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Ghana's Cocoa: Farmers' Perceptions of Climate Change and Its Effect on Yield and Livelihood

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Abstract: This study investigates the perceptions of cocoa farmers in Offinso and Adansi Districts, Ghana, regarding the impact of climate change on their yields, income, and food security. The findings aim to inform policy development and potential mitigation and adaptation strategies. A total of 282 cocoa farmers participated alongside Key Informants. The results indicate a strong consensus among farmers that climate change has negatively affected their yields (0.518 ± 0.501), increased pest and disease prevalence (0.518 ± 0.501), and contributed to cocoa tree mortality (0.482 ± 0.501). This perception is reinforced by the ranking of challenges, where poor yields and increased pest/disease emerged as the most prominent challenges (Relative Importance Index of 0.87 and 0.79, respectively). Interestingly, farmers' perceptions diverged regarding food security. They expressed neutrality towards statements suggesting a negative climate change impact on their food security status (Perception Index = 2.89). These findings highlight the critical challenge of reduced cocoa yield due to climate change for farmers. It is therefore recommended that the Ghana Cocoa Board (COCOBOD), through its extension division, implement immediate actions to educate farmers within the two districts on climate change mitigation strategies. This intervention aligns with achieving the Sustainable Development Goals 1 (No Poverty), 2 (Zero Hunger), and 13 (Climate Action).

Keywords: cocoa farmer livelihoods, cocoa production, cocoa yields, food security, farmer income

1. Introduction

An estimated 350,000 cocoa (*Theobroma cacao L.*) farms are reported to exist in Ghana [1]. The majority of its owners earn about 80% of their annual income from the sale of dry beans [2], indicating high dependence on the production system. Due to these estimates, cocoa production in Ghana has extended into forest zones rather than intensification of farm resources such as effective use of space and good farm management practices [3–5]. Over the past 15 years, there has been a continual increase in demand for cocoa dry beans, but the challenge of smallholder farmers being the major producers hinders reaching maximum output [6, 7]. About 2 million smallholder farmers depend on cocoa production in West and Central Africa, thus indicating the importance of the cash crop to the livelihood and existence of rural communities as well as economies [8–10]. The reality of climate change and its effects on agriculture remains unquestionable [11–13]. This impact is evident as Ghana's cocoa yields are currently ranging 80–95% below potential [14].

While Earth's climate naturally fluctuates over time, human activity, mainly fossil fuel burning, is causing rapid warming at an unprecedented rate [12, 15]. Climate change therefore is the variation in temperature, wind, rainfall, and other elements over at least 25 years or more. Generally, anthropogenic activities such as fossil fuel consumption, deforestation, and urbanization are Ghana's key causes of climate change [8, 13]. It was reported that the most vulnerable to climate change are developing countries. This is because there is an interaction between biophysical, political, and socioeconomic stressors that directly or indirectly undermine the adaptive capacity of many socioecological systems [13]. For instance, agriculture in Ghana is rain-fed; therefore, a shift in the rainfall pattern affects crop yield and thus income and living standards of farmers. In Asante et al. [1] and

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Sorvali et al. [16], cocoa farmers indicated high wilting and mortality of young cocoa plants, dropping of leaves, pods, and flowers, and high incidence of pests and diseases as indicators of climate change. These were also elaborated in Anning et al. [17].

Given the opportunity, local cocoa farmers have shown their perception of climate change on their cocoa yields and livelihoods in various parts of Ghana and other countries but little is reported in a comparison between different ecological zones within Ghana [4, 10, 13, 18]. The scientific novelty of this work lies in its focus on understanding cocoa farmers' perceptions of climate change on their yields and livelihoods across different ecological zones in Ghana. While previous studies have documented the impact of climate change on cocoa production and farmer perceptions, this study aims to fill a gap by comparing these perceptions across different ecological zones. This will provide location-specific data that can inform policy-making and extension practices tailored to the specific needs of farmers in the ecological zones. The study aimed to assess cocoa farmers' perception of climate change and its effect on their yields and livelihood (income and food security statuses). Specifically, the study assessed the following:

(i) The effects climate change has on yield, income, and food security statuses, as perceived by cocoa farmers.
(ii) Major constraints faced by cocoa farmers as a result of the effect of climate change on cocoa production.

The study is situated within the context of the Sustainable Livelihood Framework [19]. The framework seeks to enhance the understanding we have about the poor in society, as Figure 1 shows [19]. It seeks to categorize issues that prevent or improve livelihood opportunities and describes how they are connected [20, 21]. The Sustainable Livelihood Framework serves as a fundamental tool for developmental projects, providing a technique to rationalize objectives, possibilities, and priorities for project implementation [19, 22]. The Sustainable Livelihood Framework gives room to consider the ways the poor and vulnerable in society can sustain their living daily and the effect of policies and institutions on them [23]. While not a perfect tool, the approach facilitates the identification of essential objectives for actions that address the concerns of affected groups. Serat [19] indicated that the approach does not replace other tools such as participatory development, sector-wide approaches, or integrated rural development. It does however generate a link between society and the overall enabling environment that affects livelihood strategies. The framework highlights the inherent capacities or potentials in people about their skills, relationships, physical, and financial resources and the impact of major institutions [24]. These factors, including all actors in the cocoa sector (COCOBOD, Licence Buying Companies, processing companies, farmers, and researchers), necessary inputs, and a suitable production ecosystem, significantly influence the livelihoods and living standards of cocoa farmers, particularly in the face of climate change.

2. Materials and Methods

2.1. Study area description

The Offinso municipality (Figure 2) lies in the Ashanti Region's northwestern Dry Semi-Deciduous Zone, between latitudes 6°95′N and 7°15′N and longitudes 1°35′W and 1°50′W [25]. With a population of 76,895, nearly half (48%) are males [26]. Agriculture dominates the municipality, employing about 68% of

Figure 1
The sustainable livelihood approach

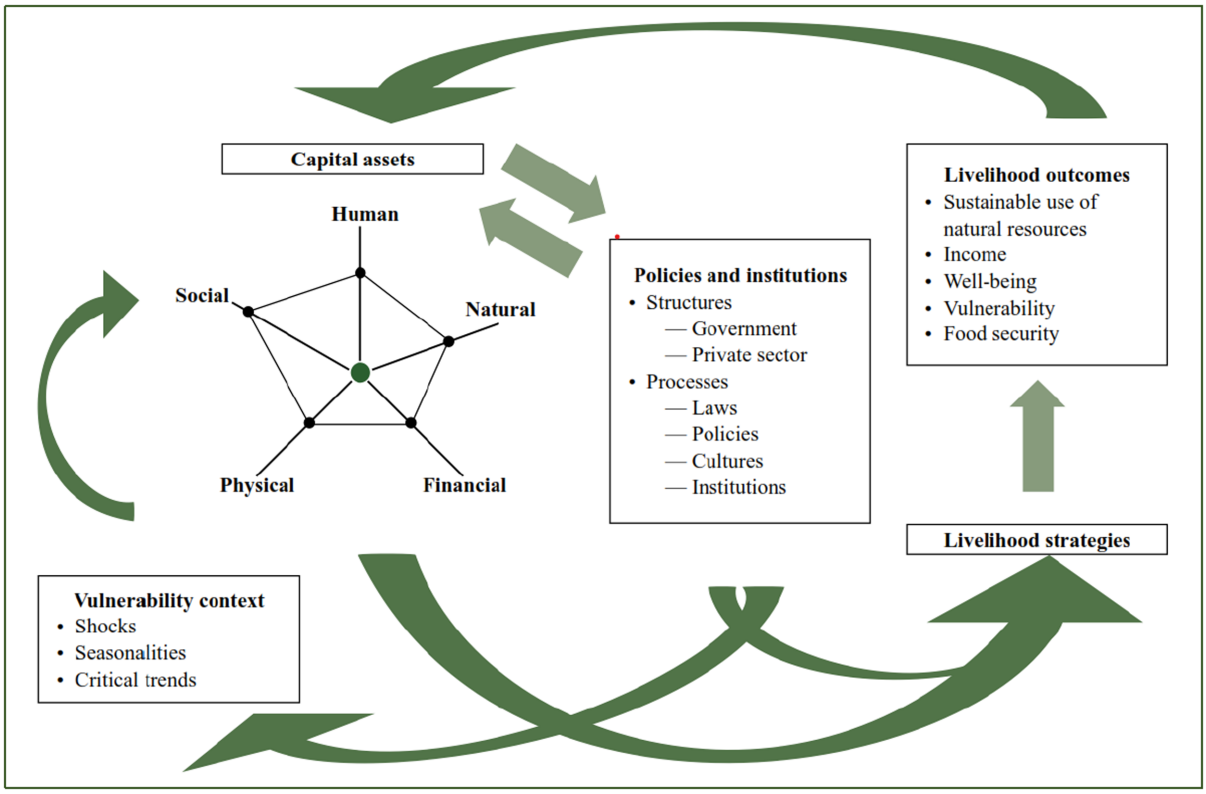
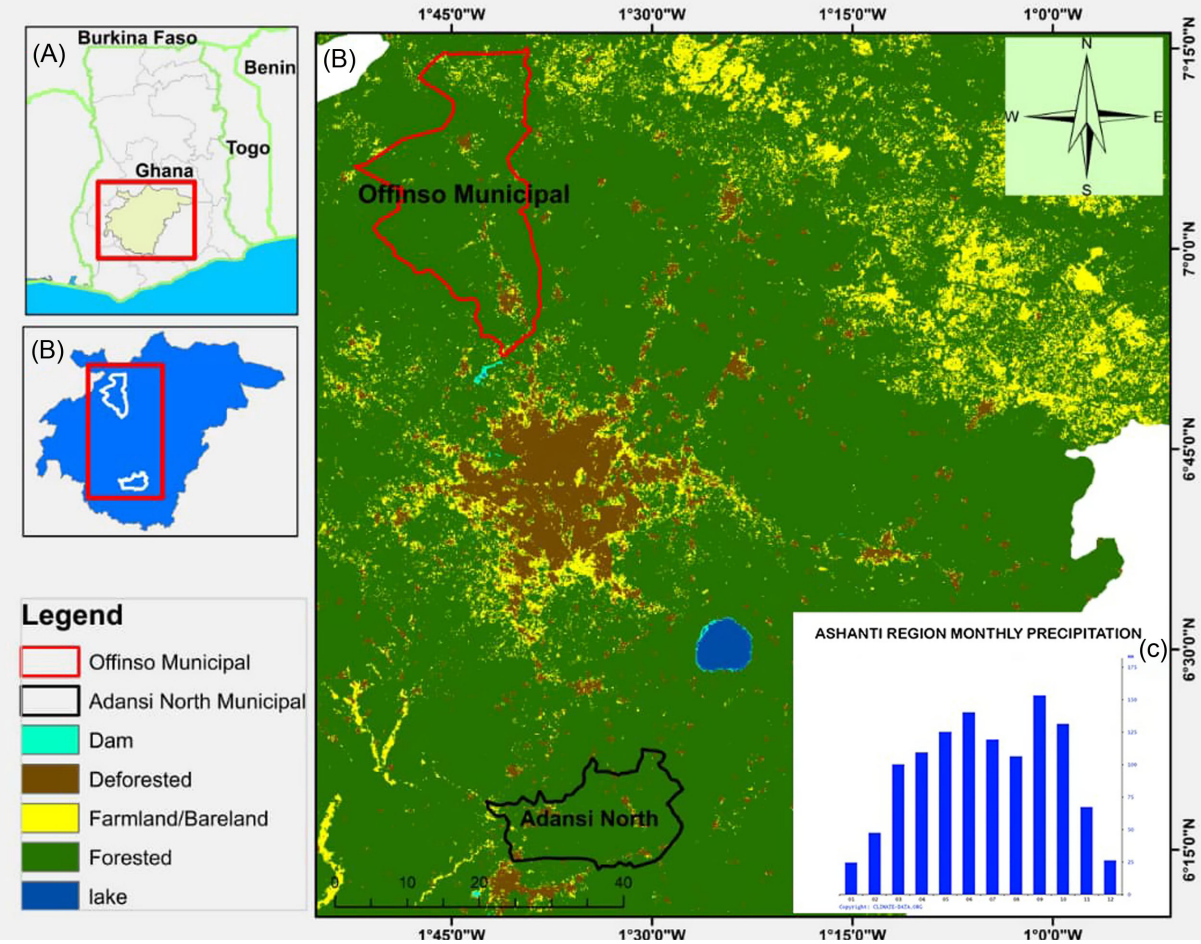


Figure 2
Map of the study site with selected communities in two different ecological zones and their locations in the Ashanti Region of Ghana



the workforce and relying primarily on rainfall [26]. The weathered soils consist mainly of low-activity kaolinite clays and iron and aluminium sesquioxides [27]. Dense undergrowth and forest trees characterize the vegetation, with dominant species including *Celtis mildbraedii* (Natal white stinkwood), *Triplochiton scleroxylon* (African white wood), *Ceiba pentandra* (Silk-cotton tree), *Milicia excelsa* (Odum), *Khaya ivorensis* (Mahogany), *Terminalia ivorensis* (Black Afzelia), *Terminalia superba* (Ofram), and *Bambusa spp* (Bamboo) [28]. The area experiences an average annual rainfall of 1038 mm, with a double maxima pattern. The rainy seasons occur from April to June and September to October, while the dry seasons span from August to September and December through February.

For comparison, the Adansi North District (Figure 2) resides within the Ashanti Region's Moist Semi-Deciduous Zone [25]. Covering 853.63 km^2 [25], it represents approximately 4.7% of the Ashanti Region's total area. Similar to Offinso, agriculture thrives here, employing 77% of the labor force due to the favorable climate and ecological conditions [25]. The topography is generally flat or gently rolling, with elevations ranging from 300 m to 410 m above sea level. Unlike Offinso's dense undergrowth, Adansi North features a sparse woody understory and a well-lit forest floor. Teak (Tectona grandis) plantations and taungya system agroforestry define the landscape. Ochrosols, soils suited for cocoa, citrus, and oil palm cultivation, dominate the area and develop well under moderate annual rainfall ranging from 900 mm to 1650 mm [25]. The average temperature sits around 27°C, with annual rainfall averaging between 1250 and 1750 mm [29].

2.2. Research design, sampling technique, and size

The approach for data enumeration was interactive rather than an exercise to extract information from respondents and Key Informants. Questions were posed to farmers in the form of a conversation and not necessarily how they appeared on the data collection tool. Farmers were allowed to interject with their ideas and questions. Enumerators then extract vital details from conversations to complete the data collection process.

This study utilized a multistage sampling approach. To capture the contrasting effects of rainfall and temperature on cocoa production across Ghana's major cocoa-growing regions, we deliberately selected two ecological zones: the Moist Semi-Deciduous Zone and the Dry Semi-Deciduous Zone. Again, the two ecological zones were specifically selected due to the rapid decline in cocoa yield and low standards of living among cocoa farmers indicating the intense impact of climate change [30] Previous studies have assessed cocoa farmers' perceptions of yield and food security but within a single and different ecological zone [31], this study, therefore, sought to explore the relationships

between two unique cocoa zones. In the second stage, we applied purposive sampling to select districts. Offinso Municipality and Adansi North District were chosen due to their established involvement in cocoa production [29], ease of access for researchers, historical yield trends within the districts, and the distribution and accessibility of individual cocoa-growing communities. Purposive sampling continued for community selection within each district. Here, the selection criteria focused on communities with proximity to the district capital for logistical feasibility, a high level of involvement and intensity in cocoa production, readily available data on cocoa farmers residing in the community, and trends in cocoa yields over past years. Following these criteria, three communities were selected from each district: Offinso Municipality (Camp 31, Abofour, and Koforidua), and Adansi North District (Ayokoa, Akrofuom, and Brofoyedu). Stratified random sampling was employed in the fourth stage to ensure representation of both male and female cocoa farmers. Finally, systematic random sampling identified individual cocoa farmer respondents within each gender group. This approach involved selecting every 11th name on a list of farmers within each gender category.

$$\text{By use of Israel's [32] formula} = \frac{N}{(1 + N(e^2))} \tag{1}$$

where n is the sample size, N = population (957), and e = significance level.

Using e (error margin) = 0.05, with a confidence level of 95% a total sample size of 282 was derived. For the Adansi North District, a total of 205 respondents were selected, 73 females and 132 males. In the Offinso Municipality, 26 females and 51 males were sampled, totaling 77 respondents. According to Bisseleua et al. [33], studies have shown that there is uneven male and female participation in opportunities that enhance the quality of life in Africa and inform the stratification of respondents by gender.

To gather primary data, this study employed a combination of semi-structured questionnaires and interviews with Key Informants. Key Informants included personnel from the Cocoa Health and Extension Division (CHED), community leaders (chief farmers), representatives from Produce Buying Companies, leaders of Cocoa Farmer Cooperative Unions, and License Buying Companies. Questionnaires were piloted in Daasu, Offinso Municipality, and Bodwesango, Adansi North District. These communities were chosen due to their similar demographic, political, and economic characteristics to the main study area. Piloting ensured the clarity, user-friendliness (understandability) of the questions, and their effectiveness in measuring aspects relevant to the study objectives [34, 35]. Limitations include the unavailability and unwillingness of some pre-selected respondents from the systematic sampling approach to engage in the data collection exercise, therefore had to be changed. The use of three communities within each district could be increased to enhance accurate representation and long-time duration used in a single enumeration which renders most respondents tired.

2.3. Data analysis

Descriptive statistics was used to analyze farmers' perceptions of a 5-point Likert scale approach on the effect of climate change on their yield, food security, and livelihood statuses. Here 1 indicated "strongly disagree", 2 indicated "disagree", 3 indicated "neutral", 4 indicated "agree", and 5 indicated "strongly agree" to a particular perception statement. Perception indexes for each theme were interpreted using an interpretation scale interval; 1–1.8 (strongly disagree), 1.81–2.60 (disagree), 2.61–3.4 (neutral), 3.41–4.2 (agree), and 4.21–5.0 (strongly agree) according to [36]. The non-parametric Mann–Whitney *U*-test was used to test the statistical difference in the perception of cocoa farmers' response to each statement based on their gender (male or female), district (Offinso Municipality or Adansi North), and access to credit for cocoa farming activities (yes or no). This was done for all statements under the three themes: yield status, food and security status, and income status. In addition, the Relative Importance Index (RII) [37] was used to find the weight attached to each perception statement by farmers.

$$\text{Relative Importance Index (RII)} = \frac{5n_5 + 4n_4 + 3n_3 + 2n_2 + 1n_1}{A * N} \tag{2}$$

where *n5* represents the number of respondents for strongly agree, *n4* is the number of respondents for agree, *n3* is the number of respondents for neutral, *n2* is the number of respondents for disagree and *n1* is the number of respondents for strongly disagree. The highest weight is represented by A = 5, whereas N is the total number of respondents (282).

3. Results

3.1. Perception of cocoa farmers on climate change effect on cocoa yield and livelihoods

The perception of cocoa farmers on the effect of climate change on their cocoa yields and livelihoods is shown in Table 1. Generally, more cocoa farmers agree that they have poor yields on their farms (0.518 ± 0.501). Similarly, they also agree to increased pest and disease attacks on their farms (0.5018 ± 0.501) as a result of climate change. A high proportion of farmers reported experiencing a significant increase in pod rot and mortality of cocoa trees on their farms (0.482 ± 0.501). The perception index for 'Yield status' was 3.92, signifying a high level of agreement among farmers with the statements regarding climate change's impact on yields. However, under the theme "Food security status", cocoa farmers were neutral or disagreed with the statement "*I am not able to afford food"* (0.255 ± 0.437 and 0.248 ± 0.433, respectively). Farmers reported experiencing difficulty accessing food, as evidenced by their agreement with the statement "I am not able to access food." However, they remained neutral on statements regarding reduced market availability ("there is less available food on the market") and limitations on dietary balance ("I am not able to eat a balanced diet"). With a perception index of 2.89, farmers were neutral in their response to the questions under the theme "Food Security Status". These questions were deduced from the four main pillars for food security: food availability, food accessibility, food utilization, and food stability [38]. In addition to the above quantitative outputs, qualitative data revealed;

> *"Though I harvest very little bags of cocoa, I have intercropped annuals like cassava, yam, plantain and vegetables for subsistence purposes. Therefore, my family does not go hungry. I also keep some poultry at home." (cocoa farmer, Offinso District).*

Again, the Offinso District CHED Officer indicated that "*Through a programme termed Farmer Business Group, we have trained cocoa farmers to established some selected food crops and animals which will reduce dependence on income from the sale of cocoa dry beans"*

Table 1
Perception of cocoa farmers on the effect of climate change on their cocoa yields, food security, and income status in the Offinso Municipality and Adansi North District of Ghana

Perception statement	Mean	SE
Yield status		
I have poor yields		
Strongly agree	0.422	0.495
Agree	0.518	0.501
Neutral	0.057	0.232
Disagree	0.004	0.06
Strongly disagree	0.422	0.495
Pest and disease attacks on my farm have increased		
Strongly agree	0.252	0.435
Agree	0.518	0.501
Neutral	0.17	0.376
Disagree	0.046	0.21
Strongly disagree	0.014	0.118
I now use more inputs (fertilizers, labor, pesticides) on my farm		
Strongly agree	0.167	0.373
Agree	0.404	0.492
Neutral	0.316	0.466
Disagree	0.106	0.309
Strongly disagree	0.007	0.084
I have a high incidence of cherrels/pods wilt		
Strongly agree	0.174	0.38
Agree	0.511	0.501
Neutral	0.273	0.446
Disagree	0.043	0.202
Strongly disagree	0	0
I have lost some cocoa trees by death		
Strongly agree	0.216	0.412
Agree	0.482	0.501
Neutral	0.234	0.424
Disagree	0.064	0.245
Strongly disagree	0.004	0.06
Perception index	**3.92**	
Food security status		
I am not able to afford food		
Strongly agree	0.099	0.3
Agree	0.34	0.475
Neutral	0.255	0.437
Disagree	0.248	0.433
Strongly disagree	0.057	0.232
I am not able to access food		
Strongly agree	0.149	0.357
Agree	0.259	0.439
Neutral	0.202	0.402
Disagree	0.248	0.433
Strongly disagree	0.142	0.35
There is less available food on the market		
Strongly agree	0.089	0.285
Agree	0.209	0.407
Neutral	0.284	0.452
Disagree	0.152	0.36
Strongly disagree	0.266	0.443
I am not able to eat a balanced diet		
Strongly agree	0.067	0.251
Agree	0.145	0.353
Neutral	0.379	0.486
Disagree	0.188	0.391
Strongly disagree	0.22	0.415
Perception index	**2.89**	
Income status		
I have less income		
Strongly agree	0.145	0.353
Agree	0.316	0.466
Neutral	0.358	0.48
Disagree	0.16	0.367
Strongly disagree	0.021	0.145
I am unable to provide for my family		
Strongly agree	0.067	0.251
Agree	0.305	0.461
Neutral	0.351	0.478
Disagree	0.213	0.41
Strongly disagree	0.064	0.245
I borrow a lot		
Strongly agree	0.018	0.132
Agree	0.152	0.36
Neutral	0.372	0.484
Disagree	0.216	0.412
Strongly disagree	0.241	0.429
Perception index	**3.00**	

*SE denotes the standard error of the mean. Total number of respondents is 282.

Farmers' perceptions of climate change's impact on income status remained neutral. This is reflected in both the individual statement means and a perception index of 3.00, indicating a neutral response tendency on this theme (Table 1).

The results of the non-parametric Mann–Whitney *U*-test on the difference in response to farmers' perception of gender, district, and access to credit are represented in Table 2. The null hypothesis of no statistical difference between the farmers' responses was individually tested. Specifically, the test of no statistical difference between the perception statements was individually tested against gender, district, and access to credit. Within the 'Yield status' theme, only the statement "I have lost some cocoa trees by death" emerged as statistically significant ($p < 0.05$) in relation to access to credit. This suggests a potential association between climate-induced tree mortality and credit access for cocoa farmers. Analysis of the 'Food security status' theme identified two significant associations at the 5% level. Farmers' gender was associated with the statement "I am not able to access food," while district location influenced responses to "I am not able to eat a balanced diet". Female farmers reported significantly greater difficulty accessing food compared to male farmers. Conversely, farmers' location within the Offinso Municipality was associated with limitations in consuming a balanced diet. Analysis of the 'Income status' theme revealed the highest proportion of statistically significant associations compared to other themes. Six out of nine statements (66.7%) showed significant differences between climate change perceptions and income status ($p < 0.05$) as detailed in Table 2. Perceptions of reduced income ('I have less income') were significantly associated with gender, district location, and access to credit, suggesting these factors may influence climate change's impact on income security.

Table 2
Differences in responses on farmers' perceptions of gender, district, and access to credit basis (n = 282)

Perception statement	Gender	District	Access to credit
Yield status			
I have poor yields			
U-test	−0.83 (0.45)	−0.29 (0.77)	−1.79 (0.85)
Mean rank	M = 138.97, F = 146.57	O = 139.43, A = 142.28	Y = 161.88, N = 138.80
Pest and disease attacks on my farm have increased			
U-test	−1.16 (0.25)	−1.79 (0.73)	−0.10 (0.92)
Mean rank	M = 137.85, F = 148.81	O = 128.50, A = 146.48	Y = 140.27, N = 141.66
I now use more inputs on my farm			
U-test	−0.27 (0.79)	−2.45 (0.14)	−1.27 (0.21)
Mean rank	M = 142.37, F = 139.76	O = 123.11, A = 148.41	Y = 157.50, N = 139.38
I have a high incidence of cherrels/pods wilt			
U-test	−0.92 (0.36)	−0.23 (0.82)	0.54 (0.59)
Mean rank	M = 144.48, F = 135.74	O = 139.88, A = 142.12	Y = 148.06, N = 140.63
I have lost some cocoa trees by death			
U-test	−1.21 (0.23)	0.52 (0.60)	−1.92** (0.05)
Mean rank	M = 137.63, F = 149.24	O = 145.36, A = 140.05	Y = 165.42, N = 138.33
Food security status			
I am not able to afford food			
U-test	−0.44 (0.66)	−0.29 (0.83)	−0.67 (0.50)
Mean rank	M = 140.04, F = 144.41	O = 139.90, A = 142.10	Y = 150.08, N = 140.36
I am not able to access food			
U-test	−2.24** (0.03)	−0.26 (0.81)	0.25 (0.81)
Mean rank	M = 133.99, F = 156.53	O = 143.47, A = 140.76	Y = 138.23, N = 141.93
There is less available food on the market			
U-test	−0.81 (0.42)	−1.04 (0.29)	−0.30 (0.98)
Mean rank	M = 144.20, F = 136.10	O = 149.54, A = 138.48	Y = 141.12, N = 141.55
I am not able to eat a balanced diet			
U-test	−0.58 (0.56)	−2.33** (0.02)	−0.27 (0.79)
Mean rank	M = 139.58, F = 145.35	O = 159.29, A = 134.82	Y = 144.94, N = 141.04
Income status			
I have less income			
U-test	−2.25** (0.03)	−3.61*** (0.00)	−2.39** (0.02)
Mean rank	M = 148.36, F = 126.73	O = 168.90, A = 131.21	Y = 171.97, N = 137.46
I am unable to provide for my family			
U-test	−0.57 (0.58)	−3.93*** (0.00)	−2.26** (0.02)
Mean rank	M = 143.36, F = 137.78	O = 171.36, A = 130.29	Y = 170.39, N = 137.67
I borrow a lot			
U-test	0.13 (0.89)	−0.06 (0.95)	−2.03**(0.04)
Mean rank	M = 141.07, F = 142.35	O = 141.67, A = 141.05	Y = 167.42, N = 138.06

Note: Figures for the *U*-test are *z*-values, and those in the parentheses are *p*-values, *** denotes significance at 1% level, ** denotes significance at 5% level, * denotes significance at 10% level. Alphabets M represents males F, represents females, O represents Offinso Municipality A, represents the Adansi North District, and Y, represents yes whereas N stands for no.

Respondents reported experiencing severe financial hardship due to climate change's impact on cocoa yields.

A farmer stated, *'I barely have money to buy anything into my home, by the moment I sell my cocoa dry beans, the money is finished upon arrival.'* This quote exemplifies the significant financial constraints faced by many cocoa farmers.

Generally, results showed male farmers and those residing in the Offinso Municipality reported lower income levels. This suggests a potential spatial or gender-based disparity in income security. Interestingly, access to credit also emerged as a factor associated with lower income. However, these same farmers with access to credit indicated difficulty providing for their families, suggesting the credit might be used to cope with income shortfalls rather than boost income generation. This highlights the complex interplay between income, access to credit, and household well-being in the context of climate change.

Table 3 shows the RII of all perception statements indicating the statements with the highest and least importance attached. Analysis of RII revealed farmers' primary concern to be declining cocoa yields. The statement "I have poor yield" received the highest RII (0.87), signifying its critical importance. This concern aligns with a farmer's observation: "I used to harvest about four to five bags of cocoa dry beans per acre, now I do not harvest up to a bag per acre". Pest and disease attacks (RII = 0.79) and loss of cocoa trees by death (RII = 0.77) were ranked second and third in importance, respectively. These findings highlight the multifaceted nature of climate change's impact on cocoa production. Interestingly, "I am not able to eat a balanced diet" received the lowest RII (0.53),

Table 3
Relative Importance Index to perceptions statement by cocoa farmers in Offinso Municipality and the Adansi North District of Ghana

	Perception statement	RII	Rank
1	I have poor yields	0.87	1st
2	Pest and disease attacks on my farm have increased	0.79	2nd
3	I now use more inputs on my farm	0.72	5th
4	I have a high incidence of cherrels wilt	0.75	4th
5	I have lost some cocoa trees by death	0.77	3rd
6	I am not able to afford food	0.64	8th
7	I am not able to get access to food items	0.61	10th
8	There is less available food on the market	0.54	11th
9	I am not able to eat a balanced diet	0.53	12th
10	I have less income	0.69	7th
11	I am unable to fully provide for my family	0.62	9th
12	I borrow money a lot	0.70	6th

suggesting food security might not be a primary concern for farmers. This is supported by a farmer's statement: "As for food to eat, it is not a challenge, I have in abundance. There are times I give some of the yield from my farm to researchers like you when they come around for at no cost because there is no market for it here." However, further investigation into potential variations in food security across different farmer subgroups or locations might be warranted.

4. Discussion

Generally, farmers agreed to the perception statement on "Yield Status" with an index of 3.92. Climate change poses a significant threat to cocoa production in Ghana. Research highlights several detrimental impacts, including reduced yields on Ghanaian farms, likely due to factors associated with climate change [17, 39]. Changing weather patterns and environmental conditions are believed to contribute to a rise in pest and disease outbreaks, further jeopardizing cocoa crops [40]. Farmers are experiencing diminishing returns despite the increased application of agricultural inputs, suggesting a potential negative effect of climate change on input effectiveness [41]. Climate change factors may also be contributing to an increase in cocoa tree death and disruptions to the delicate flowering cycle of cocoa trees, both of which can significantly reduce farm productivity [10, 30]. This reported trend is not different from the results in the present study as farmers agreed to perception statements on the negative impact of climate change on their farms, indicating the persistence of the impact of climate change.

Farmers' responses regarding food security (affordability, accessibility, utilization, and stability) suggest that despite experiencing poor cocoa yields, their access to food appears to be unaffected. Farmers remained indifferent and, thus, neutral in their response to perception statements. This is so because cocoa farmers diversify their production into food crops for either subsistence purposes, commercial purposes, or both in all growing areas in Ghana. Due to this, though they might harvest very little cocoa dry beans, it does not have a direct relationship to their food security status [31, 42]. Again, in Danso-Abbeam et al. [43], it was reported that all rural dwellers diversify their income sources and these were mainly into rearing of animals or growing food crops which can be used for subsistence purposes. Thus, low yield from cocoa farms will not have direct implications on the food security status of cocoa farmers' households. To support this, qualitative data revealed a farmer clearly stating

> *"As for food to eat, it is not a challenge, I have in abundance. There are times I give some of the yields from my crop farm to researchers like you when they come around for free because there is no market for it."*

Furthermore, in Salifu and Salifu [44], it was reported that farmers had the privilege to establish food crops they could use for subsistence purposes.

Analysis of 'Income status' revealed a concerning trend. Farmers exhibited strong agreement with statements regarding low income, frequent borrowing, and difficulty providing for their families. This suggests that the diversification efforts undertaken by farmers, potentially as a response to climate change, might not be generating sufficient profits to improve their financial security. Cocoa dry beans are the primary source of income for farmers, as evidenced by previous research [2] and corroborated by the findings of the present study.

The Mann–Whitney *U-test* identified a statistically significant association ($p < 0.05$) between access to credit and the perception of cocoa tree death ('I have lost some cocoa trees by death'). Farmers who have access to credit indicated they have lost some cocoa trees to death. This can be explained as individual farmers who have lost cocoa trees to death, see the severity of climate change impact and in return can present a better appeal to creditors for assistance. As stated by van Vliet et al. [2], extreme events can bring farmers into a negative spiral or poverty; therefore, farmers are willing to go the extra in enhancing their living conditions. Male farmers had less income compared to their female counterparts, and this is probably explained as a result of the high dependency rates of families on men [45]. This makes men spend more and causes them to perceive returns on cocoa to be less due to higher expenditure.

Income and family support revealed a spatial disparity. Farmers residing in the Offinso Municipality reported lower income and difficulty providing for their families compared to those in the Adansi North District. This aligns with findings by Anyimah et al. [46] who attributed lower yields in Offinso to high cocoa stress from factors like higher temperatures and lower precipitation. Reduced yields can translate to lower income for farmers [46]. Access to credit also emerged as a factor associated with lower income, challenges in supporting families, and high borrowing levels. This could be explained by a cycle of debt. Low income

from cocoa sales might drive farmers to seek credit to improve production. However, poor returns on investments or potential misuse of credit could lead to increased debt and continued financial strain, as noted by Nyemeck et al. [47] regarding the influence of farm size and productivity on credit decisions.

Declining cocoa yields emerged as the primary concern for farmers. Analysis of RII revealed the statement "I have poor yield" receiving the highest score (0.87), signifying its critical importance to farmers. This agrees with the findings of Kosoe and Ahmed [48] who stated that climate change has a tremendous negative impact on cocoa yields. Other reports [49, 50] also agree to reduce pod numbers on cocoa trees due to climate change impact. Studies in Indonesia by Idawati et al. [51] documented similar findings of declining cocoa yields. They attributed this phenomenon to climate change and limitations in farmers' adaptive capacity. Respondents were generally unprejudiced when it came to perception statements on food security. This is because though yields from cocoa farms are mostly poor, the majority of cocoa farmers cultivate food crops for subsistence use; hence, poor yields do not affect their food security status as discussed earlier [31, 42].

Diversification strategies employed by cocoa farmers appear to be associated with improved income security and food availability, as evidenced by an analysis of their responses. A higher proportion of farmers disagreed with the statement "I borrow a lot", suggesting a potential for income diversification strategies to reduce reliance on credit. This finding aligns with Hashmiu et al. [31], who reported that cocoa farmers often diversify into cashew and food crop production to lessen their dependence on cocoa income. This diversification strategy could potentially explain the lower incidence of borrowing observed in our study.

Furthermore, the statement "I am not able to eat a balanced diet" received the lowest RII score (0.53). This suggests that food security might be a less pressing concern for farmers compared to other issues. This observation aligns with the reported diversification into food crop production by Hashmiu et al. [31] and Acheampong et al. [52]. By cultivating food crops alongside cocoa, farmers might be able to secure their food supply, reducing their dependence on purchasing food and potentially contributing to a lower RII for balanced diet.

There is a need for researchers, Governments, and Non-Governmental organizations to swiftly find long-lasting solutions to activities that lead to climate change. There is a need to engage all actors to find effective mitigation and adaptation strategies within the shortest possible time. This will in tend help cocoa farmers gain friendly environmental conditions to continue production. Some successful climate change mitigation strategies that have been employed in comparable cocoa-growing regions include integrating shade trees into cocoa farms (agroforestry) for microclimate regulation has been effective in mitigating heat stress [53]. Studies demonstrate the value of utilizing climate-resilient cocoa varieties bred for tolerance to drought, heat, and pests and diseases, which can significantly improve yields in a changing climate [54]. Improved soil management practices such as composting, mulching, and cover cropping have been shown to enhance soil moisture retention, fertility, and beneficial microbial communities [55]. Water management techniques, including rainwater harvesting and efficient irrigation, can ensure adequate moisture availability during dry periods, as successfully implemented in Turkey [56]. Finally, employing integrated pest management strategies that promote natural predators, biological controls, and judicious use of pesticides can minimize reliance on chemical inputs and protect biodiversity, as documented in Deguine et al. [57]. Furthermore, concentration should be given to adaptive measures that seek to enhance their financial profit margins such as alternative livelihood strategies and savings systems (Village Savings and Loans) instead of food for consumption. Attention should be drawn to the pricing of cocoa and not just the sustainability of the ecological production system. Organizations such as the Cocoa Farmer Cooperative Unions and other actors in the cocoa production sector should focus on lucrative business options within the specific communities of cocoa farmers. This will increase their profit margins and enable them to have better living conditions.

5. Conclusions

Findings provide evidence that cocoa farmers perceive climate change to have a negative impact on their yields. This aligns with the high RII assigned to the statement "I have poor yield", suggesting that declining cocoa production is a primary concern. Despite increased inputs, farmers report harvesting very little, highlighting the potential ineffectiveness of traditional farming practices in the face of a changing climate. This reinforces the need for further research into climate-resilient agricultural techniques.

Farmers' responses regarding food security were more neutral. The low RII assigned to statements on balanced diet suggests that food insecurity might not be a major concern for cocoa farmers in both districts. This could be due to successful diversification strategies, as observed in the reported neutrality towards statements about food availability. To gain a more comprehensive understanding of the relationship between diversification and food security, future studies could investigate the specific crops cultivated and their influence on the diversity of household diets. Additionally, longitudinal studies could provide a clearer picture of how climate change might influence this observed relationship between diversification and food security.

Finally, farmers' responses regarding income align with the potential limitations of diversification efforts. Agreement with statements highlighting low income suggests that while farmers may have diversified their livelihoods, these efforts might not be generating sufficient income to improve their financial security. This is further supported by the reported need for continued borrowing. Further research is needed to explore the effectiveness of various diversification strategies in enhancing income security for cocoa farmers in the context of climate change.

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Ethical Statement

This study does not contain any studies with human or animal subjects performed by any of the authors.

Conflicts of Interest

The authors declare that they have no conflicts of interest to this work.

Data Availability Statement

Data available on request from the corresponding author upon reasonable request.

Author Contribution Statement

John Tennyson Afele: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Data Curation, Writing - Original Draft, Writing - Review & Editing, Visualization. **Olivia Agbenyega:** Conceptualization, Methodology, Validation, Resources, Writing - Review & Editing, Supervision, Funding acquisition. **Victor Rex Barnes:** Conceptualization, Resources, Supervision, Project administration, Funding acquisition. **Steve Amisah:** Conceptualization, Project administration, Funding acquisition. **Finn Plauborg:** Writing - Review & Editing. **Søren Marcus Pedersen:** Writing - Review & Editing. **Torsten Rødel Berg:** Conceptualization. **Joseph Anokye:** Methodology, Data Curation. **Stephen Yaw Opoku:** Methodology, Data Curation. **Eunice Nimo:** Conceptualization, Data Curation, Writing - Review & Editing, Visualization. **Richard Asante:** Methodology, Data Curation. **Evans Dawoe:** Conceptualization, Supervision.

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