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ANALYSIS OF DROUGHT OCCURRENCE AND FARMERS ADAPTATION STRATEGIES IN BILLIRI LOCAL GOVERNMENT AREA, GOMBE STATE, NIGERIA

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Abstract **https://doi.org/10.65760/sjgs.v4.i2.11**

Drought remains one of the most persistent climatic hazards affecting large populations worldwide, particularly in West Africa, where northern Nigeria is highly vulnerable. This study assessed drought occurrence and farmers' adaptation strategies in the Guinea Savanna of Billiri Local Government Area. A mixed-methods research approach was employed using both primary and secondary data. Primary data were collected through Key Informant Interviews (KIIs) conducted with 15 participants purposively selected. Secondary data comprised annual rainfall records (1996–2025) obtained from NASA POWER database. The Standardized Precipitation Index (SPI) was used to analyse rainfall variability and classify drought occurrence, and qualitative interview data were analysed thematically. The results revealed considerable inter-annual rainfall variability, with drought conditions ranging from near normal to severe and extreme drought. Persistent drought episodes were recorded between 1999 and 2015, whereas the period from 2021 to 2025 was characterized predominantly by high rainfall, the climatic conditions with no major drought events. These findings indicate that rain-fed farming systems in the study area remain highly vulnerable to rainfall variability. Farmers primarily adapted through changing planting dates, mixed cropping, mixed farming, rainwater harvesting, and livelihood diversification. In contrast, asset sales, begging, and technically intensive adaptation measures requiring substantial financial investment were rarely adopted. The study concludes that drought has remained a recurrent constraint to agricultural production in the study area, despite recent improvements in rainfall conditions. Farmers continue to rely predominantly on indigenous and low-cost adaptation strategies. The study recommends strengthening farmers' access to technical drought adaptation practices, promoting improved drought-tolerant crop varieties, and encouraging tree planting to enhance agricultural resilience under changing climatic conditions.

Keywords: *Drought occurrence, Adaptation Strategies, Farmers, and Rural Areas.*

Introduction

Drought is one of the most devastating climatic hazards affecting agricultural production and rural livelihoods worldwide. It is particularly severe in developing countries where agriculture depends largely on rainfall and where farmers possess limited adaptive capacity. Among the world's regions, Sub-Saharan Africa remains the most vulnerable to drought because of its high dependence on rain-fed agriculture, widespread poverty, rapid population growth, and increasing climate variability (Henchiri et al., 2021).

Over the past six decades, drought has accounted for approximately 25% of all natural disasters recorded in Africa, with more than 300 documented drought events (Dakalo et al, 2019). Recent evidence also indicates that drought occurrence in West Africa has fluctuated considerably between 2002 and 2025 as a result of increasing climate variability and changing rainfall patterns (Magaji and Abaje, 2025).

Climate change has intensified the frequency and severity of drought worldwide through rising greenhouse gas concentrations caused by human activities. Although drought occurs throughout West Africa, its intensity varies spatially. The northern part of the West Africa experiences severe and extreme drought more frequently than the humid southern region because of lower annual rainfall, higher evapo-transpiration, and the influence of the Sahara Desert (Owagbemi, 2022). In Nigeria, drought affects almost every ecological zone but is more severe in the northern states (Nigerian Meteorological Agency, 2018). The high vulnerability of northern Nigeria is associated with its semi-arid climate and its proximity to the northeast trade winds, which transport dry continental air from the Sahara Desert.

According to Abaje (2022), the regions are most severely affected by drought are those bordering the Republic of Niger. NiMet (2018) identified Borno, Yobe, Katsina, Gombe, Kebbi, Zamfara, Kano, Jigawa, and Sokoto States as the most drought-prone areas in Nigeria. Globally, drought affects hundreds of millions of people each year. More than half a billion people live in arid and semi-arid regions where livelihoods depend primarily on rain-fed agriculture (Henchiri et al., 2021). In Africa, over 200 million people reside in drought-prone areas and are highly vulnerable to its impacts (Meron et al., 2024). Furthermore, more than 300 million Africans have been affected by drought over the last four (4) decades (Mavhura et al., 2015). It has also been estimated that approximately 65% of the population in Sub-Saharan Africa is vulnerable to drought, while about 25% is highly vulnerable because of limited adaptive capacity and dependence on climate-sensitive livelihoods (Lelethu et al., 2024). Agriculture is usually the first sector to experience the adverse effects of drought because crop production depends largely on adequate soil moisture. During prolonged drought, soil moisture declines rapidly, resulting in dry and cracked soils that reduce crop growth and productivity (Jude, 2018). Rain-fed farming is more vulnerable to drought than irrigated agriculture because it depends entirely on seasonal rainfall. Nevertheless, irrigated agriculture can also be affected when prolonged drought reduces river flows, reservoirs, and groundwater supplies (Gideon et al., 2021). Consequently, drought often leads to crop failure, livestock mortality, and loss of farm income, food insecurity, poverty, and livelihood stress (Jude et al., 2020).

Nigeria is particularly vulnerable because more than one-third of its population lives in the northern region, where subsistence rain-fed agriculture is the dominant source of livelihood (Jude et al., 2018). States such as Borno, Yobe, Jigawa, Kano, Gombe, Sokoto, and Kebbi have experienced recurrent severe droughts that have resulted in declining crop yields, livestock losses, poverty, and periodic food shortages (Abaje, 2022). For example, drought experienced during the 2023-farming season contributed to a sharp increase in the prices of staple foods, including maize, rice, and beans, across Nigeria (Federal Republic of Nigeria, 2024). Similarly, the severe drought of 1997 contributed to widespread food shortages and famine (Ibrahim and Abdullahi 2022). Earlier estimates by Mortimore (1989) indicated that farmers in Kano State lost approximately ₦4 billion due to drought, while livestock losses in Yobe State exceeded 10,000 cattle, sheep, and goats as a result of water and pasture shortages (Jude, 2018).

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To reduce the adverse effects of drought, farming communities have developed various adaptation strategies aimed at sustaining agricultural production and household livelihoods (Abdulrashid and Yaro, 2020). These strategies include mixed cropping, mixed farming, crop diversification, rainwater harvesting, livelihood diversification, seasonal migration, conservation agriculture, and the use of climate information services. Such climate-smart agricultural practices have been widely promoted across Africa as effective measures for reducing drought risks and enhancing resilience among smallholder farmers (Owagbemi, 2022).

Despite the growing body of literature on drought occurrence and farmers' adaptation strategies in Nigeria, important geographical gaps remain. Most previous studies have focused predominantly on the Sahel region (Abubakar et al., 2018; Abaje and Magaji, 2022, Magaji and Abaje, 2025), with relatively little attention given to the Guinea Savanna ecological zone, where climatic conditions and farmers' adaptation practices differ considerably. Furthermore, many existing studies have relied exclusively on either quantitative or qualitative research methods.

The use of a single research approach limits the depth and comprehensiveness of findings because each method has inherent strengths and weaknesses. A mixed-methods approach combines quantitative and qualitative techniques, thereby providing a more comprehensive understanding of drought occurrence, farmers' adaptation strategies, and the factors influencing adaptation decisions through triangulation of evidence.

Against this background, this study assesses drought occurrence and farmers' adaptation strategies in the Guinea Savanna Agricultural Zone of Billiri Local Government Area, Gombe State. Specifically, the study employs a mixed-methods approach by integrating questionnaire surveys with qualitative interviews involving farmers and agricultural experts to generate a more comprehensive understanding of drought occurrence and adaptation practices in the study area.

MATERIALS AND METHODS

Study Area

Billiri Local Government Area (LGA) is located in the southern part of Gombe State, Nigeria (Figure 1). It is a local government area where the majority of the population dwell in rural areas, with farming as their major economic activity. Billiri lies approximately between latitude 9°40' and 9°55' North and longitude 11°05' and 11°20' East (Bello et al., 2020). It shares boundaries with Akko LGA to the north, Kaltungo LGA to the south, Shongom LGA to the west, and Balanga LGA to the east. It has a mean annual rainfall of between 850mm and 1100mm, with onset in late May and cessation in early October (Bello and Paul, 2022).

Research Design

The study adopted a mixed-methods research design, combining quantitative and qualitative data. Quantitative data were sourced from documented rainfall records, while qualitative data were obtained through Key Informant Interviews with experienced farmers and experts from the Ministry of Agriculture. The quantitative data were subjected to descriptive statistics, and the qualitative data were analysed using thematic analysis.

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Sources and Methods of Data Collection

The paper utilised bothprimary and secondary data**.** Primary data were collected through a Key Informant Interview (KII) guide, generated information from individuals with relevant experience of drought, farming, and expertise in the agricultural sector in the study area; the data collected included farmers' experience on drought occurrence and adaptation strategies. Secondary data consisted of 30 years of annual rainfall records from 1996 to 2025**,** obtained from **(**NASA POWER) database. The rainfall data were used to examine the occurrence, variability, and temporal characteristics of drought in the study area.

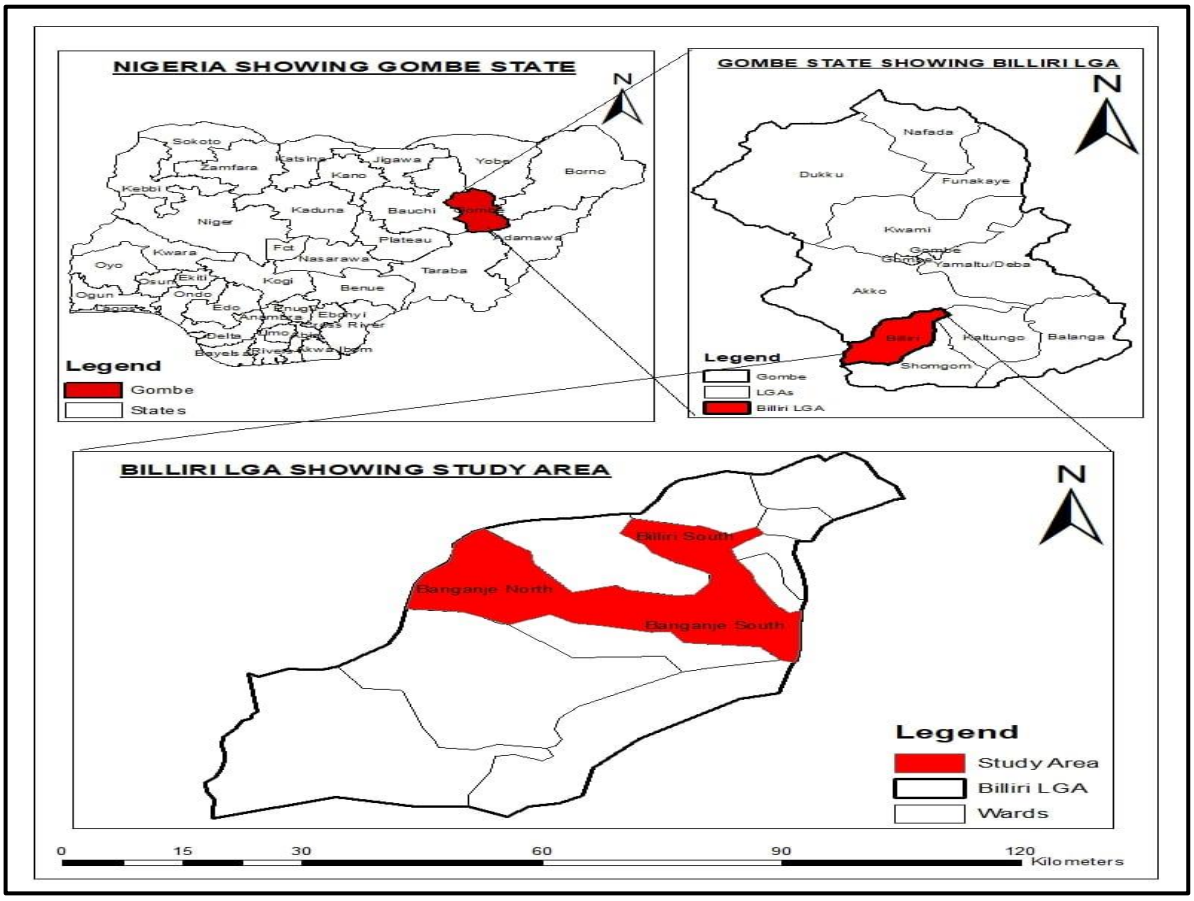


Figure 1: Map of Billiri Showing the Sample Areas
Adopted and modified from administrative map of Gombe Nigeria.

Sampling Procedure

Billiri South, Banganje North, and Banganje South wards were purposively selected based on accessibility and proximity. Fifteen key informants were purposively selected based on their experience and professional background: nine (9) were indigenous farmers with over 30 years' experience in the area, and six were experts from the Ministry of Agriculture and Extension Services. In each ward, three farmer key informants were selected for the interview guide, while six experts were selected from the Ministry of Agriculture within the local government area.

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Limitations of the Study

This study is subject to some limitations. The qualitative findings are based on a relatively small number of Key Informant Interviews (15 participants) drawn from three wards, which may not capture the full range of adaptation experiences across the wider Billiri Local Government Area; the findings are therefore interpreted as indicative rather than statistically generalisation. In addition, the SPI analysis relied on a single gridded rainfall data source (NASA POWER), therefore, this observed pattern should accordingly be treated as descriptive.

Data Analysis

Descriptive statistics were used to analyse the mean and standard deviation of the annual rainfall record. Both qualitative and quantitative analyses (Thematic Analysis and the Standardized Precipitation Index, SPI) were used. The rainfall data were analysed using SPI,a quantitative measure of meteorological drought. The SPI values were classified as follows: ≥ 2.00 is Extreme Wet, 1.50 to 1.99 is Very Wet, 1.00 to 1.49 is Moderate Wet, -0.99 to 0.99 is Near Normal condition, -1.00 to -1.49 is Moderate Drought, -1.50 to -1.99 is Severe Drought, and ≤ -2.00 is Extreme Drought. The formula for SPI is $= \frac{x-\bar{x}}{\sigma}$ where Xi=total rain fall of each year, $\bar{x}$= mean of the 30 year annual rainfall, and σ= standard deviation. The qualitative data obtained from the KII were analysed with thematic analysis**.** The qualitative data were reviewed, coded, and grouped into themes corresponding to the objectives of the study. The identified themes were interpreted by providing contextual explanations of farmers' experiences on drought occurrence, and visual plates were used to support the KII findings. The findings on farmers' experience on drought occurrence corroborate the results of the SPI analysis. However, the interpretation of farmers' adaptation strategies is based solely on the qualitative approach, as these data were collected through qualitative methods only.

The rainfall variation in the area

The rainfall data collected for the 30-year period from 1996-2025 indicate that the total amount of rainfall received in the study area varied from year to year, as shown in Table 1. The year 2022 recorded the highest amount of rainfall (2625.85 mm), while 2004 recorded the least (673.35 mm). This indicates high inter-annual variability in the 30-year rainfall data. The mean total annual rainfall received over the 30 years is 1069.91 mm, with a standard deviation of 179.16.

Drought occurrence categorization of the study area

Near Normal Conditions were the most frequently occurring category over the study period, recorded in 15 of the 30 years examined: 1996, 1997, 1998, 2001, 2002, 2007, 2008, 2010, 2012, 2015, 2016, 2017, 2018, 2023, and 2025, as shown in Table 1. Extreme, Severe, and Moderate Drought combined were recorded in 9 years (nearly one-third of the 30-year rainfall record): 2004 was Extreme Drought (SPI = -2.21); 2003, 2006, and 2011 were Severe Drought; and 1999, 2005, 2009, 2013, and 2014 were Moderate Drought. The year 2004 recorded the lowest annual rainfall in the entire series (673.35 mm) and the most severe SPI value overall. Notably, eight of these nine dry years occurred within a single 12-year window, 2003–2014, with 1999 as the only dry year recorded outside this period.

Wet conditions (Moderately Wet and Extremely Wet combined) were recorded in 6 years, less than one-third of the 30-year rainfall record, comprising 2000, 2019, and 2020 (Moderately Wet) and 2021, 2022, and 2024 (Extremely Wet). Five of these six wet years were concentrated within the

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more recent 2019-2024 period. The SPI values recorded in 2021 (6.80) and 2022 (8.68) were markedly higher in magnitude than any other value in the 30-year series, corresponding to annual rainfall totals of 2288.49 mm and 2625.85 mm, respectively more than double the long-term mean.

Table 1. Annual Rainfall and Drought Analysis and Categorization

S/N	YEAR	Annual rainfall record	SPI $= \frac{x - \bar{x}}{\sigma}$	DROUGHT CATEGORIZATION
1	1996	1141.83	0.40	NNC
2	1997	1083.21	0.07	NNC
3	1998	1101.21	0.17	NNC
4	1999	836.32	-1.30	MD
5	2000	1264.35	1.08	MW
6	2001	977.7	-0.51	NNC
7	2002	919.9	-0.83	NNC
8	2003	732.88	-1.88	SD
9	2004	673.35	-2.21	ED
10	2005	825.17	-1.36	MD
11	2006	726.58	-1.91	SD
12	2007	1144.93	0.41	NNC
13	2008	904.61	-0.92	NNC
14	2009	859.87	-1.17	MD
15	2010	1012.75	-0.31	NNC
16	2011	765.63	-1.69	SD
17	2012	1205.11	0.75	NNC
18	2013	839.51	-1.28	MD
19	2014	841.73	-1.27	MD
20	2015	898.66	-0.95	NNC
21	2016	1202.05	0.73	NNC
22	2017	1079.67	0.05	NNC
23	2018	1080.2	0.05	NNC
24	2019	1252.15	1.01	MW
25	2020	1300.32	1.28	MW
26	2021	2288.49	6.80	EW
27	2022	2625.85	8.68	EW
28	2023	1080.66	0.06	NNC
29	2024	1567.28	2.77	EW
30	2025	935.2	-0.75	NNC

Source: computed by Author (2026)

EW = Extreme Wet, VW = Very Wet, MW = Moderate Wet, NNC = Near Normal Condition, MD = Moderate Drought, SD = Severe Drought, and ED = Extreme Drought.

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Farmers' Perceptions of Drought occurrence in the area

The Key Informant Interview (KII) findings, summarised in Table 2, validate the quantitative SPI results. Meteorological drought, a product of insufficient rainfall, bears a direct relationship to the agricultural drought experienced by farmers at the onset of the rainy season. Four recurring themes emerged from the KII data: (i) intermittent drought spells within the rainy season, (ii) late rainfall onset, (iii) early cessation of rainfall, and (iv) broader rainfall variability.

Table2. Nature of Drought Experience among Farmers in the Study Area

Farmers experience/ perception of drought description		Thematic Area
i.	Rainfall ceases after germination; seeds germinate but may dry up again. After planting, crops undergo moisture stress, and wilting is frequently experienced	• Drought spell/ intermittent drought
ii.	Rainfall is delayed; it arrives up to a month after neighbouring areas have already received rain, affecting the timing of planting	• Late on set of rainfall/ delay of coming of rainy season
iii.	Rainfall duration is consistently short; crops mature under difficult conditions as the harmattan arrives quickly, so some farmers plant for fodder purposes.	• Early cessation of rainfall
iv.	There is variation in the rainy season; the rainfall received is constantly changing Compared with previous years, rainfall has increased considerably in recent years	• Rainfall variation

Source Field Work (2026)

Intermittent or Drought Spell

Farmers experience intermittent drought spells every rainy season. KII participants unanimously agreed that drought spells are part of every rainfall season, typically occurring from mid-June to the first or second week of July, sometimes lasting 21-26 days without rainfall. When drought lasts longer than the crop's tolerance limit, it significantly affects growth and yield. As reported by one participant in Banganje North:

> *"We experience drought every year, around month early June - to first week of July for the past 25 years, therefore prefer to start planting late June or early July due drought that occur. KII-07,28/July 2026".*



Plate1: Drought Spells in July, 2026

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Late Onset of Rainfall or Rainfall Delay: According to the KII analysis in Table 2, more than one-third of participant responses agree that rainfall delay has increased. This finding indicates a strong fluctuation in rainfall. Seasonal fluctuation is strongly supported by the SPI analysis in Table 1, which shows dry conditions from 1999-2003 alongside wet conditions from 2021-2025; this variation makes it difficult for farmers to plan effectively and could reduce crop yield. As reported by KII participants:

> *"For past years there have been inconsistency of rainfall onset in this area, last I plant my sorghum very early despite that they will be likely ```be short period of drought but this plant may crop around KII 05, 7th July 2026, Banganje south".*

Early Cessation of Rainfall: The KII report indicates that more than majority of participant responses agreed that rainfall duration has gradually shortened over the years. As indicated in Table 2, the majority of participants observed that, for almost every year over the past 5 years, the duration of rainfall has reduced by days or weeks; some KII participants stated that the duration of rainfall received in 2025 was shorter, while 2024 had a longer duration. This indicates that early cessation is increasing rainfall variability:

Rainfall Variation: All KII participant responses agreed that rainfall has fluctuated in characteristics such as intensity, duration, and timing, among others. Participants agreed that rainfall received over the past 30 years has changed, recalling years of persistent drought, for instance in 2006, 2008, and 2004, as reported by KII participants. These recollections corroborate the SPI findings, which show Extreme Drought in 2004 and Severe Drought in 2006 and 2008 (Table 1). This implies that farmers may experience food insecurity due to persistent drought. As reported by a KII participant:

> *"I always those years of drought where I plant my crops after they germinate, they all dry and replant it but raincease before the matured, but alhamdullahi now we having rainfall to point we can plant rice and maize. KII 06, 26th July, 2026 Billiri North".*

This finding concurred with that of Nicholson (2013) attributed these fluctuations to interactions among the West African Monsoon anomalies, and large-scale atmospheric circulation. Also, the study concurred with Tefera et al., (2025); Salami and Togo, (2026) both reported that rainfall variability significantly reduces crop yields in the Guinea Savanna region o f Nigeria, underscoring the need for climate-resilient agricultural practices and effective drought adaptation strategies.
This finding also agreed with that of IPCC, (2023).; Tefera et al., (2025) that climate change is increasing the frequency and intensity of hydro climatic extremes, including both droughts and extreme rainfall events, across sub-Saharan Africa. Similar patterns have been reported in northern Nigeria, where short-term increases in rainfall were followed by renewed climatic fluctuations, highlighting the continuing uncertainty associated with rainfall under a changing climate (Ayanlade et al., 2018; Salami & Togo, 2026).

Farmers Adaptation Strategies to Drought Occurrence in the Study Area

Farmers in the study area employed several adaptation strategies to reduce the adverse effects of drought, including adjusting planting dates, cultivating drought-resistant and early-maturing crop

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varieties, practicing mixed cropping, diversifying household income sources, water harvesting, seeking external assistance, and selling household assets.

Mixed cropping and the cultivation of drought-tolerant crops were the most common adaptation practices. Farmers predominantly cultivated millet, sorghum, cowpea, groundnut, hibiscus, and beans because these crops are more tolerant of prolonged dry conditions and erratic rainfall. As reported according to one of the key informants in Banganje North of the study area:

> *"We cultivate millet, sorghum, and groundnut because they survive drought better than crops such as maize and rice, which require higher rainfall KII 08, 27 July, 2026, Banganje North".*

The cultivation of early-maturing crop varieties is another important adaptation strategy adopted by farmers in the study area. The introduction of improved early-maturing maize varieties has enabled farmers to cultivate crops that were previously considered unsuitable for drought-prone environments. During the Key Informant Interviews (KIIs), participants reported that a locally introduced maize variety, *KwanaSistenMasara*, matures within approximately 60 days and produces higher yields than traditional varieties despite the short rainy season. The adoption of this variety has increased farmers' confidence in maize production under conditions of erratic rainfall.

Table3. Farmers' Adaptation Strategies to Drought Occurrence in the Study Area

	Various Adaptation Strategies	Thematic area
I.	Coping with rainfall cessation by planting sorghum and millet, which are more tolerant of moisture deficit; fast-maturing crops (40-60 days) requiring a shorter rainfall period; improved seeds	• Drought resistant/Early matured crop
II.	Planting different varieties of crops, or two or more crops on the same piece of land, to offset crop failure; fast-maturing crops (40-60 days) requiring a shorter rainfall period; improved seeds; planting different crops together to maintain soil fertility.	• Mixed Cropping
III.	Animal rearing, trading, side work, selling animal dung, skill work in dry season, transportation business	• Livelihood diversification
IV.	Land cultivation, digging planting basins (seed holes), and draining water channels to the farm, terracing	• Farm water harvesting
V.	Calling for help, reporting crop failure, seeking to exchange property for food, migrating away from the area, and selling household property to purchase food items	• Sale of Assets, Begging, and Migration

Source field Work (2026)

Mixed cropping was also widely practiced as a strategy for reducing the risks associated with drought. Farmers cultivated different crop species or varieties on the same farmland to minimize the likelihood of complete crop failure and stabilize household food production. Intercropping cereals with legumes, such as sorghum with groundnut or millet with beans, was commonly reported. In addition to improving production stability, mixed cropping contributes to better soil fertility through the complementary use of soil nutrients and biological nitrogen fixation by legumes.One Key Informant explained:

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> *"We cultivate different crops on the same farm so that if one crop fails because of drought, the other crops can still provide a harvest."* KII 06, 23rd July, 2026. Banganje North".

These findings imply that mixed cropping is an effective risk management strategy that enhances resilience to rainfall variability. Livelihood diversification was another important adaptation strategy adopted by respondents. Most farming households combined crop cultivation with livestock rearing and other income-generating activities to reduce their dependence on rain-fed agriculture. During periods of drought-induced crop failure, livestock served as a financial buffer, allowing households to generate income for food and other essential needs. A Key Informant remarked:

> *"Most households combine crop farming with livestock rearing and other small businesses. These activities complement one another and reduce farmers' vulnerability to drought. Farmers who depend on a single livelihood source are more exposed to the impacts of climate variability".* KII03, 23/07/2026 Banganje North

A Key Informant Interview (KII) participant explained:

> *"Most of us combine crop farming with livestock rearing. This allows us to obtain manure for our farms since chemical fertilizer is too expensive for many farmers."* KII 03/23rd /07/2026 Banganje North

In order to improving soil moistured retention capacity, farmers adopted farm water-harvesting practices to minimize the adverse effects of drought. Common techniques include digging planting basins (seed holes), terracing on sloping land, and contour cultivation to conserve soil moisture and reduce surface runoff. These practices enhance water infiltration and moisture storage, thereby improving crop performance during periods of moisture stress.

Adjustment of planting dates also emerged as one of the most important drought adaptation strategies adopted by farmers. KII participants unanimously agreed that decisions regarding the timing of planting are strongly influenced by the onset, distribution, and reliability of rainfall. Rather than relying solely on meteorological information, farmers complement scientific knowledge with indigenous environmental indicators that have been passed down through generations. According to the respondents, the appearance of a local bird species known as *Shadowr*, the emergence of red soldier ants (*Gara*), the sprouting of new tamarind leaves (*Tsaymia*), and the emergence of fresh baobab leaves are reliable indicators of the onset of the rainy season. These indigenous indicators guide planting decisions and help farmers reduce the risk of crop failure associated with false rainfall onset. As one participant stated:

> *"Once we observe the movement of red ants or termites building their nests, we know that rainfall is likely within a week. Most farmers then begin planting because the risk of crop failure is greatly reduced".* KII 09 Billiri ward, 25 July 2026

The continued reliance on indigenous environmental knowledge demonstrates that traditional ecological knowledge remains an important component of drought adaptation among smallholder

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farmers. Integrating such knowledge with scientific climate information could strengthen farmers' adaptive capacity and improve the effectiveness of climate-smart agricultural interventions.

Begging and the sale of household assets were among the least adopted drought adaptation strategies in the study area. This may be attributed to prevailing socio-cultural norms, which discourage begging and the disposal of valuable productive assets, such as land and houses, even during periods of severe drought. Rather than resorting to distress coping strategies, farmers generally prefer adaptation measures that preserve their livelihoods and productive capacity.

The low reliance on begging and asset sales indicates that farmers regard these strategies as measures of last resort after exhausting more sustainable adaptation options. This finding underscores the importance of strengthening proactive adaptation measures through improved access to climate information services, drought-tolerant crop varieties, soil and water conservation technologies, agricultural credit, and extension services. Such interventions would reduce farmers' dependence on erosive coping strategies while enhancing the resilience and sustainability of smallholder farming systems under increasing climate variability.

These findings concur with Gana et al. (2021), Idris and Abdullahi (2018), Francis et al. (2015), and Jude et al. (2020), whose studies found drought-tolerant crops to be an important adaptation strategy for improving agricultural resilience in drought-prone environments. The study was consistent with Abubakar et al. (2018) and Abaje and Magaji (2022), who reported that early-maturing crop varieties improve farmers' resilience to drought in northern Nigeria. Similarly, Quandt (2021) found that the adoption of improved crop varieties significantly enhanced climate change adaptation among smallholder farmers in Kenya. Abubakar et al. (2018) and Abaje and Magaji (2022) similarly identified mixed cropping as one of the most widely adopted strategies among smallholder farmers in northern Nigeria. This finding is consistent with Abubakar et al. (2018), who reported that in-situ water conservation practices, particularly planting basins, significantly improve soil moisture retention and support crop growth under drought conditions. Despite these benefits, many respondents indicated that constructing planting basins and undertaking other water-harvesting measures are labour-intensive, time-consuming, and financially demanding. This finding also agrees with Gana et al. (2021), who observed that the high labour and financial requirements associated with these practices often limit their widespread adoption among resource-constrained smallholder farmers.Ibrahim and Abdullahi (2022) noted that rural farmers are highly dependent on indigenous weather forecasting. Abaje and Magaji (2022) reported that smallholder farmers in northern Nigeria adopt multiple adaptation strategies to enhance resilience to drought, while Mavhura et al. (2015) reported that social and cultural values significantly influence farmers' adaptation choices during climate-related shocks. Similarly, Abiodun and Collins (2022) and IPCC (2023) described the sale of productive assets as a regressive coping strategy because it depletes household livelihood assets and increases vulnerability to future climatic and economic shocks.

Conclusion

This study examined drought occurrence and the adaptation strategies of smallholder farmers in Billiri LGA, Gombe State, Nigeria. SPI analysis and Key Informant Interviews confirmed that drought is a recurrent hazard that significantly affects agricultural production and rural livelihoods.Farmers respond mainly with low-cost adaptation strategies based on local resources and indigenous knowledge: adjusting planting dates, growing drought-resistant and early-maturing crops mixed cropping, livelihood diversification, applying organic manure, and harvesting water. Less

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coping strategies such as begging, selling household assets, migration, and change of feeding habits were rarely used, owing to socio-cultural values and their negative effects on livelihoods.

Technology-intensive measures, such as drip irrigation and improved post-harvest storage, remain largely out of reach because of limited finances, inadequate technical knowledge, and weak institutional support.

Recommendations

i. The findings underscore the need to strengthen the adaptive capacity of smallholder farmers through coordinated policy and institutional interventions. Government agencies, agricultural extension services, research institutions, and development partners should collaborate to promote climate-smart agricultural practices by providing regular training, technical advisory services, and timely climate information.

ii. Investment in small-scale irrigation infrastructure, water-harvesting technologies, and affordable agricultural credit should be prioritised to facilitate the adoption of improved drought adaptation technologies.

iii. Furthermore, the promotion of agro forestry and economically valuable tree crops should be encouraged to diversify household income sources, improve environmental sustainability, and enhance resilience to recurrent drought.

iv. Indigenous ecological knowledge should be systematically integrated with scientific climate information, incorporated into national and sub-national climate adaptation policies, and programmes to improve the effectiveness, sustainability, and local relevance of drought adaptation interventions in drought-prone farming communities.

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