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Climate change coping and adaptation strategies: How do cocoa farmers in Ghana diversify farm income?

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ABSTRACT

Climate change poses a serious threat to many farmers' yield and income. Previous studies often applied a general approach to examine climate change mitigation strategies implemented by farmers. Our study focuses on income diversification of cocoa farmers in Ghana as a strategy to cope with climate change. We compiled data from 400 cocoa farmers, and applied a Heckman two-step regression to investigate the probability and extent of cocoa farm income diversification. Further, we used beta regression to determine the share of annual farm income generated by diversification. Most cocoa farmers in our study region diversify farm income as a strategy to reduce climate change impacts. These strategies comprise crop and livestock diversification, intercropping of cocoa farms, provision of labour for other farmers, and agricultural-related economic off-farm activities. Factors that influence income diversification include the age of the farm, access to credits, extension contacts, the information sources on climate change, and government support. The study provides recommendations for policy- and decision-makers to enhance diversification strategies in the country's cocoa sector. These include the provision of financial credits, farm input subsidies, and farmers' training on farm management.

1. Introduction

Cocoa, *Theobroma cacao* L., is a perennial crop cultivated in the forest zones of West Africa and other parts of the world. In Ghana, cocoa plays a critical role in the socioeconomic development of farmers and the country as a whole (Ali et al., 2018). The cocoa sector is central to employment creation, health, education, road construction, and the generation of foreign exchange earnings. The sector is estimated to have created some 800,000 jobs in the country (Bunn et al., 2019; Asamoah and Owusu-Ansah, 2017). Ghana is the second-largest producer and exporter of cocoa beans after Cote d'Ivoire (GSS, 2017). Regardless of the crop's importance to the Ghanaian economy, many farmers in this sector are vulnerable to the impact of climate change, which is a major challenge for crop production in Africa (Tesso et al., 2012; Paavola, 2008; Obeng, 2014; Fussel, 2007).

Uncertain climatic conditions (precipitation and temperature) make cocoa cultivation in Ghana a risky business (Bunn et al., 2019). Cocoa generally requires temperatures ranging between 21 °C and 23 °C, and annual rainfall between 1000 and 2500 mm to achieve optimum yields (Ameyaw et al., 2018). The adverse ramifications of climate change in the cocoa sub-sector have negative consequences for the Ghanaian economy (Bunn et al., 2019). Afriyie-Kraft et al. (2020) reported that 90% of the cocoa farms in Ghana are exposed to negative effects of climate change, yet about 25% of farmers implement no adaptation strategies.

A recent climate change adaptation study focused on annual crops (Gunathilaka et al., 2018). Other studies have investigated a wide range of issues related to climate change and variability in the cocoa sector of Ghana and West Africa as a whole (Oyekale, 2020; Afriyie-Kraft et al., 2020; Bunn et al., 2019; Ameyaw et al., 2018; Abdulai et al., 2018; Schroth et al., 2017; Schroth et al., 2016; Ruf et al., 2015). These studies dealt with issues related to cocoa farmers' vulnerability to climate change, their perceptions of climate change, and challenges in implementing mitigation strategies. Some studies investigated cocoa farmers' climate change coping and adaptation strategies in general. According to Kabir et al. (2017), agricultural productivity and profitability are highly sensitive to climatic stress. Läderach et al. (2011) documented an inverse relationship between progressive climate change and cocoa suitability in Ghana and Cote D'Ivoire. Given the recent trend of climate variables (i.e., rising temperatures, and prolonged drought), cocoa productivity is expected to reach an all-time low by 2050 (Läderach et al., 2011). Sivakumar and Stefanski (2011) examined the effect of climate change on food security in Asia and concluded that seasonal fluctuations of climate-related factors have adverse

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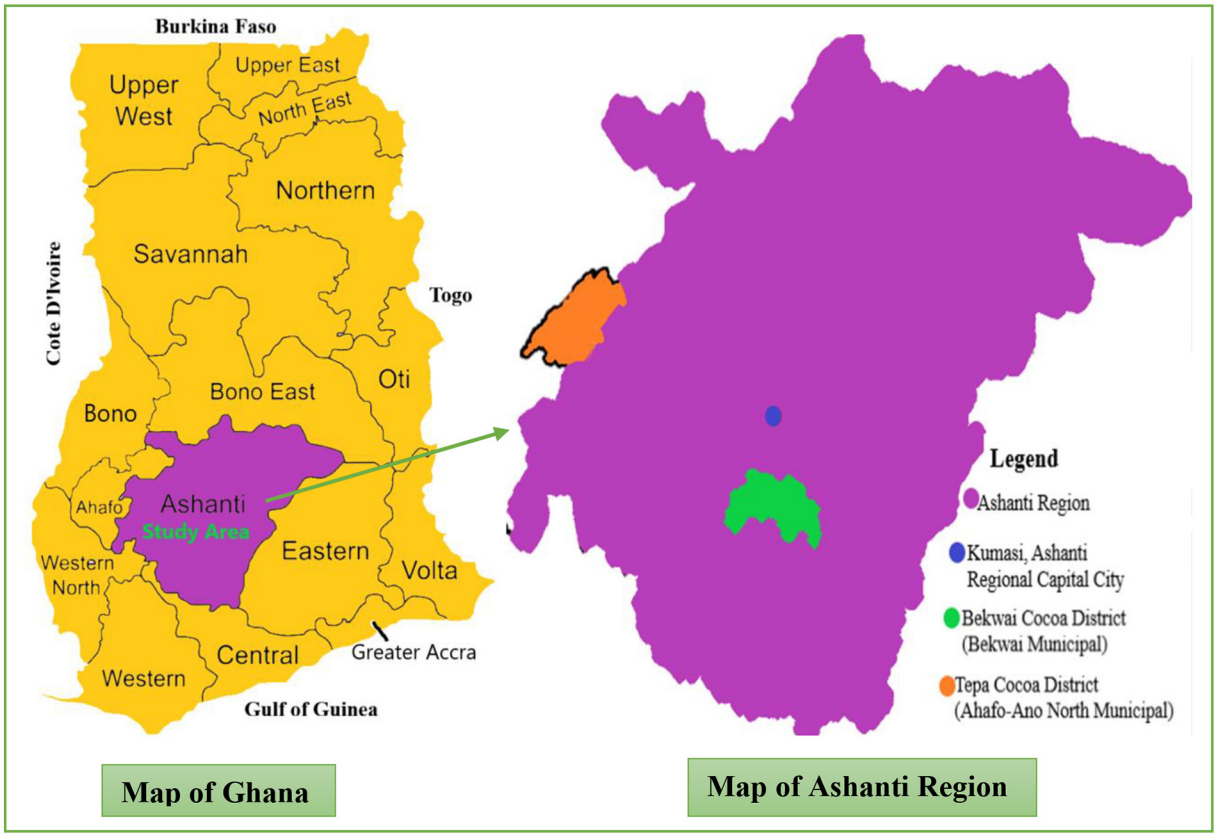

Fig. 1. Map of Ghana indicating the study location.
(Source: Authors)

effects on crop productivity. A study by Oluwatusin (2014) revealed that 75% of cocoa farmers in Nigeria perceive increasing temperature as a severe issue of climate change. In addition, 94% believed that climate change has drastically affected the timing of seasonal rainfall. This affects farmers' preparedness towards the season's farming activities with negative consequences for the productivity.

Drastic changes in climatic conditions lead to drought, high temperatures, reduced precipitation, and fluctuations in seasonal rainfall (World Bank, 2008). According to Oyekale (2012), increasing minimum temperatures tend to boost production, whereas changing rainfall patterns can have diverse effects: on the one hand, excessive rainfall may lead to flooding, which may create favourable conditions for the growth and multiplication of pathogens that cause cocoa diseases like the black pod (Oyekale, 2012). On the other hand, a decrease in rainfall may eventually lead to drought, thereby depriving the ability of cocoa plants to synthesize soil nutrients for proper growth and development (Oyekale, 2012).

Against this background, Ndamani and Watanabe (2016) examined the factors that influence farmers' adaptation to climate change. They observed that the majority of farmers in the Upper West Region of Ghana adopt crop diversification as a mitigation strategy to deal with the impacts of climate change. They also found that farmers adopt strategies to cope with floods and droughts as well as to improve soil fertility and crop productivity. Oluwatusin (2014) showed that on-farm climate change coping strategies are common in Nigeria. As a result, 59% of cocoa farmers adopt improved varieties, while 83% focus on land and water management practices. In contrast, only 21% adapt to climate change by seeking off-farm employment. Orimogunje et al. (2020) observed that farmers diversify by cultivating other crops that serve as 'shock absorbers' in times of cocoa crop failure due to climate change.

These previous studies applied a more general approach to examine the different strategies employed by farmers to cope with climate change. Our study rather focuses on farm income diversification, given that a significant impact of climate change is a reduction in yield, and hence, farmers' income (Nkeme and Ndaeyo, 2013; Fraser et al., 2011; Deressa et al., 2009). Therefore, there is a need to investigate, whether cocoa farmers diversify their income as an adaptive approach against risks to cocoa production resulting from changing climatic conditions.

Paavola (2008) argued that diversification is often considered as 'always good'. Yet, farmers diversify for many reasons, e.g., to fully utilize previously under-employed labour or land, rather than to manage risk through a portfolio of income sources with different risk attributes (Paavola, 2008). Despite the different motivations for diversification, our study aims to inquire from cocoa farmers, whether they diversify farm income as a mitigation strategy against climate change. Focusing on a particular probable climate change adaptive strategy and delving deeper into it, differentiates this study from previous ones. Besides, this study provides scientific results as a basis for practice-relevant policy advice.

While other studies have examined diversification of farm, rural incomes, and livelihoods, among farmers (Donkoh et al., 2017; Sekumade and Osundare, 2014; Lama, 2014; Adepoju and Obayelu, 2013; Khatun and Roy, 2012; Asmah, 2011; Saha and Bahal, 2010; Ellis, 2000), no link has been drawn between climate change adaptation and farm income diversification. Thus, we focused on the following research questions: Do cocoa farmers in Ghana diversify farm income to protect themselves against climate change? What is the proportion of annual income obtained from income diversification? What are the determinants of income diversification and their contribution to farmers' income? Answering these questions is crucial to understand how cocoa farmers perceive diversification and the respective strategies available to them. Moreover, understanding coping strategies within the farmers' socioeconomic context is vital for developing better and

effective policies that can help improve their future adaptation efforts (Bryan et al., 2013).

2. Materials and methods

2.1. Study location and characterization of cocoa farming

The study was conducted in the Tepa and Bekwai Cocoa districts in the Ashanti Region of Ghana (Fig. 1). The Ghana Cocoa Board (COCOBOD) is a Ghanaian government-controlled institution in charge of promoting and encouraging the production, processing, and marketing of cocoa in Ghana. The COCOCBOD has divided Ghana into cocoa districts that are different from the administrative districts of Ghana. Hence, this study used COCOBOD's cocoa districts for the selection of the study sites. The Tepa Cocoa District belongs administratively to the Ahafo-Ano North Municipal, while Bekwai Cocoa District is located in the Bekwai Municipal. Fig. 1 shows a map of Ghana with the Ashanti Region with Tepa and Bekwai Cocoa districts.

The Ashanti Region is the second leading cocoa-producing region in Ghana (GSS (Ghana Statistical Service), 2013a). Tepa and Bekwai Cocoa Districts are among the leading cocoa-producing districts in the country. Agriculture is the main economic activity, and it employs the majority of the active working population in these districts. The main agricultural activity is crop farming, of which cocoa is one of the main crops cultivated (GSS (Ghana Statistical Service), 2013a).

According to Ghana's 2010 Population and Housing Census (PHC), 94,285 people live in Ahafo-Ano North Municipal, representing 2.0% of the total population of the Ashanti Region. The population of Bekwai Municipal sums up to 118,024, representing 2.5% of the region's total population. Slightly more than 80% of the population in the two municipalities reside in rural areas. This makes agriculture, especially cocoa production, a predominant source of livelihood in these municipalities. Hence, as much as 74% of the households in Ahafo-Ano North Municipal and 65.5% in Bekwai Municipal depend on agriculture, of which about 98% are engaged in crop farming (GSS (Ghana Statistical Service, 2014a, 2014b).

According to the 2010 PHC, the average household of the Ahafo-Ano North and Bekwai Municipals consists of four persons. Children form the highest percentage of household members (44.5% in Ahafo-Ano North and 42.3% in Bekwai). The share of the elderly population is also substantial. Therefore, the total age dependency ratios for Ahafo-Ano North Municipal (84.2) and Bekwai Municipal (90.0) are high. These high dependency ratios make income diversification pertinent for the working population when facing climate change and its negative impact on farming activities. Furthermore, 71.4% and 80.0% of the population (aged 11 years and older) in Ahafo-Ano North and Bekwai Municipals are literates, respectively. However, the educational level of farmers in both municipalities is generally low.

Only 36.2% of the population in Ahafo-Ano North and 70.1% in Bekwai have electricity in their houses. Less than half of the households in both municipalities has access to boreholes and pipe-borne water. There are few tarred roads, mainly in the municipal capitals and other major towns. Further, there are only few health centres (i.e., hospitals and clinics) in the two municipalities. The majority of the towns in the municipalities have basic schools (primary and junior high schools), with few urban areas having senior high schools. Thus, the level of infrastructure in the Ahafo-Ano North and Bekwai Municipals is generally low and heavily skewed towards urban areas. Farming households suffer most from the poor technical and educational infrastructure since the majority of these farmers live in rural localities. For instance, 84.0% and 75.2% of the rural population in Ahafo-Ano North and Bekwai, respectively, are agricultural households (GSS, 2014a; 2014b).

There are both individual cocoa farms and family cocoa farms in the study area. Although our study considers both farm management systems, it is presumed from the responses that the management of individual cocoa farms is dominating. Furthermore, the majority of cocoa farmers in Ghana are low-income smallholders, which makes it hardly possible for most of them to pay for hired labour (Amfo, 2019). Thus, to reduce production costs, the majority uses family labour (Amfo, 2019). Like in other parts of Ghana, only few cocoa farmers in the two sampled cocoa districts own production assets, such as farm machinery and irrigation pumps.

Nevertheless, the ownership and use of knapsack and motorized sprayers to apply agrochemicals is widespread in all cocoa-producing localities of Ghana. Cocoa farmers who do not own sprayers (especially motorized sprayers) usually hire them from other farmers. The majority of cocoa farmers in Ghana operate small-scale farms, averaging 2–5 ha. With such small farm sizes, coupled with poor agronomic practices, annual yields are usually low, averaging between 350 and 400 kg per hectare with a median cocoa yield of about 234 kg per hectare (Aneani and Padi, 2016). However, there are a few outliers that have less than two hectares or far more than five hectares, leading to varying results within the described margin. The aforementioned characterization of cocoa farms in the Tepa and Bekwai Cocoa Districts shows that they belong to the low-income group, and are, thus, more likely to suffer from climate change, which makes income and livelihood diversification crucial but also difficult.

2.2. Data and sampling

We gathered primary data from interviews with 400 cocoa farmers using the multi-stage sampling technique. In the first stage, a list of major cocoa-producing communities in Tepa and Bekwai cocoa districts was obtained from the Cocoa Health and Extension Division of COCOBOD. Ten cocoa communities were then randomly selected from each of the two districts. In the second stage, we employed simple random sampling to select 20 cocoa farmers from each of the 20 communities.

We used a semi-structured questionnaire for data collection from October to November 2018 (2017/2018 cocoa season). It comprised questions on cocoa farmers' socioeconomic and farm-level characteristics, institutional factors, and primary sources of information on climate change. The following questions were included to explore whether cocoa farmers use farm income diversification to protect their farms from the negative impact of climate change: (1) Have you perceived or experienced negative impacts of climate change on cocoa production? (2) If yes, which ones? We found that the major effect of climate change relates to the reduction of cocoa yield, and thus, cocoa farm income. Therefore, questions on climate change adaptation strategies were narrowed down to cocoa farm income diversification. The aim was to make the study precise, explicit, and clear-cut for policy recommendations and academic contributions. As a result, we specified further questions: (3) Do you diversify farm income to compensate the probable low yield (and hence, farm income) due to climate change? (4) If yes, which farm income diversification strategies do you employ?

Before conducting the survey cocoa extension officers who understood the vernacular of the study area were trained on the questionnaire to assist the authors in the data collection. Primary data from the cocoa farmers was obtained through face-to-face interviews. This type of data collection was preferred, first, because it allowed the enumerators (authors) to freely interact with the respondents. Second, it enabled us to provide a detailed interpretation of the questions to respondents with low or no formal education. Third, it enabled the enumerators to discuss certain general issues about the study that were not captured in the questionnaire.

Ethical issues are very crucial in field surveys. Before starting the questionnaire, enumerators sought the consent of respondents by explaining the purpose of the study. The enumerators also guaranteed the anonymity of the respondents and the information provided. Additionally, respondents were informed that participation was voluntary. In all, 400 questionnaires were completed during the field

survey, implying a 100% response rate.

2.3. Analytical framework

The Heckman two-step model was used to determine the probability and extent of cocoa farm income diversification. The model was used to estimate cocoa farmers' decision to diversify farm income (first stage); and the number of diversifications used as climate change coping and adaptation strategies (second stage). We subsequently applied a beta regression to estimate the proportion of annual income from diversification, i.e., the contribution of cocoa farm income diversification to total annual farm income.

2.3.1. Heckman two-step model

To cope with climate change, cocoa farmers diversify their income to a different extent, which was measured by the number of farm income diversifications. The observed outcome of diversification was modelled by use of a random utility function. Consider the cocoa farmer faced with the decision, whether to diversify farm income or not. The utility a cocoa farmer obtains from diversifying farm income is given by U_{iA}, and from no diversification by U_{i0}. Considering utility maximization and rationality, a cocoa farmer diversifies farm income if:

$$P^* = U_{iA} - U_{10} > 0 \quad (1)$$

The net utility P* can be expressed as a function of observed characteristics (Z_i) and error term (ε_i) as:

$$P_i^* = Z_i\beta + \varepsilon_j;\ P_i^* = 1 \text{ if } P_i^* > 0 \text{ and } P_i^* = 0, \text{otherwise} \quad (2)$$

where P_i^* denotes cocoa farm income diversification decision (a dummy variable); $P_i^* = 1$, if there is farm income diversification, and $P_i^* = 0$, if not. Z_i is a vector representing explanatory variables. β is a vector of parameters to be estimated, and ε_i is the error term.

Not all cocoa farmers will diversify their farm income. Hence, a vital econometric problem that arises is sample selection bias. Excluding farmers who did not diversify farm income infers that the response variable is censored, and will not satisfy the condition that the sum of residuals should be equal to zero (Maddala, 1983). We addressed the problem of sample selection bias by applying the Heckman two-step model (Heckman, 1979). Therefore, diversification of cocoa farm income entails a two-step process. The first step is the decision of cocoa farmers to diversify farm income in coping with climate change using the probit model. The second step is to determine the number of farm income diversifications (the extent or intensity) using an Ordinary Least Square (OLS) estimator, where the latter decision depends on the former. Hence, the procedure in the second step may not be random, leading to selectivity bias. Only cocoa farmers, to which the determinants of diversification apply, diversify their income. Based on the foregoing, the Heckman two-stage model seems appropriate to address sample selection bias (Heckman, 1979). The first step of the model (selection equation) is given as:

$$A_i^* = \beta_0 + \beta_1 X_1 + \varepsilon_1 \quad (3)$$

where A* is an unobserved latent variable denoting a cocoa farmer's decision to diversify farm income; X_i denotes the explanatory variables (Table 1); β denotes parameters to be estimated, and ε_i denotes the error term. The observed binary variable is given as:

$$A = 1 \text{ if } A_i^* > 0 \text{ (cocoa farmers who diversify farm income)} \quad (4)$$

$$A = 0 \text{ if } A_i^* \leq 0 \text{ (cocoa farmers who do not diversify farm income)} \quad (5)$$

The second step of model (substantive equation) is estimated with an OLS estimator given as:

$$Y_i = \alpha_0 + \alpha_i Z_i + \mu_i \quad (6)$$

Eq. 6 represents a sub-category of Eq. 3, and it is only estimated for cocoa farmers who diversified farm income. To correct for self-selection bias in the substantive equation, an Inverse Mills Ratio (IMR) represented by λ is used as an additional explanatory variable (Green, 2008), resulting in Eq. 7:

$$Y_i = \alpha_0 + \alpha_i Z_i + \delta_i \lambda_i + \mu_i \quad (7)$$

where δ_i denotes the coefficient of the IMR (λ_i). If lambda (λ) is statistically significant, sample selection bias is a problem, and Heckman's two-step estimation is appropriate (Marchenko and Genton, 2012).

2.3.2. Beta regression model

The beta regression model accommodates a response variable greater than 0 but less than 1 (Bonat et al., 2014; Bayes et al., 2012). In our case, the response variable is the proportion of annual income from cocoa farm income diversification. A linear regression model would be unsuitable for such data since it yields fitted values for such data exceeding the confined domain and fails to account for asymmetries between variables (Galvis et al., 2014; Ferrari and Cribari-Neto, 2004). The beta model is a generalized linear model, and the beta density has a flexible shape, which represents a variety of distributions appropriate for modelling outcomes confined by lower and upper limits (Bonat et al., 2014; Smithson and Verkuilen, 2006). The beta regression estimator was introduced by Ferrari and Cribari-Neto (2004) and extended by Smithson and Verkuilen (2006). The probability beta density for the response variable is defined in its general form as:

$$f(y;p,q) = \frac{\Gamma(p+q)}{\Gamma(p)\Gamma(q)} y^{p-1}(1-y)^{q-1},\ 0 < y < 1 \quad (8)$$

where y is the response variable; p and q are unknown parameters controlling the shape of the distribution, p, q > 0; and $\Gamma(.)$ is the gamma function.

3. Results

First, the descriptive statistical analysis of the variables is reported briefly. Second, we present the type and number of farm income diversification implemented by cocoa farmers to cope with climate change. Third, the proportion of annual income from cocoa farm diversification is illustrated. Finally, we present the empirical analysis based on the Heckman and beta regressions.

3.1. Descriptive statistics

More than half of the cocoa farmers are men (Table 2), suggesting that cocoa production in our study region is a male-dominated activity. Female farmers mostly engage in the cultivation of vegetables, cereals, and other annual crops, while assisting their husbands in cultivating perennial crops such as cocoa, coconut, oil palm, orange, and cashew. The mean age of 53 years suggests that the workforce in the cocoa sector has an advanced age. An average cocoa farmer has completed primary education (Class 6), although few had tertiary education, while others had no formal education. The mean for nativity suggests that about 40% of cocoa farmers have migrated to the study area. Comparably, the 2010 PHC revealed that 43% of the population of Ahafo-Ano North Municipal are migrants (GSS, 2014a), whereas this holds for approximately 24% of farmers in the Bekwai Municipality (GSS, 2014b). This finding is consistent with Amfo (2019), who reported that migrants play a crucial role in cocoa production in Ghana. The average distance from the respondents' community to the regional capital (Kumasi) is about 120 km.

Cocoa farmers in the study area have engaged in cocoa production for many years, inferring a high level of acquaintance with cocoa production and knowledge accumulation over the years (Table 2). The average cocoa farm size is 8 ha, which is higher than the national average of 2–5 ha (GSS (Ghana Statistical Service), 2013b). On average, cocoa farms are 14 years old, suggesting that these farms have not yet reached the rehabilitation age recommended by COCOBOD for over-

Table 1
Variables for the Heckman and beta regressions.

Variable	Measurement	Expected sign
Response variable		
Diversification	1 = a cocoa farmer diversifies farm income in guarding against climate change; 0 = otherwise	n.a.
Number of farm income diversifications	Number of farm income diversifications used by a cocoa farmer as a climate change coping and adaptation strategy	n.a.
Proportion of annual income from farm income diversification	Annual income from cocoa farm income diversification as a ratio of total annual income	n.a.
Explanatory variable		
Sex	1 = male, 0 = female	+/−
Age	Years	+/−
Education	Years	+
Household size	Number of people	+/−
Nativity	1 = indigene, 0 = migrant	+/−
Distance to regional capital	Kilometres	+/−
Cocoa production experience	Years	+/−
Farm size	Hectares	+/−
Age of cocoa farm	Years	+/−
Main type of labour	1 = hired, 0 = family	+/−
Annual income from cocoa sales	GH¢*	+/−
Credit for cocoa production	GH¢*	+
Extension contacts	Number of extension visits	+
FBO	Years of membership	+
Media	1 = main source of climate change information is radio or television, 0 = otherwise	+/−
Institutions	1 = main source of climate change information is extension officers, FBOs or NGOs, 0 = otherwise	+/−
Other farmers, community leaders	1 = main source of climate change information is other farmers and community leaders, 0 = otherwise	+/−
Ghana Meteorological Service	1 = main source of climate change information is Ghana Meteorological Service, 0 = otherwise	+/−
Education by information sources	1 = information sources educate farmer on climate change adaptation strategies, 0 = otherwise	+
Government support	1 = farmer benefitted from subsidized fertilizers and farm tools, 0 = otherwise	+
Training on farm management	1 = farmer has received farm management training, 0 = otherwise	+

Note: *GH¢ denotes Ghana cedis, the currency of Ghana, US$1 = GH¢5.62. n.a. denotes not applicable.

aged cocoa farms (30 years). Most cocoa farmers use family labour instead of hired workers, taking advantage of their large family size to provide labour for their farms.

Table 2 further shows that less than half of the cocoa farmers (i) have extension contacts, (ii) belong to Farmer-based Organizations (FBOs), or (iii) obtained credits for cocoa production. Moreover, more than 50% of the respondents had accessed government support, such as subsidized fertilizers and farm tools, which is consistent with Owusu (2018) and Fearon et al. (2015). The primary sources of information on climate change for cocoa farmers are (i) media (radio and television), (ii) institutions (agricultural extension officers, FBOs, and non-governmental organizations (NGOs)), (iii) other farmers, (iv) community leaders, or (v) the Ghana Meteorological Service. About 43% of the cocoa farmers indicated that these information sources help to inform them on climate change coping and adaptation strategies. Less than half of the farmers have received training on farm management practices.

3.2. Diversification of farm income by cocoa farmers in guarding against climate change

All 400 farmers indicated that they had experienced negative impacts of climate change on cocoa production in recent times (Table 3). The farmers further stressed that the major ramification of climate change relates to a reduction in cocoa yield and the subsequent decrease in income. The cocoa farmers indicated that climate change reduced the yield of cocoa through (i) a reduction in soil fertility (72.3%), (ii) high incidence of pests and diseases (42.3%), and (iii) unpredictable rainfall patterns (98.3%). The latter mainly include insufficient and irregular rainfall, and a prolonged dry season with delayed rains to begin a new cocoa season.

As a result, a significant impact of climate change is the reduction of crop yield, which consequently reduces farmers' income (Nkeme and Ndaeyo, 2013; Fraser et al., 2011; Deressa et al., 2009). Thus, cocoa farmers engage in several coping and adaptation strategies to reduce the impacts of climate change on their income level. Specifically, this study inquired whether they diversify farm income to compensate the losses of yield and income caused by climate change. We found that 85.5% of cocoa farmers diversify their farm income for this purpose (Table 3).

Crop diversification and intercropping of cocoa farms are common in Ghana because different crops require different climatic conditions. Most cocoa farmers had other crops in addition to their cocoa production. Farmers with less dense cocoa plantations (less developed canopies), especially new and old cocoa farms, intercrop their farms with food crops such as cocoyam, plantain, and cassava. Cocoa farmers can supplement the low cocoa revenues with extra income from selling other crops. Although climate change could have adverse effects on both cocoa and other crops, the severity varies as different crops require different climatic conditions, as well as different planting and harvesting periods during the year. Thus, the cultivation of different crops serves as insurance against the variability of climatic conditions.

Rearing of farm animals (cattle, sheep, goat, and domestic fowls) to compensate low cocoa yield is common practice because crops and animals require different climatic conditions. In addition, young and energetic cocoa farmers provide labour for other farmers to supplement the household income. These include weeding, application of fertilizers and weedicides, harvesting, and carrying farm produce for other farmers. Others engage in agricultural-related economic off-farm activities, such as agro-processing, petty trading of farm produce and provision of agricultural services, such as selling agrochemicals, farm tools and equipment, and veterinary drugs.

Table 3 shows the type and number of coping strategies adopted by cocoa farmers to cope with climate change. Only a few cocoa farmers do not diversify their income, while some have three to four of these as additional economic activities, with a maximum of five. On average, cocoa farmers apply two strategies, including other crops, intercrop their cocoa farms, rear livestock, provide labour for other farmers, and engage in economic off-farm activities.

Table 2
Summary statistics.

Variable	Mean	Std. dev.	Minimum	Maximum
Socioeconomic characteristics				
Gender (1 = male)	0.570	0.496	n.a.	n.a.
Age (years)	52.935	13.378	23	89
Formal education (years)	7.850	5.583	0	18
Household size (number of people)	7.705	4.236	1	20
Nativity (1 = indigene)	0.590	0.492	n.a.	n.a.
Distance to regional capital (kilometres)	119.165	72.043	8	280
Farm-level characteristics				
Cocoa production experience (years)	14.020	10.402	2	60
Farm size (hectares)	7.972	6.211	1	35
Age of cocoa farm (years)	13.605	9.584	1.5	60
Main type of labour (1 = hired)	0.425	0.495	n.a.	n.a.
Institutional factors				
Credit for cocoa production (1 = yes)	0.480	0.500	n.a.	n.a.
Amount of credit (US$)	301.157	483.962	0	269.039
Extension contacts (1 = yes)	0.410	0.492	n.a.	n.a.
Number of extension contacts	1.785	2.254	0	7
FBO membership (1 = yes)	0.385	0.487	n.a.	n.a.
Years of FBO membership (years)	1.540	2.300	0	9
Government support (1 = farmer obtained government support)	0.560	0.497	n.a.	n.a.
Main sources of information on climate change				
Media (1 = yes)	0.580	0.494	n.a.	n.a.
Institutions (1 = yes)	0.415	0.493	n.a.	n.a.
Other farmers and community leaders (1 = yes)	0.320	0.467	n.a.	n.a.
Ghana Meteorological Service (1 = yes)	0.505	0.501	n.a.	n.a.
Whether information sources educate farmers on climate change adaptation strategies (1 = yes)	0.430	0.496	n.a.	n.a.
Training on farm management (1 = farmer has received farm management training)	0.400	0.491	n.a.	n.a.

Note: US$1 = GH¢5.62. n.a. denotes not applicable (for the dummy variables). Std. dev. Denotes standard deviation.

Table 3
How cocoa farmers diversify farm income to cope with climate change.

Farm income diversification as climate change coping strategy	Percentage (n = 400)
Whether cocoa farmers have experienced the negative impacts of climate change	100.0
Type of negative impact of climate change on cocoa production	
Reduction in soil fertility	72.3
High incidence of pests and diseases	42.3
Unpredictable rainfall patterns	98.3
Proportion of cocoa farmers who diversify farm income	85.5
Type of farm income diversification	
Crop diversification	75.0
Intercropping of cocoa farms	20.5
Livestock diversification	42.0
Provision of labour for other farmers	26.0
Agricultural-related off-farm economic activities	49.0
Number of coping strategies	
None (zero)	14.5
One	20.5
Two	26.5
Three	22.0
Four	12.0
Five	4.5
Mean	2.1
Minimum	0.0
Maximum	5.0
Standard deviation	1.4

3.3. Proportion of annual income from cocoa farm diversification

The mean annual income from selling cocoa sums up to about US$ 3000, while income generated by diversification activities is about US$ 600 (Table 4). Therefore, diversification of income contributes about 18% to the overall annual income of cocoa farmers in our study region.

3.4. Empirical estimates from Heckman and beta regressions

Table 5 shows the Heckman two-step estimates for the determinants of cocoa farm income diversification (first stage) and the number of diversifications farmers use as climate change coping strategies (second stage). The table also shows the beta regression for the determinants of the contribution of income diversification to total annual income. The mean-variance inflation factor (see Appendix) shows no multi-collinearity among the explanatory variables. The censored observations show that 58 farmers did not diversify farm income. The Wald Chi-squared and log-likelihood Chi-squared are statistically significant, suggesting that the explanatory variables jointly contribute to the variations in the diversification of cocoa farm income.

Gender significantly influenced the number of cocoa farm diversifications (Table 5). This result implies that male cocoa farmers have a higher probability of employing more cocoa farm diversification strategies than their female counterparts. The statistically significant and negative coefficient of age in the second stage of the Heckman estimation implies that the number of diversifications decreases with increasing age. Thus, younger cocoa farmers have a higher likelihood of adopting more coping strategies than older ones. Education significantly and positively influences farmers' decision to diversify and the proportion of annual income from diversification. The statistically significant and positive coefficient of the nativity in the second stage of the Heckman regression implies that indigenes have a higher probability of using more income diversifications in coping with climate change.

'Distance to the regional capital' has a significant negative impact in the two-stage Heckman and beta regressions (Table 5) on income diversification and the proportion of annual income from diversification. 'Experience in cocoa production' is significant and negative in the beta regression. The proportion of annual income from diversification is lower the higher the experience in cocoa production. 'Farm size' is significant and positive in the first stage of the Heckman and beta regression. Thus, bigger farm size favours farmers' decision to diversify income and the contribution of diversification to the total annual income.

The significant and negative coefficient of the 'main type of labour' in stage two of the Heckman regression implies that cocoa farmers who employ hired labour use fewer climate change coping strategies than their counterparts who use family labour. The 'age of cocoa farms' significantly and positively influences cocoa farmers' decision to diversify farm income and the proportion of annual income from diversification. This implies that farmers with older cocoa farms have a higher probability to diversify farm income in dealing with the impact of climate change. 'Extension contacts' and 'FBO membership' significantly and positively influence the diversification of income.

The 'source of information' on climate change has varying influence on coping strategies (Table 5). Farmers, whose main source of climate change information are the media (radio or television) have a higher likelihood of diversifying farm income. These farmers also have a higher likelihood of employing more climate change coping strategies, as well as obtaining a higher share of annual income from diversification. Obtaining climate change information from institutions (cocoa extension officers, FBOs, or NGOs) is only significant and positive for the number of coping strategies employed. Furthermore, obtaining climate change information from Ghana Meteorological Service tends to reduce the number of income diversifications employed as well as the share of annual income from diversification. However, obtaining

Table 4
Proportion of annual income from cocoa farm income diversification.

Description	Mean	Std. dev.	Minimum	Maximum
Annual income from cocoa sales (US$)	3089	3858	125	17794
Annual income from cocoa farm diversification (US$)	633	892	9	5338
Total annual income from cocoa sales and farm diversification (US$)	3722	4592	151	23,132
Proportion of annual income from cocoa farm diversification	0.179	0.081	0.011	0.411

Note: US$1 = GH¢5.62. Std. dev. Denotes standard deviation.

Table 5
Estimates from Heckman and beta regressions.

Variable	Heckman: farm income diversification		Beta regression: proportion of income from diversification
	Stage one: diversification (binary)	*Stage two: number of coping strategies (continuous)*	
	Coefficient (z-value)	*Coefficient (z-value)*	*Coefficient (z-value)*
Gender	0.005 (0.010)	0.045 (1.760)*	0.077 (1.280)
Age	−0.011 (−0.640)	−0.014 (−1.730)*	0.003 (0.190)
Education	0.730 (3.030)***	0.005 (1.380)	0.033 (3.910)***
Household size	0.003 (0.060)	0.006 (0.250)	−0.003 (−0.450)
Nativity	0.909 (1.040)	0.151 (4.700)***	−0.005 (−0.060)
Distance to regional capital	−0.021 (−3.990)***	−0.073 (−16.930)***	−0.003 (−4.150)***
Cocoa production experience	−0.051 (−0.670)	−0.001 (−0.920)	−0.008 (−2.170)**
Farm size	0.067 (2.380)**	−0.039 (−0.250)	0.010 (2.490)**
Main type of labour	−0.735 (−0.310)	−0.156 (−3.010)***	−0.112 (−0.950)
Age of cocoa farm	0.136 (1.820)*	−0.094 (−0.610)	0.007 (1.890)*
Annual income from cocoa sales	–	8.200 (7.620)***	0.003 (−10.550)***
Credit for cocoa production	–	0.075 (9.420)***	0.001 (8.350)***
Extension contacts	–	0.041 (3.070)***	−0.088 (−2.440)**
FBO membership	–	0.038 (4.210)***	0.004 (0.190)
Media	0.876 (1.870)*	0.049 (2.370)**	0.122 (2.440)**
Institutions	–	0.156 (3.160)***	0.105 (0.850)
Other farmers and community leaders	–	−0.029 (−0.700)	−0.164 (−1.610)
Ghana Meteorological Service	–	−0.178 (−4.860)***	−0.328 (−3.680)***
Education by information sources	–	0.043 (1.100)	0.015 (0.170)
Government support	1.159 (1.400)	0.150 (4.550)***	−0.045 (−0.570)
Training on farm management	–	0.073 (1.780)*	−0.079 (−0.770)
Constant	1.711 (1.150)	2.556 (26.640)***	−0.997 (−5.040)***
Mills			
Lambda	0.038 (4.750)***		n.a.
Rho	0.214		n.a.
Sigma	0.175		n.a.
Number of observations	400		400
Censored observations	58		n.a.
Uncensored observations	342		n.a.
Wald chi-squared (21)	13,297.760		n.a.
Log likelihood (LR) chi-squared (21)	n.a.		212.350
Probability chi-squared	0.000		0.000
Link function	n.a.		g(u) = log(u / (1-u))
Slink function	n.a.		g(u) = log(u)
Log-likelihood	n.a.		533.582

Notes: n.a. denotes not applicable. ***, ** and * denote statistical significance at 1%, 5% and 10% respectively.

climate change information from other farmers and community leaders is neither significant in the Heckman nor in the beta regressions. Cocoa farmers who obtained government support in form of subsidized fertilizers and farm tools have a higher probability to adapt to climate change with more farm income diversifications.

4. Discussion

The relationship between climate change adaptation and income diversification has policy implications in Ghana and other developing countries. Cocoa farmers in Ghana are exposed to severe adverse effects of climate change (Afriyie-Kraft et al., 2020), which makes cocoa production a risky business (Bunn et al., 2019). Changing climatic conditions mainly include inadequate, excessive, and untimely rainfall patterns. As reported by other studies (Afriyie-Kraft et al., 2020; Ameyaw et al., 2018; Nkeme and Ndaeyo, 2013; Fraser et al., 2011; Deressa et al., 2009), cocoa farmers sampled for this study also affirmed that the major impact of climate change on cocoa production is reducing yield and income. This calls for policy interventions aimed at diversifying farmers' income-generating activities. Farm income diversification has additional value in the advent of a downward shift of global cocoa demand and prices, as well as of an outbreak of a new cocoa pest or disease, among others.

Cocoa farmers in Ghana have experienced negative corollaries of climate change such as the rise and huge variations in atmospheric and soil temperatures, high incidence of pests and diseases, prolonged dry seasons (droughts), short wet/rainy seasons, insufficient rainfall, and declining soil fertility. This ultimately leads to a reduction in cocoa output. Likewise, Oluwatusin (2014) reported that 94% of cocoa farmers in Nigeria believe that climate change has drastically influenced the timing of seasonal rainfall, while 75% perceive increasing temperature as a serious issue of climate change. The present study

found that 86% of cocoa farmers diversify crop production and farm income, which corroborates with previous studies such as Donkoh et al., 2017, Ndamani and Watanabe (2016), Afriyie-Kraft et al. (2020), and Bunn et al. (2019).

Nevertheless, 25% do not implement any coping strategy (Afriyie-kraft et al., 2020). This might partly be due to the unequal access to diversification based on differences in production factor ownership and access to information on varying income-generating activities.

The results of this study suggest that about 40% of cocoa farmers engaged in three to five extra income-generating activities. These findings are in line with Donkoh at el. (2017), who reported that the number of livelihood activities among Ghanaian farmers ranged from one to six, with a mean of three. The wide-ranging sources of income to cocoa farmers are vital in ensuring that they are less vulnerable to cocoa production risks, especially related to climate change. Nevertheless, livelihood diversification activities generally take place within the agricultural sector, which could be due to limited knowledge and inadequate production resources to engage in economic off-farm activities. Therefore, any challenge affecting agriculture, such as climate change, could adversely influence these economic activities, though to different degrees. Moreover, the agricultural sector employs about 60% of the Ghanaian population (GSS (Ghana Statistical Service), 2017; GSS (Ghana Statistical Service), 2013b, 2017). Enhancing education through awareness raising and training programmes would enable cocoa farmers to realize more and different economic activities.

Unequal access to income diversification among cocoa farmers has important policy implications. Policy should be directed towards the promotion of more livelihood activities to protect cocoa farmers from changing climatic conditions. Thus, apart from other farming activities, such as crop diversification, production of farm animals, provision of farm labour -especially by young farmers-, policy interventions should focus on off-farm income-generating activities. This reduces the risk of climatic conditions having a cumulated negative impact on farmers' primary and supplementary income sources.

While our study shows that cocoa farmers diversify their income as a strategy to mitigate climate change impacts, there may be other motivations as outlined by (Paavola, 2008). As a result, farm income diversification is paramount in complementing declining cocoa income when faced with climate as well as other risks. Furthermore, the determinants of cocoa farmers' decision to diversify farm income and the intensity of diversification are important to policy formulation. This study identified four main aspects: (i) socioeconomic characteristics, (ii) farm-level characteristics, (iii) institutional factors, and (iv) main sources of information on climate change. Policy interventions aimed at improving cocoa farmers' coping and adaptation strategies to climate change should consider these factors. Gender, age, education, nativity, and distance to the regional capital are the socioeconomic characteristics of cocoa farmers considered in this study. In Ghana, men are, in most cases, household heads, community leaders, and have better access to production factors like land, capital, and information than women. Further, men are often used to approve new economic activities their wives would want to undertake. These circumstances discriminate women in terms of undertaking extra farm-related income-generating activities. In consequence, women have a lower probability of diversifying farm income and livelihoods (Donkoh et al. (2017), Lama (2014), Asmah (2011)).

Young people are assumed to be more energetic than elderly people; hence, they are more likely to engage in multiple economic activities. For instance, younger cocoa farmers are more inclined to provide labour for other farmers or produce additional crops than older farmers. Donkoh et al. (2017), Khatun and Roy (2012), Asmah (2011) reported that younger farmers diversify farm income and livelihood activities more than older farmers. Usually, higher educated farmers have better access to agricultural information. Education also boosts people's capacity to process information and the propensity to innovate (Umidjon et al., 2014). This is expected to influence cocoa farmers' decision to diversify farm income. Thus, educated cocoa farmers are more likely to diversify farm income efficiently and profitably through better management skills and better access to agricultural and business information. In consequence, educated cocoa farmers can increase the share of income from farm diversification. Lama (2014), Khatun and Roy (2012), Asmah (2011), and Oluwatayo (2009) find education to increase the tendency of diversification. However, Donkoh et al. (2017), Sekumade and Osundare (2014), Adepoju and Obayelu (2013) report otherwise.

Natives are more likely to diversify their income than migrants. Since natives have lived in their respective communities for a long time, they are expected to have better access to agricultural land, credit, and agricultural technologies in their localities. As a result, the probability increases that native cocoa farmers have an advantage in employing more farm income diversification strategies than migrants. Living close to cities creates awareness about other business opportunities and farm products with higher prices and market demand. Hence, farmers living closer to cities are more likely to convey their farm products to the market than those farther away, who mostly sell to wholesalers at farm gates (or at production centres/villages).

The production or farm level characteristics considered in the study are experience in cocoa production, farm size, age of the cocoa farm, and main type of labour for cocoa production. In most cases, experienced cocoa farmers rely on applying knowledge they have gathered over the years rather than diversifying farm income. In contrast, young cocoa farmers - although inexperienced - are more likely to try new income-generating activities to increase their annual earnings. Additional economic activities require energy and strength, which younger farmers most likely possess (Donkoh et al., 2017). Hence, young farmers who have been in cocoa production for a few years, only, are more likely to obtain higher income from diversification.

Increasing cocoa income is usually favoured by a large farm size. Since farm income diversification requires extra resources, farmers with larger cocoa farms have a higher likelihood of diversifying farm income. This subsequently leads to higher income from diversification than for those with smaller cocoa farms. Similarly, annual income from selling cocoa and access to credits for cocoa production are significant and positive in the second stage of the Heckman and beta regressions. Hence, cocoa farmers with larger farms, higher income, and access to credits have higher probabilities of affording additional costs associated with farm income diversification. This finding is in line with Sekumade and Osundare (2014) as well as Khatun and Roy (2012) concluding that high-income farmers take advantage of more diversification options.

Older cocoa farms are at a higher risk with respect to climate change, since soil nutrients in such farms are usually deteriorated, and older cocoa trees are less productive. Further, older cocoa farms are susceptible to frequent pruning and cutting of cocoa trees infested with swollen shoot disease. In addition, some cocoa trees become less productive or die after about 30 years, depending on soil and weather conditions, and agronomic practices. Older cocoa farms are often less densely populated with cocoa trees, probably resulting in a reduced quantity harvested and low income per farm. When faced with climate change, farmers with older cocoa farms are more likely to diversify farm income as a coping strategy to supplement farm income.

Farm income diversification is often associated with additional production costs. Cocoa farmers who acquired farm inputs at lower prices through government subsidy programmes can save the subsidized amount, which gives them the option to afford the cost of diversification. Moreover, access to credit, extension contacts, FBO membership, and government support are the institutional factors that determine cocoa farmers' decision to diversify farm income and the intensity of diversification. Extension agents inform farmers on recommended agronomic practices, new technologies, agribusiness, and climate change and adaptation strategies. Further, FBO membership enables cocoa farmers to share and learn from the success stories of other group members. Extension agents and NGOs are more likely to

provide agricultural training in groups, such as climate change workshops for farmers. Financial institutions are more likely to offer credits to FBOs than to individual cocoa farmers. All these aspects increase the probability of cocoa farmers to diversify farm income in coping with climate change.

Furthermore, the main sources of information on climate change are the media (radio or television), institutions (extension agents, FBOs or NGOs), other farmers and community leaders, and Ghana Meteorological Service. Sources of information on climate change have varying influences on coping strategies. For instance, the media usually provide programmes on climate change, its impacts on agricultural production, and coping and adaptation strategies. These programmes educate farmers on how to minimize the impacts of climate change on their incomes. In contrast, the Ghana Meteorological Service only provides daily updates and forecasts of weather conditions (rainfall, temperature, and humidity). They usually inform farmers on weather patterns and climate change without providing education on coping strategies. Thus, farmers who rely on Ghana Meteorological Service for climate change information are less likely to apply coping and adaptation strategies.

5. Conclusions

Most cocoa farmers in Ghana use farm income diversification as a climate change coping and adaptation strategy. They diversify farm income through crop and livestock diversification, intercropping of cocoa farms, provision of labour for other farmers, and agricultural-related economic off-farm activities. On average, cocoa farmers choose two of these strategies. Diversification of income contributed about 18% of cocoa farmers' total annual income. The age of cocoa farms, distance to the regional capital, access to credit, extension contacts, FBO membership, source of climate change information, government support, and training on farm management are the major determinants for applying climate change coping and adaptation strategies.

Credit accessibility, extension contacts, and formation of FBOs should be considered when designing programmes to effectively assist cocoa farmers in coping with climate change through farm income diversification. Information on climate change should be provided to cocoa farmers via media (radio and television) and institutions (cocoa extension officers, FBOs, or NGOs). The government and NGOs should support cocoa farmers through training programmes on farm management practices to enhance productivity. Future research should delve into the contribution of the number of diversification to farmers' ability to cope with the repercussions of climate change as well as the challenges that hinder farmers from diversifying amidst climate change impacts. Future studies should also investigate the differences in the coping and adaptation strategies implemented by farmers owning and managing individual cocoa farms compared to family cocoa farms.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix. Test for multicollinearity.

Variable	Variance inflation factor (VIF)	1/VIF
Extension contacts	11.250	0.089
Institutions	7.400	0.135
Main type of labour	7.090	0.141
Annual income from cocoa sales	6.720	0.149
Credit for cocoa production	6.070	0.165
FBO membership	5.490	0.182
Distance to regional capital	5.310	0.188
Training on farm management	5.110	0.196
Other farmers and community leaders	4.850	0.206
Ghana Meteorological Service	4.500	0.222
Education by information sources	4.200	0.238
Education	3.750	0.266
Government support	3.070	0.325
Nativity	2.610	0.383
Cocoa production experience	2.440	0.410
Age of cocoa farm	2.440	0.411
Gender	1.730	0.579
Age	1.320	0.757
Household size	1.230	0.811
Farm size	1.110	0.902
Media	1.100	0.906
Mean VIF	*4.230*	

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