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Cocoa Farmers' Perceptions of Drought and Adaptive Strategies in the Ghana–Togo Transboundary Cocoa Belt

Afi Amen Christèle Attiogbé [1], Udo Nehren [2,*], Emmanuel Quansah [3], Enoch Bessah [4], Seyni Salack [5], Jean Mianikpo Sogbedji [6] and Sampson K. Agodzo [4]

[1] West African Science Service Centre on Climate Change and Adapted Land Use, Kwame Nkrumah University of Science and Technology (WASCAL KNUST), Kumasi AK-385-1973, Ghana; attiogbe.a@edu.wascal.org
[2] Institute for Technology and Resources Management in the Tropics and Subtropics (ITT), Faculty of Spatial Development and Infrastructure Systems, University of Applied Sciences, 50679 Cologne, Germany
[3] Department of Meteorology and Climate Science, College of Sciences, Kwame Nkrumah University of Science and Technology, Kumasi AK-385-1973, Ghana; equansah.cos@knust.edu.gh
[4] Department of Agricultural and Biosystems Engineering, Kwame Nkrumah University of Science and Technology, Kumasi AK-385-1973, Ghana; enochbessah@knust.edu.gh (E.B.); skagodzo7@usa.net (S.K.A.)
[5] WASCAL Competence Center, West African Science Service Center on Climate Change and Adapted Land Use (WASCAL CoC), Ouagadougou 9507, Burkina Faso; salack.s@wascal.org
[6] Department of Soil Sciences, Université de Lomé, Lomé 01 BP 1515, Togo; msogbedji@univ-lome.tg
* Correspondence: udo.nehren@th-koeln.de

Abstract: This study investigated the perception of drought by cocoa farmers and explored the effectiveness of adaptive strategies (ASs) used in smallholding farms in the transboundary region between Ghana and Togo. Drought significantly threatens cocoa production in this region, affecting farmers' livelihoods and cocoa supply chains. This study used a multistage sampling approach, which involved surveys with questionnaires administered to 330 cocoa farmers throughout the study area, along with on-site observations. Statistical analysis included binary logistic and Poisson regression models to explore the relationship between farmer socioeconomic characteristics and adaptation practices. The findings revealed that cocoa farmers in the region have a nuanced understanding of drought, attributed to changing climatic patterns and unsustainable land management practices such as deforestation. To mitigate its impacts, farmers employ a variety of ASs, including investment in farm management, soil management, and intercropping with crop diversification. Furthermore, socioeconomic factors, including age, formal education, household size, land tenure right, adaptation cost assessment, and an underestimation of self-efficacy, were shown to affect the choice in the AS. Among the ASs adopted, only farm management practices (weeding, pruning, fertilizer application, etc.) significantly improved the cocoa yield. This study contributes to understanding drought as a critical issue for cocoa farmers and the adaptation practices used by smallholder cocoa farmers. Given that among the strategies adopted, only farm management practices, also known as good agricultural practices (GAPs), significantly improves yield, this study recommends well-designed and innovative packages of sustainable farm management based on farm and owner characteristics. These include irrigation schemes, timely soil fertilizer monitoring and supply, and the provision of drought-resistant varieties along with technical itineraries. Additional interventions require drought emergency responses, with other factors such as education and financial support mechanisms expected to improve farmers' timely decision-making to adapt and improve cocoa production resilience to drought episodes in international transboundary regions with complex governance structures.

Keywords: cocoa farming; adaptation strategies; smallholding farms; Ghana; Togo

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1. Introduction

It is commonly acknowledged that climate change increases interannual variability and the occurrence of extreme climate events. Drought is one of these emerging climate extremes considered as a devastating global environmental threat. Its effects are widespread and inevitable [1,2], creating harsh environments through reduced rainfall and limited availability of soil moisture [3]. Drought affects the sustainability of economic activities, including agriculture, which is the main economic activity of developing countries [4]. Since climate change is projected to persist, extreme events such as drought are projected to severely impact key sectors such as agriculture, health, and water [5,6].

Cocoa is a highly produced commodity in West Africa and has economic relevance to producing countries, providing livelihoods for millions of smallholder farmers. However, changes in climate patterns pose a growing threat to cocoa cultivation, with drought emerging as a major concern. Cocoa production requires favorable climatic conditions at every stage of its growth. Therefore, any change in climate patterns can result in reduced cocoa yields, as well as reduced cocoa bean quality. Several studies have revealed that rainfall and temperature are more important than any other climatic factors for cocoa growth, as they are sensitive to soil water deficiency [7–10]. In the cocoa belt of West Africa, including Ghana and Togo, climate change is expected to negatively affect cocoa productivity and reduce the suitability of the area for cocoa cultivation. Furthermore, climate change has the potential to modify the development of cocoa insect pests and diseases and could change the resistance of the crop to pests and diseases [11–13]. The high relative humidity resulting from changing climate can also intensify the incidence of black pods, a major cocoa disease [13]. The results of recent studies have shown that cocoa cultivation cannot survive in certain regions, including the region of interest in this study, without adaptation [10,14]. Transformation, resilience, expansion, and systemic strategies were some key recommendations of research to improve the productivity of cocoa farms and the livelihoods of farmers. However, it is agreed that most of these adaptive strategies (ASs) are quite costly and difficult for the average cocoa farmer to adopt because they require well-designed programs and key stakeholders often prioritize short-term supply over long-term climate change considerations [15].

According to [16], cocoa farmers rely on indigenous knowledge to adapt and mitigate the effects of climate-related impacts, thus developing resilience. However, these strategies are likely insufficient to deal with potential climatic events of unknown magnitude, which would require the development of novel solutions. It is believed that through the analysis of farmers' strategies based on their traditional knowledge, it is possible to identify the adaptation mechanisms they currently use and subsequently determine additional mechanisms that would promote sustainability in these systems [17,18].

Adaptation is identified as one of the policy options to reduce the negative impact of a shock on a system [19]. In the context of climate change, adaptation involves initiatives and measures to reduce the vulnerability of natural and social systems to actual or expected effects due to climate change. Adaptation activities include behavioral, institutional, and technological adjustments in society [8]. Following Moser and Ekstrom's model, the adaptation process can be subdivided into three major phases: (i) understanding the problem, (ii) planning options, and (iii) managing the options that were made and put into action [20]. Ref. [21] highlights the empirical view of the first phase, which refers to farmers' knowledge and perceptions of the threat (drought, in this case), specifically whether individuals or social groups can discern a long-term change from the day-to-day variability of local weather. This awareness component is important and key to addressing drought vulnerability and plays a decisive role in reducing vulnerability and increasing resilience.

Substantial studies have been conducted, with the main focus being the exploration of adaptive strategies used by cocoa farmers in West Africa to address climate change challenges. This interest is due to the increasing cocoa yield gap, concerns about predicted climate extremes, and the superior economic performance of cocoa crops compared to other crop options in the region [12,22]. However, specific knowledge about ASs of cocoa cropping systems in response to climate extremes such as drought is limited. Given the aforementioned issues, it is critical to understand ASs and the internal and external aspects that influence farmers' adaptive capacity to address drought challenges. This study aims to fill this gap by examining the perceptions of cocoa farmers of drought and exploring the ASs employed in smallholding farms in the Ghana–Togo border region. It reports on the findings of a survey conducted in smallholder cocoa communities in a transborder region of Ghana and Togo. According to the study objectives, it is expected that farmers have different perceptions of drought and that sex, age, educational status, migrant status, and family/household status within communities will influence their choice in ASs. Specifically, this study aims to (i) review available adaptation studies on climate change and drought, (ii) analyze cocoa farmers' perceptions of drought, and (iii) assess their adaptation strategies and the drivers behind them in response to drought challenges.

2. Adaptation Strategies of Cocoa Farmers to Climate-Related Risks

Agriculture is the main activity of many communities in the global south and has been extensively studied by scholars. It is argued that farmers possess adaptive capacity due to their experience and knowledge in agricultural management and their farming enterprises [22]. General adaptive strategies outlined in agricultural system studies include changes in planting dates, the use of new and resistant varieties (such as early maturing crop varieties that are less sensitive to climate stress), the adoption of off-farm activities, and migration [23–25].

2.1. Characteristics of Adaptive Behavior in Cocoa Production

The literature reports some findings on ASs specific to cocoa crop systems, and they include behavioral, institutional, and technological adjustments. In terms of behavior, it is argued that cocoa farmers adapt their practices through activities such as spraying, fertilizer application, weed control, and other maintenance tasks such as regular pruning, removal of damaged, diseased, or dead pods and trees, removal of mistletoe from trees, clearing piles of cocoa husks, as well as draining stagnant water on the farms. However, it is crucial to emphasize that these activities vary in frequency depending on the socioeconomic status of the farm household. For instance, ref. [26] found that cocoa farmers reduced the density of cocoa trees on farms while increasing the density of plantain saplings to provide more shade and increase economic value. Ref. [27] highlighted permanent densification and cutting-back practices, while [28] found that farm management practices, namely the control of capsid and black pod disease, fertilizer application, and pruning, were used by cocoa farmers in Ghana. Prayers, changes in cropping patterns, and control of soil erosion are also common strategies employed by farmers. Irrigation and crop diversification are additional minor strategies adopted by farmers [7]. Agroforestry practices are a widely promoted and utilized strategy to mitigate climate change effects on cocoa [29]. Although agroforestry practices typically result in a 25% lower yield compared to monoculture systems, they can contribute to food security and diversified incomes for cocoa households [30]. It is important to note that cocoa yields in Agroforestry Systems (AFSs) are not always low, as often assumed. They can vary under different management conditions of the system, such as the density and height of the shade trees, shade coverage, and other ecological properties of the associated species [31–33]. Additionally, studies have indicated that farmers' practices such as weeding, seedling planting, insect pest and disease control, bush clearing, tree felling, pruning, and burning before planting are considered effective ASs for cocoa production.

Ref. [34] found that improving nutrient management through better potassium (K) applications based on soil types, location, cocoa varieties, and bio-stimulants are complementary strategies to be used alongside others to improve cocoa's drought resilience.

From a technological and institutional adaptation perspective, the switch to hybrid varieties is one of the most important measures [35–37]. In addition, some experts highlight certification as a promising AS [38,39]. Recent studies have shown that crop insurance has a significant positive impact on cocoa farmers' income in some cocoa-growing regions and have recommended well-designed agricultural insurance policies that accommodate various categories of farmers to enhance their incomes and reduce poverty. Awareness, knowledge, and promotion of insurance strategies through public seminars, training, and media advertising are also seen as important for achieving AS goals [40]. Another promising strategy is contract farming. It is argued that this practice introduces farmers to new technologies and thus helps those with limited financial, health, and human resources to improve their livelihoods [41]. However, this practice needs to be adapted to the local context to increase farmers' interest. Similarly, ref. [42] found that farmers' membership in cocoa cooperatives and obtaining organic certification are strategic measures to make cocoa farms more resilient in the face of climate change. In addition, cocoa growing areas should be reclassified as cocoa districts to facilitate management and monitoring by cocoa institute officials [10,14].

After investigating the implemented and planned adaptation strategies of cocoa farmers in response to a changing climate in Ghana, ref. [17] found that, on one hand, some cocoa farmers were not adapting their farming practices to the climate, while on the other hand, a group of cocoa farmers was focused on on-farm management. These differences in the choice of adaptation were accordingly explained by socioeconomic characteristics such as age, educational level, gender, economic status, and land ownership. Cocoa rehabilitation decisions, along with changing cocoa farms to other useful crops like coffee and rubber trees, are also strategies being considered. It is concluded that cocoa plants are nearing the end of their useful lives [43].

2.2. Driving Mechanisms in the Adaptation of Cocoa Cultivation

It is acknowledged that the above-highlighted ASs are driven by socioeconomic characteristics such as gender, marital status, educational level, household size, engagement in other economic activities, farming experience, access to extension services, access to credit/loans, and cocoa income, all of which influence the cocoa farmers' choice in AS [3,44]. Other scholars have found that the AS adopted by farmers is influenced by indicators such as monthly income, type of land tenure, and perception of climate risk [17,45,46]. However, the relationship between perception and adaptation behavior in cocoa farming is not always correlated but is influenced by factors such as institutional support, access to credit, and farmer cooperatives, which play a crucial role in enabling farmers to translate their perceptions of climate risks into concrete adaptation actions. For example, cocoa farmers who recognize drought risks may not adopt appropriate strategies due to financial constraints or lack of knowledge about effective adaptive practices [47,48]. Therefore, the scientific question addressed in this study is not merely whether cognition influences adaptation but also how socioeconomic and institutional factors shape this relationship and consequently the effectiveness of adaptation strategies adopted by cocoa farmers, particularly in mitigating drought risks.

The review of ASs reported by cocoa farmers in response to climate challenges revealed that no specific ASs were focused on measures to address drought issues. We consider this critical, as drought remains one of the most damaging hazards to cocoa farms and is expected to become even more extreme under climate change. This study therefore sought to examine the AS developed by cocoa farmers to combat drought and assess their effectiveness. However, a starting point was to assess farmers' perceptions of drought challenges, as it is argued that ASs are a result of perceiving a challenge as a threat. Furthermore, understanding the socioeconomic drivers behind the AS used could help to better formulate recommendations for sustainable cocoa production.

3. Methodology

3.1. Study Area

The study area covers the southern part of the Atakora Mountains in the southwest of Togo, which shares a border with Ghana (Figure 1). Ghana and Togo are ranked second and 15th among cocoa-producing countries worldwide, respectively [49].

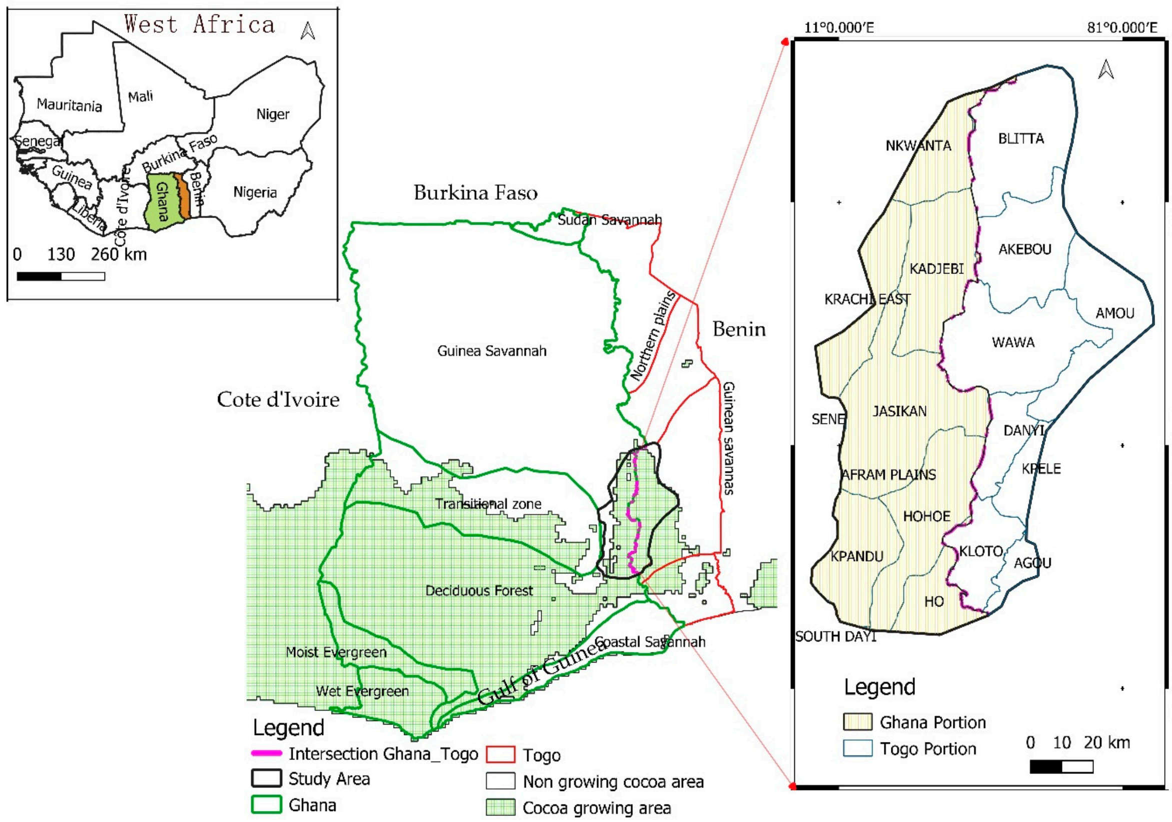

Figure 1. Study area.

The region experiences a transitional sub-equatorial climate with four seasons: a "major rainy season" from March to July, followed by a "minor dry season" in August. This is succeeded by a "major dry season" from November to February, preceded by a "minor rainy season" of two months from September to October [50]. The annual temperature ranges from 21 to 28 °C, and the annual rainfall ranges from 1300 to 1800 mm. The study area is suitable for the production of cocoa and coffee. In addition to these tree crops, the area is also recognized as the "basket" of fruit, vegetables, and spices in both countries. Most farming households own livestock, which consists mainly of cattle, sheep, goats, and poultry, while very few are involved in off-farm activities.

3.2. Data Collection

This study was conducted from May to September 2023. A sample of 330 cocoa farmers was randomly selected using the multistage sampling approach for individual questionnaire administration from fifteen communities, seven in Ghana and eight in Togo (Figure 1). This sample was chosen from 16,000 cocoa farmers using the Yamane method, Equation (1).

$$n = \frac{N}{1 + N(e^2)} \tag{1}$$

where n is the sample size, N is the population size, and "e" is the error margin (acceptable sampling error); for this study, a 95% confidence interval was used, thus p-value = 0.05.

After selecting the cocoa districts, three to five communities were chosen within each district where cocoa farming is practiced intensively. Individuals were randomly selected to conduct the survey. The research relied on primary and secondary sources of data. Primary data were obtained through a questionnaire administered to the selected participants which included open-ended and closed-ended questions. The evaluation of drought perceptions included farmers' perceptions of drought severity and the impacts they have experienced. The questionnaires also included socioeconomic characteristics and farm details. Secondary data consisted of documented information obtained from the Cocoa Institutes on their support for cocoa farmers. The objective of collecting this information from cocoa institutes was to gain a clear picture of AS patterns in the area. After carefully reviewing the literature and consulting experts, the questionnaire was considered appropriate, coded in KoboTool Box (version 2.0), and pretested for data collection to answer the research questions raised for this study.

3.3. Data Analysis

The responses to the survey questions were first summarized by coding the information in Microsoft Excel (2016), and statistical software R (version 2022.12.0) was used for the statistical analysis. Descriptive analysis, such as frequencies and percentages, was used to summarize the data. A chi-square test was performed to test the differences in variables between Ghana and Togo. Individual questions on knowledge and perception of climatic changes, causes, and related impacts (Table 1) were used as dependent variables. The Wilcoxon rank sum test was performed to test the differences between Ghanaian farmers and Togo. Principal Component Analysis (PCA) was conducted to reduce the data dimensionality of socioeconomic characteristics collected from cocoa farmers. A binary logistic regression was performed to assess the relationship between reduced socioeconomic characteristics and different categories of ASs. Furthermore, a Poisson regression model was performed to test the relationship between the characteristics of the farmer's household and the number of ASs using the command glm().

Table 1. Socioeconomic variables of cocoa farmers of the study area.

Characteristic Variables	**Ghana**		**Togo**		**Profile Comparison**		
F (Frequency), P (Percentage)	**F**	**P (%)**	**F**	**P (%)**	**X-sq.**	***p*-Value**	**Remarks**
Gender					0.83	0.36	no difference
Female (0)	11	9.24	12	5.69			
Male (1)	108	90.76	199	94.31			
Marital status					0.05	0.82	no difference
Married	106	89.08	191	90.52			
Unmarried	13	10.92	20	9.48			
Ethnical background					9.92	<0.001	difference
Native to the area	98	82.35	138	65.4			
Nonnative	21	17.65	73	34.6			
Number of cocoa plots					16.38	<0.001	difference
≤2	61	51.26	156	73.93			
>2	58	48.74	55	26.07			
Primary source of income					16.15	<0.001	difference
Cocoa	110	92.44	155	73.46			
Another activity	9	7.56	56	26.54			
Use of hired labor					8.38	<0.001	difference
Yes	97	81.51	139	65.88			
No	22	18.49	72	34.12			
Consumption water availability					10.25	<0.001	difference
Yes	29	24.37	90	42.65			
No	90	75.63	121	57.35			
Farmer age (years)					1.20	0.55	no difference
<35	11	9.24	16	7.58			
35–60	75	63.03	124	58.77			
>60	33	27.73	70	33.18			

Table 1. *Cont.*

Characteristic Variables	Ghana		Togo		Profile Comparison		
F (Frequency), P (Percentage)	**F**	**P (%)**	**F**	**P (%)**	**X-sq.**	***p*-Value**	**Remarks**
Household size					1.87	0.39	no difference
< 5	23	19.33	34	16.11			
from 5 to 10	79	66.39	135	63.98			
>10	17	14.29	42	19.91			
Formal education					13.18	<0.001	difference
Not attended	1	0.84	7	3.32			
Primary	94	78.99	127	60.19			
Secondary	23	19.33	76	36.02			
Tertiary	1	0.84	1	0.47			
Cocoa plantation age (years)					9.45	0.01	no difference
<7 years	12	10.08	15	7.11			
from 7 to 30	97	81.51	151	71.56			
>30	10	8.4	45	21.33			
Average farm size (in hectares)					67.00	<0.001	difference
<1	5	4.2	91	43.13			
from 1 to 3	90	75.63	112	53.08			
>3	24	20.17	8	3.79			
Experiences in cocoa farming (years)					1.55	0.46	no difference
<5	6	5.04	13	6.16			
from 5–30	107	89.92	170	80.57			
>30	6	5.04	28	13.27			
Land tenure right					3.24	0.20	no difference
Inherited	65	54.62	133	63.03			
Purchase	19	15.97	25	11.85			
Sharecropping	49	41.18	69	32.7			
Distance to the farm					12.04	<0.001	difference
Close (0–2 km)	17	14.29	66	31.28			
Moderate (2.1–5 km)	51	42.86	67	31.75			
Distant (>5 km)	51	42.86	78	36.97			
Previous land use of the cocoa farm					52.22	<0.001	difference
Forest	94	78.99	82	38.86			
Old cocoa farm	19	15.97	100	47.39			
Old coffee farm	0	0	6	2.84			
Short fallow land	6	5.04	15	7.11			
Unknown	0	0	8	3.79			

Considering n independent observations $y_1, \ldots, y_n$ for which we assume a Poisson distribution conditionally on a set of p categorical or numerical covariates x_j, for $j = 1, \ldots, p$. The model is given by Equation (2):

$$\ln(E[y_i|x_i]) = \ ln\lambda_i = \beta_0 + \beta_1\ x_{i1} + \beta_p\ x_{ip} = x_i^T\beta \tag{2}$$

with $i = 1, \ldots, n$, $x_i^T\beta = \left(1, x_{i1},\ \ldots,\ x_{ip}\right)^T$, and $\beta = \left(\beta_0,\ \ldots,\ \beta_p\right)$. The natural link function between the dependent variable and the independent variable is the log link. This ensures that $\lambda_i\ \geq 0$ and follow Equation (3) as:

$$\mathrm{E}[y_i|x_i] = \lambda_i = e^{\beta_0+\beta_1\ x_{i1}+\beta_p\ x_{ip}=x_i^T\beta} \tag{3}$$

3.4. Study Limitations

Some limitations of this study are highlighted and should be taken into account in future studies to provide more insight. First, the sample size may not fully represent the range of farmer experiences across other locations, which may limit the applicability of the findings to other cocoa-producing countries, given the focus on only two regions: Ghana and Togo. Furthermore, the use of farmers' self-reported data raises the possibility of recollection bias or other errors, which could compromise the accuracy of the findings. This study's temporal scope is further constrained by the fact that it does not account for how adaption techniques may alter over time in response to shifting climatic and economic conditions, although this has been addressed in the discussion section.

Another drawback is that this study skips over qualitative elements such as historical and cultural influences, which can shed more light on the reasons behind farmers' decisions to embrace or reject particular tactics. Additionally, while this study acknowledges the importance of financial access, it does not thoroughly examine specific financial tools such as microloans or insurance policies, which may offer viable solutions to improve farmers' adaptive skills. Lastly, age-related biases were also observed, as older farmers were less likely to adopt new ASs, but this study does not fully explore how younger generations could embrace more innovative or technological approaches. Addressing these limitations in future research could provide a more comprehensive understanding of the drivers and barriers to effective adaptation planning in cocoa farming.

4. Results

4.1. Socioeconomic Profile of Cocoa Farmers in the Ghana–Togo Transboundary Cocoa Belt

The characteristics and attributes of cocoa farmers in the study area are summarized in Table 1. Cocoa farmers were predominantly male, with females comprising less than 10% of the total sample size. In the Togo region, 65% of the farmers were native to the area, while 82% were natives of the area in the Ghana region; the remainder identified as migrants. The majority of households consisted of 5 to 10 members. Cocoa farmers had experience ranging from 5 to 30 years and owned their farms through inheritance, sharecropping, or purchase contracts. No significant differences in these characteristics were observed between the two investigated regions (p-value = 0.20).

In terms of formal education, most farmers had completed primary school, with less than 35% having reached the secondary level. The literacy rate was higher in the Ghana region (79%) compared to Togo (60%). More than 60% of the farmers cultivated less than two plots, with an average farm size of one hectare. They faced challenges related to shortages of hired labor and water availability, especially during dry periods. In Togo, cocoa farming contributed less than three-quarters of household income, while in Ghana, 92% of the respondents' households derived 75 to 100% of their income from cocoa production. Other crops, such as plantain, cassava, and maize, together with livestock rearing, supplemented household incomes.

The size of the farms ranged from 1 to 3 hectares, with small farmers dominating cocoa cultivation. Cocoa farms were established on primary forest land, old cocoa and coffee farms, and fallow land, the majority acquired by inheritance (60%).

4.2. Cocoa Farmers' Perceptions of Drought

Figure 2 shows that cocoa farmers in the study area have a good understanding of climate challenges and perceive drought as a significant threat to cocoa production and their livelihoods, among other limiting factors. Most farmers (60–80%) perceived an increased frequency of drought over the past four decades and considered changes in rainfall patterns, rising temperatures, and deforestation to be contributing factors (Figure 3). There were no significant differences in drought perceptions between farmers in the Ghana and Togo regions (p-value = 0.747). Evidence of drought and climate-related phenomena could explain these similarities in the awareness of drought issues. The knowledge of the farmer about drought also highlights its understanding based on experience and the crucial importance of addressing the drought challenge.

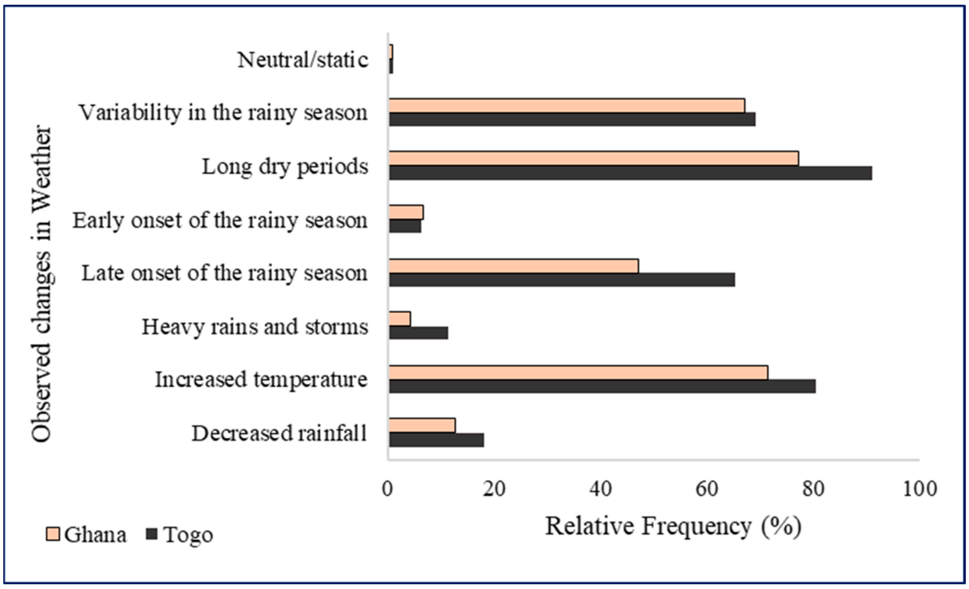

Figure 2. Perceptions of cocoa farmers about drought.

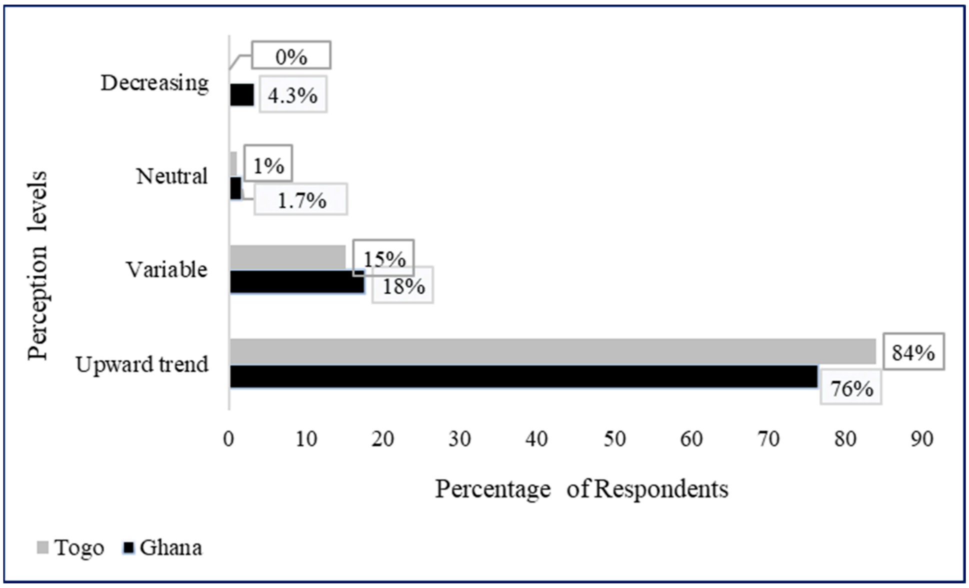

Figure 3. Perception of the trend of drought intensity among cocoa farmers.

4.3. Drought Adaption Strategies Used by Cocoa Farmers

In response to drought challenges, farmers have adopted various ASs to cope with and minimize its impacts on cocoa yields (Figure 4). These can be categorized into the following:

(i) Farm management practices: Farmers integrate or reduce shade trees, use more drought-resistant cocoa hybrid varieties, and increase fertilizer use. Other strategies that cocoa farmers use to cope with drought include regular pruning, black pod disease control, capsid control, changes in weeding schedules, and replacement of dead cocoa trees. For example, some farmers reduced weeding from three times to once a year to maintain soil moisture for cocoa trees, especially in the early stages of farm establishment. The farmer argues that excessive fertilizer use improves the resilience of the cocoa tree to avoid further impacts. The decision to integrate or reduce shade trees within the farmland depends on the farmer's perception of the role of shade trees since some perceive them as having negative effects while others see positive effects under drought conditions. The difference in associated shade tree values may help distinguish shade trees with an optimum value. The use of black pod disease and capsid control, which are recognized as agronomic practices, was mentioned as a way to protect cocoa trees from further damage after drought stress. Some cocoa farmers highlighted the setup of firewalls, as it is known that severe drought contributes to bushfires.

(ii) Soil and water management: Some respondents reported the implementation of rainwater harvesting systems, watering schemes, and mulching techniques to conserve water and improve soil moisture retention during dry periods. These practices were specifically applied to young cocoa trees.

(iii) Crop diversification and intercropping: Cocoa farmers diversify their agricultural activities by intercropping cocoa with other crops such as plantains, bananas, and cocoyam and participating in other economic activities (ranging from 1 to 4) to improve their socioeconomic resilience to drought. Although, generally, cocoa farmers have other farms for subsistence farming when faced with drought stress, they shift their interest toward more diversification.

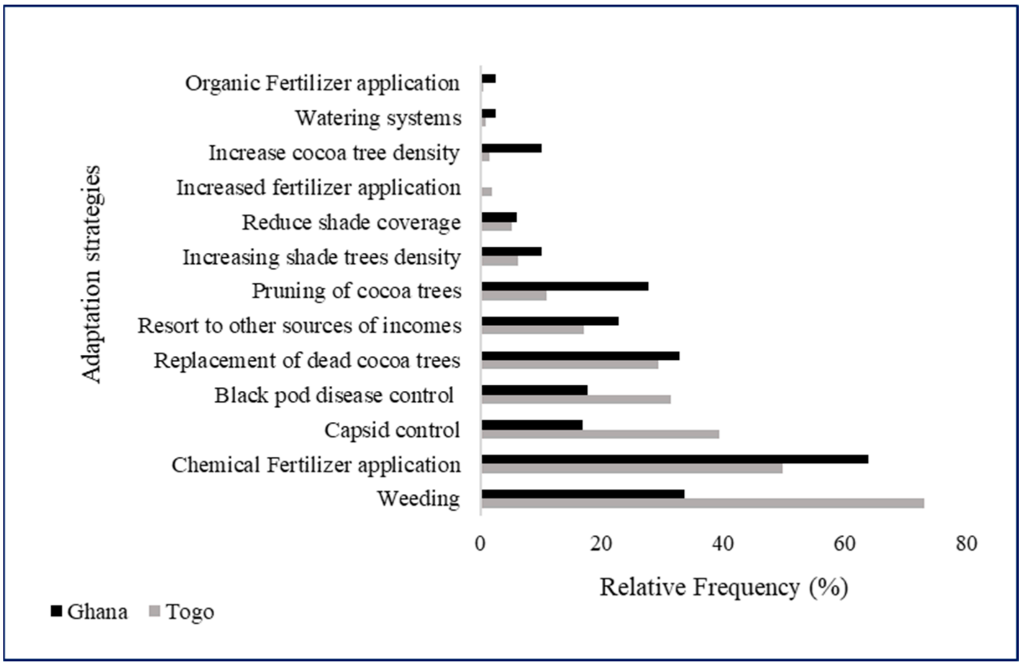

Figure 4. Drought adaptation strategies used by cocoa farmers.

The adoption rates of drought ASs among cocoa farmers were the following: farm management (67.15%), soil management (46.32%), and crop diversification and intercropping (61.70%). The relatively higher adoption rates for farm management and crop diversification compared to soil management can be attributed to their affordability. However, the use of organic matter as part of farm management practices was low, with only 2.42% of farmers in Ghana and 0.47% in Togo adopting this sustainable practice. Farmers mentioned challenges such as a lack of knowledge and means for proper soil management, as well as land insecurity, which discouraged long-term investments in sustainable practices. A small percentage (6%) of farmers did not adopt any drought adaptation strategies, believing in the natural resilience of their production systems. The limited availability of labor was also a major constraint in the adoption of improved agronomic practices. Socioeconomic vulnerability, particularly among women and elderly farmers, further undermined their ability to implement adaptive strategies.

Farm management was the only adaptation strategy that showed a significant positive relationship with cocoa yield, highlighting its importance in improving drought resilience,

Table 2. The fact that diversification practices do not positively influence farm yield is not surprising because diversification of income sources is not directly related to the outcome of the yield but rather to household income, an indicator that was not documented in our study. Additionally, farmers did not mention migration or crop shift strategies as adaptive strategies in this study, possibly due to the age of the respondents and the perennial nature of cocoa. More than 70% of the respondents were between 35 and 60 years old, which may explain their reluctance to migrate.

Table 2. Relationship between adaptive strategies (ASs) and cocoa production at the farm gate level.

	Ghana				Togo			
Coefficients	**Estimate**	**Std. Error**	**t Value**	**Pr(>|t|)**	**Estimate**	**Std. Error**	**t Value**	**Pr(>|t|)**
(Intercept)	378.35	102.04	3.708	<0.05 ***	197.09	76.17	2.587	0.0104 *
Farm management	154.84	88.97	1.740	0.084	62.09	75.09	0.827	0.040
Soil management	40.28	40.83	0.986	0.326	33.28	23.95	1.389	0.16
Crop diversification	−99.47	70.92	−1.403	0.163	11.84	18.99	0.623	0.53
Number of ASs	−29.57	13.88	−2.130	0.035 *	2.452	6.18	0.397	0.69

*** (highly significant); * (significant).

Only 6% of the respondents reported that they did not use adaptive measures and expressed skepticism about the effectiveness of the available strategies. Their reasons for inaction included limited access to credit, insecurity of land tenure rights, and lack of extension services. These challenges were also noted as reasons for the ineffectiveness of the strategies currently used by many farmers.

4.4. Drivers of Drought Adaptation Strategies

Poisson regression and binary logistic regression models were used to assess the drivers of drought adaptation strategies among cocoa farmers. The dependent variables included both the number of ASs and the type of strategy (farm management, soil and water management, and crop diversification and intercropping). The data summarized from the PCA helped identify relevant socioeconomic characteristics as independent variables.

In the Ghana region, farming experience, access to training, and self-sufficiency assessment were found to positively influence the number of ASs. For example, a unit increase in farming experience was associated with a 49% increase in ASs, while access to training led to a 15% increase, and self-sufficiency improved AS adoption by 52%. On the other hand, sharecropping reduced the number of strategies by 34% and high adaptation costs decreased it by 44%. A household size larger than 10 members reduced ASs by 15%. In the Togo region, the number of ASs decreased by 39% when the land was shared compared to purchased or inherited land. A lower educational level reduced ASs by 18%. Cooperative membership was found to negatively influence the adoption of soil management practices, while gender, land tenure rights, farming experience, self-sufficiency, cooperative membership, formal education, and financial aid were all statistically significant variables influencing the number of ASs in Togo. Despite these findings, not all predictors were statistically significant in both regions, Tables 3 and 4.

Furthermore, older farmers and nonnative farmers with lower educational levels were found to adopt fewer ASs in both regions. The use of hired labor increased the likelihood of adopting a greater number of adaptive measures, and access to credit at specific stages of the cocoa season enabled farmers to purchase farm inputs that improved yield and income. However, the effectiveness of adaptation measures was not guaranteed, and several farmers mentioned their limited ability to adapt due to socioeconomic challenges.

Table 3. Estimates of socioeconomic variable relationship with adaptation strategies (ASs), Ghana.

	(i) Farm Management Practices		(ii) Soil Management		(iii) Crop Diversification and Intercropping		Number of Adaptive Strategies		
	Estimate	**Pr(>∣z∣)**	**Estimate**	**Pr(>∣z∣)**	**Estimate**	**Pr(>∣z∣)**	**Estimate**	**IRR**	**Pr(>∣z∣)**
(Intercept)	7.09×10^{1}	0.117	3.74×10^{1}	0.998	-2.66×10^{1}	0.915	0.09·	2.46	0.030 *
Gender (male)	4.58×10^{1}	0.519	1.21	0.038 *	-2.57×10^{-7}	0.035	0.29	1.34	0.237
Marital status (not married)	-5.50×10^{1}	0.830	-1.70×10^{1}	0.995	-1.13×10^{-6}	0.937	−0.14	0.87	0.726
Farmer age (years)	-3.43×10^{-1}	0.135	1.91×10^{-2}	0.503	9.43×10^{-10}	0.940	0.00	1.00	0.051 *
Land tenure (sharecropping)	-3.48×10^{-1}	0.026 *	−1	0.387	1.60×10^{-7}	0.978	−0.31	0.73	0.103
Formal education (attended)	2.91×10^{1}	0.286	-2.14×10^{1}	0.998	-5.68×10^{-6}	0.074·	−0.18	0.84	0.780
Household size	−1.50	0.458	-1.51×10^{-1}	0.179	-2.87×10^{-8}	0.833	0.00	1.00	0.979
Farming experience (years)	4.90×10^{-1}	0.062·	1.58×10^{-2}	0.066	-1.15×10^{-8}	0.811	0.00	1.00	0.063·
Cooperative member (yes)	-1.02×10^{1}	0.475	-7.71×10^{-1}	0.409	-5.93×10^{-7}	0.388	−0.27	0.76	0.142
Use of hired labor (yes)	-3.87×10^{1}	0.660	-4.50×10^{-1}	0.055 *	4.57×10^{-7}	0.685	0.10	1.11	0.053 *
Training access (yes)	1.58	0.064·	6.60×10^{-1}	0.648	5.31×10^{1}	0.004 **	−0.06	0.94	0.836
Financial facilities access (yes)	5.84×10^{1}	0.657	1.67	0.152	-3.86×10^{-8}	0.007 **	0.02	1.02	0.045 *
Household size (yes)	3.81×10^{1}	0.705	1.80×10^{1}	0.994	-1.87×10^{-7}	0.208	0.11	1.12	0.574
Adaptation cost (high)	−4.46	0.032 *	-1.78×10^{1}	0.995	9.54×10^{-7}	0.066·	−0.02	0.98	0.949
Self-sufficiency (Agree)	5.21	0.074·	-9.05×10^{-1}	0.368	-2.12×10^{-6}	0.612	0.02	1.02	0.936

Pr(>∣z∣) = *p*-value ** (very significant); * (significant); .(marginally significant); IRR (Incidence Rate Ratios).

Table 4. Estimates of socioeconomic variables relationship with adaptation strategies (ASs), Togo.

	(i) Farm Management Practices		(ii) Soil Management		(iii) Crop Diversification and Intercropping		Number of Adaptive Strategies		
	Estimates1	**Pr(>∣z∣)**	**Estimates2**	**Pr(>∣z∣)**	**Estimates3**	**Pr(>∣z∣)**	**Estimates**	**IRR**	**Pr(>∣z∣)**
(Intercept)	1.17×10^{2}	0.37	2.26×10^{1}	0.99	-2.66×10^{1}	0.03 *	0.899	2.46	0.30
Gender (male)	1.18×10^{1}	0.05 *	-5.76×10^{-1}	0.48	-2.10×10^{-6}	0.06·	0.290	1.34	0.23
Marital status (not married)	8.25	0.73	6.88×10^{-1}	0.39	3.23×10^{-6}	0.09·	−0.05	0.95	0.86
Farmer age (years)	6.70×10^{-1}	0.15	-9.08×10^{-3}	0.60	1.61×10^{-6}	0.18	3×10^{-3}	1	0.05 *
Land tenure (sharecropping)	−3.914	0.05 *	2.76×10^{-1}	0.60	1.36×10^{-7}	0.25	−0.311	0.73	0.10
Formal education (attended)	-3.58×10^{1}	0.03 *	−1.83	0.07·	-1.23×10^{-7}	0.31	−0.324	0.84	0.06·
Household size	1.35	0.97	3.04×10^{-2}	0.62	6.02×10^{-9}	0.52	-5×10^{-4}	1	0.98
Farming experience (years)	7.34×10^{-1}	0.04 *	-1.77×10^{-2}	0.40	7.64×10^{-9}	0.54	-3.6×10^{-3}	1	0.63
Cooperative member (yes)	-1.95×10^{1}	0.83	−1.01	0.03 *	1.80×10^{-7}	0.60	−0.269	0.76	0.14
Use of hired labor (yes)	1.09×10^{1}	0.21	3.64×10^{-1}	0.43	1.83×10^{-7}	0.66	0.104	1.11	0.04 *
Training access (yes)	-2.58×10^{1}	0.18	3.65×10^{-2}	0.94	5.31×10^{1}	0.09·	−0.057	0.94	0.83
Financial facilities access (yes)	1.94×10^{1}	0.18	1.66×10^{1}	0.09·	8.27×10^{-8}	0.08·	0.015	1.02	0.95
Household size (yes)	-3.30×10^{1}	0.30	−1.67	0.03	3.23×10^{-7}	0.80	0.144	1.12	0.48
Adaptation cost (high)	-3×10^{-1}	0.29	1.89×10^{1}	0.99	4.64×10^{-6}	0.43	−0.015	1.05	0.09·
Self-sufficiency (Agree)	3.74×10^{1}	0.06·	2.22×10^{-1}	0.03 *	-2.81×10^{-7}	0.45	0.017	1.02	0.93

Pr(>∣z∣) = *p*-value * (significant); .(marginally significant); IRR (Incidence Rate Ratios).

5. Discussion

5.1. Socioeconomic Background of Cocoa Farmers and Their Perceptions of Drought

The results confirm that cocoa production in both Ghana and Togo is male-dominated, in line with previous studies by [23], which reported that males comprise the majority of cocoa farmers in Ghana. The physical nature of agricultural work and the limited access to land for women may explain this male dominance. To address gender disparities, policies should focus on improving women's access to land and other incentives, as noted by [51]. Furthermore, the educational levels of the farmers reflect the limited formal training in these regions, with most farmers having primary education and fewer than 35% attaining secondary education. This trend was also observed [23], which highlighted the need for targeted educational programs to improve farmers' skills, especially in modern agricultural practices.

Most cocoa farmers in Ghana rely heavily on cocoa as their primary source of income, highlighting the economic value of the crop, as described by [24]. In contrast, farmers in Togo depend on a more diversified income portfolio, which includes food crops and livestock, similar to the findings of [26]. This diversification suggests that farmers in Togo may be slightly more resilient to fluctuations in cocoa production compared to their counterparts in Ghana.

The perceived increase in the drought frequency and the awareness of farmers of climate challenges are significant. As noted by [52], these perceptions are likely influenced by the visible impacts of changing rainfall patterns, rising temperatures, and deforestation. Recognizing drought as a major threat underscores the need for ASs to mitigate the adverse effects on cocoa production. Farmers' knowledge of climate-related challenges, as found in this study, reinforces the importance of integrating local knowledge with scientific interventions to build resilience against future climate shocks. Ref. [24] also clarified that drought issues and other related climate challenges are not new to farmers in Ghana.

5.2. How Do Cocoa Farmers Respond to Drought Challenges?

Cocoa farmers adopted different sets of practices. A high adoption rate was denoted for farm management and crop diversification compared to soil management. This reflects farmers' preference for affordable and accessible ASs, similar to findings reported by [52] in Pakistan. The limited adoption of soil and water management practices is likely due to a lack of knowledge and financial resources, as supported by research by [53]. Furthermore, the low adoption of organic matter use, despite its recognized benefits for soil fertility and water storage, emphasizes the need to promote sustainable land management practices among cocoa farmers. Land tenure systems may play a significant role in farmers' reluctance to invest in sustainable long-term soil management practices, a concern echoed by [54,55], as it has been highlighted by our study that the land tenure type influences the type of adaptive strategies. These challenges are particularly pressing in regions where farmers fear losing their farms or investments due to the lack of secure land titles. Additionally, the reluctance to adopt more sophisticated ASs due to economic vulnerabilities aligns with findings by [24], who noted that low monthly incomes and financial insecurity often drive farmers toward less costly and less effective ASs. Labor shortages have emerged as a critical barrier to adopting agronomic practices. While there is a willingness among farmers to hire labor, the inability to do so is a concern, as also documented by [56]. This issue particularly affects women and elderly farmers who are physically unable to perform intensive activities such as pruning, weeding, and spraying against pests. This reflects broader issues of socioeconomic vulnerability that exacerbate the impacts of drought on cocoa production, as discussed by [57].

Despite farmers' knowledge of climate challenges and their belief in being key agents for sustainable cocoa production, they acknowledged their limited control over broader systemic issues such as market prices and access to inputs. These findings are consistent with those of [58,59], who highlighted that climate adaptation is often influenced by external factors beyond farmers' direct control, including government policies and market structures.

This supports the statement of a non-logical correlation between farmers' perception and adaptation strategies adoption. The absence of migration or crop-shifting strategies among the respondents can be explained by the age of the farmers and the perennial nature of the cocoa trees. These factors, coupled with the economic dependence on cocoa farming, limit farmers' options for more transformative ASs, as seen in other studies [10,17].

The non-adoption of any AS, stated by 6% of farmers despite perceiving the increasing threats of drought, underscores the need for more inclusive and comprehensive adaptation plans. The problems of credit access, inadequate financial support, and inadequate extension services are critical obstacles that must be addressed to ensure the success of adaptation efforts in the cocoa sector. These findings are consistent with the work of [60], who noted similar barriers to adaptation in other agricultural systems.

5.3. What Socioeconomic Factors Need to Be Improved in the Drought as Framework?

The findings revealed that socioeconomic factors such as farm experience, training, and self-sufficiency significantly influence the adoption of drought ASs. This aligns with previous studies by [23,45]. Farmers who perceive themselves as self-sufficient were more likely to adopt a larger number of ASs, highlighting the role of financial security in facilitating adaptation. Training plays a crucial role in improving adaptive capacity, as supported by studies in other agricultural sectors [61]. These results demonstrate the need to support farmers with socio-cognitive training to improve their ability to cope with the drought hazard. The impact of land tenure on adaptation, particularly the negative effect of shared land on ASs, emphasizes the importance of secure land rights to promote sustainable practices. This aligns with the findings of [62], who stress the need for reforms in tree tenure to encourage long-term investments in land management. Farmers' reluctance to invest in ASs due to insecure land tenure mirrors the challenges faced in other regions, as noted by [54].

This study also highlights the role of cooperative membership, which, contrary to expectations, negatively influenced the adoption of soil management practices in Togo. This could be linked to the internal organization of cooperatives rather than their overall effectiveness. Previous research has shown that well-organized cooperatives can facilitate access to resources and knowledge [63]. Therefore, improving the structural organization and support of cooperatives could improve their role in promoting sustainable practices to combat drought challenges.

Gender differences in ASs were also evident, with male-headed farms less likely to diversify income sources compared to their female counterparts. This result aligns with previous studies showing that women are often more involved in various income-generating activities, in part due to their responsibility for the security of household food [64]. Access to hired labor also played a significant role in increasing adaptation, particularly for tasks that require physical strength, such as the application of pesticides, which women often struggle to perform alone [56]. Furthermore, the influence of financial access on ASs was evident, reinforcing the importance of credit availability in allowing farmers to adopt more costly adaptation measures. This is consistent with the findings of [24], who noted that financial constraints are a major barrier to effective adaptation in cocoa farming. The introduction of cocoa insurance schemes, such as rainfall insurance, could help mitigate these challenges by providing farmers with payouts during extreme weather events [40].

The absence of migration or crop change strategies among the respondents could be attributed to the age of the farmers and the perennial nature of cocoa. Older farmers are less likely to relocate or adopt drastically different cropping systems. This suggests that adaptation strategies for older, more established farmers should focus on improving existing practices rather than promoting transformative changes that may not be feasible for them. This point also highlights the socio-ethical consideration of cocoa crops by the farmers, who may not want to shift to other food crops even if situations become more critical.

Finally, this study points to the need for a holistic approach to adaptation, one that integrates economic incentives, agricultural interventions, and social support services. This is crucial to ensure that cocoa farmers can effectively adapt to drought and other climate-related risks. The continued development of the agri-food sector in rural areas could also support income diversification and reduce the pressure on cocoa farming as the sole source of income [65,66].

5.4. Embracing Tomorrow: Farmers' Willingness to Drought Adaptation

The sustainability of the cocoa sector remains influenced by socioeconomic factors, including behavioral ones. Consequently, a question on a typical farmer's readiness to pursue cocoa growing was introduced to assess their perspectives under two scenarios: (i) business as usual (meaning no improvement in weather conditions and the adaptive capacity) and (ii) worsening climate conditions. The analysis revealed that considering both regions, about 90% of farmers are willing to continue cocoa production under both scenarios. The explanations given by farmers are based on social and economic arguments. From a societal point of view, cocoa growers contended that cocoa is a characteristic crop of their region, is inherited, and is associated with respect, wealth, and greatness. Cocoa farms also serve as long-term insurance for farmers and their families. Similar views have been reported where family, cultural, or personal values outweigh the economic losses from cocoa [55]. For example, ref. [55] reported from Talamanca in Costa Rica that indigenous cocoa farmers will not cut down an old cocoa orchard planted by their grandfather 60 years ago, even if it does not produce any cocoa and it is a source of inoculum and disease affecting the rest of the farm.

Economically, cocoa is argued to be a highly valuable crop that cannot be compared to other staple crops in the area, such as maize, cassava, and rice. A similar finding was reported by [26] where farmers continued cocoa farming despite low yields because they believed in the systems and thought it was far better than productive cereal cropping systems that offer low returns when compared to cocoa. These staple food crops are purposively grown for household consumption and possess only economic value in cases of excess production or urgent financial needs. Another argument raised is the economic value of associated trees in cocoa plots since farmers have adopted agroforestry practices.

Unlike the majority, some farmers (about 10%) expressed their willingness to abandon cocoa production and convert the land to coffee, rubber, rice, or maize fields. The main reasons raised are the potential benefits and lower cost investments compared to cocoa farming. For example, a 45-year-old cocoa farmer in Odomi in the Ghana region recounted: "Two years ago, I converted 2 hectares of my cocoa plot to a rice field and 1 hectare to a maize field out of a 5 hectare cocoa plot. *All benefits together were two times more than the 5 hectares of the cocoa plot. So it is better to convert the rest of the land and collect the benefits to invest in other economic activities that could support my family for the long term*". These diverse perspectives of farmers on the future of cocoa land use are critical and should be considered for targeted interventions.

6. Conclusions

Drought is one of the emerging challenges with a high potential for crop yield loss and impacts on livelihoods. This paper seeks to contribute to improving drought adaptation strategies (ASs) for sustainable cocoa cultivation. This study investigated perceptions of drought, the ASs practiced, and the socioeconomic factors driving these strategies. The results show that drought is not new to cocoa farmers in the study area of the Ghana–Togo Transboundary Cocoa Belt. Drought is being experienced and its effects are well known by cocoa farmers. In response to these challenges, cocoa farmers adopt a set of strategies ranging from one to seven, depending on their socioeconomic status. This study revealed that the number of ASs practiced by a cocoa farmer did not positively influence cocoa yield. Therefore, there is room for improvement in the ASs practiced by cocoa farmers, as the ASs may not be adequate for particular farming conditions. The fact that only farm management positively influenced cocoa yield suggests the inadequacy of other ASs in addressing drought challenges. The set of practices used by cocoa farmers was overall inadequately designed for drought purposes, as most of them were highlighted in the literature as ASs for global challenges. This study also revealed that farmers are passionate about continuing to grow cocoa despite experiencing drought events and anticipate further challenges from anthropogenic climate forcing. This result represents an opportunity for potential investments by both the private and public sectors. We argue that various supports and well-designed policies will strengthen and encourage farmers to maintain cocoa production and avoid shortages in global production, as cocoa demand continues to increase. These strategies should address both short-term coping mechanisms and long-term resilience building of the farming system. A holistic approach should involve stakeholders from various fields and cover topics such as irrigation techniques suitable for the cocoa life cycle, soil water conservation techniques, drought-tolerant varieties, pruning and canopy cover management, shade trees management, integrated pest and disease management, monitoring and early warning systems, financial and risk management, as well as capacity building and access to agroclimatic information. Education, along with land tenure policies and recommended ASs, is expected to improve the resilience of cocoa farmers against drought.

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