Research in
ISSN : P-2409-0603, E-2409-9325
AGRICULTURE, LIVESTOCK and FISHERIES
An Open Access Peer-Reviewed International Journal

Article Code: 453/2024/RALF
Article Type: Research Article

Res. Agric. Livest. Fish.
Vol. 11, No. 2, August 2024: 215-230.

Perceived Phytosanitary Impacts of Climate Change and Climate Change Adaptation among Cocoa Farmers in Cameroon

Abayomi Samuel Oyekale* and Thonaeng Charity Molelekoa

Department of Agricultural Economics and Extension, North-West University Mafikeng Campus, Mmabatho 2735, South Africa.

***Corresponding author:** Abayomi Samuel Oyekale; E-mail: asoyekale@gmail.com

ARTICLE INFO

Received
04 August, 2024

Revised
30 August, 2024

Accepted
31 August, 2024

Online
September, 2024

Key words:
Cocoa
Farmers
Climate change
Phytosanitary
Cameroon

ABSTRACT

Cocoa productivity is dependent on favourable weather variables. In Cameroon, climate change presents some phytosanitary challenges to cocoa farmers due to weed and cocoa pest problems. This paper analyzed the perceived phytosanitary impacts of climate change and the determinants of selected mitigation options in Cameroon. The data were collected using stratified random sampling from 303 farmers in Centre Cameroon. The data were analyzed with Probit regression. The results showed that cocoa farming operations were affected by climate change through weed control problems (51.48%), more incidence of black pod disease (65.02%), more incidence of malaria (68.98%), more cocoa pests (72.94%), death of cocoa trees (74.26%) and general reduction in cocoa yields (78.88%). The Probit regression results revealed that some adaptation methods were significantly influenced by perceived phytosanitary impacts of climate change such as perception of more pests, difficulties in weed control, death of cocoa trees, and black pod diseases. Other impacts such as malaria, pneumonia, lack of drinking water, inability to effective spray cocoa pod and dry the beans also showed some statistical significances with different impacts on adaptation. Cocoa farmers' demographic characteristics such as education, gender, farming experience and primary occupation also influenced some adaptation methods. It was concluded that climate change presents significant constraints to cocoa production, and efforts to address the problem should integrate proper education on perception of the phytosanitary impacts and relevant mitigation with sensitivity on farmers' gender, education level and the nature of primary occupation.

To cite this article: Oyekale A. S. and T. C. Molelekoa, 2024. Perceived phytosanitary impacts of climate change and climate change adaptation among Cocoa farmers in Cameroon. Res. Agric. Livest. Fish. 11(2): 215-230.

DOI: https://doi.org/10.3329/ralf.v11i2.76069

INTRODUCTION

Cocoa is a perennial crop that is largely grown in tropical rainforest zone of many countries, and contributes significantly to rural livelihoods, agro-processing value addition, and international trade. Some farmers in Côte d'Ivoire, Ghana, Nigeria, Cameroon, and other emerging African cocoa growers are reaping the dividend of their capital and labour investments in cocoa production, although climate change remains a significant production constraint. There is fundamental wisdom in cocoa farmers' decisive efforts in adapting to climate change, subject to their perceived vulnerability and the spectrum of their risk mitigating options. This is particularly important for about 600,000 Cameroonian smallholding cocoa farmers who primarily depend on the incomes realized from cocoa cultivation for their daily economic sustenance (African Development Bank, undated).

Although cocoa production in Cameroon has steadily increased over the past few decades, there are still several constraints confronting its productivity. As the fourth African leading producer, cocoa yield in Cameroon (300-400 kg per hectare) is lower than what obtains in Ghana (404 kg per hectare) (Kolavalli and Vigneri, 2011) and Ivory Coast (500–600 kg per hectare) (Kroeger et al., 2017). More importantly, climate change is partly responsible for low cocoa yields, although recent expansion in cocoa land areas has sustained steady increases in Cameroon's cocoa outputs. Available statistics revealed that total outputs increased from 269,495 tonnes in 2015/2016 (Economist Intelligence, undated) to 292,471 tonnes in 2020/2021 (Cameroon National Shippers' Council, undated). Moreover, although agriculture is generally perceived as a sector that is highly vulnerable to climate change, cocoa farming is particularly notable for its absolute sensitivity to extreme weather events (Ehiabor et al., 2016; Schroth et al., 2017). In addition to fertile soils, cocoa productivity is agronomically facilitated by favourable climatic conditions with maximum annual average temperature in the range of 30-32ºC, and a minimum annual average temperature of 18-21ºC (Yoroba et al., 2019; Abdulai et al., 2020). Cocoa also requires a wet climate with average annual rainfall in the range of 1200-3000 mm, and not more than three months of dry season with average rainfall less than 100 mm (Brou et al., 2003; Yoroba et al., 2019; Abdulai et al., 2020). Therefore, cocoa productivity responds with utmost sensitivity to extreme climatic events such as drought, flooding, and extreme cold (Oyekale and Oladele, 2012; Santosa et al., 2020). The need for adequate climatic condition for optimal cocoa productivity can be emphasized from associated yield losses resulting from unprecedented weather vagaries. Precisely, cocoa productivity losses due to water stress can be so tremendous, with some landmark impacts on farm investment and households' welfare. In some previous studies, cocoa yield losses due to drought were estimated at 62% in Indonesia (Keil et al., 2008), 27% in West Africa, 19% in Ecuador (Vos et al., 1999), and 89% in Brazil (Gateau-Rey et al., 2018). Other estimate put yield losses due to drought at between 10-46% for Ecudaor (Macías Barberán, et al., 2019) and at about 50% from a generic SUCROS-Cocoa physiological simulation model (Zuidema et al., 2005).

In addition to water stress, cocoa productivity is also affected by pests and diseases, the incidences of which are influenced by changes in the patterns of rainfall and temperature (Medina and Laliberte, 2017). The implication of climate change for promoting cocoa pests and diseases can be further emphasized from the phytosanitary requirements for controlling pests and diseases, and their expected impacts on the international standard expected of traded cocoa beans. Specifically, cocoa yield is highly affected by pests and diseases (Abdulai et al., 2020; Babin et al., 2010; Mahob et al., 2015) and indiscriminate utilization of agrochemicals for their control is a major problem in Cameroon. In some instances, internationally banned chemicals may still be freely traded and used by cocoa farmers, with some daunting consequences on the quality and international acceptability of cocoa beans (Mahob et al., 2014; Pouokam et al., 2017).

Black pod remains the major cocoa disease, which is caused by two pathogenic agents - *Phytophthora palmivora and Phytophthora megakarya* - and promoted by high humidity during the period of high rainfall (Akrofi et al., 2015). In Cameroon, *Phytophthora megakarya* is the dominant cause of black pod disease, although *P. palmivora* is not completely absent (Nyasse, 1992). Depending on farmers' compliance with recommended sanitary agronomic practices, such as timely application of fungicide, removal of infected pods, and pruning of cocoa trees, black pod can account for 60-100% decline in cocoa outputs (Adeniyi, 2019; Akrofi, 2015). Some experimental studies have highlighted the efficacy of phytosanitary pod removal with 22% and 31% reduction in black pod rates in two sites in Cameroon (Ndoumbe-Nkeng et al., 2004) and between 35% and 66% reduction in Peru (Soberanis et al., 1999). In addition, the development of some cocoa pests such as mirids and shield bugs is facilitated by high temperatures (Babin et al., 2010; Mahob et al., 2015). Mirids can account for about 40% yield losses through piercing of young and soft tissues of cocoa stems that leads to cocoa dieback disease (Mahob et al., 2015; Oluyole et al., 2013; Anikwe & Otuonye, 2015). The productivity impact of shield bugs is manifested through their attacks on cocoa pods, thereby promoting premature ripening.

Although some studies on climate change in cocoa agriculture had been conducted, little emphases had been placed on the phytosanitary impacts of climate change, particularly in Cameroon. This study seeks to fill this gap given that a proper understanding of cocoa farmers' perception of the phytosanitary implications of climate change can facilitate their adaptive capacity. This will also enhance policy interventions and design of programmes to facilitate the capability of cocoa farmers in identifying cognizant phytosanitary requirements as climate changes. It will also provide some insights into adaptation strategies being used by cocoa farmers and their phytosanitary correlates.

MATERIALS AND METHODS

The Study Area

The Centre Region of Cameroon comprises of ten Departments, which are Haute-Sanaga, Lekié, Mbam and Inoubou, Mbam and Kim, Méfou and Afamba, Méfou and Akono, Mfoundi, Nyong and Kéllé, Nyong and Mfoumou and Nyong and So'o. The study was carried out in the Department of Méfou and Akono and Department of Nyong and So'o because of their very high concentration of cocoa farmers. The Department of Méfou and Akono comprises of four communes (Akono, Bikok, Mbankomo and Ngoumou) and covers an area of 1329 sq km. Its administrative headquarter is Ngoumou. The Department of Nyong and So'o comprises of six communes (Akoeman, Dzeng, Mbalmayo, Mengueme, Ngomedzap and Nkolmetet) and covers a land area of 3581 sq km. Mbalmayo is its administrative headquarter.

Sampling Methods

Stratified sampling method was used to interview cocoa farmers in the two selected Departments (Méfou and Akono and Nyong and So'o). The stratification was done at the commune level with all the four communes and two communes selected from the Department of Méfou and Akono and Nyong and So'o, respectively. The selected communes in Nyong and So'o were Ngomedzap and Mengueme. Samples were allocated to each commune based on estimated cocoa farmers. The sample size (n') was calculated using the online sample size calculator as (Calculator Net, Undated):

$$n' = \frac{n}{\left(1 + \frac{z^2 * \hat{p}(1-\hat{p})}{\varepsilon^2 N}\right)} \quad .1$$

In equation 1, $n = \frac{z^2 * \hat{p}(1-\hat{p})}{\varepsilon^2}$, z is 1.96 which denotes th z-score at 95 confidence level, $\hat{p}$ is 50% which is the population proportion, ε is 0.05 and denotes the margin of error (0.05) and N is the estimated population size of cocoa farmers in the selected communes (6500). Therefore, the estimated sample size was 363 the survey targeted to achieve this. However, due to logistic and research budget constraints, only 303 farmers were successfully interviewed, with sample size allocated in proportion to the size of the strata. Table 1 shows the distribution of the respondents across the selected communes in the selected Departments.

Table 1. Distribution of respondents across the selected communes

Department/Communes	Sample size	% of Total
Méfou and Akono		
Akono	115	37.95
Bikok	76	25.08
Mbankomo	10	3.30
Ngoumou	50	16.50
Nyong and So'o		
Ngomedzap	27	8.91
Mengueme	25	8.25

Ethical procedures were followed in the conduct of the survey by seeking the permission of local chiefs in every community before proceeding to interview farmers. The team was led by a local extension agent who understood the terrain very well and had built some cordial relationships with the farmers over the years. The extension agent relayed the objectives of the study to the farmers, and those who were willing to participate were identified and listed for sampling. The respondents were adults of more than 18 years old, and no one was coerced into participating. There were 10 trained enumerators who interviewed the farmers. The questionnaire, which was divided into four sections was designed in French and administered by enumerators from the University of Yaounde II. Moreover, the study was confronted with a few limitations. Specifically, some farmers decided not to participate for some personal reasons. Also, research funding was insufficient to reach many respondents.

Analytical Model

The Probit regression model was estimated to determine the factors influencing climate change adaptation options among the cocoa farmers. The model presents a binary dependent variable with adopters coded as 1 and zero otherwise. The model can be specified as:

$$Y_{ik} = \alpha_k + \sum_{l=1}^{15} \beta_{kl} X_{ik} + \sum_{z=1}^{13} \pi_{kz} M_{ik} + \epsilon_{ik} \quad .1$$

In equation 1, $Y_{ik}$is adoption decision of ith household on kth adaptation method. The demographic explanatory variables (X_{ik}) are gender (male =1, 0 otherwise), primary education (yes = 1, 0 otherwise), secondary education (yes = 1, 0 otherwise), tertiary education (yes = 1, 0 otherwise), household size, years of growing cocoa, cocoa as primary crop (yes = 1, 0 otherwise), farming as primary occupation (yes = 1, 0 otherwise), member of household sick (yes = 1, 0 otherwise), missed cocoa spraying (yes = 1, 0 otherwise), number of cocoa farm, own cocoa farm (yes = 1, 0 otherwise), cocoa land areas (acres), proportion of cocoa trees (%), and farm distance (kms). Also, the perceived climate change impact variables are more pests (yes = 1, 0 otherwise), difficulty in weed control (yes = 1, 0 otherwise), increase in malaria (yes = 1, 0 otherwise), scarce drinking water (yes = 1, 0 otherwise), increase in pneumonia (yes = 1, 0 otherwise), increase in cholera (yes = 1, 0 otherwise), increase in death of cocoa trees (yes = 1, 0 otherwise), increase in cocoa tree falling (yes = 1, 0 otherwise), reduction in cocoa yields (yes = 1, 0 otherwise), more black pod diseases (yes = 1, 0 otherwise), more wild fire (yes = 1, 0 otherwise), inability to properly spray cocoa (yes = 1, 0 otherwise) and inability to properly dry cocoa beans (yes = 1, 0 otherwise).

RESULTS AND DISCUSSION

Demographic Characteristics of Cocoa Farmers

The results presented in Table 2 showed the distribution of cocoa farmer's selected demographic characteristics. The results showed that 24.42% of the farmers resided in households with less than 5 members, 51.82% had between 5 and 10 members, 13.2% had between 10 and 15 members, 6.27% had between 15 and 20 members and 4.29% had 20 or more members. In terms of the farmer's level of education, it was revealed that the majority of the farmers (56.11%) had secondary education, followed by those who had primary education (34.65%), tertiary (5.28%) and 3.96% had no education. Majority of the farmers (29.7%) were 40<50 years old. This was followed by those who were 50<60 years old (25.08%). The farming experiences revealed that the majority of the farmers (25.08%) had 20<30 years of cocoa farming experience, followed by 19.14% of those who had 30<40 years of experience, 17.16% had 10<20 years of experience, 14.52% had 40<50 years of experience, 12.54% had more than 50 years of experience and 11.55% had less than 10 years of cocoa farming experience.

Perceived Phytosanitary Impacts of Climate Change

Table 3 shows the perceived phytosanitary impacts of climate change among cocoa farmers in Cameroon. It reveals that death of cocoa trees was reported by 74.26% of the cocoa farmers. Droughts are largely responsible for cocoa tree death (Gateau-Rey et al., 2018). In some previous studies, death of cocoa trees had been highlighted as part of the effects of climate change (Owoeye and Sekumade, 2016; Abdulai et al., 2018). More pests were also perceived by 72.94% of the respondents. Climate dynamics in the form of rainfall instability and droughts are closely related to development of some cocoa pests (N'Guessan et. al., 2010). The issues of pests in cocoa farming are of fundamental importance due to their impacts on establishment of cocoa trees and yields (Adu-Acheampong et al., 2015; Amon-Armah et al., 2023). Climate change promotes the infestation of some pests (Asitoakor et al., 2022). These include mirids, stem borer, among others (Oyedokun et al., 2022). The results further revealed that more malaria and black pod diseases were observed by 68.98% and 65.02% of the respondents, respectively. In some previous studies, cocoa farmers had highlighted a higher prevalence of malaria resulting from changes in some weather parameters (Oyedokun and Oyelana, 2016; Oyekale, 2015). Also, black pod disease is associated with high rainfalls that increase the relative humidity on cocoa farms (Oyekale, 2012; Owoeye and Sekumade, 2016). Finally, climate change often influences the pattern of weed growth and frequency of their control (Peters et al., 2014). In this study, 51.48% of the farmers indicated weed control problems resulting from changes in some climatic parameters.

Climate Change Adaptation Options

The results presented in Figure 1 showed the climate change adaptation options by cocoa farmers in Cameroon. The results revealed that farmers mitigated the impact of climate change by regularly spraying cocoa pods (79.54%), planting hybrid varieties (48.18%) and monitoring weather through the media (35.31%). It was also revealed that 4.62% of the farmers were irrigating their cocoa farms, 44.2% reduced their spraying time intervals and 51.82% were respraying their pods. The results further showed that farmers were monitoring weather with indigenous knowledge system (IKS) (20.13%), using cocoa beans' drying machine (1.32%), diversification with non-farm activities (32.34%) and changed of planting seasons (32.67%).

Table 2. Frequency distribution of cocoa farmer' selected demographic characteristics

Household size	**Freq.**	**Percent**
<5	74	24.42
5<10	157	51.82
10<15	40	13.2
15<20	19	6.27
>=20	13	4.29
Education		
None	12	3.96
Primary	105	34.65
Secondary	170	56.11
Tertiary	16	5.28
Age of farmers		
<30	16	5.28
30<40	43	14.19
40<50	90	29.7
50<60	76	25.08
60<70	46	15.18
>=70	32	10.56
Cocoa farming experience (years)		
<10	35	11.55
10<20	52	17.16
20<30	76	25.08
30<40	58	19.14
40<50	44	14.52
>=50	38	12.54

Table 3. Perceived Phytosanitary Impacts of Climate Change

Perceived Problems	%
Weed control problems	51.48
More incidence of black pod disease	65.02
More incidence of malaria	68.98
More cocoa pests	72.94
Death of cocoa trees	74.26

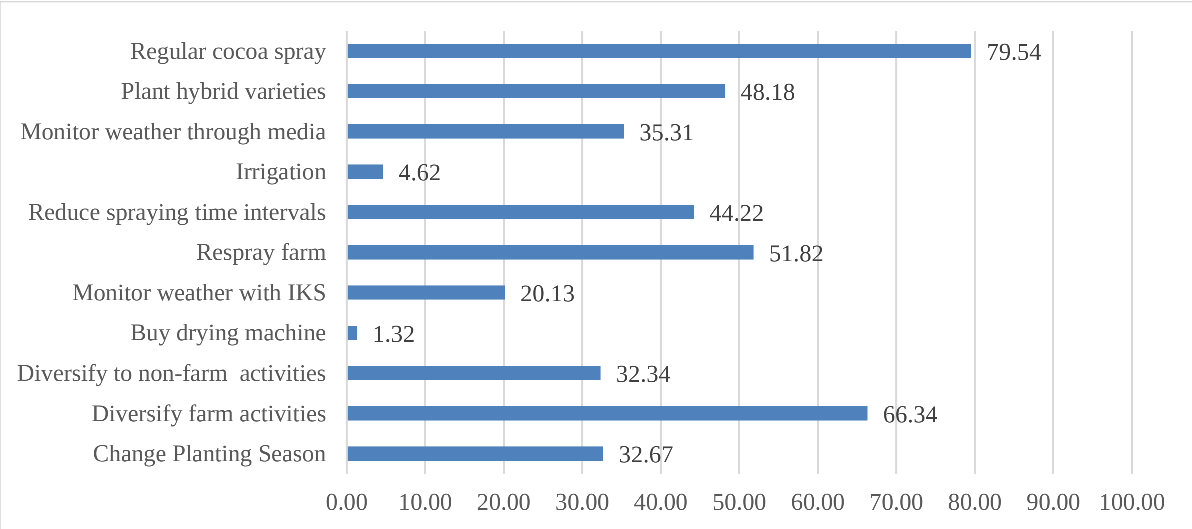

Figure 1. Climate change mitigation options among Cocoa farmers

Determinants of Climate Change Adaptation Choices

The Probit regression results presented in Table 4a show the factors influencing climate change mitigation options among cocoa farmers. According to Mugiyo et al. (2021) it is crucial to adjust the time of planting as planting too early or late can adversely affect crop yields due to climate change. The results revealed that the probability of changing planting time was significantly and negatively influenced by being a male ($p<0.05$), missing cocoa spraying ($p<0.01$), perceived more pests ($p<0.05$), perceived difficulty in weed control ($p<0.01$), inability to dry cocoa beans ($p<0.1$) and inability to properly spray cocoa ($p<0.05$), while it was positively influenced by farmers' having secondary education, tertiary education and primary farming ($p<0.1$).

The results imply that male farmers had lower probability of changing planting time. This finding is consistent with those of Tinda et al. (2020) in South Africa, who revealed that males had significantly lower probabilities of adopting climate change adaptation strategies, including changing planting dates. However, these results are contrary to those of Mwinkom et al. (2021) who revealed that male-headed households had a higher probability of changing planting times in North-Western Ghana. The farmers who missed cocoa spraying had lower probabilities of changing planting time. This may be attributed to significant constraints on resources that inhibit adaptation for cocoa production optimization.

The results further imply that the farmers who perceived more pests, experienced difficulties in weed control, unable to dry cocoa beans, and unable to properly spray cocoa had lower probabilities of changing planting times. Some of these significant findings can be attributed to the stage cocoa farm development. Specifically, a farmer with fully developed cocoa farms may not be engaged in planting of young cocoa plants, thereby reducing adaptation of any option that is related to replanting (Boateng et al. 2023). The results further revealed that the probability of changing planting time was positively influenced by other members being sick and scarcity of drinking water. Adoption of an adaptation methods will be determined by availability of adequate labour force. Sickness is a constraint on farm labour, which will make farmers to adopt less labour-intensive adaptation options (Yaro et al. 2024). Also, scarcity of drinking water reflects prolonged droughts, which may compel significant adjustment to cocoa planting time (Maguire-Rajpaul et al., 2020). The results also imply that farmers with secondary and tertiary education had higher probabilities of changing planting times. These results are in line with those of Singh (2020), who also found that educated farmers are more likely to change their planting dates due to adequate climate-related information. The farmers who had farming as their primary occupation had higher probabilities of changing cocoa planting time. This is in line with the finding of Van Aelst and Holvoet (2016).

The results in Table 4a also revealed that the probability of adopting crop diversification was negatively influenced by years of growing cocoa ($p<0.05$) and positively influenced by farming as a primary occupation ($p<0.01$). Being a farmer is expected to positively influence adaptation, especially crop diversification. Also, the use of crop diversification on cocoa farms can be restricted by availability of open spaces. Given the agroforestry nature of cocoa plantations, over the years, old farmers may have completely utilized available open spaces, thereby making it very difficult to plant other crops within the farms. This result is different from those of Lavison (2013) who found that additional year of farming significantly and positively influenced adoption of crop diversification. The results also showed that the probability of adopting crop diversification was significantly and positively influenced by cocoa farm distance ($p<0.1$). The results of this study are similar to those of Hassan and Nhemachena (2008) who found positive association between farm distance and adoption of climate change mitigation. Also, the probability of utilizing crop diversification increased with death of cocoa trees ($p<0.05$), perception of more black pod diseases ($p<0.05$) and inability to dry cocoa beans effectively. Death of cocoa trees is often associated with drought or some pests and disease infestations (Gateau-Rey et al., 2018). Therefore, in the event of increase in cocoa tree death and cocoa pod disease, crop diversification can provide a means of sustaining food security (Schroth and Ruf, 2014; Hashmiu et al., 2022). Adoption of crop diversification was also negatively influenced by the number of cocoa farms ($p<0.05$). This can be explained by the fact that possession of many cocoa farms may promote production specialization (Ruf, 2015).

The results presented in Table 4a revealed that the probability of adopting non-farm enterprise diversification was significantly and negatively influenced by primary ($p<0.05$) and secondary education ($p<0.1$). These results are reemphasizing the fact that adaptation to climate change through non-farm enterprise diversification among cocoa farmers will require access to requisite financial resources and inherent business acumens that may not be correlated with formal education (Phelan, 2014). The results are contrary to those of Salam and Bauer (2022) who indicated that having some formal education boosted farmers' chance of engaging in non-farm activities. Also, engagement in farming as a primary occupation ($p<0.01$) significantly and negatively influenced the probability of adopting non-farm diversification. This is expected because cocoa farming requires full attention of farmers due to its sensitivity to time variant environmental parameters (Schroth et al., 2016). Cocoa farm ownership ($p<0.1$) and perception of more pests ($p<0.05$). Other variables such as cocoa production as a primary crop ($p<0.01$), proportion of cocoa trees ($p<0.1$), perceived increase in the death of cocoa trees ($p<0.05$) and inability to dry cocoa beans ($p<0.05$) had positive and significant influence on the probabilities of non-farm diversification. Our results are contrary to those of Chepkoech et al. (2023) who revealed that farmers with various income sources diverts time from agricultural activities preventing them from investing in agricultural technologies. This might imply that farmers with farming as a primary occupation has all of their time, labour and investments dedicated to farming leading to them being unable to practice other non-farm activities.

The results in Table 4a also revealed the determinants of monitoring weather using some indigenous knowledge. The results showed that the probability of monitoring weather using indigenous knowledge was significantly and positively influenced by being a male ($p<0.05$) and inability to effectively dry cocoa beans ($p<0.05$), while perception of more pests ($p<0.1$), difficulties in weed control ($p<0.05$) and scarcity of drinking water ($p<0.1$) were significant with negative parameters. Our findings are supported by those of Apraku et al. (2021) who revealed that male farmers are able to monitor the weather via indigenous knowledge because those skills of predicting precipitations and seasons are transferred to them at a younger age. In addition, the impacts of climate change are often expressed from inadequate sunshine or too much rainfall that prevent effective drying of cocoa beans. Therefore, the farmers may have to rely on indigenous knowledge to predict days and time with possibility of sunshine. This is very fundamental in the whole processes of cocoa production because adequate drying of cocoa beans promotes their quality and monetary value.

The results presented in Table 4b show the factors influencing some other climate change adaptation options among cocoa farmers in Cameroon. The results revealed that farmers' probabilities of regularly spraying cocoa beans was significantly and positively influenced by having primary level of education ($p<0.01$), and tertiary level of education ($p<0.1$). These results are in line with those of Fosu-Mensah (2022) who also revealed that farmers with some levels of education are more likely to master the practice of regular spraying. Also, farm ownership showed statistical significance ($p<0.01$) with positive sign. This result is consistent with that of Fadeyi et al. (2022) who revealed that farmers who owned their cocoa farmland had higher probabilities of adopting climate change mitigation options like regular spraying of cocoa pods. Perception of increase in malaria ($p<0.05$) and scarcity of drinking water ($p<0.05$) significantly increased the probability of spraying cocoa beans much more regularly. The farmers who were infected by malaria may have a higher compliance with regular cocoa spraying as a way of not having backlogs of essential farming activities in case of being sick. The table further revealed that the probability of regular spraying was statistically significant and negatively influenced by perceived difficulty in weed control ($p<0.1$), perceived increase in pneumonia ($p<0.1$) and perceived increase in cholera ($p<0.1$).

The results presented in Table 4b also show that farmers who had primary ($p<0.1$), secondary ($p<0.05$) and tertiary ($p<0.05$) education had higher probabilities of planting hybrid seeds. Education is perceived as one of the factors with significant influence on adoption of climate change mitigation options (Mkondiwa, 2023). These results are in line with those of Adebayo et al. (2022) who revealed that more years of education results in farmers being more likely to adopt hybrid seeds. However, these results are contrary to those of Lu et al. (2021) and Asante et al. (2023) who found out that the more the years of farmers' education, the less likely it was to use hybrid seedlings as a mitigation option. Farmers with large household sizes had higher probabilities of planting hybrid seeds. In addition, increase in years of cocoa farming reduced the probabilities of planting hybrid seeds. These results are consistent with those of Wongnaa et al. (2022) who found that farmers with long existing farms had lower probabilities of using hybrid seedlings. This might be attributed to the establishment of existing farms, with farmers indicating reluctance to remove old cocoa trees. It is further revealed that farmers who reported difficulty in weed control ($p<0.01$) and increase in malaria ($p<0.05$) had lower probabilities of planting hybrid seeds while those who reported scarce drinking water and increased death of cocoa trees had higher probabilities.

Table 4a. Factors influencing climate change adaptation options among the cocoa farmers

Variables	**Change Planting Time**		**Crop Diversification**		**Non-farm diversification**		**Monitor weather using Indigenous knowledge**	
	Coeff	z-stat	Coeff	z-stat	Coeff	z-stat	Coeff	z-stat
Demographic characteristics								
Gender (male)	-0.8973	-2.07**	-0.5231	-1.15	-0.3895	-1.00	1.2330	2.03**
Education level								
Primary	0.5949	1.19	-0.4062	-0.84	-0.9760	-2.24**	-0.1318	-0.26
Secondary	0.8239	1.67*	0.1280	0.27	-0.8243	-1.91*	0.1483	0.30
Tertiary	1.0521	1.75*	-0.2810	-0.47	-0.2615	-0.47	-0.5611	-0.77
Household size	-0.0099	-0.55	0.0192	1.17	0.0220	1.33	0.0122	0.66
Years of growing cocoa	-0.0011	-0.15	-0.0128	-1.98**	-0.0264	-3.53	0.0074	1.04
Cocoa as primary crop	0.2094	0.78	0.3213	1.24	0.7905	2.75***	0.1814	0.57
Farming as primary occupation	0.5572	1.67*	0.9802	3.34***	-0.9922	-3.19***	0.0692	0.21
Other members sick	0.6242	2.70***	-0.1377	-0.62	-0.2692	-1.21	0.3392	1.32
Missed cocoa spraying	-0.8079	-4.18***	0.1095	0.61	0.2801	1.53	0.1809	0.93
Number of cocoa farms	-0.0938	-0.95	-0.2084	-2.20**	-0.0761	-0.80	0.0263	0.25
Farm ownership	-0.5002	-1.30	-0.3111	-0.83	-0.6242	-1.72*	0.5648	0.97
Cocoa land areas	-0.0391	-0.73	0.0230	1.39	-0.0065	-0.61	-0.0106	-0.32
Proportion of cocoa trees	-0.0026	-0.45	-0.0059	-1.05	0.0111	1.93*	0.0005	0.08
Farm distance	0.0275	0.88	0.0693	1.91*	0.0338	1.15	0.0076	0.24
Perceived Phytosanitary and other impacts								
More pests	-0.4147	-2.16**	-0.2271	-1.15	-0.4174	-2.15**	-0.3723	-1.79*
Difficulty in weed control	-0.5157	-2.78***	-0.2631	-1.45	0.1144	0.63	-0.4688	-2.38**
Increase in malaria	-0.0442	-0.24	0.0946	0.52	0.0662	0.35	0.2161	1.03
Scarce drinking water	0.4148	2.10**	0.1750	0.86	-0.0930	-0.45	-0.4730	-1.83*
Increase in pneumonia	-0.0989	-0.45	-0.3010	-1.36	0.2127	0.96	0.2960	1.20
Increase in cholera	0.4898	0.47	0.9038	1.00	0.0000	-	0.7229	0.88
Increase in death of cocoa trees	0.3558	1.58	0.4631	2.11**	0.5921	2.54**	0.3396	1.29
Increase in cocoa tree falling	0.1918	0.92	0.3076	1.55	0.0542	0.27	0.0581	0.26
Reduction in cocoa yields	-0.0101	-0.05	0.0342	0.16	-0.0840	-0.38	-0.0795	-0.33
More black pod diseases	-0.1240	-0.68	0.3725	2.08**	-0.2115	-1.15	-0.1021	-0.52
More wildfire	-0.0712	-0.20	0.2540	0.66	0.2127	0.61	-0.2248	-0.62
Inability to properly spray cocoa	-0.4222	-1.99**	-0.1744	-0.86	0.1367	0.67	0.4364	2.12
Inability to dry cocoa beans	-0.3605	-1.84*	-0.4651	-2.38**	0.4012	2.08**	0.4121	1.98**
Constant	0.2123	0.21	0.7540	0.79	0.6495	0.72	-3.6104	-2.99***
Diagnostic indicators								
Number of observations	303		303		300		303	
LR chi2(28)	77.30		66.63		68.27		5.35	
Prob > chi2	0.0000		0.0000		0.0000		0.0203	
Log likelihood	-152.796		-160.23		-155.40		-129.50	

Table 4b. Factors influencing climate change adaptation options among the cocoa farmers

Parameters	Regular Spraying		Planting of Hybrid seeds		Reduce Spraying Time Intervals		Media Monitoring	
	Coeff	z-stat	Coeff	z-stat	Coeff	z-stat	Coeff	z-stat
Gender (male)	-0.2787	-0.52	0.4670	1.21	-1.1381	-2.59***	0.3149	0.77
Education level								
Primary	1.3682	3.02***	1.0829	1.88*	-1.3500	-2.58***	1.0632	1.68*
Secondary	1.0157	2.33	1.3911	2.43**	-1.3952	-2.69***	1.1508	1.83*
Tertiary	1.1519	1.89*	1.7276	2.54**	-0.9487	-1.56	0.9732	1.35
Household size	-0.0008	-0.05	0.0297	1.89*	0.0212	1.35	0.0221	1.40
Years of growing cocoa	-0.0001	-0.01	-0.0163	-2.49**	-0.0042	-0.65	-0.0059	-0.89
Cocoa as primary crop	-0.0074	-0.02	0.3568	1.41	0.3308	1.29	0.2028	0.76
Farming as primary occupation	-0.0023	-0.01	0.3682	1.24	0.2332	0.82	-0.0012	0.00
Other members sick	-0.0931	-0.38	0.2703	1.28	0.2038	0.98	0.7370	3.20***
Missed cocoa spraying	0.2477	1.23	-0.0676	-0.39	0.1318	0.77	0.0015	0.01
Number of cocoa farms	-0.0404	-0.38	-0.1201	-1.29	0.0262	0.29	0.0441	0.47
Farm ownership	1.1123	3.10***	0.5230	1.31	0.5558	1.42	0.1835	0.46
Cocoa land areas	0.0158	0.70	-0.0408	-0.84	-0.0009	-0.10	-0.0190	-0.90
Proportion of cocoa trees	-0.0085	-1.38	0.0044	0.84	-0.0055	-1.06	0.0016	0.29
Farm distance	-0.0578	-1.86*	0.0113	0.38	-0.0246	-0.93	-0.0137	-0.49
Perceived Phytosanitary and other impacts								
More pests	-0.2323	-1.03	-0.1849	-1.00	0.0665	0.36	-0.4689	-2.54**
Difficulty in weed control	-0.3889	-1.94*	-0.5501	-3.12***	-0.1504	-0.89	-0.2886	-1.63
Increase in malaria	0.5023	2.48**	-0.3556	-2.00**	0.2709	1.55	-0.3598	-2.01**
Scarce drinking water	0.6751	2.46**	0.4901	2.41**	-0.4910	-2.36**	-0.2667	-1.31
Increase in pneumonia	-0.4587	-1.94*	-0.0479	-0.22	-0.2165	-1.00	0.5977	2.79***
Increase in cholera	-1.6129	-1.90*	0.5998	0.64	0.3331	0.41	0.0001	0.02
Increase in death of cocoa trees	-0.2101	-0.85	0.5292	2.44**	0.1921	0.91	0.0354	0.16
Increase in cocoa tree falling	0.2008	0.92	0.2694	1.38	-0.1501	-0.80	0.0364	0.19
Reduction in cocoa yields	0.2938	1.21	0.0203	0.10	-0.3044	-1.48	0.2279	1.08
More black pod diseases	-0.0357	-0.18	-0.1214	-0.70	-0.3685	-2.16**	-0.3755	-2.15**
More wildfire	0.5836	1.44	0.6300	1.62	0.4242	1.36	0.1685	0.54
Inability to properly spray cocoa	0.0809	0.36	-0.1444	-0.74	-0.0804	-0.43	-0.1139	-0.59
Inability to dry cocoa beans	0.0997	0.47	0.1274	0.70	-0.0530	-0.29	0.4189	2.21**
Constant	-0.3216	-0.32	-3.0997	-2.99***	1.8344	1.86*	-2.4141	-2.32**
Number of obs	303		303		303		303	
LR chi2(28)	50.9900		66.1100		50.03		52.89	
Prob > chi2	0.0050		0.0001		0.0064		0.0021	
Log likelihood	-128.05		-176.77		-182.98		-168.99	

The results further revealed that the probability of reducing spraying time intervals was negatively influenced by being a male ($p<0.01$), primary and secondary level of education ($p<0.01$) and perception of scarce of drinking water and perceived more black pod diseases ($p<0.05$). These results are contrary to those of Miyittah et al. (2022) who revealed that females were less likely to reduce their spraying time intervals compared to their male counterparts. However, our result is similar to that of Cooper et al. (2024) who found that males were the ones who owned sprayers and involved in cocoa spraying. Miyittah et al. (2022) finding are contrary to the ones of this study, revealing that farmers with some formal level of education are more likely to reduce spraying time intervals due to their safe conscious behaviour.

The results in Table 4b further revealed that the probability of weather monitoring through media was positively influenced by primary and secondary level of education, other members being sick and perceived increased pneumonia at 1% level of statistical significance while perceived inability to dry cocoa beans was positively and statistically significant at 5% level of significance. According to Denkyirah et al. (2017), it is expected of farmers with education to have higher probabilities of adopting climate change strategies because they are more likely to get critical information and can make informed decisions. Factors such as perceived more pests, perceived increase in malaria and perceived more black pod diseases were revealed to have negatively influenced weather monitoring through media at the 5% level of significance. The results on education are contrary to those of Oyekale and Oladele (2012) who also found out that as farmers' years of education increase, the less likely it becomes for them to adopt weather monitoring.

CONCLUSION

A proper understanding of the phytosanitary impacts on cocoa husbandry is very essential for promoting climate change adaptation and cocoa productivity in Cameroon. The results of the explored demographic variables have shown the need for gender sensitivity and interventions to educate farmers on some phytosanitary impacts of climate change and associated adaptation methods. Within rural setting, gender and education attainment often induce differences in access to resources and information for responding to some climatic shocks. More importantly, our findings have also underscored the role of farming experience, primary occupation, farm distance and morbidity among household members in explaining climate change adaptation. Specifically, although more pests were perceived by many cocoa farmers, this did not promote adoption of any climate change adaptation strategy. There is therefore the need to facilitate cocoa farmers' knowledge on pest induced adaptation methods that can reduce the impacts of climate change. The results also indicated that some pest and weed control problems resulted from climate change. However, these perceptions did not promote adoption of any of the adaptation strategies. Therefore, there is the need to facilitate and promote research into environmentally friendly pest and weed control methods in the event of climate extremes on cocoa farms. Currently, farmers apply more agrochemicals to control black pod disease and weeds, but they are costly with potentials for several environmental damages and food safety issues. The results also revealed that other domestic impacts that were felt by cocoa farmers such as inability to get drinking water, increase in pneumonia and increase in cholera had different impacts on adaptation. The implication is that provision of safe drinking water for cocoa farmers should be one of the basic priorities of development stakeholders in addressing the consequences of climate change. This also underscores the need for general education on the health consequences of climate change.

CONFLICT OF RESEARCH INTEREST

The authors declare no conflict of interest

AUTHORS' CONTRIBUTIONS

The article was written by both authors with equal contributions to the conceptualization, data analysis and report presentation.

REFERENCES

1. Abdulai I, Hoffmann M P, Jassogne L, Asare R, Graefe S, Tao H H, and Rötter, R P, 2020. Variations in yield gaps of smallholder cocoa systems and the main determining factors along a climate gradient in Ghana. Agricultural Systems, 181: 102812.
2. Abdulai I, Vaast P, Hoffmann M P, Asare R, Jassogne L, Van Asten P, and Graefe S, 2018. Cocoa agroforestry is less resilient to sub-optimal and extreme climate than cocoa in full sun. Global Change Biology, 24(1): 273-286.
3. Adebayo S T, Oyawole F P, Sanusi R A & Afolami C A, 2022. Technology adoption among cocoa farmers in Nigeria: what drives farmers' decisions? Forests, Trees and Livelihoods, 31(1): 1-12.
4. Adeniyi D, 2019. Diversity of cacao pathogens and impact on yield and global production. Theobroma Cacao-Deploying Science for Sustainability of Global Cocoa Economy.
5. Adu-Acheampong R, Sarfo J E, Appiah E F, Nkansah A, Awudzi G, Obeng E, and Sem R. 2015. Strategy for insect pest control in cocoa. American Journal of Experimental Agriculture, 6(6): 416-423.
6. African Development Bank (AfDB), undated. Cameroon, new seed varieties help cocoa crops bloom and farmers thrive. Available online: https://www.afdb.org/en/success-stories/cameroon-new-seed-varieties-help-cocoa-crops-bloom-and-farmers-thrive-33940#:~:text=There%20are%20600%2C000%20cocoa%20farmers,vital%20sector%20for%20rural%20communities (accessed on 16 July 2023).
7. Akrofi A Y, 2015. Phytophthora megakarya: A review on its status as a pathogen on cacao in West Africa. African Crop Science Journal, 23(1): 67-87.
8. Amon-Armah F, Baah F, Owusu-Ansah F, Adu-Acheampong R and Awudzi G K, 2023. Farmers' knowledge of major insect pests and their occurrence in cocoa plantations in Ghana. International Journal of Pest Management, 69(1): 1-13.
9. Anikwe J C and Otuonye H A, 2015. Dieback of cocoa (Theobroma cacao L.) plant tissues caused by the brown cocoa mirid Sahlbergella singularis Haglund (Hemiptera: Miridae) and associated pathogenic fungi. International journal of tropical insect science, 35(4): 193-200.
10. Apraku A, Morton J F, and Gyampoh B A, 2021. Climate change and small-scale agriculture in Africa: Does indigenous knowledge matter? Insights from Kenya and South Africa. Scientific African, 12: e00821.
11. Asante B O, Addai K N, Prah S, Temoso O, and Ng'ombe J N, 2023. Hand pollination, mass spraying, and hybrid seedlings: Do these technologies affect the welfare of smallholder cocoa farmers in Ghana? Review of Development Economics, 27(4): 2271-2300.
12. Asitoakor B K, Asare R, Ræbild A, Ravn H P, Eziah V Y, Owusu K and Vaast P, 2022. Influences of climate variability on cocoa health and productivity in agroforestry systems in Ghana. Agricultural and Forest Meteorology, 327: 109199.
13. Babin R, Ten Hoopen G M, Cilas C, Enjalric F, Yede, Gendre P and Lumaret J P, 2010. Impact of shade on the spatial distribution of Sahlbergella singularis in traditional cocoa agroforests. Agricultural and forest entomology, 12(1): 69-79.
14. Boateng K O, Dankyi E, Amponsah I K, Awudzi G K, Amponsah E, and Darko G, 2023. Knowledge, perception, and pesticide application practices among smallholder cocoa farmers in four Ghanaian cocoa-growing regions. Toxicology Reports, 10: 46-55.
15. Brou Y T, N'Goran J A K, Bicot S and Servat E, 2003. Risque climatique et production agricole en Côte d'Ivoire: effet des variations pluviométriques sur la production cacaoyère. In: 14th International Cocoa Research Conference, Accra, Ghana (pp. 259-267).

16. Calculator.Net, undated. Sample Size Calculator. Available online: https://www.calculator.net/sample-size-calculator.html?type=1&cl=95&ci=5&pp=50&ps=2500&x=55&y=6 (Accessed 15 June 2018).
17. Cameroon National Shippers' Council, undated. Cameroon cocoa production witnesses a 12% rise. Available online: https://www.cncc.cm/en/article/cameroon-cocoa-production-witnesses-a-12-rise-170 (accessed on 16 July 2023).
18. Chepkoech W, Stöber S, Kurgat B K, Bett H K, Mungai N W and Lotze-Campen H, 2023. What drives diversity in climate change adaptation strategies for African indigenous vegetable production in Kenya? Economic Analysis and Policy, 77: 716-728.
19. Cipriano I M, Onautsu D O, Tarassoum, T D, Adejumobi I I, and Bolakonga B A, 2022. Uptake of conservation agriculture technology through farmer field schools in the Democratic Republic of Congo and Mozambique. Journal of Agricultural Extension, 26(1): 44-58.
20. Denkyirah E K, Okoffo E D, Adu D T and Bosompem O A, 2017. What are the drivers of cocoa farmers' choice of climate change adaptation strategies in Ghana? Cogent Food & Agriculture, 3(1): 1334296.
21. Economist Intelligence, undated. Cocoa output to falter in 2016/17 season. Available online: https://country.eiu.com/article.aspx?articleid=1914629575&Country=Cameroon&topic=Economy&subtopic=_9#:~:text=The%20country%20produced%20a%20record,because%20of%20favourable%20weather%20conditions (accessed on 16 July 2023).
22. Fadeyi O A, Ariyawardana A and Aziz, A A, 2022. Factors influencing technology adoption among smallholder farmers: a systematic review in Africa. Journal of Agriculture and Rural Development in the Tropics and Subtropics 123(1): 13-30
23. Fosu-Mensah B Y, Okoffo E D and Mensah M, 2022. Assessment of farmers' knowledge and pesticides management in cocoa production in Ghana. International Journal of Advanced and Applied Sciences, 9(3): 100-110.
24. Gateau-Rey L, Tanner E V, Rapidel B, Marelli J P and Royaert S, 2018. Climate change could threaten cocoa production: Effects of 2015-16 El Niño-related drought on cocoa agroforests in Bahia, Brazil. PloS One, 13(7), e0200454.
25. Hashmiu I, Agbenyega O and Dawoe E, 2022. Determinants of crop choice decisions under risk: A case study on the revival of cocoa farming in the Forest-Savannah transition zone of Ghana. Land Use Policy, 114: 105958.
26. Hassan R M and Nhemachena C, 2008. Determinants of African farmers' strategies for adapting to climate change: Multinomial choice analysis. African Journal of Agricultural and Resource Economics, 2(1): 83-104.
27. Hyde-Cooper W, Tham-Agyekum E K, Bakang J E A, Ntem S, Ankuyi F and Mohammed R, 2024. Cocoa farmer's use of approved pesticides and compliance with safety standards in Obuasi Municipality, Ghana. International Journal on Food, Agriculture and Natural Resources, 5(2): 83-94.
28. Keil A, Zeller M, Wida A, Sanim B, Birner R, 2008. What determines farmers' resilience towards ENSO-related drought? An empirical assessment in Central Sulawesi, Indonesia. Climate Change, 86: 2
29. Kinuthia, K J, 2018. Factors influencing farmers' response to climate variability in Narok east sub-county, Kenya (Doctoral dissertation, Egerton University).
30. Koissy Y V A and N'Zue F F, 2020. Climate change and cocoa production in côte d'ivoire: should we worry? Journal of Economics and Business, 3(2).
31. Kolavalli S and Vigneri M, 2011. Cocoa in Ghana: Shaping the success of an economy. Yes, Africa can: success stories from a dynamic continent, 201, 258643-1271798012256.
32. Kroeger A, Koenig S, Thomson A, Streck C, 2017. Forest-and climate-smart cocoa in Cote d'Ivoire and Ghana: aligning stakeholders to support smallholders in deforestation-free cocoa. World Bank; 2017 Dec 15.
33. Lavison R, 2013. Factors influencing the adoption of organic fertilizers in vegetable production in Accra (Doctoral dissertation, MSc Thesis, Accra Ghana).
34. Lu W, Addai K A and Ng'ombe J N, 2021. Does the use of multiple agricultural technologies affect household welfare? Evidence from Northern Ghana. Agrekon, 60:370–387. https://doi.org/10.1080/03031853.2021.1992290

35. Macías Barberán R, Cuenca Nevárez G, Intriago Flor F, Caetano C M, Menjivar Flores J C and Pacheco Gil H A, 2019. Vulnerability to climate change of smallholder cocoa producers in the province of Manabí, Ecuador. Revista Facultad Nacional de Agronomía Medellín, 72(1): 8707-8716.
36. Maguire-Rajpaul V A, Khatun K and Hirons M A, 2020. Agricultural information's impact on the adaptive capacity of Ghana's smallholder cocoa farmers. Frontiers in Sustainable Food Systems, 4: 28.
37. Mahob R J, Ndoumbe-Nkeng M, Ten Hoopen G M, Dibog L, Nyassé S, Rutherford M and Bilong C B, 2014. Pesticides use in cocoa sector in Cameroon: characterization of supply source, nature of actives ingredients, fashion and reasons for their utilization. International Journal of Biological and Chemical Sciences, 8(5): 1976-1989.
38. Mahob R, Baleba L, Dibog L, Cilas C, Bilong C F B and Babin R, 2015. Spatial distribution of Sahlbergella singularis Hagl.(Hemiptera: Miridae) populations and their damage in unshaded young cacao-based agroforestry systems. Int. J. Plant Anim. Environ. Sci., 5 (2): 121-132.
39. Miyittah M K, Ansah B, Kwadzo M, Seidu-Larry S and Kosivi R K, 2022. Assessment of pesticide exposure risks among cocoa farmers in Western region of Ghana. International Journal of Pest Management, 28: 1-9.
40. Mkondiwa M, 2023. Is wealth found in the soil or in the brain? Investing in farm people in Malawi. Review of Development Economics, 27(1): 134-157. https://doi.org/10.1111/rode.12946
41. Mugiyo H, Mhizha T, Chimonyo V G and Mabhaudhi T, 2021. Investigation of the optimum planting dates for maize varieties using a hybrid approach: A case of Hwedza, Zimbabwe. Heliyon, 7(2).
42. Mwinkom F X, Damnyag L, Abugre S and Alhassan S I 2021. Factors influencing climate change adaptation strategies in North-Western Ghana: evidence of farmers in the Black Volta Basin in Upper West region. SN Applied Sciences, 3: 1-20.
43. Ndoumbe-Nkeng M, Cilas C, Nyemb E, Nyassé S, Bieysse D, Flori A and Sache I, 2004. Impact of removing diseased pods on cocoa black pod caused by Phytophthora megakarya and on cocoa production in Cameroon. Crop protection, 23(5): 415-424.
44. Oluyole K A, Emaku L A, Aigbekaen E O and Oduwole O O, 2013. Overview of the trend of climate change and its effect on cocoa production in Nigeria. World Journal of Agricultural Research, 1(1): 10-13.
45. Owoeye R S and Sekumade A B, 2016. Effect of climate change on cocoa production in Ondo state, Nigeria. Journal of Social Science Research, 10(2): 2014-2025.
46. Oyedokun A V, Buari R A, Olorunmota R T and Asumbo O I, 2022. Effects of climate elements on population dynamics of insect pests of cocoa-a review. European Journal of Applied Sciences, 10(5): 231-237.
47. Oyedokun F O and Oyelana A A, 2016. Effects of Climate Change on Cocoa Farmers' Production. Journal of Human Ecology, 53(3): 233-244.
48. Oyekale A S, 2012. Impact of climate change on cocoa agriculture and technical efficiency of cocoa farmers in South-West Nigeria. Journal of Human Ecology, 40(2): 143-148.
49. Oyekale A S, 2015. Climate change induced occupational stress and reported morbidity among cocoa farmers in South-Western Nigeria. Annals of Agricultural and Environmental Medicine, 22(2): 357-361
50. Oyekale A S and Oladele O I, 2012. Determinants of climate change adaptation among cocoa farmers in southwest Nigeria. ARPN Journal of Science and Technology, 2(1): 154-168.
51. Peters K, Breitsameter L and Gerowitt B, 2014. Impact of climate change on weeds in agriculture: a review. Agronomy for Sustainable Development, 34: 707-721.
52. Phelan C J, 2014. Understanding the farmer: An analysis of the entrepreneurial competencies required for diversification to farm tourism (Doctoral dissertation, University of Central Lancashire).
53. Pouokam G B, Lemnyuy Album W, Ndikontar A S and Sidatt M E H, 2017. A pilot study in cameroon to understand safe uses of pesticides in agriculture, risk factors for farmers' exposure and management of accidental cases. Toxics, 15(4): 30.
54. Ruf F, Schroth G, Doffangui K, 2015. Climate change, cocoa migrations and deforestation in West Africa: What does the past tell us about the future? Sustainability Science,10: 101-111. doi: 10.1007/s11625-014-0282-4

55. Ruf F, 2015. Diversification of cocoa farms in Côte d'Ivoire: Complementarity of and competition from rubber rent. In: Economics and Ecology of Diversification: The Case of Tropical Tree Crops (pp. 41-86). Dordrecht: Springer Netherlands.
56. Salam S and Bauer S, 2022. Rural non-farm economy and livelihood diversification strategies: evidence from Bangladesh. GeoJournal, 87(2): 477-489.
57. Santosa A E, Sakti A G P, Fattah B M Z, Zaman A S and Wachjar A A, 2018. Cocoa production stability in relation to changing rainfall and temperature in East Java, Indonesia. Journal of Tropical Crop Science, 5(1): 6-17.
58. Schroth G, and Ruf F, 2014. Farmer strategies for tree crop diversification in the humid tropics. A review. Agronomy for Sustainable Development, 34(1):139-154.
59. Schroth G, Läderach P, Martinez-Valle A I, Bunn C and Jassogne L, 2016. Vulnerability to climate change of cocoa in West Africa: Patterns, opportunities and limits to adaptation. Science of the Total Environment, 556: 231-241.
60. Singh S, 2020. Farmers' perception of climate change and adaptation decisions: A micro-level evidence from Bundelkhand Region, India. Ecological Indicators, 116: 106475.
61. Soberanis W, Rıos R, Arévalo E, Zuniga L, Cabezas O and Krauss U, 1999. Increased frequency of phytosanitary pod removal in cacao (Theobroma cacao) increases yield economically in eastern Peru. Crop Protection, 18(10): 677-685.
62. Suh N N and Molua E L ,2022. Cocoa production under climate variability and farm management challenges: Some farmers' perspective. Journal of Agriculture and food Research, 8:100282.
63. Thinda K T, Ogundeji A A, Belle J A and Ojo T O, 2020. Understanding the adoption of climate change adaptation strategies among smallholder farmers: Evidence from land reform beneficiaries in South Africa. Land Use Policy, 99:104858.
64. Medina V and Laliberte B, 2017. A Review of Research on the Effects of Drought and Temperature Stress and Increased CO2 on Theobroma Cacao L., and the Role of Genetic Diversity to Address Climate Change. Bioversity International, Costa Rica (2017). https://www.bioversityinternational.org/fileadmin/user_upload/Review_laliberte_2017_new.pdf (accessed on 9th June 2024).
65. Van Aelst K and Holvoet N, 2016. Intersections of gender and marital status in accessing climate change adaptation: evidence from rural Tanzania. World Development, 79:40-50.
66. Vos R, Velasco M, Labastida E, 1999. Economic and social effects of" El Nino" in Ecuador, 1997–8. ISS Work Pap SeriesGeneral Series, 292: 1-55.
67. Wongnaa C A, Jelilu F, Apike I A, Djokoto J G and Awunyo-Vitor D, 2022. Effect of hybrid cocoa seedlings adoption on profit efficiency in Ghana. Sustainable Futures, 4: 100074.
68. Yaro J A, Teye J K and Wiggins S, 2024. Changing land and labour relations on cocoa farms in Sefwi, Ghana: Continuity and change. World Development Perspectives, 34: 100584.
69. Yoroba F, Kouassi B K, Diawara A, Yapo L A, Kouadio K, Tiemoko D T and Assamoi P, 2019. Evaluation of rainfall and temperature conditions for a perennial crop in tropical wetland: a case study of cocoa in Côte d'Ivoire. Advances in Meteorology, 1-10, https://doi.org/10.1155/2019/9405939
70. Zuidema P A, Leffelaar P A, Gerritsma W, Mommer L, Anten N P R, 2005) A physiological production model for cocoa (Theobroma cacao): model presentation, validation and application. Agricultural Systems, 84: 195-225.