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Gendered vulnerabilities to climate change and farmers' adaptation responses in Kwara and Nassarawa States, Nigeria

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This study examines gender vulnerabilities and responsive strategies to climate change, comparing evidences from Kwara and Nassarawa States in Nigeria. Changes in climate parameters, gender-based perceptions of climate, as well as gender-based response and adaptation practices were assessed in accordance with specific research objectives. A total of 200 participants were surveyed through a mixed method approach using 41 years of climate data. Semi-structured questionnaires were administered equally in the two States and 52 in-depth interviews were conducted within male and female farmers that were 40 years and above age using a purposive sampling method. Results from Nassarawa State showed a downward trend in rainfall and an upward trend in both minimum and maximum temperatures. The farmers perceived climate change differently, with observed changes in climate variables: temperature and precipitation, resulting in extreme floods, drought, and rainfall onset and leading to varying adaptation practices. The study concluded that gender plays a significant role in the adoption of adaptation practices in the agricultural sector and that males often have more access to resources and decision-making power in farming as the heads of households. There is a need for better gender-sensitive approaches to adaptation planning and implementation to ensure that both men and women have equal opportunities to benefit from adaptation options in agriculture.

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Background

Climate change is a complex global issue. Associated with it is alteration in temperature and precipitation patterns, leading to water and food scarcity, in many parts of the world (Pörtner et al., 2022; Ipcc, 2021; Ayanlade et al., 2023; Trisos et al., 2022). Studies have found the African region to be vulnerable to rapid climate warming due to geography, economic conditions, and limited infrastructure. (Trisos et al., 2022; WMO, 2020; Diop et al., 2021; Ayanlade et al., 2022b; Diouf et al., 2022). Nigeria's agricultural sector is vulnerable to climate change due to its rain-fed nature and reliance on smallholder farmers, who are often ill-equipped to adapt (Deji, 2020; Ayanlade et al., 2020; Onoja et al., 2019). Nigeria's smallholder farmers play a crucial role in food security as they contribute over 70% of the country's food production, thus, ensuring climate change resilience is a very important way forward (Oluwasola, 2015; Ahmed, 2020). However, climate extreme events resulting from delays in the onset and offset of season, erratic rainfall, frequent droughts, and other weather-related hazards have resulted to reduction in agricultural productivity, food insecurity, and upsurges in poverty, especially among smallholder farming communities (Ayanlade et al., 2017; Ojo and Baiyegunhi, 2020; Ayanlade et al., 2022b). Nigeria's Guinea savannah ecological zone, covering 50% of Nigeria's land, is vulnerable to climate change impacts due to its agricultural economy and rain-fed agriculture (Ayanlade and Ojebisi, 2020). Smallholder farmers face significant vulnerability to climate change impacts due to limited resources, limited credit access, and insufficient information on climate-resilient farming practices (Nyasimi et al., 2018; Ackerl et al., 2023).

Studies have shown that climate change is affecting the livelihoods of smallholder farmers in Nigeria, making them vulnerable to food crises due to reduced yield (Ayanlade et al., 2017; Tambo and Abdoulaye, 2013; Othniel Yila and Resurreccion, 2013; Enete et al., 2012). Studies have also shown that climate change is affecting their livelihoods and making them vulnerable to food crises (Ayanlade et al. (2017) and Tambo and Abdoulaye (2013). Nigerian smallholder farmers, relying on subsistence farming, are more susceptible to climate change impacts. High temperatures cause heat stress on crops, resulting in reduced yields and quality. Rice, a staple food crop in Nigeria, is particularly vulnerable to high temperatures, with studies suggesting a 10–30% decrease in yield due to a 2 °C increase (Akinbile et al., 2020; Oluwatimilehin and Ayanlade, 2021; Noel et al., 2020), while Oluwatimilehin and Ayanlade (2021) reported a 40% reduction in rice, maize, and cassava yield due to climate change.

Gender roles and expectations impact climate change, affecting individuals' experiences and responses to risks and impacts. These vulnerabilities stem from unequal access to resources, limited decision-making power, social norms, cultural practices, and institutional constraints. Gender roles are crucial in climate change adaptation and mitigation, as males and females in agriculture face distinct impacts (Prakash et al., 2022; Babugura et al., 2010; Nyasimi et al., 2018; Deji, 2020). Women, a significant portion of smallholder farmers in Guinea's savannah ecological zone, face vulnerability to climate change impacts due to limited land, credit, and resource access, limiting their ability to adapt (Denton, 2002; Farnworth and Colverson, 2015; Prakash et al., 2022). Despite the growing recognition of the gendered dimensions of climate change, there is still limited empirical evidence on effective gender-responsive strategies to mitigate the impacts of climate change among smallholder farmers, particularly in the Guinea-savannah ecological zone in Nigeria. Importantly, studies (Denton, 2002; Farnworth and Colverson, 2015; Prakash et al., 2022; Trisos et al., 2022) have highlighted the need for gender-responsive strategies to enhance the adaptive capacity of smallholder farmers. Strategies aim to empower women in climate change adaptation and mitigation efforts, but due to the limited empirical evidence in existence in Nigeria, further research for policy and practice is required (Trisos et al., 2022). This study analyses climate change perceptions, impacts, and adaptation options among smallholder farmers, focusing on men and women. This study also examines gendered climate change perceptions, vulnerability, and adaptation responses among smallholder farmers in Nigeria's Kwara and Nassarawa States. It aims to inform policy and interventions for gender-responsive climate change adaptation in the agricultural sector. The research focused on adult males and females aged 40 years and above, using interchangeable terms for male and female sex. Findings could aid in designing gender-responsive climate change policies and intervention programmes to support smallholder farmers in adapting to climate change impacts.

Methods

Study area. The study sites are Kwara and Nassarawa States (Fig. 1). Kwara State is situated in the western part of the northcentral geopolitical zone of Nigeria with Ilorin as the State capital. The State has 16 local government areas (LGAs). Kwara State is located between latitude 7°45' and 9°30' North of the Equator and longitude 2°30' and 6°25' East of the Greenwich meridian, with a landmass covering 32,500 square kilometres and a total land size of 3,682,500 ha (Oladimeji et al., 2015). The State has a total population of 2.4 million according to the population census of 2006 and by projection in 2021, the population was put at 3.09 million with an annual growth rate of 3.2% and a population density of 95 persons per kilometres square (km^2) (Akpenpuun and Busari, 2013; Oladimeji et al., 2015). Kwara State is characterized by a tropical wet and dry climate dominated by double rainfall maxima and two distinct seasons lasting for about 6 months each, and annual rainfall ranges from 1000 to 1500 mm (Oluwatimilehin and Ayanlade, 2021). The temperature of the State ranges between 25 and 30 °C in the wet season, except for July and September in which the cloud cover prevents direct insolation which can lead to heatstroke, while in the dry season, the temperature ranges between 33 and 34 °C. During the rainy season, the relative humidity in Kwara State can range between 75% and 80% while in the dry season, it is about 65%, with the daytime usually sunny for about 6.5–7.7 h daily from November to May (Akpenpuun and Busari, 2013). The climate of Kwara State supports the growth of tall grasses interspersed with short scattered trees. The vegetation is derived savanna coined from a changed forest ecosystem to a savanna type. The savanna vegetation makes farming of cereals like maize and rice convenient. In addition, food crops are grown as they constitute the main staple aside from cereals. The common trees are shear butter (*Vitalera paradosa*) and locust bean trees (*Parkia biglobosa*) (Akpenpuun and Busari, 2013; Suleiman et al., 2018; Ajao et al., 2014).

Nassarawa State on the other hand is located within latitude 7°45' and 9°25' N of the equator and between longitude 7°00' and 9°37'E of the Greenwich meridian on the landmass of 27,137.8 km^2 with 13 LGAs (Tade et al., 2019). In this State, the population density is about 88 persons km^2 as the total population is about 2,523,395 according to the 2006 Nigerian population census, with the majority of the people living in rural communities. Males and females are into smallholding agricultural practices as their primary source of livelihood. Most males are majorly engaged in root and tuber crops, while female smallholders are mainly into cereals and vegetables. However, both males and females are into the rearing of animals (Tarfa et al., 2019). The popular crops farmed in the State include rice, beans, cassava, groundnuts, maize (corn), melon, millet, sorghum,

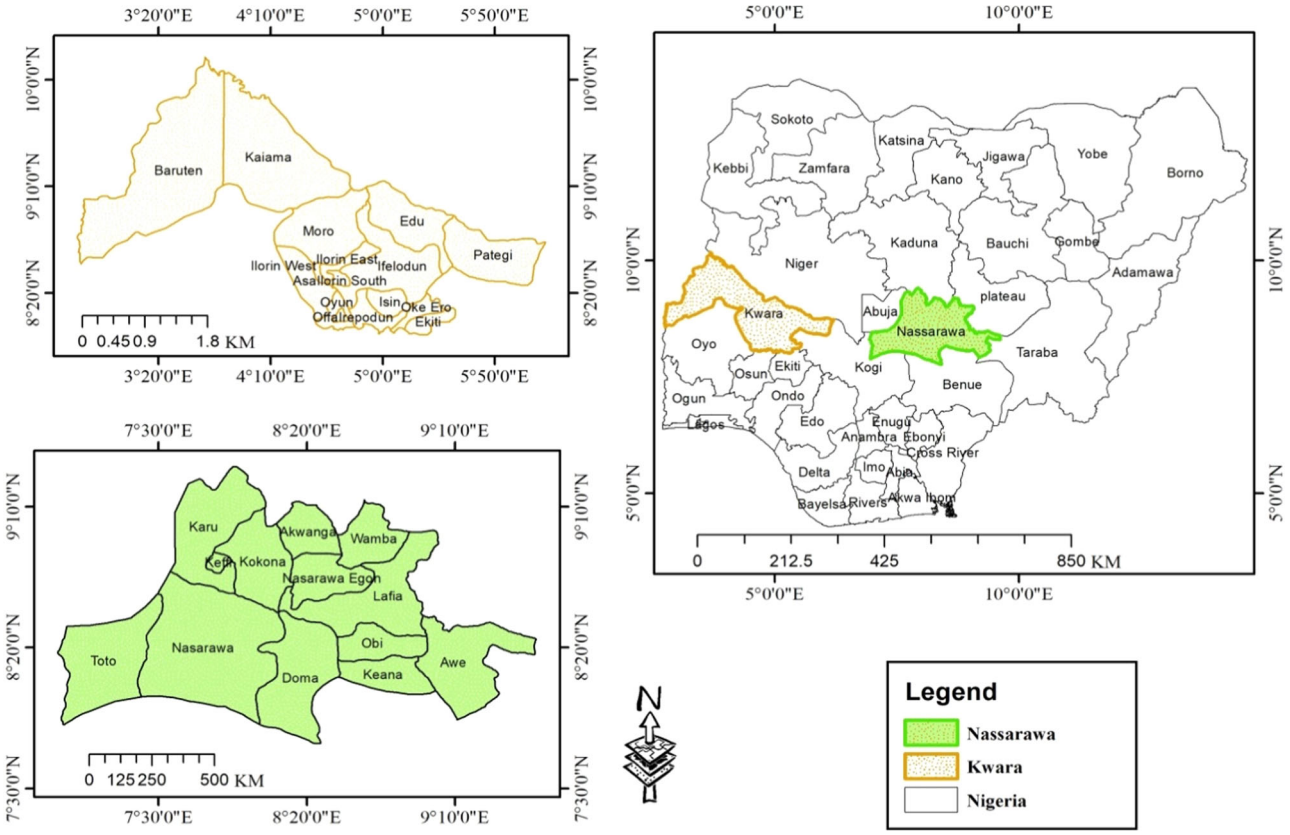

Fig. 1 Maps of the study areas. The points represent the villages used as study sites.

and yam tubers. In addition, some farmers are into livestock agriculture such as cattle, goats, pigs, sheep, and various species of birds. Nassarawa State lies in the tropical zone with near-temperate climatic conditions. It has a mean annual rainfall between 600 and 1650 mm and an annual temperature range of 13–34 °C. The average rainy days vary from 187 to 220 annually, with the rainy season lasting for seven months. The first rain begins in April and the last rain is seen in October. The temperature and rainfall are experienced in two distinct seasons, the Wet season and the Dry season. The dry season begins in November and ends in March with an average annual temperature of 28.4–33.5 °C (Tarfa et al., 2019).

Data collection and analysis. Temperature and rainfall data between 1981 and 2021 were collected for the two States under consideration. The climate data were sourced through an Earth Science/Applied Science power project of the United States' National Aeronautics and Space Administration (NASA), Langley Research Center (LaRC) (https://power.larc.nasa.gov/data-access-viewer/). The data were recorded using a satellite system recording air temperature and rainfall at 2 m. One hundred participants each were selected from Kwara and Nassarawa States and administered copies of a semi-structured questionnaire. State-centred quota system technique was adopted to ensure all the LGAs in each State were represented. Two villages were selected from each of the LGAs in the States. A hierarchical master sampling frame was developed for the study using the multi-stage cluster sampling technique and employed to purposively select the villages (Taherdoost, 2016). Further, in-depth interviews were conducted with 52 smallholder farmers each from the two States comprising 26 men and 26 women. In order to remove gender bias as women had limited asset-based resources, the selection criteria used were: household heads and a minimum of 1 ha of farmland.

Data for the climatic variables for this research were depicted using line graphs with the aid of Microsoft Corporation's Microsoft Excel version 2016. Mann–Kendall statistical analysis was then used to show the trend in the climate time series data. The analysis was done using Past 3.20 Copyright Øyvind Hammer 1999–2018 (Hammer et al., 2001). The software measures the strength and direction of a trend using the S statistic and the Z statistic, with a positive Z value indicating an upward trend and a negative Z value indicating a downward trend. A significant trend is considered at the 0.05 level (Oluwatimilehin and Ayanlade, 2021). Further, the in-depth interview data collected were summarized using themes. The interviews were conducted in the predominant native languages (Yoruba in Kwara State and Hausa in Nassarawa State). The transcripts were then translated to the English language for analysis. The data collected from the semi-structured questionnaires were presented on graphs, tables and charts, while the qualitative results were presented on themes. In addition, using the Local Indicator of Climate Change (LICCI) framework developed by the University of Barcelona's LICCI research group for climate change adaptation, some adaptation options were selected and the usage or adoption by farmers was assessed and presented using bar charts.

Results and discussion

Socio-economic characteristics of respondents. The study survey captured an equal representation of male and female farmers, with each group constituting 50% of the total sample set (Table 1). The gender parity within the farming communities signified a potentially equitable involvement of both men and women in agricultural activities in these regions. The majority of the

Table 1 Socio-economic characteristics of respondents.

Questionnaire respondents	Responses	Location		Total
		Kwara	Nassarawa	
Sex	Male	50	50	100
	Female	50	50	100
	Total	100	100	200
Age group	40–49	36	23	59
	50–59	40	28	68
	60–69	20	34	54
	70 and above	4	15	19
	Total	100	100	200
Education	Primary	60	56	116
	Secondary	24	33	57
	College/ University	10	11	21
	Higher degree	6	0	6
	Total	100	100	200
Residence Length	10–19	5	8	13
	20–29	43	23	66
	30–39	39	49	88
	40 and above	13	20	33
	Total	100	100	200
Other occupations different from farming	None	42	69	111
	Artisan	14	27	41
	Civil service	18	4	22
	Business	26	0	26
	Total	100	100	200
Interviewees respondents				
Gender	Male	13	13	26
	Female	13	13	26
	Total	26	26	52
Age_Group	40–49	9	5	14
	50–59	10	8	18
	60–69	6	9	15
	70 and above	1	4	5
	Total	26	26	52
Education	Primary	15	13	28
	Secondary	6	11	17
	College/ University	3	2	5
	Higher degree	2	0	2
	Total	26	26	52
Residence length	10–19	0	3	3
	20–29	11	7	18
	30–39	10	11	21
	40 and above	5	5	10
	Total	26	26	52
Other occupation	None	14	23	37
	Artisan	2	3	5
	Civil service	3	0	3
	Business	7	0	7
	Total	26	26	52

surveyed farmers comprising 127 respondents fell within the 40–59 years age range. This suggests that middle-aged and slightly older individuals were prominently engaged in farming activities. In addition, a substantial proportion of the farmers were within the 60–69 years age group, possibly indicating a persistence of older individuals in the farming sector. The relatively smaller representation of farmers aged 70 years and above could point to challenges faced by older farmers in sustaining agricultural livelihoods. The prevalence of only primary level education among the respondents, a total of 116 individuals, may imply a substantial proportion of farmers having limited formal education. Conversely, there was a low representation of six individuals with higher degrees. These findings could signify a gap in accessing advanced agricultural knowledge within the surveyed population. Regarding the length of residency, the majority of the farmers in both States had been living in their current locations for between 20 and 39 years, indicating a degree of stability and local integration (Table 1). This extended residency might imply a stronger connection to the lands and communities, potentially influencing farming practices. Furthermore, a significant number of the farmers had alternative livelihood means, with individuals diversifying into artisanal work, civil service, and business ventures to enhance their overall socio-economic resilience (Table 1).

Real and observed climate change among men and women

Real climate change. The climate analysis revealed variations in minimum and maximum temperature and rainfall values for each year investigated in both Kwara and Nassarawa States, as well as between the States. The minimum temperature ranged from 17.89 °C in 1982 to 19.71 °C in 2021 in Kwara State, while that of Nassarawa State rose from 18.62 °C in 1983 to 21.33 °C in 2019 (Figs. 2 and 3). These results were consistent with the findings of Akinbile et al. (2020) who reported a warming trend in Nigeria between 1981 and 2018, with a significant increase in the minimum temperature across the country. In addition, they are consistent with the increasing trend in minimum temperature observed in both Kwara and Nassarawa States in the provided data (Figs. 2 and 3). Furthermore, studies by Mereu et al. (2015) and Apata (2011) analysed the impact of climate change on the agricultural sector in Nigeria and found that rising temperatures negatively affect crop yields and food security. Therefore, the increase in minimum temperature observed in the two States could have implications for the agricultural sector in these areas.

Regarding Kwara State, significant increases were observed in the maximum temperatures for the months of July–September, as well as in the annual maximum temperature (Table 2). In contrast, there was no noteworthy trend in the minimum temperatures shown, except for a decrease in the month of December. Rainfall showed an increasing trend in October and a decreasing trend in July. The annual rainfall also did not show a significant trend. The results of the Mann–Kendall test are consistent with previous studies that have reported an increasing trend in temperature in Nigeria. The decreasing trend in rainfall in July in Kwara State (Table 2) is consistent with a study by Olubanjo (2019) which reported a significant decreasing trend in rainfall in the region. However, the increasing trend in rainfall in October is not consistent with the reported decreasing trend in rainfall in Nigeria, suggesting that more research is needed to understand the regional variations in rainfall trends.

Statistical analysis of the climate parameters in Nassarawa State is also shown in Table 2. The absolute value of Z (5.85) greater than the critical value (1.96) showed significant ($p \leq 0.05$) increasing positive trends in both minimum and maximum temperatures as well as decreasing negative trend in rainfall. The trend is positive (+). The maximum temperature results also showed a statistically significant increasing trend in maximum temperature as the absolute value of Z is greater than the critical value (1.96) at a significance level of 0.05. The trend is positive (+). Regarding rainfall, there is a statistically significant decreasing trend as the absolute value of Z is greater than the critical value (1.96) at a significance level of 0.05. The trend is negative (−). Nassarawa State in Nigeria experiences a significant increase in temperature and a decrease in rainfall, aligning with climate change models' predictions of rising global average temperatures and increased droughts in some regions.

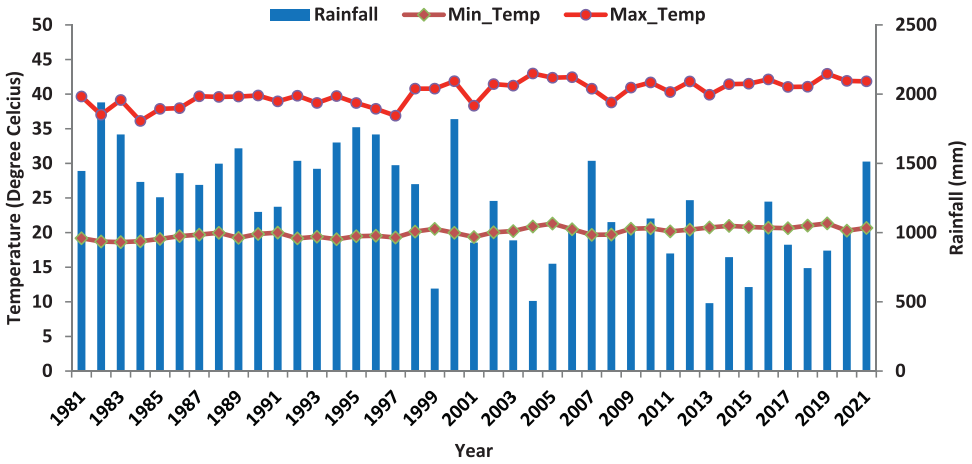

Fig. 2 Climate variability in Nassarawa State. Blue bars represent values of rainfall while lines indicate the minimum and maximum temprature values. Substantial variability were noted in temperature and rainfall values.

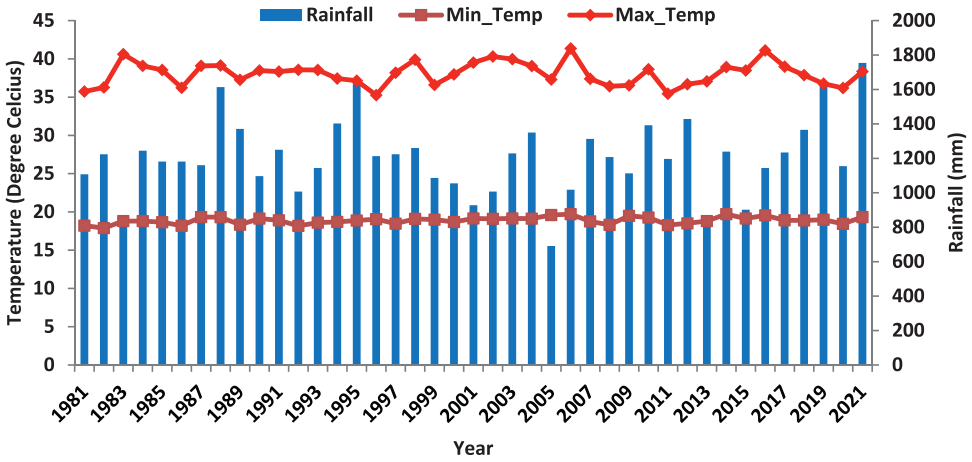

Fig. 3 Climate variability in Kwara State. Blue bars represent values of rainfall while lines indicate the minimum and maximum temprature values. Substantial variability were noted in temperature and rainfall values.

Observed climate change by men and women. The results showed gender differences in climate perceptions in both States studied (Figs. 4 and 5). More female respondents (49.2%) than males (44.4%) perceived the climate to be increasingly warmer in Kwara State during the study period, between 1981 and 2021. In contrast, more male farmers (31.5%) than females (15.2%) noted the reverse to be true. Further, more female farmers (50.8%) than their male counterparts (35.2%) perceived the temperature during the wet season to be unchanged. A similar trend was observed about the increasing warmth in temperature during the period investigated, with more females (38.6%) perceiving it as such than males (29.6%). Increased frequency of flood occurrences were noted by 42.6% of men and 44.1% of women respectively, while about 19% of males and 6.8% of females believe floods to be more intense. Some farmers perceived droughts to be less frequent (42.6% of men and 27.1% of women), while 16.7% of men and 44.1% of women observed it to be more frequent (Fig. 4).

Female farmers interpreted the coldest season temperatures as same (Fig. 4), while the males perceived them as warmer. In addition, males perceived the onset of rain as being earlier, while females perceived it as same. These findings suggest that gender may play a role in shaping how individuals perceive climate-related changes and responses. A similar study has also reported gender differences in climate perceptions. Perception of climate change is critical to the adoption of adaptation practices by smallholder farmers (Nyasimi et al., 2018). Further, a similar study by Akyala et al. (2023) showed that men and women smallholder farmers do not oftentimes grow the same crops and that men spend more time on the farm than women because of gender roles. Therefore, men are likely to perceive climate change differently.

On the whole, the study highlighted the differences in the perceptions of climate by gender in Nassarawa State. Figure 5 shows the perceptions of participants on climate variables in the State for the study period (1981–2021). More males perceived temperature as the same (70.9%), while fewer females perceived it as warmer (31.5%). In addition, male respondents perceived the temperature as the same throughout the coldest season, while females perceived it as different. However, more females (45.2%) perceived the temperature to be warmer than males (40%). Regarding rain generally, 31.5% each of males and females viewed it as the same, while more female farmers than males perceived the rain to be higher. Further, equal numbers of male and female farmers viewed the extreme floods to be the same. However, more females than males estimate extreme floods to be more common than males (Fig. 5). Regarding extreme drought, 50.9% of males and 32.1% of females perceived it as the same. However, more females believe extreme drought to be more common than males

Table 2 Mann-Kendall results for Kwara and Nassarawa States.

	Minimum temperature				Maximum temperature				Rainfall			
Month	***S***	***Z***	***P***	**Trend**	***S***	***Z***	***P***	**Trend**	***S***	***Z***	***P***	**Trend**
Kwara state												
Jan	−87	0.97	0.30		−22	0.24	0.81		−4	0.05	0.96	
Feb	58	0.64	0.52		−74	0.82	0.41		61	0.75	0.45	
Mar	127	1.42	0.16		−30	0.33	0.75		−49	0.54	0.58	
Apr	25	0.27	0.79		−92	1.02	0.31		−43	0.47	0.63	
May	143	1.6	0.11		63	0.7	0.49		−50	0.55	0.58	
Jun	51	0.56	0.57		7	0.07	0.95		35	0.38	0.7	
Jul	328	3.67	0.00	+	223	2.49	0.01	+	−28	0.3	0.76	
Aug	293	3.28	0.00	+	45	0.49	0.62		−65	0.72	0.47	
Sep	373	4.18	0.00	+	−66	0.73	0.46		107	1.19	0.23	
Oct	104	1.16	0.25		30	0.33	0.75		186	2.08	0.03	+
Nov	125	1.39	0.16		17	0.18	0.86		147	1.72	0.08	
Dec	−95	1.06	0.29		−58	0.64	0.52		61	0.8	0.42	
Annual	−116	1.29	0.19		−34	0.37	0.71		68	0.75	0.45	
Nassarawa state												
Jan	288	3.22	0.00	+	416	4.66	0.00	+	0	0	0	
Feb	272	3.04	0.00	+	381	4.20	0.00	+	−8	0.1	0.91	
Mar	404	4.5	0.00	+	367	4.11	0.00	+	−114	1.3	0.18	
Apr	231	2.58	0.00	+	264	2.95	0.00	+	−184	2.06	0.03	−
May	400	4.48	0.00	+	342	3.83	0.00	+	−309	3.4	0.00	−
Jun	336	3.76	0.00	+	344	3.85	0.00	+	−188	2.1	0.03	−
Jul	345	3.87	0.00	+	411	4.61	0.00	+	−204	2.28	0.02	−
Aug	227	2.54	0.01	+	313	3.51	0.00	+	−216	2.42	0.01	−
Sep	193	2.16	0.03	+	158	1.76	0.07		−315	3.53	0.00	−
Oct	230	2.57	0.01	+	387	4.34	0.00	+	−188	2.1	0.03	−
Nov	266	2.98	0.00	+	446	4.99	0.00	+	24	0.28	0.77	
Dec	366	4.1	0.00	+	392	4.39	0.00	+	5	0.12	0.90	
Overall	522	5.85	0.00	+	456	5.11	0.00	+	−320	3.58	0.00	−

Trend: (+) Positive Trend; (−) Negative Trend; () Random; (*) Significant at 0.05.

(Fig. 5). Regarding rain onset, 70.9% of males and 61.9% of females believe it to be the same, while more females (28%) than males (20%) believe the rain begins earlier.

Studies have reported that women are more perceptive of climate variability, showing concern, and taking action to address it than men (Kisauzi et al., 2012; Assan et al. 2020; Bhadwal et al., 2019a; Trisos et al., 2022; Prakash et al., 2022). The findings of the survey in the study areas confirmed that gender influences individual perception and response to climate-related changes. These results may have important implications for efforts to address climate change, as understanding gender differences in climate perceptions can help policymakers develop targeted interventions and communication strategies to effectively engage diverse populations.

Findings from the in-depth interviews from the two study sites showed that perceptions of climate change by both male and female respondents were associated with extreme rainfall and temperature in the study areas. Both the male and female farmers expressed that they had experienced decreases in rainfall which they associated with drought.

> I can't quantify it because it falls unprecedentedly. But I have observed that the rainfall here has been decreasing (Translated)—Woman, aged 62 years from Shao in Moro L.G.A., Kwara State.

> We have experienced a lot of changes compared to the past 35 years. In the past, we often experienced rainfall from January until it will gradually decrease. For instance, this year (2020), we experienced a late and unprecedented seizure of rains. The rain fell when farmers were expecting to begin their harvest (Translated)—Woman, aged 55 years from Giza in Keana L.G.A., Nassarawa State.

> We have experienced a shortage of groundwater in the past few years. Sometimes it lasts for weeks and even months. The rains that fell early this year did not touch the roots of our crops, and the ones that went through them were not enough to support maximum production (Translated)—Man, aged 58 years from Kiguna in Lafia L.G.A., Nassarawa State.

The decline in soil moisture was associated with drought and dry spells, while the washed nutrients was associated with flooding and erosion. Both occurrences had significantly reduced the crop yields and resulted in total losses in the study areas. Bole male and female farmers reported that dry spells occurred more frequently in recent times than in the past 35 years.

> In recent years, I have noticed that the rain often seizes after the first, second or third fall. Afterwards, it takes a longer time before we experience it again. It seizes unprecedentedly. Mostly in June and July (Translated)—Woman, aged 56 years from Ogbondoroko in Asa L.G.A., Kwara State.

Gendered-differentials and gender-responsive approaches to adaptation

Gender-based adaptation. Both Kwara and Nassarawa States respectively had a higher percentage of male respondents (70.2% and 67.1% respectively) compared to females (29.8% and 32.9% respectively) who adopted agricultural diversification as an adaptation option (Figs. 6 and 7). Male respondents had more land and resources for crop rotation, similar to agricultural diversification. This is because men often have more control over

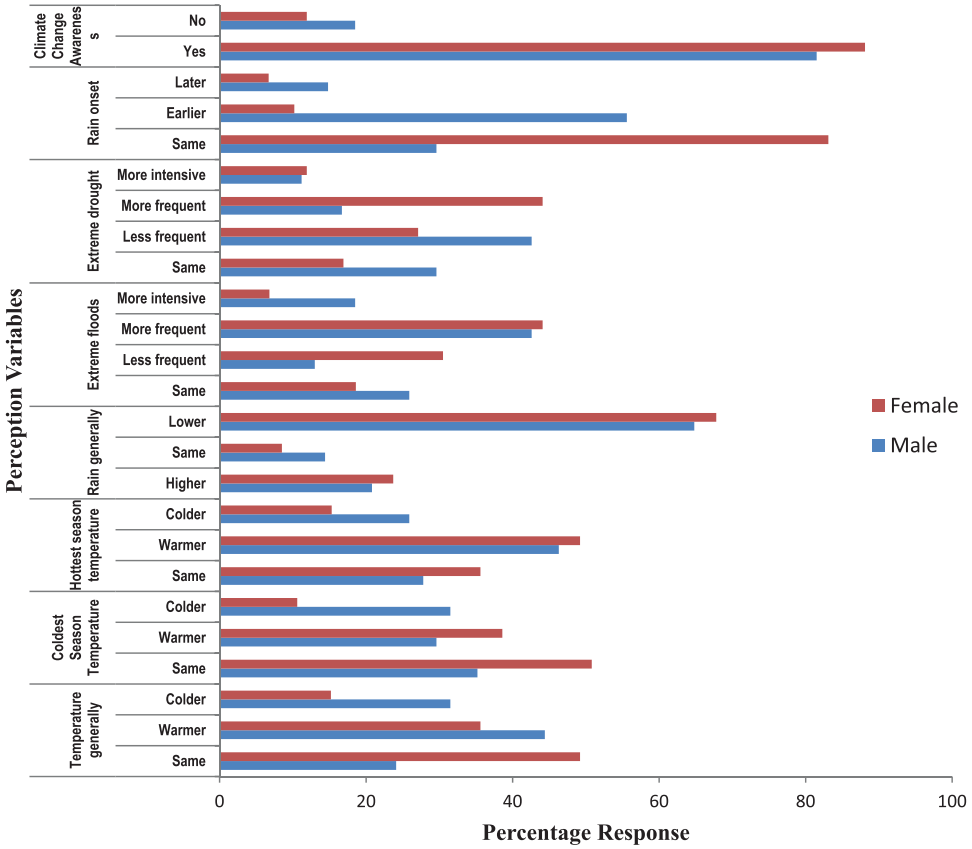

Fig. 4 Gender-based perception of recent climate in Kwara State. Dark red and blue bars represent the observed climate change by female and male farmers, respectively. It is obvious that climate change awareness was high among the crop farmers, but much more among female farmers. Individual perception and response to climate-related changes varies by gender.

decision-making and resource allocation in farming households. In addition, the two States showed a higher percentage of male respondents (73.8% and 64.4% respectively) compared to females (26.2% and 35.6% respectively) who adopted mixed cropping as an adaptation option. This is because men are more likely to engage in multiple cropping practices to diversify income streams.

Male respondents from the two States reported using agricultural intensification techniques, while female respondents preferred bush-fallowing as an adaptation strategy due to the men having access to resources and decision-making authority. This could be because men often have control over land use decisions in farming households. Kwara State had a higher percentage of female respondents (37.8%) compared to Nassarawa State (34.1%) who adopted agroforestry as an adaptation option. However, both States had higher percentages of male respondents (62.2% and 65.9% respectively) who adopted this option. This could be because men often have authority over tree planting and management practices. Further, the two States had higher percentages of male respondents (86% and 79.8% respectively) compared to females (14% and 20.2% respectively) who adopted changes in harvest time as an adaptation option. This is because men often had control over harvest decisions and labour allocation in farming households. Similarly, higher percentages of male respondents (70% and 62% respectively) compared to females (30 and 38% respectively) adopted the use of irrigation as an adaptation option. This was partly due to men often having access and authority over irrigation resources.

In addition, more male respondents in Kwara and Nassarawa States respectively (68.9% and 62.6% respectively) than female respondents (31.1% and 37.4% respectively) chose fertilizer application as an adaptation option. This may be due to men frequently exercising greater control over input choices in farming homes. Male respondents from the two States preferred pesticide application as an adaptation strategy, while female respondents preferred the option of collecting targeted loans and credit facilities. Further, male farmers had more access to credit and financial resources, leading to higher adoption of food storage adaptations in the two States (Fig. 7). This could be because men often have authority over food storage decisions in farming households. Both States had higher percentages of male respondents (80% and 70.7% respectively) compared to females (20% and 29.3% respectively) who adopted changes in residence as an adaptation option. This could be because men often have control over migration and relocation decisions in farming households. Overall, the findings imply that gender has a big impact on how agriculture adopts adaptation methods. In farming households, the greater access to resources by men and their decision-making authority has an impact on the habits they adopt. In order to ensure that men and women have an equal opportunity to benefit from adaptation alternatives, gender-sensitive methods for adaptation planning and implementation are essential.

Gender-responsive approaches. The results further showed that focusing on drought-resistant crops helped to reduce the vulnerability of both male and female farmers to climate change (Table 3). The majority of the farmers stated that they "plant crops like beans, cowpea, tomatoes, pepper and watermelon which require little water to grow". These crops are available in drought-resistant varieties and have mostly been planted in recent

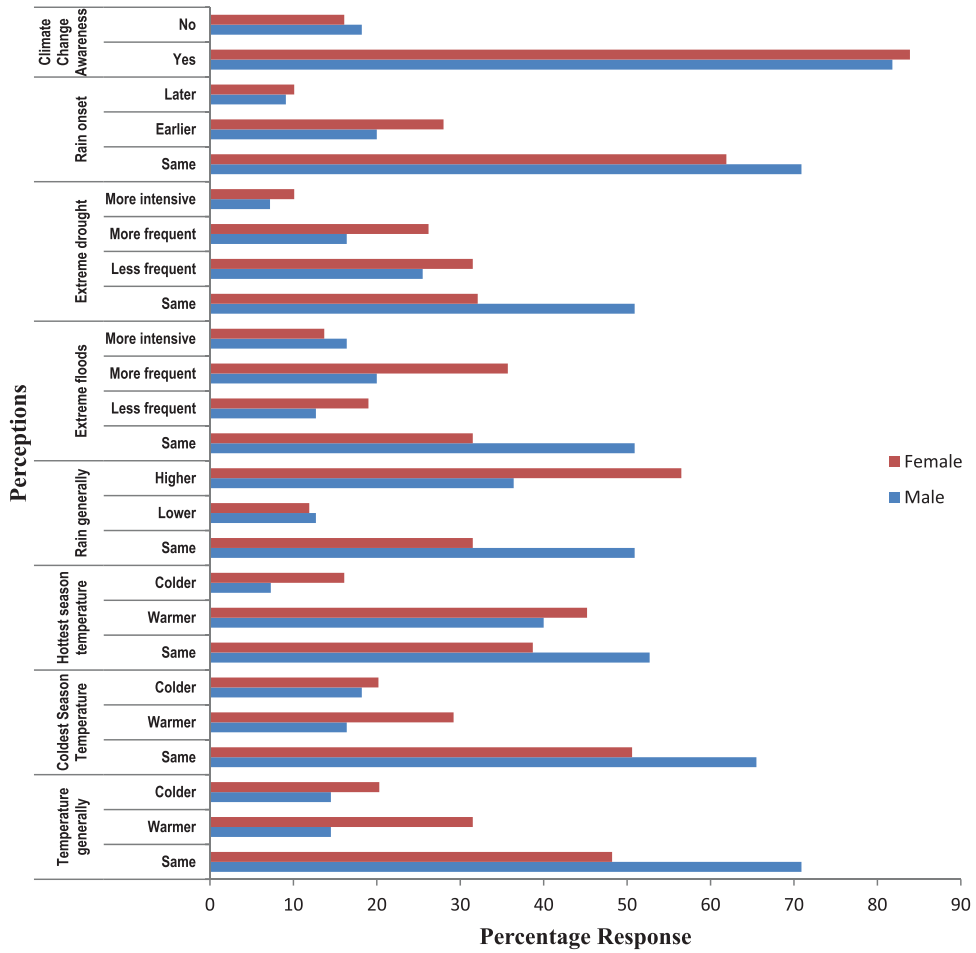

Fig. 5 Gender-based perception of recent climate in Nassarawa State. Dark red and blue bars represent the observed climate change by female and male farmers, respectively. It is obvious that climate change awareness was high among the crop farmers, but much more among female farmers. Individual perception and response to climate-related changes varies by gender.

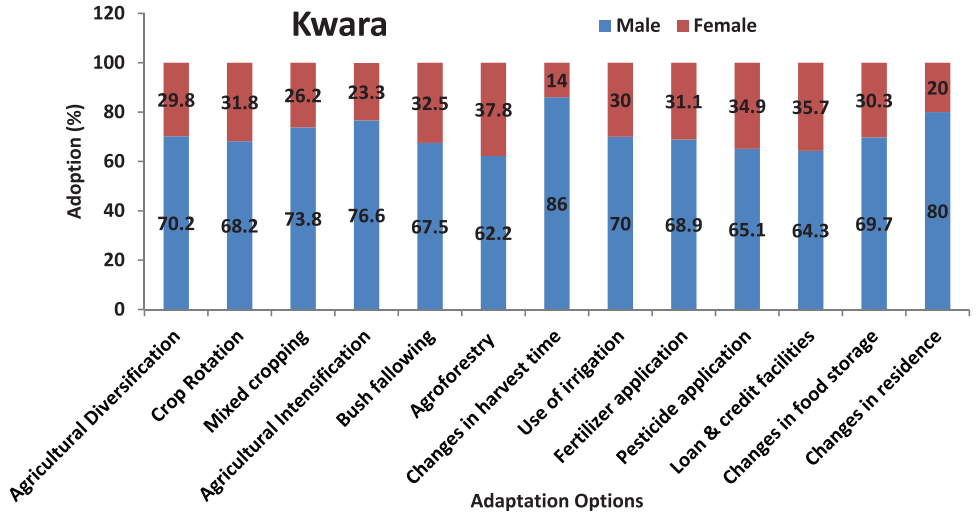

Fig. 6 Gender-based differences in adaptation methods in Kwara State. Dark red and blue bars represent the adaptation methods used by female and male farmers, respectively. Farmers adoption of adaptation methods varies gender. In many households, men frequently have greater access to resources than female.

years as a responsive approach to climate change. Findings from this study showed that most women who primarily practised rained farming used drought-resistant crops to help them cope and adjust to the impacts of climate change. Table 3 summarizes the gender-responsive approaches to the use of drought-resistant crops by both male and female farmers, and how their roles in the household and community influence their adoption of drought-resistant crops

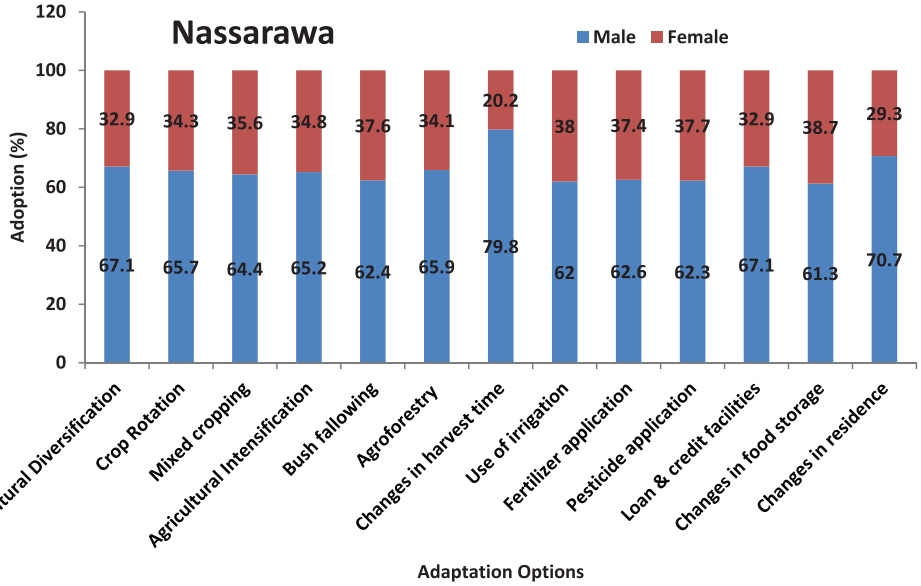

Fig. 7 Gender-based differences in adaptation methods in Nassarawa State. Dark red and blue bars represent the adaptation methods used by female and male farmers, respectively. Farmers adoption of adaptation methods varies gender. In many households, men frequently have greater access to resources than female.

Real climate change versus observed climate change. Climate change is a global phenomenon that disproportionately affects various populations, particularly women and men due to pre-existing gender inequalities. Gendered vulnerability discussions in climate change stem from the differing social roles, responsibilities, access to resources, and decision-making power between genders. The statistical analysis revealed that there is a decrease in rainfall in Kwara and Nassarawa States. This is consistent with a study by (Olubanjo, 2019) which reported a significant downward trend in rainfall in the region, especially in July which is in the middle of the cropping season. Although more studies are needed in the region to establish the intra-annual rainfall change both men and women surveyed perceived the rainfall differently. The statistical analysis also revealed an upward trend in both minimum and maximum temperature in the two states which is also different from the observations of men and women in the two states. The findings of this study showed that the majority of men and women who participated in the study perceived the rainfall generally to be lower in Kwara state which is partly in accordance to the real change of the climate analysis, their perception about temperature is however different. The men perceived men perceived the temperature to be warmer while the women perceived it to be the same. In Nassarawa state, on the other hand, they both perceived the temperature to have remained the same over the years. However, a higher proportion of the men perceived the rain to have remained the same, and, a higher proportion of women perceived the rain as higher.

Despite many reports from studies on increasing temperature with reduced rainfall trends in Nigeria, it is however surprising that male farmers in Nassarawa and females in Kwara still perceived it to have remained the same. Studies (e.g. Akinbile et al., 2020; Mereu et al., 2015; Apata, 2011) found that rising temperatures are becoming prevalent in Nigeria and it is negatively affecting crop yields and food security. The increase in temperature and reduction in rainfall is the same across the country (Adejuwon, 2005), and with reported implications for the agricultural sector in many areas. However, wrong perceptions and observations by selected farmers about climate change would have the preparedness and response. Different scholars have submitted opinions on the differences in the observation/perception of climate change, impact and adaptation by men and women in agriculture. Akyala et al. (2023) submitted that this difference is often influenced by gendered roles and interactions with the environment. As women often engaged in subsistence farming and natural resource management, may closely monitor changes in rainfall patterns, crop yields, and access to water, their observations can be more localized, focusing on immediate household impacts (Meyiwa et al., 2014). Men, on the other hand, might be more engaged in market-oriented farming and might observe climate change through market fluctuations, production losses, and changing pest patterns (Maracchi et al., 2005). Also, climate change impacts on the crops grown by men and women are more likely to influence the way they perceive or observe climate change.

The variation between real climate change and the observed perceptions of farmers could also stem from a combination of scientific complexity, localized experiences, and differing perspectives. The scientific measurement of climate change involves the analysis of long-term trends and statistical modelling, which might not align with immediate, localized experiences. In the opinion of Ayanlade et al. (2017), farmers' observations are often grounded in day-to-day interactions with their environment and can encompass short-term fluctuations. Also, Ayanlade et al. (2020) argued about who to believe when the climate turns nasty (i.e. climate record or farmers?). The implications of this variation are significant. Farmers' perceptions, although valuable, might not capture the full extent of the long-term changes that constitute climate change. This discrepancy could lead to inadequate preparedness and low adoption of adaptation strategies. If farmers do not align their practices with the actual change in climate trends, it could lead to decreased agricultural productivity, food insecurity, and economic instability.

Gendered impacts of climate change. Gendered impacts of climate change manifest in various ways. Women are more susceptible to malnutrition and food insecurity due to their roles as caregivers and food providers (Ruel, 2013). They might face health risks related to increased waterborne diseases or exposure to indoor air pollution from traditional cooking methods. Women's reduced mobility and decision-making power can limit

Table 3 Gender-responsiveness on the use of drought-resistant crops.

	Labour	Time	Resources	Culture
Use of drought-resistant crops				
Men	− Cultivated drought-resistant crops.	− Availability of drought-resistant crops in drought.	− Did not have access to and knowledge of drought-resistant crops.	− Government agencies did not distribute drought-resistant crops.
Women	+ Cultivated drought-resistant crops.	+ Availability of drought-resistant crops in drought.	+ Access to and knowledge of drought-resistant crops.	+ NGOs distributed drought-resistant crops.
Households	+ Women-headed households cultivated drought-resistant crops.	+ Availability of drought-resistant crops in drought.	? Access to and knowledge of drought-resistant crops.	+ NGOs distributed drought-resistant crops to women-headed households. − government agencies did not distribute drought-resistant crops to households.
Communities	? Cultivated drought-resistant crops.	? Availability of drought-resistant crops in drought.	? Had access to and knowledge of drought-resistant crops.	+ NGOs distributed drought-resistant crops to communities. − Government agencies do not distribute drought-resistant crops to communities.
Crop diversification				
Men	+ Cultivated cash crops.	− Could not save time for crop diversification.	− Did not have access to knowledge of a variety of crops.	− Did not diversify crops.
Women	+ Cultivated cash and staple crops.	+ Saved time for crop diversification.	+ Had access to knowledge of a variety of crops.	+ Diversified crops.
Households	+ Cultivated cash and staple crops.	? Saved time for crop diversification	+ Had access to knowledge of a variety of crops.	+ Diversified crops.
Communities	+ Cultivated cash and staple crops.	? Saved time for crop diversification	+ Had access to knowledge of a variety of crops.	+ Women practiced crop diversification.
Changing crop pattern				
Men	− Low skills in specific crop changing pattern.	+ Available time to practice.	+ Access to land and variety of crops. − Knowledge about effective crop patterns.	+ Gender norms allowed to change crop patterns.
Women	+ High skills in specific crop-changing patterns.	− Limited time to practice.	+ Access to land and a variety of crops. + Knowledge about effective crop patterns.	+ Gender norms allowed to change crop patterns.
Households	? Skill level in specific crop changing patterns.	? Amount of time to practice.	+ Access to land and a variety of crops. ? knowledge about effective crop patterns.	+ Gender norms allowed to change crop patterns.
Communities	? Skill level in specific crop changing patterns.	? Amount of time to practice.	+ Access to land and variety of crops. ? Knowledge about effective crop patterns.	+ Gender norms allowed to change crop patterns.
Mixed farming				
Men	? Skilful in mixed farming.	? Time to practice.	− Had no livestock.	+ Do not mix crops and livestock.
Women	+ Skilful in mixed farming.	− Limited time to practice.	+ Land, crops and livestock.	+ Mixed crop and livestock.

Table 3 (continued)

	Labour	Time	Resources	Culture
Households	? Skilful in mixed farming.	? Time to practice.	+ Land, crops and livestock.	+ Mixed crop and livestock.
Communities	? Skilful in mixed farming.	? Time to practice.	+ Land, crops and livestock.	+ Mixed crop and livestock.
Sustainable forestry and cover cropping				
Men	+ Skilful in sustainable forestry. + Unskilled in cover cropping.	+ Available time.	+ Access to land for practice.	+ Practiced sustainable forestry.
Women	+ Skilful in sustainable forestry and cover cropping.	− Limited time.	+ Had access to land for practice and generated additional income.	+ Practiced both sustainable forestry and cover cropping.
Households	+ skilful in sustainable forestry and cover cropping.	? Amount of time.	+ Had access to land for practice and generated additional income.	+ Practiced both sustainable forestry and cover cropping.
Communities	+ Skilful in sustainable forestry and cover cropping.	? Amount of time.	? Had access to land for practice and generated additional income.	+ Practiced both sustainable forestry and cover cropping.

their ability to access resources, markets, and information necessary for adaptation (Ibnouf, 2009). Findings from this study showed that men's and women's perceptions of climate change were inextricable to climate risk. This implies that climate risk and impacts vary (Lawson et al., 2020). This corroborates with the works of Khan et al. (2020), Pandit et al. (2019), and Azadi et al. (2019) that farmers with higher perceptions of climate change understand climate risks and are able to make adjustments.

From the study of different authors across the globe (e.g. Onwutuebe, 2019; Moritz et al., 2019; Khandekar et al., 2019; Bhadwal et al., 2019a, 2019b; Speis et al., 2019; Pandey, 2020; Van Valkengoed and Steg, 2019; Nyantakyi-Frimpong, 2020; Sharma et al., 2020; Sharafati et al., 2020; Cvetković and Grbić, 2021; Smur et al., 2021), Men and women in agricultural communities may have differing observations and perceptions of climate change due to varying roles, responsibilities, and interactions with the environment. Observations and perceptions of climate change among male and female farmers can be influenced by several factors. For instance, men might be more engaged in outdoor agricultural activities, allowing them to directly experience shifts in weather patterns. Their observations could include changes in growing seasons, increased frequency of extreme weather events, or alterations in pest and disease patterns. Women, often responsible for household activities and food processing, might observe climate change through shifts in water availability, changes in crop yields affecting family nutrition, and altered natural resource availability. Perceptions of climate change and its impacts among men and women could also be influenced by traditional gender roles and knowledge dissemination patterns. Women might rely on indigenous knowledge and community networks for information, potentially leading to distinct perceptions compared to men who might have access to more formal information sources. Women's observations might be more locally focused, centred around household and subsistence concerns, while men might engage in broader discussions on market-oriented farming practices.

More so, women perceive more heat waves and warm spells in the study area. This is because women often work day and night and are more likely to experience heat stress, which is exacerbated by heat waves and dry spells (Foster et al., 2020). Most women reported sudden dizziness that followed household chores in hot weather while the men often rested in cool places (e.g. under trees during temperature increases) waiting for their food to be prepared. While heat waves and dry spells were observed to have affected crops in the study area, findings also showed that the effects of heat waves were disproportionate to livestock, especially birds in the study area (Damma and Alhassan, 2020). This supports the findings made by Budhathoki et al. (2019) who noted that farmers with livestock were predominantly affected by heatwaves. Women comprised most livestock farmers in the study area. This is like the study of Galiè et al. (2019) and Uduji and Okolo-Obasi (2019) who Stated that are livestock keepers. Women perceived climate change as related to extreme temperatures when tending to their livestock. Extreme temperatures have affected livestock, thus revealing to women how the temperature in the study area is changing (Trisos et al., 2022; Prakash et al., 2022).

Climate change poses a complex and multifaceted challenge that magnifies existing vulnerabilities within societies, disproportionately affecting men and women due to prevailing gender inequalities. This disparity emerges from distinct social roles, limited access to resources, and varying levels of decision-making power between genders. Women often find themselves on the frontline of climate impacts, particularly in developing countries where they play a central role in agricultural and household activities. Observations reveal that women and men experience

climate change differently. Women, frequently responsible for subsistence farming and water collection, have a more localized perspective. They witness changing rainfall patterns, dwindling crop yields, and water scarcity firsthand. Conversely, men's roles, often tied to market-oriented farming, might lead them to focus on broader market fluctuations and production losses. Risk appraisal also diverges based on gender roles. Women, as caregivers and food providers, tend to prioritize household resilience and adaptability. In contrast, men might emphasize economic risks and market instability (Bhadwal et al., 2019a, 2019b; Speis et al., 2019; Pandey, 2020).

Gendered exposure to climate change results from occupational divides and social norms. Limited access to education, resources, and decision-making power leaves women particularly vulnerable. Increased workloads due to household and agricultural responsibilities exacerbate their exposure. The impacts are far-reaching: women's vulnerability to malnutrition and food insecurity is heightened. Health risks stemming from the aforementioned waterborne diseases and indoor air pollution disproportionately affect women because of their caregiving roles (Cvetković and Grbić, 2021; Smur et al., 2021). Keellings and Hernandez Ayala (2019), Nnadi et al. (2019), and Ayanlade et al. (2022a) were all of the opinion that women felt more impacts of water insecurity caused by climate change. This is in line with the results of this study that demonstrated that the decrease in intense rainfall in the study area posed more water stress to the women (Ayanlade, 2023), and this is because women predominated in the study area depend on frequent rainfall because of the type of crops they cultivate. Also, most women are smallholders and even a subtle change could have a significant impact on their cropping.

Gender-differentials in adaptation and responsive approaches. Since women in the study area are more vulnerable to the impacts of climate change, one would expect they should practice more adaptation, but this is not exactly the case. However, studies (Kisauzi et al., 2012; Assan et al., 2020; Bhadwal et al., 2019a; Trisos et al., 2022; Prakash et al., 2022) have reported that women who can perceive climate change and its impacts are more likely to express concern about climate change and take action to address it. These results may have important implications for efforts to address climate change, as understanding gender differences in climate perceptions can help policymakers develop targeted interventions and communication strategies to effectively engage diverse populations (Okyere and Usman, 2021; Mensah and Fosu-Mensah, 2020; Smur et al., 2021). In other studies (Eeswaran et al., 2021; Pires et al., 2020), women were reported to be predominantly livestock keepers who can use manure as a method of producing drought-resistant varieties. According to Bedeke et al. (2019), the drought-resistant potentials of crops can be enhanced by using animal manure and crop waste. Both manure and crop wastes can boost soil water retention and moisture content during dry seasons. The use of drought-resistant crops by women was found by this study to be a responsive approach to climate change in the study area.

On medium and long-term scales, diversification into high-value crops was practical among men and women in the study area. Findings from this study showed that crop diversification was a top adaptation priority adopted by men and women who practised both irrigated and non-irrigated farming (Table 3). Crop diversification is one of the most popular climate change adaptation strategies employed by both men and women. According to Ponce (2020), crop diversification is means of responsive approaches to climate change. The crop diversification approach has reduced climatic risks while also delivering the co-benefits of a diverse and healthy food supply in the study area (Birthal and Hazrana, 2019; Teklewold et al., 2019). Men and women who grow more than once a year have reported integration of their livelihoods in the study area. This study found that crop diversification engenders the abilities of men and women to subdue disease outbreaks, although men and women in the area practised crop diversification. The general adoption of this method could be a result of some peculiarities (e.g. large livestock ownership). Findings from this study from the gender analysis showed that women adopted the crop diversification practice more than men. Women in the study area grew millets, beans, ground nuts, sorghum and vegetables for subsistence use and also generated income from it. This corroborates with De Pinto et al. (2019) who found that crop diversification has a strong relationship with women's empowerment under a changing climate.

The most common responsive approach to climate change is the changing crop pattern and mixed farming. These include both changing crop varieties and crop planting calendars. Findings from this study showed that women are the majority of smallholder farmers who adopted that changing crop pattern. More men had land rights than women in the study area and predominantly grew perennial crops while women also relied on cash crop production from sustainable forestry and cover cropping as means of livelihood diversification (Table 3). Varieties of crops were mixed in the same plot while changing crop patterns to help other low-resistant crops build resilience to climate change (Singh, 2020; Prakash et al., 2022; Trisos et al., 2022). This corroborates with Acevedo et al. (2020) that women were more likely to adopt changing crop patterns because of their knowledge about seedlings. To both male and female farmers who participated in the present study, mixed farming is their responsive approach to addressing the impacts of climate change, as it was also established by Yamba et al. (2019), Kumasi et al. (2019) and Steiner et al. (2020). In addition, Lawson et al. (2020) found that mixed farming is a significant adaptation strategy as it addresses inequities in access to asset-based resources like land. Mixed farming also contributed to the improvement in soil fertility from the application of manure in the study area (Parajuli et al., 2019). On the other hand, the present study shows that gender-differential adoption in sustainable forestry and cover cropping practices were based on land rights. More so, women and men may assess climate-related risks differently due to other distinct roles. Women's responsibilities for food security and family welfare might lead them to prioritize resilience and adaptability, focusing on diversifying crops and income sources. Men's roles might lead them to focus on financial aspects, viewing risks in terms of economic losses and market instability. The gendered exposure to climate change can be said to be generally influenced by occupation, social norms, and access to resources. However, the vulnerability of women is exacerbated by limited access to credit, education, and decision-making power, which can hinder their capacity to adapt. Women are often exposed to increased workloads as they may be responsible for both agricultural and household activities, intensifying their vulnerability to climate stressors.

Conclusion

This study investigated the gendered vulnerabilities and responsive approaches to rapid climate warming among crop smallholder farmers, using a mixed methods approach. This study showed that male and female smallholder farmers perceive climate change differently, and have different experiences and varied levels of adaptation practices. Although men have access and control over tangible asset-based resources more than women

in the study area. Women had more access to intangible yet strategic asset-based resources that included basic knowledge and skills, as shown in the gender perceptions of climate change. The females have gender roles like fetching water for household chores and fuels for firewood connected closer to nature. The study concluded that females' perception of climate is quite different from that of male farmers and that it is playing a crucial role in their inability to adapt. Also, male farmers had more access to land tenure than females in the study area. Females who cultivated smaller plots around the community on homesteads had more knowledge and information that could govern their lands than males. Therefore, there is a need for policymakers to integrate gender into the distribution of climate finance to help smallholder farmers respond to adapt appropriately. This study concludes that there is a need for better gender-sensitive approaches to adaptation planning and implementation to ensure that both men and women have equal opportunities to benefit from adaptation options in agriculture.

Gender-responsive adaptation strategies are crucial to address these vulnerabilities. Empowering women through access to education, training, and resources can enhance their resilience. Encouraging women's participation in decision-making processes ensures that their unique knowledge and needs are incorporated into adaptation planning. Implementing climate-smart agriculture techniques, such as drought-resistant crops and water-saving technologies, can benefit both women and men. Addressing this variation requires a holistic approach that integrates scientific climate data with indigenous knowledge and local observations. Encouraging communication between farmers, researchers, and policymakers can enhance understanding and adaptation strategies. Additionally, empowering women in agriculture by recognizing their unique insights and challenges is crucial for comprehensive climate change adaptation and mitigation efforts.

Data availability

Data will be provided by the authors upon request. However, due to ethical and privacy concerns, neither the source of the data nor the participant biodata may be made public.

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Author contributions

AA, IAO, and OSA conceived and designed the study; AA, IAO, OA and OSA contributed to methods development and conducted the analysis and interpretation. OA and SA-U contributed to data/literature collection/analysis. All authors contributed to the manuscript preparation and write-up.

Competing interests

The authors declare no competing interests.

Ethical approval

We confirm that we have complied with the Obafemi Awolowo University's ethical standards in the treatment of their participants. All data collection methods were performed with the informed consent of the participants and followed the Institutional Review Board

Informed consent

Following Obafemi Awolowo University protocol, participation was voluntary, and all subjects provided informed consent.

Additional information

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