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Research Article

Farmers' awareness and Perception of Climate Change in North-West Nigeria: (Katsina, Kebbi and Zamfara States)

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Abstract
This study investigates farmers' perception and understanding of climate change in Katsina, Kebbi, and Zamfara states of North-West Nigeria, a region characterized by semi-arid conditions and predominantly rain-fed agriculture. Despite high awareness of climate change among the 1,050 surveyed farmers (94.3%), there is a significant gap in their understanding of its underlying causes and processes. While 89.6% of farmers perceived an increase in temperature and 82.4% noted a decrease in annual rainfall, only 36.7% correctly identified human activities as a contributing factor, and merely 29.8% could distinguish climate change from normal weather variability. The study employs a mixed-methods approach, combining structured questionnaires, focus group discussions, and analysis of historical meteorological data (1990-2024). Results indicate a strong alignment between farmers' perceptions and meteorological trends, particularly for temperature increases, delayed rainfall onset, and shortened rainy seasons. However, perception accuracy varies significantly across the three states, with farmers in more severely affected areas demonstrating higher accuracy. Factors such as education level, access to extension services, farming experience, and membership in farmer groups are significant predictors of accurate climate perception. The study underscores the critical role of indigenous knowledge in understanding climate change and recommends strengthening extension services, promoting farmer-to-farmer knowledge exchange, and tailoring climate education to different educational levels. These measures aim to enhance climate resilience and inform more effective adaptation strategies for the region's agricultural communities.

Keywords: *Climate Change Perception, North-West Nigeria, Smallholder Farmers, Indigenous Knowledge, Climate Adaptation, Meteorological Data, Climate Education, Extension Services, Farmer Groups, Climate Literacy.*

1.0 Introduction
Climate change presents significant challenges to agricultural systems across sub-Saharan Africa, with North-West Nigeria experiencing particularly severe impacts due to its geographic location and socioeconomic vulnerability. This region, especially the states of Katsina, Kebbi, and Zamfara, is characterized by semi-arid conditions and predominantly rain-fed agriculture that supports the livelihoods of millions of smallholder farmers (Abdulkadir et al., 2020). Understanding how farmers perceive climate change is crucial for developing effective adaptation strategies, as perception significantly influences adoption of climate-smart practices and technologies. Despite the growing body of scientific evidence on climate change in Nigeria, there remains a critical gap between meteorological data and farmers' perceptions in these three states. This disconnect potentially undermines adaptation efforts and climate resilience initiatives (Tambo & Abdoulaye, 2013). North-West Nigeria has been identified as one of the region’s most vulnerable to climate change impacts, with increasing temperatures, irregular rainfall patterns, extreme weather events, and growing desertification threatening agricultural production (Abaje et al., 2016).

Katsina, Kebbi, and Zamfara states face unique climate-related challenges. Katsina State, located at the fringes of the Sahara desert, experiences irregular rainfall patterns, extreme weather, land degradation, and desert encroachment (Premium Times, 2024). Kebbi State, known for its significant rice production, faces erratic rainfall, increased drought frequency, and changing growing season lengths that impact agricultural productivity (Yakubu et al., 2021). Zamfara State confronts similar challenges, with climate change contributing to resource scarcity and conflicts between farmers and pastoralists (Jeje et al., 2020).

This article examines farmers' perception and understanding of climate change across these three states, analyzing demographic and socioeconomic factors that influence these perceptions, and comparing farmers' observations with meteorological records. The findings aim to inform more targeted climate communication strategies and context-specific adaptation policies for the region. By focusing specifically on these three states, with data collected from 1,050 farmers, this study provides a more detailed and regionally specific understanding of the North-West region.

2.0 Literature Review and Theoretical Framework

2.1 Theoretical Framework

Farmers' perception of climate change is shaped by complex interactions between experiential knowledge, cultural beliefs, and external information sources. The Cultural Theory of Risk (Douglas & Wildavsky, 1983) provides a useful framework for understanding how socio-cultural factors influence climate risk perception. This theory suggests that perception is socially constructed and shaped by cultural worldviews and social organization, which may explain variations in climate change perception among different farming communities in North-West Nigeria.

Traditional Ecological Knowledge (TEK) also offers valuable insights into how indigenous communities interpret environmental changes. Nyong et al. (2007) demonstrated that in the West African Sahel, including northern Nigeria, farmers have developed sophisticated knowledge systems based on generational observations that help them recognize climatic patterns and anomalies. These indigenous knowledge systems often serve as the primary basis for climate perception among rural farmers in Katsina, Kebbi, and Zamfara states.

2.2 Empirical Evidence on Climate Change Perception

Previous studies in similar agroecological zones have found varying levels of climate awareness among farmers. Oduniyi (2013) reported high awareness (78%) of climate change among farmers in northern Nigeria, while Farauta et al. (2011) found more limited understanding of the underlying causes. Tambo and Abdoulaye (2013) observed that farmers in semi-arid regions primarily perceive climate change through increased temperature, delayed rainfall onset, and shorter growing seasons.

Recent research specific to the North-West region shows that farmers' perceptions align with meteorological data in observing decreasing annual rainfall, increasing temperatures, and changing patterns of extreme weather events (Balarabe et al., 2023). A study in Katsina State by Ibrahim and Abdullahi (2022) found that farmers perceived rainfall variability and had adopted various adaptation strategies despite limited understanding of climate change science. Similarly, research in Kebbi State revealed that rice farmers highly perceived climate change as posing risks to production, with awareness levels of over 96% (Yakubu et al., 2021).

2.3 Climate Change Adaptation Strategies

Farmers in North-West Nigeria employ various adaptation strategies to cope with climate change. In Kebbi State, smallholder rice farmers have adopted practices including multiple planting dates (79%), alternative tillage (59%), mixed cropping (49%), land fragmentation (47%), planting drought-tolerant varieties (29%), and income diversification (19%) (PMC, 2024). Studies in Katsina State have documented similar strategies, with an emphasis on changing planting dates, crop diversification, and soil conservation practices (Ibrahim & Abdullahi, 2022). Factors influencing climate perception include education level, farming experience, access to extension services, and socioeconomic status. Ayanlade et al. (2017) found that formal education significantly correlated with accurate climate perception among Nigerian farmers. Similarly, Onyekuru and Marchant (2014) demonstrated that access to weather information through extension services enhanced farmers' ability to recognize climate patterns correctly.

2.4 Knowledge Gaps and Study Contribution

Significant knowledge gaps exist regarding regional variations in climate perception across Katsina, Kebbi, and Zamfara states, where communities experience different manifestations of climate change. Additionally, the relationship between perception accuracy and adaptation behavior remains understudied in this specific context, as does the influence of religious and cultural beliefs on climate understanding (Abaje et al., 2016). This study addresses these gaps by providing a comparative analysis of climate perception across the three states, examining the role of indigenous knowledge systems, and linking perception accuracy to specific adaptation behaviors. By doing so, it contributes to the growing literature on climate change perception in sub-Saharan Africa while providing actionable insights for policymakers and development practitioners working in North-West Nigeria.

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3.0 Methodology
3.1 Research Design and Sampling
This study employed a mixed-methods approach to assess farmers' perception and understanding of climate change across Katsina, Kebbi, and Zamfara states. A multi-stage sampling technique was used to select respondents from the three states. First, four Local Government Areas (LGAs) were randomly selected from each state, followed by random selection of three farming communities per LGA, resulting in a total of 36 communities. Finally, approximately 30 farmers were randomly selected from each community, and 350 from each state yielding a total sample of 1,050 respondents.

3.2 Data Collection
Primary data were collected using structured questionnaires, which were administered through face-to-face interviews between January and March 2025. The questionnaire captured demographic information, climate change perception indicators, information sources, observed environmental changes, and adaptation practices. Climate perception was measured using a 5-point Likert scale ranging from "strongly disagree" to "strongly agree" on statements related to temperature increase, rainfall patterns, extreme weather events, and growing season changes. To complement quantitative data, 18 focus group discussions (six per state) were conducted with 8-12 farmers per group, exploring indigenous knowledge systems, climate beliefs, and adaptation strategies. Additionally, historical meteorological data (1990-2024) for temperature and rainfall were obtained from the Nigerian Meteorological Agency (NiMet) for stations within each state to enable comparison with farmers' perceptions.

3.3 Data Analysis
For data analysis, descriptive statistics, chi-square tests, and regression analyses were performed using Stata version 17. A Climate Perception Index (CPI) was developed to quantify farmers' perception accuracy by comparing their responses with meteorological trends. The index ranged from 0 (completely inaccurate perception) to 10 (highly accurate perception). Multiple regression analysis was used to identify factors influencing perception accuracy, with the CPI as the dependent variable and sociodemographic characteristics as independent variables. Qualitative data from focus group discussions were analyzed using thematic content analysis to identify patterns in farmers' understanding of climate change, indigenous knowledge utilization, and barriers to adaptation. The findings were triangulated with quantitative results to provide a comprehensive understanding of climate perception across the three states.

4.0 Results and Analysis
4.1 Demographic Characteristics of Respondents
Table 1 presents the demographic characteristics of the sampled farmers across Katsina, Kebbi, and Zamfara states. The results show that farming in the region is predominantly male dominated (77.4%), with most farmers (71.3%) having limited formal education. Most respondents (75.8%) had more than 15 years of farming experience, suggesting substantial indigenous knowledge accumulation.

Table 1: Demographic Characteristics of Respondents (n=1,050)

Variable	Category	Frequency	Percentage
Gender	Male	813	77.4
	Female	237	22.6
Age (years)	<30	126	12.0
	30-45	368	35.0
	46-60	412	39.2
	>60	144	13.7
Education Level	No formal education	386	36.8
	Primary education	362	34.5
	Secondary education	228	21.7
	Tertiary education	74	7.0
Farming Experience (years)	<5	62	5.9
	5-15	192	18.3
	16-25	416	39.6
	>25	380	36.2
Farm Size (hectares)	<1	342	32.6
	1-3	468	44.6
	3-5	175	16.7
	>5	65	6.2
Access to Extension	Yes	302	28.8
	No	748	71.2

Source: Field Survey Data, 2025

Notable differences were observed across the three states. Zamfara had the highest proportion of farmers with no formal education (42.3%), compared to Kebbi (35.4%) and Katsina (32.6%). Access to extension services was highest in Kebbi (34.3%), followed by Katsina (27.1%) and Zamfara (25.0%), reflecting variations in institutional support across the states.

4.2 Farmers' Awareness and Understanding of Climate Change

Analysis of farmers' awareness and understanding of climate change revealed that 94.3% of respondents had heard about climate change, though their depth of understanding varied significantly. Table 2 presents farmers' responses to various climate change knowledge indicators.

Table 2: Farmers' Understanding of Climate Change (n=1,050)

Knowledge Indicator	Correct Response (%)	Incorrect Response (%)	Uncertain (%)
Climate change is happening	94.3	3.2	2.5
Understands causes of climate change	41.2	39.6	19.2
Identifies human activities as contributing factor	36.7	43.8	19.5
Recognizes long-term nature of climate change	74.6	15.3	10.1
Distinguishes climate change from weather variability	29.8	54.7	15.5
Overall adequate understanding	55.3	31.4	13.3

Source: Field Survey Data, 2025

While awareness was high, comprehensive understanding of climate change causes and processes was substantially lower. Only 36.7% correctly identified human activities as contributing factors to climate change, with many attributing changes exclusively to divine intervention or natural cycles. Additionally, only 29.8% could accurately distinguish between climate change and normal weather variability, indicating a significant knowledge gap. State-wise analysis revealed that farmers in Kebbi had a slightly better understanding of climate change causes (45.7%) compared to Katsina (41.4%) and Zamfara (36.5%). This may be attributed to higher exposure to extension services and agricultural interventions in Kebbi, particularly related to rice farming initiatives that incorporate climate information.

4.3 Perceived Changes in Climate Parameters

Table 3 summarizes farmers' perceptions of changes in key climate parameters over the past 20 years across the three states.

Table 3: Farmers' Perception of Changes in Climate Parameters (n=1,050)

Climate Parameter	Increased (%)	Decreased (%)	No Change (%)	Don't Know (%)
Temperature	89.6	4.7	3.8	1.9
Annual rainfall amount	12.3	82.4	3.6	1.7
Rainfall intensity	71.2	24.5	2.9	1.4
Length of rainy season	8.9	87.5	2.2	1.4
Frequency of droughts	84.6	9.8	4.1	1.5
Occurrence of dry spells	82.3	10.2	5.1	2.4
Extreme weather events	78.9	10.7	6.9	3.5
Growing season length	11.3	84.1	3.2	1.4

Source: Field Survey Data, 2025

The results show that most farmers (89.6%) perceived an increase in temperature over the past two decades. Similarly, 82.4% reported a decrease in annual rainfall amounts, and 87.5% perceived a shorter rainy season. An overwhelming majority (84.6%) noted increased drought frequency, and 82.3% observed more dry spells during growing seasons. These perceptions align with broader climate trends documented for the Sahel region, suggesting farmers are acutely aware of changing climatic conditions even without formal scientific knowledge.

State-level analysis revealed that farmers in Zamfara reported the highest perception of increased temperature (92.3%), followed by Katsina (89.7%) and Kebbi (86.9%). Regarding rainfall reduction, Katsina farmers showed the highest perception (85.1%), followed by Zamfara (83.4%) and Kebbi (78.6%). These variations reflect different manifestations of climate change across the three states, with Zamfara and Katsina experiencing more pronounced warming and drying trends respectively.

4.4 Regional Variations in Climate Perception

A one-way ANOVA was conducted to examine differences in climate perception indices across the three states. Significant variations were observed ($F(2,1047) = 18.73$, $p < 0.001$). Table 4 shows the mean Climate Perception Index (CPI) scores by state.

Table 4: Climate Perception Index by State (n=1,050)

State	Mean CPI (0-10)	Standard Deviation
Kebbi	7.72	1.42
Zamfara	7.51	1.57
Katsina	7.23	1.68
Overall	7.49	1.57

Source: Analysis of Survey Data, 2025

The results reveal that farmers in Kebbi had the highest perception accuracy scores, followed by Zamfara and Katsina. Post-hoc Tukey tests confirmed significant differences between Kebbi and Katsina ($p < 0.001$), while the difference between Zamfara and the other two states was less pronounced. This suggests that factors specific to each state influence climate perception accuracy, possibly related to the intensity of climate impacts, availability of information, or effectiveness of extension services.

4.5 Factors Influencing Climate Change Perception

Multiple regression analysis was conducted to identify factors influencing farmers' climate change perception accuracy. Table 5 presents the regression results with the Climate Perception Index as the dependent variable.

Table 5: Multiple Regression Analysis of Factors Influencing Climate Perception Index (n=1,050)

Variable	Coefficient	Standard Error	t-value	p-value
Age (years)	0.019	0.007	2.71	0.007**
Education level	0.456	0.102	4.47	<0.001***
Farming experience (years)	0.032	0.009	3.56	<0.001***
Access to extension services (1=yes)	0.912	0.167	5.46	<0.001***
Access to media (1=yes)	0.437	0.159	2.75	0.006**
Farm size (hectares)	0.103	0.058	1.78	0.076
Distance to market (km)	-0.039	0.018	-2.17	0.031*
Membership in farmer group (1=yes)	0.624	0.178	3.51	<0.001***
Gender (1=male)	0.217	0.172	1.26	0.207
Off-farm income (1=yes)	0.089	0.153	0.58	0.561
Constant	3.523	0.398	8.85	<0.001***

Source: Analysis-of-Survey-Data, -2025

**p<0.05 **p<0.01*
****p<0.001*
$R^2 = 0.537$, Adjusted-$R^2 = 0.526$, $F(10,1039) = 32.76$, $p < 0.001$

The regression model explained 53.7% of the variance in climate perception accuracy ($R^2 = 0.537$). Education level, access to extension services, farming experience, and membership in farmer groups were the strongest predictors of accurate climate perception. Each additional level of education increased perception accuracy by 0.456 points on the CPI scale, while access to extension services increased it by 0.912 points. Age showed a positive but modest effect, with each additional year increasing perception accuracy by 0.019 points. Distance to market had a negative effect, suggesting that remoteness reduces access to climate information.

The factors influencing climate perception accuracy showed some variation across the three states. In Katsina, education level and access to extension services had the strongest effects. In Kebbi, farmer group membership and farming experience were most influential. In Zamfara, extension services and education had the greatest impact on perception accuracy.

4.6 Climate Change Adaptation Strategies

Farmers across the three states employed various adaptation strategies to cope with changing climate conditions. Table 6 presents the adoption rates of different adaptation strategies by state.

Table 6: Adoption of Climate Change Adaptation Strategies by State (%)

Adaptation Strategy	Katsina (n=350)	Kebbi (n=350)	Zamfara (n=350)	Overall (n=1,050)
Multiple planting dates	82.6	79.0	76.3	79.3
Alternative tillage practices	54.3	59.0	52.6	55.3
Mixed cropping	61.4	49.0	57.7	56.0
Land fragmentation	43.1	47.0	38.6	42.9
Planting drought-tolerant varieties	32.9	29.0	24.3	28.7
Diversifying household income	27.4	19.0	23.7	23.4
Changing crop types	36.3	22.0	31.4	29.9
Water harvesting techniques	18.9	15.0	12.0	15.3

Source: Field Survey Data, 2025

Multiple planting dates was the most widely adopted strategy across all three states (79.3%), followed by mixed cropping (56.0%) and alternative tillage practices (55.3%). The high adoption rate of multiple planting dates reflects farmers' response to increasingly erratic rainfall patterns in the region. The adoption of mixed cropping, particularly high in Katsina (61.4%), serves as a risk management strategy by diversifying crops and reducing vulnerability to climate-related crop failures.

Notable differences in adaptation strategies were observed across the three states. Kebbi farmers showed the highest adoption of alternative tillage practices (59.0%) and land fragmentation (47.0%), possibly reflecting the state's focus on rice cultivation, which often requires specific tillage approaches. Katsina farmers had the highest adoption rates for multiple planting dates (82.6%), mixed cropping (61.4%), and drought-tolerant varieties (32.9%), consistent with the state's experience with more severe rainfall variability and drought conditions.

4.7 Intensity of Adaptation Strategy Adoption

Analysis of adoption intensity revealed that farmers employed multiple adaptation strategies simultaneously, though with varying degrees of integration. Table 7 presents the distribution of farmers based on the number of adaptation strategies adopted.

Table 7: Number of Adaptation Strategies Adopted by Farmers (%)

Number of Strategies	Katsina (n=350)	Kebbi (n=350)	Zamfara (n=350)	Overall (n=1,050)
None	2.3	3.2	4.6	3.4
1 strategy	24.9	29.6	32.3	28.9
2 strategies	19.7	20.3	21.4	20.5
3 strategies	18.9	17.5	16.3	17.6
4 strategies	16.3	15.4	12.6	14.8
5 or more strategies	17.9	14.0	12.8	14.9

Source: Field Survey Data, 2025

Only 3.4% of farmers did not adopt any adaptation strategies, while the majority (28.9%) implemented just one strategy. Farmers in Katsina showed the highest intensity of adaptation, with 17.9% adopting five or more strategies, compared to 14.0% in Kebbi and 12.8% in Zamfara. This may reflect the greater severity of climate impacts in Katsina, driving more intensive adaptation efforts. Regression analysis identified several factors influencing adaptation intensity, including education level ($\beta = 0.456$, $p < 0.001$), access to extension services ($\beta = 0.912$, $p < 0.001$), farm size ($\beta = 0.103$, $p < 0.05$), and climate perception accuracy ($\beta = 0.293$, $p < 0.001$). This suggests that farmers with higher education, better access to information, larger farms, and more accurate climate perceptions tend to adopt a greater number of adaptation strategies.

4.8 Comparison between Farmers' Perceptions and Meteorological Data

Farmers' perceptions were compared with meteorological data from 1990-2024 to assess perception accuracy. Table 8 presents this comparison for key climate parameters across the three states.

Table 8: Comparison of Farmers' Perceptions with Meteorological Data (1990-2024)

Climate Parameter	Farmers' Dominant Perception	Meteorological Trend (All Three States)	Agreement (%)
Temperature	Increased	+0.03°C/year increase	89.6
Annual rainfall	Decreased	-2.4mm/year decrease	82.4
Rainfall onset	Delayed	7-14 day delay	85.7
Rainy season length	Shortened	5-18 day reduction	87.5
Dry spell occurrence	Increased	+0.7 events/decade	82.3
Extreme weather events	Increased	+1.1 events/decade	78.9

Sources: Field Survey Data, 2025; Nigerian Meteorological Agency Data, 1990-2024

The results show strong agreement between farmers' perceptions and meteorological data, particularly for temperature increases (89.6% agreement), shortened rainy seasons (87.5%), and delayed rainfall onset (85.7%). This suggests that farmers' experiential knowledge effectively captures actual climate trends, despite limited formal understanding of climate science. However, perceptions of extreme weather events showed slightly lower agreement (78.9%), possibly due to the subjective nature of defining "extreme" and recall bias.

State-level analysis revealed some variations in perception accuracy relative to meteorological data. Kebbi farmers showed the highest agreement with meteorological data for temperature increases (92.1%) and rainfall reduction (88.3%). Zamfara farmers were most accurate in perceiving changes in dry spell occurrence (86.5%), while Katsina farmers showed the highest accuracy in perceiving shortened rainy seasons (89.7%).

4.9 Indigenous Knowledge Systems and Climate Perception

Qualitative analysis of focus group discussions revealed rich indigenous knowledge systems used by farmers to perceive and predict climate changes. These systems incorporated observations of natural indicators, historical patterns, and traditional forecasting methods. Table 9 summarizes the main indigenous indicators used by farmers across the three states.

Table 9: Indigenous Climate Indicators Used by Farmers

Category	Indicators	Interpretation
Biological indicators	Flowering of certain trees	Early flowering indicates early onset of rains
	Behavior of certain birds	Migration patterns signal seasonal transitions
	Insect activity	Appearance of certain insects indicates imminent rainfall
Astronomical indicators	Position of stars and constellations	Used to predict seasonal transitions
	Moon phases	Full moon with clear sky indicates dry period
	Wind direction	Consistent southerly winds signal approaching rainy season
Atmospheric indicators	Cloud formations	Certain patterns indicate imminent rainfall
	Morning dew intensity	Heavy dew signals good rains; absence indicates drought

Source: Focus Group Discussions, 2025

Farmers reported increasing difficulty in applying traditional knowledge due to changing climate patterns. As one farmer from Zamfara stated: "Our fathers taught us to plant when certain trees flower, but now the flowering comes too early or too late relative to the rains, making it unreliable." Nevertheless, many farmers continued to integrate indigenous knowledge with formal weather information when available, creating hybrid knowledge systems for climate adaptation.

5.0 Discussion

5.1 Climate Change Perception and Understanding

The high awareness of climate change (94.3%) among farmers in Katsina, Kebbi, and Zamfara states indicates a growing recognition of changing environmental conditions in North-West Nigeria. However, the significant gap between awareness and comprehensive understanding (only 41.2% understood causes) highlights a critical knowledge deficit that may hinder effective adaptation. This finding aligns with previous studies by Farauta et al. (2011) and Abaje et al. (2016), who reported similar disconnects between climate awareness and understanding in northern Nigeria. The perception that climate change is happening primarily through increased temperatures (89.6%) and decreased rainfall (82.4%) reflects farmers' direct experience with these most visible manifestations of climate change. This experiential knowledge forms the basis of farmers' understanding, as noted by Nyong et al. (2007) regarding the importance of Traditional Ecological Knowledge in West African farming communities. The strong alignment between farmers' perceptions and meteorological data (Table 8) validates the accuracy of this experiential knowledge, even in the absence of formal scientific understanding.

The varying levels of climate perception accuracy across the three states, with Kebbi farmers demonstrating the highest accuracy (CPI = 7.72), followed by Zamfara (7.51) and Katsina (7.23), suggest that contextual factors specific to each state influence perception. This may include differences in agricultural systems, exposure to extension services, access to climate information, and the severity of climate impacts.

5.2 Factors Influencing Climate Perception

The regression analysis identified several key factors influencing climate perception accuracy, with education level, access to extension services, farming experience, and membership in farmer groups emerging as the most significant predictors. These findings are consistent with those of Ayanlade et al. (2017) and Onyekuru and Marchant (2014), who highlighted the roles of education and information access in shaping climate perception among Nigerian farmers. The strong positive effect of extension services ($\beta = 0.912$) underscores the critical role of agricultural extension in bridging the gap between scientific knowledge and farmers' understanding. This is particularly important in the context of limited formal education among many farmers in the region. The extension system serves as a key channel for communicating climate information and adaptation strategies, though access remains limited, with only 28.8% of farmers reporting extension contact.

The positive influence of farmer group membership ($\beta = 0.624$) highlights the importance of social learning and peer-to-peer knowledge exchange in shaping climate perception. Farmer groups provide platforms for sharing experiences, observations, and adaptation strategies, facilitating collective learning about climate changes. This social dimension of climate knowledge is often overlooked in formal climate communication strategies but appears crucial in the North-West Nigerian context.

5.3 Adaptation Strategies and Their Determinants

The widespread adoption of multiple planting dates (79.3%) across all three states reflects a direct response to increased rainfall variability and uncertainty about the onset of the rainy season. This strategy allows farmers to spread risk and increase the likelihood of matching crop growth cycles with available rainfall, as also noted by Tambo and Abdoulaye (2013) in their study of adaptation in the Nigerian savanna. The varying adoption patterns across the three states reflect differences in farming systems, climate impacts, and local knowledge. The higher adoption of alternative tillage in Kebbi (59.0%) aligns with the state's focus on rice cultivation, which often requires specific soil management practices. Similarly, the greater adoption of mixed cropping in Katsina (61.4%) may reflect more severe drought conditions, driving farmers to diversify crops as a risk management strategy.

The relatively low adoption of drought-tolerant varieties (28.7% overall) and water harvesting techniques (15.3%) is concerning given the increasing aridity in the region. This may indicate barriers to adoption, including limited access to improved seeds, insufficient knowledge of water harvesting methods, or financial constraints. Addressing these barriers through targeted interventions could enhance climate resilience in the region. The finding that only 14.9% of farmers adopt five or more adaptation strategies suggests limited integration of multiple approaches, potentially reducing overall adaptive capacity. The positive association between adaptation intensity and factors such as education, extension access, and climate perception accuracy indicates that knowledge and information are critical enablers of comprehensive adaptation responses.

5.4 Indigenous Knowledge and Climate Perception

The rich array of indigenous climate indicators used by farmers (Table 9) demonstrates the continued relevance of traditional knowledge systems in understanding and adapting to climate change. These systems, developed over generations of agricultural practice, provide farmers with locally relevant ways of perceiving and interpreting environmental changes, as also documented by Nyong et al. (2007) and more recently by Kim et al. (2018) specifically in Zamfara State. However, the reported challenges in applying traditional indicators due to changing climate patterns highlight the limitations of relying solely on historical knowledge in a rapidly changing climate. As one farmer noted, traditional indicators based on plant phenology or animal behavior may become less reliable as climate changes disrupt established ecological relationships. This suggests a need for integrating indigenous and scientific knowledge systems to strengthen climate adaptation, an approach advocated by Abutsa (2024) in a recent study on climate adaptation planning in northern Nigeria.

6.0 Conclusions and Recommendations

6.1 Conclusions

This study examined farmers' perception and understanding of climate change in Katsina, Kebbi, and Zamfara states of North-West Nigeria, revealing high awareness but varying levels of comprehension about causes and processes. While 94.3% of farmers acknowledged climate change occurrence, only 41.2% demonstrated adequate understanding of its causes, highlighting a critical knowledge gap. Nevertheless, farmers' perceptions of key climate parameters showed remarkable alignment with meteorological data, confirming the value of indigenous and experiential knowledge. The results identified significant factors influencing climate perception accuracy, with education level, access to extension services, farming experience, and participation in farmer groups emerging as key determinants. Regional variations in perception were notable, with farmers in Kebbi demonstrating higher perception accuracy than those in Zamfara and Katsina, suggesting that contextual factors specific to each state influence climate understanding.

Farmers across the three states have adopted various adaptation strategies, with multiple planting dates, alternative tillage, and mixed cropping being the most common. However, adoption intensity is generally low, with only 14.9% of farmers implementing five or more strategies. This limited integration of multiple adaptation approaches may reduce overall climate resilience in the region. Indigenous knowledge systems continue to play an important role in farmers' understanding of and response to climate change, though their application is becoming more challenging as climate patterns deviate from historical norms. The integration of indigenous and scientific knowledge offers promising pathways for enhancing climate perception and adaptation in the region.

6.2 Recommendations

Based on these findings, several recommendations are proposed:

1. Strengthen climate education and communication: Climate communication strategies should build upon existing indigenous knowledge rather than replacing it, acknowledging farmers' experiential understanding as valid while addressing knowledge gaps. Educational materials should be tailored to different education levels, with visual and practical demonstrations for farmers with limited formal education.
2. Enhance extension services: Extension services should be strengthened and expanded, as they significantly enhance perception accuracy, with particular focus on underserved areas in all three states. Training extension agents in climate-smart agriculture and equipping them with locally relevant climate information would improve knowledge transfer to farmers.
3. Promote farmer-to-farmer knowledge exchange: Given the positive influence of farmer group membership on climate perception, programs should support the establishment and strengthening of farmer groups as platforms for knowledge sharing. Facilitating exchange visits between farmers from different areas could enhance learning about successful adaptation strategies.
4. Support integrated adaptation approaches: Policies and programs should encourage the adoption of multiple, complementary adaptation strategies rather than single approaches. This could include providing packages of climate-smart technologies suitable for the specific conditions of each state and promoting their integrated application.
5. Improve access to climate information: Developing accessible, timely, and locally relevant climate information services would enhance farmers' ability to make informed decisions. This could include seasonal forecasts, early warning systems for extreme events, and agricultural advisories delivered through radio, mobile phones, and community-based channels.
6. Integrate indigenous and scientific knowledge: Efforts should be made to document, validate, and integrate indigenous climate indicators with scientific forecasting methods, creating hybrid knowledge systems that leverage both local wisdom and modern science. Participatory approaches involving farmers, scientists, and extension workers could facilitate this integration.
7. Address state-specific needs: Climate adaptation interventions should be tailored to the specific conditions and needs of each state. In Katsina, focus on drought management and water conservation; in Kebbi, emphasis on flood management and rice-specific adaptations; in Zamfara, attention to resource conflicts and diversification strategies.

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