

Smallholder Cocoa Farmers' Perceptions of Climate and Variability in Ghana

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Abstract

Climate change and variability worldwide affect human lives, farmers' earnings, and food security. Climate action has been identified by the United Nations as Sustainable Development Goal 13 (UN, n.d.). Climate change damages cocoa (*Theobroma cacao*)

production and impacts the livelihoods of smallholder farmers in Ghana. Changes in rainfall and temperature directly influence yields. These changes can reduce production, harm the trees, and increase pest and disease outbreaks. This study aims to understand farmers' perceptions of climate change with respect to rainfall and temperature during the dry and wet seasons. The goal is to analyze these perceptions and see how they relate to demographic and institutional variables. Sampling followed protocols for systematic random sampling. Multiple regression and descriptive analyses were conducted. Most farmers noticed changes in rainfall and temperature related to the wet and dry seasons. Their perceptions aligned with weather data. Farming experience and education were significantly linked to their perceptions. Farmers also strongly agreed on their willingness to learn about climate change and expressed a readiness to take risks to reduce negative outcomes. Understanding farmers' perceptions and the demographic and personal factors that influence them is crucial for designing effective, locally tailored strategies and policies, especially for rural cocoa farmers.

Keywords: climate change perception, cocoa, management practices, socioeconomic, institutional

1. Introduction

Climate change and variability are increasingly affecting people's livelihoods, socioeconomic activities, and food security worldwide (Mirzabaev et al., 2023; IPCC, 2022; Birkmann et al., 2022). According to the World Meteorological Organization (2022), climate change refers to the ongoing and projected changes in weather patterns caused by sustained increases in greenhouse gas emissions (World Meteorological Organization, 2022). In Africa, climate change is expected to significantly reduce suitable habitats for many species and disrupt ecosystem services, while also leading to lower yields and losses in both food and non-food crops (IPCC, 2022).

In Ghana, the cocoa industry supports around 800,000 smallholder farm families and earns over two billion U.S. dollars annually in foreign exchange (Ghana Commercial Bank [GCB], 2022). Ghana's cocoa sector remains a high-value global commodity and a crucial input for the international chocolate industry, generating significant foreign exchange and helping grow the national economy while reducing poverty (Boysen et al., 2023; USDA FAS, 2025; IFC, 2025). However, climate-related shocks to the cocoa sector could threaten smallholder livelihoods, slow national economic development, and cause cocoa supply shortages in global markets. The negative effects of climate change tend to be more severe and disproportionately impact smallholder farmers. In Ghana's cocoa belt, smallholders are more vulnerable due to poverty, limited infrastructure, reliance on rainfed production systems, and insufficient technical and financial support (Mensah, 2025). These challenges, especially poor access to credit, hinder farmers' ability to invest in and adopt climate-resilient agricultural innovations, which increases their exposure and vulnerability to climate risks (Ogunyiola et al., 2022; UNEP, 2024).

Cocoa (*Theobroma cacao*) is a climate-sensitive crop that grows best at temperatures around 21–23°C and annual rainfall between 1,000 and 2,500 mm. Variations in these conditions can lower cocoa yields and productivity, threaten household incomes, and negatively affect

farmers' livelihoods and food security (Cilas & Bastide, 2020). To increase production and improve livelihoods, smallholder farmers have expanded cocoa cultivation by clearing forestland, which causes deforestation and other environmental issues (Cilas & Bastide, 2020; Ashiagbor et al., 2022; Kalischek et al., 2023). Deforestation exacerbates climate change and jeopardizes cocoa systems that rely on shade trees for resilience and microclimate regulation. For instance, The Guardian reported in May 2023 that about 26,000 hectares of Ghana's forest loss—out of an estimated 193,000 hectares (13.5%)—was linked to cocoa-driven deforestation. Climate change and variability also affect the spread and severity of cocoa pests and diseases, such as swollen shoot disease and black pod disease (Kosoe & Ahmed, 2022). Despite cocoa's global importance and national significance, the sector continues to face ongoing climate-related challenges (Jamal et al., 2021).

Addressing climate change and variability in cocoa production requires integrated approaches that combine both adaptation and mitigation strategies. Additionally, understanding farmers' perceptions of climate change is crucial because perceptions influence farming decisions and willingness to adopt adaptation measures (Meldrum et al., 2018; Antwi-Agyei et al., 2021; Jamal et al., 2021). Jamal et al. (2021) observed that cocoa farmers' perceptions of climate change significantly impacted their decisions to implement adaptation strategies. The authors emphasized that smallholder farmers are more likely to adopt practices when they observe clear changes in climate conditions.

Socioeconomic and sociocultural factors further affect farmers' views of climate change. Belay et al. (2022) found that age, farming experience, education, weather information access, and social networks influence how people perceive climate change. Similarly, Niemann et al. (2024) and Awoke et al. (2025) pointed out that traits like gender, household structure, labor dynamics, and culturally defined roles also shape how climate patterns are understood. Evidence from Bangladesh showed that education, farm size, family size, and training were connected to how farmers saw climate (Chowdhury et al., 2025).

Institutional factors, particularly access to weather information, extension services, and climate advisories, also heavily influence farmers' decision-making (Abdul-Fatah Alidu et al., 2022). Ricart et al. (2024) found a positive relationship between negative impacts from climate-related issues and farmers' likelihood of adopting climate-smart agricultural practices, even when perceptions do not fully align with historical climate patterns. These findings highlight the importance of considering both socioeconomic and institutional factors to understand how farmers interpret climate change and create adaptive strategies.

Although studies have examined farmers' perceptions of climate change in cocoa systems, there is limited evidence on how Ghanaian cocoa farmers perceive climate variability and change, as well as the factors shaping those perceptions. Since adaptation strategies are often specific to location, it is important to assess farmers' perceptions along with the contextual factors that influence them. This evidence can help improve understanding of the processes and practices needed to increase the adoption and scaling of climate adaptation measures (Lindner et al., 2016).

The purpose of this study was to assess smallholder cocoa farmers' perceptions of climate

change and variability in Ghana. Study objectives included (a) examining cocoa farmers' perceptions of ongoing climate change and variability in relation to observed meteorological trends in the area, (b) identifying individual and institutional factors that influence farmers' perceptions, and (c) evaluating farmers' decisions to adopt adaptive measures.

1.1 Climate Change Perceptions

Perception of climate change involves complex psychological processes that include knowledge, beliefs, attitudes, and concern about climate change (Brügger, 2021; Salas Reyes et al., 2021; IPCC, 2022). Perceptions about climate are individualized, and people in the same area often have different views on climate change even when they experience similar weather conditions (Fierros-González & López-Feldman, 2021). These differences are influenced by variation in personal experiences, access to information, socioeconomic status, and cultural and geographic contexts (van der Linden, 2015; IPCC, 2022; Leoniak & Korniluk, 2025).

Because of its complex and context-specific nature, assessing climate change perception on a global scale is challenging. Understanding perception often requires combining different methods to see how people define, interpret, and respond to climate change. Clemons et al. (2018) argue that disciplinary knowledge and climate literacy are important in determining how individuals understand climate risks. In Africa, studies frequently assess perception through farmers' reported observations of rainfall variability, rising temperatures, and irregular precipitation patterns (Ameyaw et al., 2018; Amadou et al., 2021; Antwi-Agyei et al., 2021; Kosoe & Ahmed, 2022). For example, Kosoe and Ahmed (2022) found that most cocoa farmers perceived noticeable climate changes, especially shifts in rainfall patterns. Ameyaw et al. (2018) noted that farmers' perceptions of climate change often match meteorological trends. Studying smallholder cocoa farmers in Ghana, their perceptions of climate change, and how these perceptions influence adaptation decisions requires a multidimensional theoretical approach. This study combines Climate Change Risk Perception Theory, Cultural Theory of Risk, and the Theory of Planned Behavior (TPB) to explain the cognitive, sociocultural, and behavioral factors that shape farmers' responses to climate change and variability.

Risk Perception Theory indicates that responses to environmental hazards are influenced not only by actual exposure but also by personal judgments about the severity and relevance of those hazards (Severtson & Myers, 2011). Farmers' perceptions of climate risks affect their responses and willingness to implement adaptation strategies. Evidence from sub-Saharan Africa shows that the higher the perceived climate risk, the more likely farmers are to adopt adaptation measures (Ginbo, 2023). These perceptions are further influenced by access to resources, institutional support, and beliefs about the effectiveness of adaptation options (Ndamani & Watanabe, 2015).

Ajzen's (1991) Theory of Planned Behavior (TPB) outlines a behavioral framework for understanding how perceptions and cultural interpretations influence adaptation intentions. TPB suggests that behavioral intention is the immediate predictor of behavior and is determined by subjective norms, perceived behavioral control, and attitudes toward the behavior. In Ghana, Atta-Aidoo et al. (2022) found that all three TPB constructs significantly

influenced smallholder farmers' intentions to adopt climate-smart agricultural practices and their actual adoption behavior. Similarly, Hounnou et al. (2023) observed that attitudes toward the usefulness of climate forecasts, perceived social pressures, and farmers' perceived capacity to access and interpret forecast data positively impacted the intention to use climate services in Benin. These findings highlight the importance of institutional and social environments: farmers—those who feel socially supported and technically capable—are more likely to incorporate climate information into their farm management.

The Cultural Theory of Risk emphasizes how cultural worldviews, shared beliefs, and social structures influence how groups perceive risks (Douglas & Wildavsky, 1982). When applied to climate change, this theory indicates that collective stories, local knowledge, and social identities shape how people see climate risks. Parsons (2023) found that cultural worldviews significantly affect how communities interpret natural hazards such as bushfires, floods, and storms. Similarly, Sorvali et al. (2022) reported that farmers' values determine whether they see climate change as a threat or opportunity, which influences their preparedness and responses. In rural Ghana, interpretations of climate variability may include spiritual explanations, ancestral customs, local knowledge, and long-term observations passed down through generations (Dakurah et al., 2024).

Social institutions such as chieftaincy systems, farmer cooperatives, religious groups, and lineage-based land tenure arrangements also influence how climate information is shared and how adaptation decisions are made. As a result, farmers living under similar climate conditions may draw different conclusions about climate changes, impacts, and responses. Cultural theory is therefore important to this study because it helps explain variations in perceptions and adaptation intentions that cannot be solely attributed to individual factors (Waring et al., 2023). This perspective highlights the importance of understanding farmers' climate perceptions within their broader sociocultural contexts.

2. Method

2.1 Research Design

This paper is part of a larger study that resulted in a dissertation (Adu-Gyamfi, 2024). As such, much of the content aligns with the dissertation, especially the methods and findings. The study used a quantitative research design. The participants were cocoa producers in the Birim North District, a major cocoa-growing region in Ghana's Eastern Region (MOFA, 2020). Because of their extensive cocoa farming, nine communities were selected with assistance from the Agricultural Extension officers of the district's Cocoa Health and Extension division. A systematic random sampling method was employed to ensure that each household included a woman.

A total of 150 cocoa farmers were targeted, but 106 completed the survey, resulting in a 70% response rate. Factors that may have influenced this include limited time for data collection, seasonal challenges, and difficult road conditions. Caution should be used when applying these findings to populations outside the sampled group, given potential nonresponse bias (Lindner, 2002; Lindner et al., 2001).

The survey instrument included closed-ended questions based on reviews and modifications from Ameyaw et al. (2018) and Walker's (2020) instruments. The survey was divided into three sections: (1) knowledge about climate change, (2) perception of climate change impacts, (3) perception of farmers' decisions regarding adaptation strategies, and sociodemographic characteristics.

The primary method of contact was a researcher-administered survey, and data collection was conducted using an offline Kobo Toolbox survey in 2023. A team of three Auburn University professors reviewed and refined the questionnaire for content validity. Additionally, extension officers in the study area examined and adjusted terminology or answer choices to better match the local community context. Cronbach's alpha coefficient was calculated for climate perception and adaptive decision (Cronbach, 1951). A reliability coefficient of .70 is considered acceptable; however, lower thresholds have also been used (Santos, 1999).

Farmers' perception of climate change is the dependent variable, measured through their opinions on changes in rainfall (precipitation) and temperature patterns. The responses were categorized as Stayed about the Same = 0, Decreased = 1, and Increased = 2.

The explanatory variables for the socio-economic factors, based on existing literature and used in this study, include age, education, farming experience, and gender (Ameyaw et al., 2018; Asare-Naumah & Botchway, 2019). Institutional characteristics include access to weather information (Table 1).

Table 1. Description of Study Variables, Ghana Cocoa Farmers 2023

Variable	Description of Variables
<i>Dependent</i>	
Perceived Temperature Change	Decreased= 1, Stayed Same = 0, Increased=2
Perceived Precipitation Change	Decreased = 1, Stayed Same= 0 Increased=2
<i>Independent</i>	
Education	Respondent Years of Schooling
Age	Age in years
Gender	Female=0, Male =1
Farming Experience	Total Number of Years of Farming
Access to Weather Information	Receive Weather Info (Yes=1, No=0)

2.2 Analysis

During data cleaning, inconsistency errors were identified and corrected. Data was analyzed using SPSS. Descriptive statistics, such as frequencies, percentages, and means, were used to summarize participants' perceptions of climate change, their decisions to adopt adaptive

management practices, and their individual and institutional characteristics. Additionally, multiple regression analysis was employed to determine the factors influencing smallholder farmers' perceptions of climate change.

The model is represented as:

$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_b X_b + \varepsilon$, where Y is the dependent variable; β represents the intercept coefficient; β_1 through β_b are the coefficients of the explanatory variables; X_1 through X_b are the explanatory variables; and ε is the error term. Therefore, the regression model for the study is:

Farmer perception of climate change:

$(Y) = \beta_0 + \beta_1 \text{ Gender} + \beta_2 \text{ Education} + \beta_3 \text{ Farming experience} + \beta_4 \text{ Age} + \beta_5 \text{ Access to weather information} + \varepsilon$

The study also employed the Mann-Kendall test (Mann, 1945; Kendall, 1975) to analyze climate trends in meteorological data from the study area. The Mann-Kendall test assumes that meteorological data are randomly and independently ordered (Chepkoech et al., 2018; Jaiswal et al., 2015). It was used to evaluate the hypothesis of no climate trend, focusing on rainfall and temperature indicators. Previous studies (Ameyaw et al., 2018; Baffour-Ata et al., 2021) successfully used the Mann-Kendall trend test to examine temperature and precipitation patterns in other parts of Ghana, enabling comparisons between individual farmers' experiences and broader community observations.

2.3 Hypotheses

H₀: There is no significant effect of cocoa farmers' individual and institutional characteristics on their perception of climate change.

This also indicates that all regression coefficients are equal to zero.

H₀: $\beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = 0$

H₁: There is a significant effect of cocoa farmers' individual and institutional characteristics on farmers' perception of climate change.

H₁: $\beta_1 \neq \beta_2 \neq \beta_3 \neq \beta_4 \neq \beta_5 \neq 0$

3. Results

3.1 Farmer's Socio-Demographics and Institutional Characteristics

Farmers' socio-demographics and institutional characteristics are shown in Table 2. The descriptive results indicate that males (62.2%) constitute the majority. Most respondents (50%) are between the ages of 45-59. Many farmers have secondary education (47.2%), more than 16 years of farming experience (62.3%), and earn an average monthly income between GHC 900-2000 (77-172 USD) (41.5%). About 75.5% of respondents consider cocoa farming their primary source of income.

Table 1 also presents data on participants' personal and demographic characteristics,

particularly their access to weather information. The findings show that approximately 90% of participants have access to weather data, mainly through media such as TV and radio, with 53% identifying this as their primary source. Additionally, about 20.8% depend on personal observation for weather information.

Table 2. Demographics and Institutional Characteristics, Ghana Cocoa Farmers 2023

Variables	Category	<i>f</i>	%
Gender	Female	40	37.7
	Male	66	62.3
Age	18-29	2	1.90
	20-44	30	28.3
	45-59	51	50.0
	Over 60	21	19.8
Education	No formal education	19	17.9
	Basic	30	28.3
	Secondary	50	47.2
	Tertiary	7	6.6
Farming Experience	6-10 years	15	14.2
	11-15 years	25	23.6
	Over 15 years	66	62.3
Access to Weather Information	No	16	15.1
	Yes	90	84.9

Data Source: Analysis of field Data, Ghana 2023.

3.2 Perceptions of the Impact of Climate Change on Cocoa Production

We explored cocoa farmers' views on ongoing climate change and variability. Table 3 shows the descriptive statistics of farmers' knowledge and perceptions of climate change, affected by changes in rainfall, temperature, the length of the dry season, and the wet season. Respondents noted that climate patterns have changed over the past ten years. About 66.0% of farmers reported an increase in temperature, while 71.7% observed a decline in rainfall patterns. Approximately 76.4% of farmers indicated a shorter wet season, and 70.8% reported a longer dry season.

Table 3. Participants' Views of Climate Change Conditions, Ghana Cocoa Farmers 2023

Condition	Perception	<i>f</i>	%
Temperature	Increased	94	88.7
	Decreased	9	8.5
	Stayed Same	3	2.8
Rainfall	Increased	19	17.9
	Decreased	76	71.7
	Stayed Same	11	10.4
Length of Wet Season	Increased	17	16.0
	Decreased	81	76.4
	Stayed Same	17	16.0
Length of Dry Season	Increased	75	70.8
	Decreased	21	19.8
	Stayed Same	10	9.4

Data Source: Analysis of Field Data, Ghana 2023

Almost all farmers (97.1%) expressed concern about climate change affecting their cocoa farms. Among those worried, 26.4% were concerned about decreased cocoa yields, and 23.4% feared high mortality rates among their cocoa trees (Table 4). Table 5 shows that many respondents (44%) believe that deforestation caused by illegal logging contributes to climate change.

Table 4. Participants' Perceptions of Climate Change Impact, Ghana Cocoa Farmers 2023

Perceived Impacts of Climate Change	<i>f</i>	%
Low Yield from Cocoa	89	26.4
High Mortality Rates of Cocoa trees	79	23.4
Low Income from Low Yield	71	21.1
High incidence of Pest and Diseases	51	15.1
Food Crop Loss Due to Drought	47	13.9
Multiple responses possible	106	

Data Source: Analysis of field data, Ghana, 2023. Note. Total is not equal to N (106) because of multiple responses from participants

Table 5. Farmers' Perceptions of Causes of Climate Change, Ghana Cocoa Farmers 2023

Item Noted as a Cause of Climate Change	<i>f</i>	%
Deforestation (Illegal Logging)	87	43.5
Slash and Burn Agriculture	51	25.5
Use of Wood Fuels	30	15.0
Full-Sun Cocoa Plantation	28	14.0
Caused by a Curse	4	2.0
<i>Multiple responses possible</i>	200	100.0

3.3 Study Area Climate Trends

To understand farmers' perception of climate change, the study aimed to compare their perceptions with climatic data from the study area. The climatic data were gathered from the weather station in the district over a ten-year span (2014-2022).

3.3.1 Temperature

The findings indicated that the maximum temperature in the study area stayed mostly steady, with a slight rise in the minimum temperature over the ten years. The average temperature during this period ranged from 22.6 °C to 32 °C for minimum and maximum values, respectively, and showed no notable upward trend (Figure 1).

3.3.2 Precipitation

Based on data from 2013 to 2022, overall precipitation and seasonal rainfall have slightly decreased. The Seasonal Mann-Kendall Tests (SMK) further revealed a declining trend in seasonal rainfall ($\tau = 0.261$, $p = 0.00$) (Figure 1).

3.3.3 Baseline Data

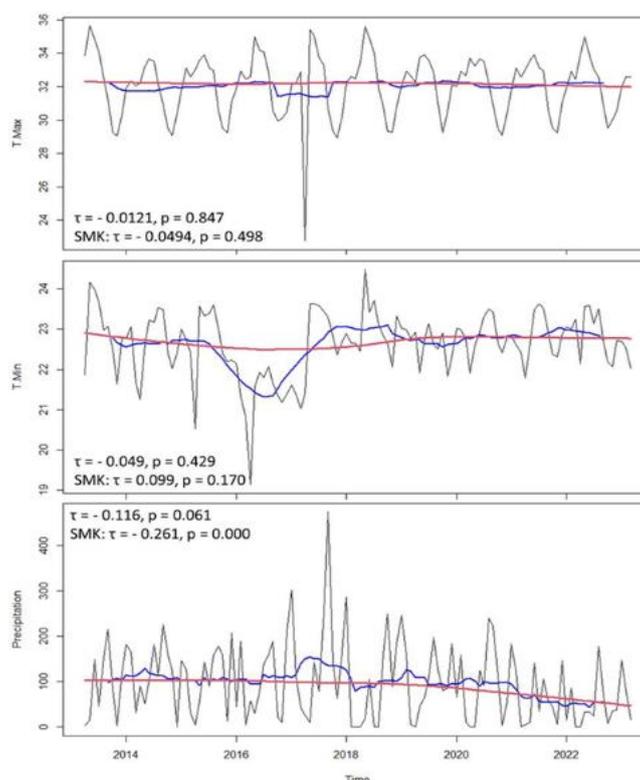


Figure 1. Monthly Trend Analysis of Precipitation in mm, Maximum and Minimum Temperature at the Birim North District Weather Station, Ghana

3.4 Factors Affecting Perception of Climate Change

We explore how socioeconomic and institutional factors influence farmers' perceptions of climate change. Table 6 displays the correlation matrix for both dependent and independent variables. Significant correlations were observed between climate change perception and several socioeconomic factors, including gender, education, farming experience, and access to weather information at the $p < .05$ and $p < .01$ levels. These relationships are further analyzed through multiple regression to evaluate their predictive roles.

Table 6. Pearson Correlations among Study Variables, Ghana Cocoa Farmers 2023

	1.	2.	3.	4.	5.	6.	7.	8.
Age	--							
Weather Information	.12	--						
Gender	.19*	.23*	--					
Education	-.03	-.10	-.13	--				
Farming Experience	.63**	0.18	.38**	.14	--			
Temperature	.05	-.17	-.05	.17	-.11	--		
Rainfall	.08	.04	-.05	-.03	0.13	-.20*	--	
Wet season	.04	.23*	-.09	-.17	.13	-.24*	.45**	--
Dry season	.03	-.14	.11	.19*	-.07	.66**	-.30**	-.22*
N	106							

* $p < 0.05$; ** $p < 0.01$

Table 7 presents the coefficients, standard errors, and standardized beta values from the multiple regression analysis. The model achieved an R^2 of 0.12, indicating that approximately 12% of the variance in the dependent variable (farmers' perceptions of changes in precipitation) is explained by the socioeconomic and institutional predictors included. The regression analysis showed a statistically significant overall relationship between these predictors and farmers' perceptions of changes in precipitation ($p < .05$).

Among the independent variables, farming experience proved to be a significant predictor. Specifically, a one-unit increase in farming experience was associated with a 0.56 (56%) rise in farmers' perceived changes in precipitation, while all other variables remained constant. Gender also had a significant effect; however, the relationship was negative, indicating that male farmers were less likely than female farmers to perceive changes in precipitation in the study area. Although access to weather information had a positive coefficient, suggesting that greater access might increase farmers' likelihood of perceiving precipitation changes, this effect was not statistically significant.

Table 7. Regression of Perceived Precipitation and Temperature Change on Sociodemographic and Institutional Factors, Ghana Cocoa Farmers, 2023

	Precipitation Change			Temperature Change		
	B	SE	β	B	SE	β
Constant	2.19*	0.65		2.00*	0.54	
Gender	-0.57*	0.25	-0.25	0.32	0.22	0.17
Education	0.19	0.29	0.07	0.22	0.25	0.09
Age	-0.32	0.17	-0.22	0.36	0.25	0.18
Farming Experience	0.56*	0.19	0.37	-0.21	0.18	-0.17
Access to Weather Information	0.39	0.25	0.15	-0.1	0.22	-0.05
R^2		0.12			0.06	
Adjusted R^2		0.07			0.01	
F-Value		2.56*			1.23	
N		106			106	

Note. * $P < .05$. Data Source: Analysis of field data, Ghana 2023.

3.5 Farmers' Decision to Adopt

We examine farmers' decisions to adopt climate-related management practices. Tables 8 and 9 show respondents' adaptation choices, grouped into learning and knowledge-seeking, and risk-taking and experimentation. About two-thirds of respondents (77.6%) strongly agreed with the statement, "I am interested in learning farm-level agricultural practices that will help me cope with climate change impacts," with a mean score of 4.77 (SD = 0.60) (Table 8). Interpreting these Likert-scale responses follows Lindner's (2024) conventions for analyzing Likert-type data.

Table 8. Interest in Learning Climate Change Practices, Ghana Cocoa Farmers 2023

	I am interested in learning farm level agricultural practices that will help me cope with climate change	
	<i>f</i>	%
Strongly Disagree	0	0
Disagree	0	0
Neither Agree nor Disagree	0	0
Agree	24	22.6
Strongly Agree	82	77.6
Mean	4.77	
SD	0.6	

The risk-taking and experimentation scale shows that 62.3% of respondents strongly agreed with the statement, “I am willing to change my current practices to cope with weather changes” ($M = 4.62$, $SD = 0.49$). Similarly, 60.4% strongly agreed with the statement, “I am willing to try new agricultural technologies and practices if other farmers are using them” ($M = 4.60$, $SD = 0.49$). Additionally, just over half of the participants (51.9%) strongly agreed to adopt management practices if government support is provided ($M = 4.40$, $SD = 0.80$).

Table 9. Risk-taking and Experimentation Intentions, Ghana Cocoa Farmers 2023

	I am willing to change my current practices to cope with the changes in weather		I am willing to try new technologies and management practices if other farmers are using it		I intent to adopt climate management practices if the government grant supports	
	<i>f</i>	%	<i>f</i>	%	<i>f</i>	%
Strongly Disagree	0	0	0	0	2	1.9
Disagree	0	0	0	0	2	1.9
Neither Agree nor Disagree	0	0	0	0	3	2.8
Agree	40	37.7	42	39.6	44	41.5
Strongly Agree	60	62.3	64	60.4	55	51.9
Mean	4.62		4.6		4.4	
SD	0.49		0.49		0.8	

4. Discussion

4.1 Climate Change Perceptions and Trends

In this study, cocoa farmers reported noticeable changes in climate conditions, including higher temperatures, shifting rainfall patterns, shorter wet seasons, and longer dry periods. These perceptions align with evidence from earlier studies, such as Antwi-Agyei et al. (2021), Kosoe and Ahmed (2022), and Ameyaw et al. (2018), which show similar trends of rising temperatures and variable rainfall in Ghana's cocoa-growing regions. Analysis of local weather data from 2013 to 2022 further supports these observations, indicating modest

increases in temperature and slight decreases in rainfall, consistent with farmers' reported experiences.

While a longer dataset dating back to the 1980s could enhance trend analysis, the agreement between farmers' perceptions and available meteorological data shows their ability to recognize weather pattern changes. Ricart et al. (2024) demonstrate that when farmers accurately identify changes like rising temperatures and decreasing rainfall, they can adjust their management practices accordingly. Respondents identified reduced cocoa yields and increased tree mortality as major climate-related issues, consistent with findings from studies by Anning et al. (2022), Bunn et al. (2018), Ameyaw et al. (2018), and reports by Rainforest Alliance (2019). Many farmers connected these climate challenges to deforestation and slash-and-burn farming practices. Perceptions that match broader environmental reports, such as those highlighted by The Guardian (May 2023).

4.2 Socio-economic and Institutional Factors

This study found that both personal and demographic characteristics influence farmers' perceptions of climate change. Farming experience shapes how farmers view climate change in cocoa production. One implication is that farmers with more experience have participated in long-term cocoa farming, creating a historical baseline for comparing past and current weather patterns. Experienced farmers have gained knowledge from observing seasonal cycles, crop performance, pest and disease outbreaks, and yield fluctuations over many years. This experiential knowledge helps them notice even subtle changes in temperature, rainfall timing, and the length of wet or dry seasons that less experienced farmers might overlook.

There was a relationship between gender and perceptions of climate change. Females were more likely than males to notice climate shifts. This may be because women in cocoa-farming households are often more involved in climate-sensitive tasks, which improves their ability to detect weather changes. Although access to weather information was not a statistically significant predictor, its positive coefficient suggests that greater access to climate data could increase farmers' likelihood of perceiving climate changes. This trend aligns with findings by Partey et al. (2018), who observed that farmers can better anticipate weather variability and adopt suitable adaptation measures when they have reliable access to climate information.

4.3 Adopting Management Practices

Farmers' adaptation choices in this study mainly focus on two areas: learning and gaining knowledge, and taking risks through experimentation. The results show that most smallholder cocoa farmers are eager to learn about new climate-smart farming practices. Many also expressed a willingness to take risks by changing current methods, trying new technologies, and adopting innovative management strategies. Farmers specifically mentioned they would do so when peers successfully use these practices or when supported by government programs.

This pattern aligns with evidence from other studies in sub-Saharan Africa, which show that farmers who recognize climate-related threats tend to seek learning opportunities and are

more open to experimentation as adaptive strategies (Asrat & Simane, 2018; Ricart et al., 2024). As cocoa farmers become more aware of climate change, they are more likely to engage in proactive learning and adopt adaptive measures.

5. Conclusion and Recommendations

This study examined cocoa farmers' perceptions of climate change and how their personal and demographic characteristics influence these perceptions in the Birim North District of Ghana. Data from a primary survey of 106 smallholder farmers were analyzed. Gender, farming experience, and access to weather information significantly affect farmers' ability to recognize changes in climate, especially in terms of precipitation and temperature shifts.

The findings also indicate that many farmers are willing to adopt adaptive management practices to address changing weather patterns, especially when these practices are already used by others or supported by government programs. These insights emphasize the importance of understanding farmers' perceptions as a foundation for developing practical and culturally appropriate climate-smart strategies.

The study also emphasizes that smallholder cocoa farmers possess valuable experiential and indigenous knowledge from years of working closely with the land and observing weather patterns. Their perceptions and responses offer vital insights into the real impacts of climate variability and should be fully integrated into adaptation planning. Recognizing and validating this knowledge is essential for developing strategies that are both effective and sustainable. Based on the findings, it is recommended that policymakers and development practitioners include farmers' experiential knowledge when designing local and national climate adaptation strategies. Co-developing solutions with farmers will enhance relevance, foster ownership, and support long-term adoption.

Although access to weather information was not a statistically significant predictor in this study, its positive correlation with climate perception indicates that improving the availability, timeliness, and reliability of climate data can strengthen farmers' adaptive decision-making. It is recommended to invest in localized weather forecasting, community radio, mobile advisory services, and support from extension officers.

Since farmers are more likely to adopt climate-smart practices when they see others doing so, extension programs should focus on demonstration plots, farmer field schools, and peer mentoring models. These approaches leverage social proof and reduce the perceived risks of trying new techniques. Government and agricultural agencies should provide targeted incentives, such as subsidized seedlings, access to credit, climate-resilient inputs, and training, to encourage the adoption of climate-smart farming. Evidence from this study indicates that such support motivates farmers to experiment and adapt.

Since gender significantly influences climate perception, adaptation strategies should be designed to ensure fair participation of both male and female farmers. Women, who often have heightened climate sensitivity due to their roles in household and farm management, should be prioritized in training, resource access, and leadership opportunities within cocoa value chains.

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Author contributions

Prof. Adu-Gyamfi was responsible for study conceptualization, design, investigation, writing original draft and revising. Prof. Molnar was responsible for supervision, conceptualization, and writing-review and editing. Prof. Lindner, McKibben, and Clemons were responsible for reviewing and editing. All authors read and approved the final manuscript.

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