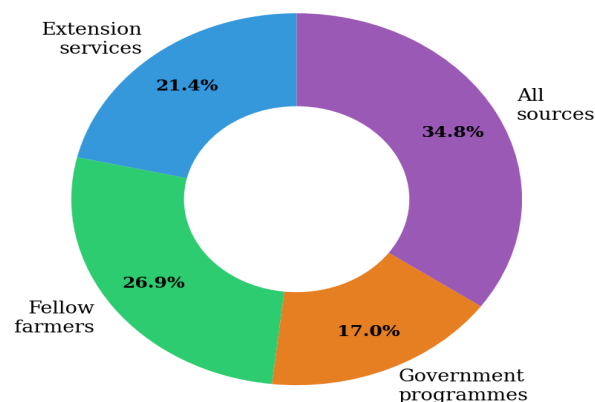


Figure 8: Sources of information and assistance on climate change adaptation among smallholder farmers.

Farmers rely on a variety of sources for information and assistance on climate change adaptation (Figure 8), with fellow farmers (26.9%), agricultural extension services (21.4%), and government programmes (17.0%) playing key roles. Notably, 34.8% of farmers utilise all available sources, highlighting the importance of a multi pronged approach to information dissemination and knowledge sharing. The findings of this study

are largely consistent with existing literature on adaptation strategies employed by smallholder farmers in sub Saharan Africa. Studies have emphasised the importance of adjusting planting dates (Tarhule and Lamb, 2018), adopting drought resistant varieties (Manyong *et al.*, 2015), diversifying crops (Omotilewa *et al.*, 2016), and implementing soil and water conservation techniques (Odekunle *et al.*, 2020). However, the relatively high proportion of farmers abandoning agriculture (10.4%) is concerning and warrants further investigation.

5. Conclusion and Recommendations

Climate change poses significant risks to agricultural livelihoods in Zaria LGA. Although farmers are adopting various adaptation strategies, their effectiveness is constrained by limited resources and institutional support. Strengthening agricultural support systems is therefore essential for improving resilience and ensuring sustainable livelihoods. Based on the findings of this study, the following recommendations are proposed.

Government and development agencies should strengthen agricultural extension services to provide farmers with current knowledge on climate smart agricultural practices. Investment in weather forecasting and early warning systems should be improved to furnish farmers with timely climate information. Agricultural research institutions should develop and promote locally suitable drought resistant crop varieties that are both affordable and accessible to smallholder farmers. Farmers should be trained on crop diversification techniques and soil and water conservation practices to enhance productivity and sustainability.

Community based adaptation initiatives should be encouraged to facilitate knowledge sharing and collective resilience building among farming communities. Financial support mechanisms such as microcredit schemes and agricultural insurance should be expanded to help farmers cope with climate related risks. The integration of indigenous knowledge with scientific climate information could yield more effective and culturally appropriate adaptation strategies. Future research should explore the gendered dimensions of climate change adaptation, assess the effectiveness of existing government programmes, and investigate the long term sustainability of the adaptation strategies currently being employed.

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