Research Article

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# Climate change adaptation and cocoa farm rehabilitation behaviour in Ahafo Ano North District of Ashanti region, Ghana

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**Abstract:** Sustainable cocoa production is the hub of economic development and growth in Ghana. Climate change has been implicated in the dwindling productivity of the Ghanaian cocoa sub-sector, although deforestation for cocoa farmland expansion poses significant long-term risks to ecosystem stability and environmental conservation. This study assessed farmers' perception of climate change, their adaptation methods and the factors explaining involvement in the renovation/rehabilitation of old cocoa farms. The data were collected from 378 cocoa farmers in Ahafo Ano North District in the Ashanti region. The data were analysed with Principal Component Analysis (PCA), Ordinary Least Square regression, Negative Binomial regression and Two-stage Probit regression. The results showed that the majority of the farmers were older than 50 years and attained primary education. High temperature (64.29%), too stormy rainfall (64.29%) and too much rainfall (61.90%) were largely perceived by cocoa farmers in 2015. The farmers were adapting to climate change through diversification into other crops (70.63%), planting of hybrid varieties (71.69%), commitment to spray cocoa pods regularly (74.87%) and initiation of some changes in the planting and harvesting times (71.96%). The adaptation was significantly influenced ($p < 0.05$) by cocoa farming experience, number of children under the age of 5 years, perception of extremely high temperature, perception too low rainfall, perception of delay in commencement of rainfall, cultivation of cocoa as the primary crop, perception of delay in rainfall stop and delay in regular farm clearing and rented farm. Cocoa rehabilitation decision was influenced by climate change adaptation indicator, monthly income, perception of extreme temperature and sharecropping. The implications of the results were that promotion of climate change perception would facilitate adaptation, and the form of cocoa farmland ownership as well as climate change adaptation indicator influenced farmers' involvement in cocoa farm rehabilitation.

**Keywords:** climate change adaptation, cocoa farm renovation, cocoa farm rehabilitation, land tenure, Ghana

## 1 Introduction

Over the past few decades, cocoa production has undergone significant transformations, although low productivity prevails partly due to changes in some weather parameters. A projected future decline in cocoa productivity portends some economic concerns to the fate and fortune of several stakeholders along its value chains (Abbott et al. 2005). More specifically, companies that utilise cocoa as a major raw material in the production of chocolates and other candy sweets are at risk of downsizing with a consequential decline in their profit levels. Although it had been projected that the global chocolate market will grow to about USD 161.56 billion in revenue by 2024 from its value of USD 103.28 billion in 2017 (Zion Market Research 2018), this is only achievable if global cocoa production is sustained.

Climate change is one of the major challenges confronting the sustainable productivity of cocoa in the world today (Gateau-Rey et al. 2018). Future projected declines in cocoa production calls for some climate-smart initiatives to closely monitor the sustainability of outputs in the two top producing countries (Cote D'Ivoire and Ghana), which jointly account for approximately 60% of global outputs. The antecedents of drought, rainfall instability and extremely high temperature in some cocoa growing agro-ecological zones in the world have undermined cocoa productivity, with some residual impacts sometimes transferred to subsequent years (Wood and Lass 1987; de Mejía et al. 2003; Jacobi et al. 2015). In

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absence of cognitive adaptation capability and institutional risk-sharing mechanisms, cocoa production is critically influenced by persistent sensitivity to unprecedented changes in some weather parameters (Hutchins et al. 2015). Policymakers in some cocoa-growing African countries are particularly worried about the inherent low capability of the majority of the farmers to withstand some climatic shocks (Läderach et al. 2013), given their low access to farm insurance and lack of other essential adaptation skills. To develop cocoa agriculture as a way of sustaining agricultural foreign exchange earnings in cocoa-producing African countries, there is a call for a clear understanding of the drivers of climate change adaptation and its impacts on some essential farm investment decisions (Anim-Kwapong and Frimpong 2008).

In addition to climate change, cocoa production is being affected by some agronomic and socio-economic issues (Asare et al. 2014). Specifically, the ageing of cocoa farmers and their farms have come under serious scrutiny (Wessel and Quist-Wessel 2015; Ruf 2007; KPMG 2012; Mejia 2011). In Ghana, although cocoa is of significant importance to economic growth and development, contributing about 9% of the gross domestic products (GDPs) (Kroeger et al. 2017), its productivity has declined over the past few years. The population of cocoa farmers is ageing, and about 23% of the cocoa land areas seem to have outlived their productive time, having been planted for more than 30 years (Kroeger et al. 2017). The generally ageing population of cocoa farmers and their farms is a reflection of low entry by youths, who are now prioritising involvement in other farm and non-farm activities to devolve a stable livelihood in cocoa agriculture (Asare et al. 2014). This 'generation gap' in cocoa agriculture is a bequest that is commonly observed in the farming sector, mainly as a result of young people's perception of farming as a job that is very tedious and full of drudgery (Fick 2015). This is alarming, given a high rate of unemployment among Ghanaian youths and the government's deficiencies in the creation of much-desired secular job opportunities.

More importantly, the practice of cocoa agroforestry presents a more sustainable system in terms of environmental conservation and cocoa productivity (Gyau et al. 2014). This practice had been replaced with cocoa monocropping, under which the majority of existing trees were removed. Although some newly introduced cocoa hybrids were high yielding, their productive lifespan seems to be short and often requiring replanting (Vekua 2013). In the context of some cultural norms surrounding cocoa farmland lease arrangements, under which some cocoa farmers operate, replanting old farms becomes a risky venture as a result of uncertainties in securing future contracts beyond the fruit yielding time of newly planted cocoa trees.

The ageing of Ghanaian cocoa trees also fundamentally reflects the dominance of old stocks of cocoa breeds that were planted several years ago (Vekau 2013). Many of these trees are susceptible to cocoa swollen shoot virus disease, which affects 17% of the cocoa land areas in Ghana (Andres et al. 2018). In absence of production insurance to cater for crop failures and given the prevalence of climatic variability, understanding the behaviour of farmers in replanting and rehabilitating old cocoa farms is of critical relevance for promoting cocoa productivity in a much more sustainable manner (Vekau 2013). Cocoa replanting and rehabilitation efforts are of vital importance along the trail of redefining a paradigm shift from extensive to an intensive production system. From the sustainability point of view, intensive cocoa production would reduce pressure on deforestation and facilitate the speedy restoration of some degraded farmlands (Gockowski and Sonwa 2011). This promises to reduce the rate of deforestation, which is currently one of the major environmental concerns in Ghana. Specifically, about 11% of Ghanaian forestland had been lost since 2000. It has also been projected that given the current climatic scenarios, some regions where cocoa is currently grown in Ghana would fail some basic agronomic suitability tests by 2050 (Kroeger et al. 2017).

The initiative for promoting climate-smart cocoa production is a move in the right direction, given its strategic emphases on forestland protection, increase in cocoa productivity and improvement in farmers' livelihoods (Kroeger et al. 2017). Understanding the adaptation strategies of cocoa farmers against climate change, and how such decisions would influence involvement in the replanting of old cocoa trees would assist policymakers in understanding the prescriptive pathways to take in order to promote environmental sustainability in cocoa production. This study is unique from some previous studies such as Vekau (2013) and Chery (2013) because it analyses the simultaneous relationship between climate change adaptation indicator and cocoa farm rehabilitation decision using some proven econometric procedures.

# 2 Materials and methods

## 2.1 The study area

The data for this study were collected among cocoa farmers in Ahafo Ano North District of the Ashanti region.

The district is located in the northwestern part of the region with Tepa as its capital. It was created in 1988 by LI 1402 Legislative Instrument through an Act of Parliament. The total landmass of the district is 573.9 km square, and the district is located between latitude 60 47′N and 70 02′N and longitude 20 26′W and 20 04′W. With a total population of 94,285, 74.0 percent of the households are engaged in agriculture, although rural dwellers engage more in agriculture with 84.0% (Ghana Statistical Services 2014). Figure 1 shows the map of the district.

## 2.2 Sampling and data collection methods

Respondents for this survey were cocoa farmers in Ahafo Ano North District. A multi-stage sampling method was used for selecting the farmers. The first stage involved a random selection of Ahafo Ano North district among those where cocoa is grown in the region. The second stage involved the compilation of the list of prominent cocoa-growing villages in the district. Among these, we selected 21 villages with the help of the resident extension agent, after which 378 cocoa farmers were sampled in those selected villages. The survey followed the conventional ethical procedures for primary data collection. First, respondents were informed about the purpose of the survey. They were also briefed about their right to withdraw from participating at any time during the interview, should they for any reason decide to do so. We also informed them about the confidential treatment to which the information being supplied would be given. The questionnaire sought to obtain information on farmers' demographic characteristics, cocoa production and input use, perception of climate change and coping methods, sources of income, stress and exposure to occupational health hazards.

## 2.3 Analytical methods

### 2.3.1 Principal component analysis (PCA)

To compute the index of climate change adaptation from some adaptation options that were being used by cocoa farmers, PCA was employed. In this case, a composite indicator that denotes farmer's adaptive index against climate change was computed from indicated responses to adaptive measures of investing in a cocoa drying machine, diversifying into other crops, diversifying into non-farm activities, monitoring weather change by indigenous knowledge, re-spraying of cocoa pods, reducing the time interval for spraying, irrigating the farm, monitoring weather change through media, planting of hybrid seeds, regular cocoa spraying and changing in the planting and harvesting time. The PCA as a statistical

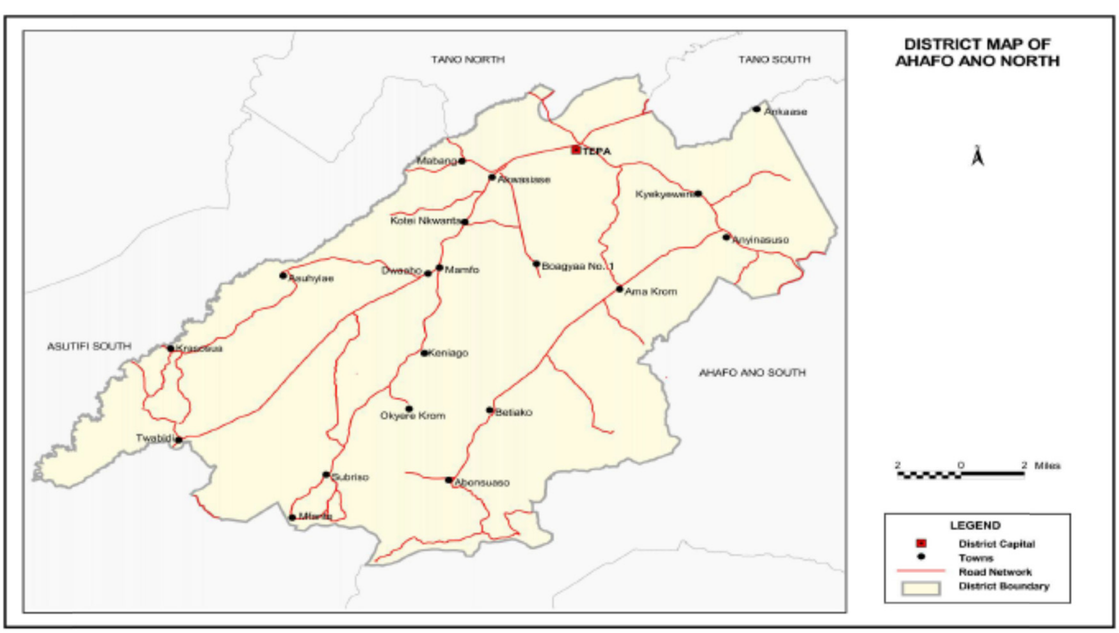


**Figure 1:** Map of Ahafo Ano North District (Source: Ghana statistical service 2014).

method helps to extract some unique linear combinations that can be found in the eleven (11) defined set data climate adaptation variables. The analyses were carried out with STATA 13 software with an indicator of adaptation computed by invoking the generate command (gen) after invoking the conventional (pca) command.

#### 2.3.2 Ordinary least square (OLS) regression

In order to determine the socioeconomic factors influencing adaptation indices that were computed with PCA, the Ordinary Least Square (OLS) Regression model was applied. This is a multiple regression model of the form:

$$\boldsymbol{Y_i} = \alpha_1 + \beta_k \sum_{k=1}^{20} \boldsymbol{x_{ik}} + \boldsymbol{\pi_s} \sum_{\boldsymbol{s}=1}^{4} \boldsymbol{V_{is}} + \boldsymbol{u_i} \quad (1)$$

In equation (1), $\boldsymbol{Y_i}$ is the PCA climate change adaptation index, $\alpha_1$, $\beta_k$ and $\boldsymbol{\pi_s}$ are the parameters to be estimated and $u_i$ is the stochastic error term. $x_{ik}$ and $\boldsymbol{V_{is}}$ are the included explanatory variables presented in Table 1. Multicollinearity among the independent variables was evaluated with variance inflation factor (VIF). High VIF is a reflection of substantial increase in the variances of estimated parameters as a result of existing collinearity among them, when compared with situation where there is no correlation (Murray et al. 2012). Heteroscedasticity was tested with Breusch–Pagan/Cook–Weisberg test. This was meant to validate the use of OLS on the assumption that the variance of the dependent variable is constant. Statistical insignificance of the estimated statistics is an indication of homoscedasticity. Should the test show statistical significance, the parameters are to be estimated with robust standard errors.

#### 2.3.3 Negative binomial regression model

In order to determine the factors influencing the number of adaptation methods that cocoa farmers were using against climate change, the Negative Binomial Regression model was estimated. This model is different from the popular multiple regression in the fact that the dependent variable is a count outcome that is assumed to follow a negative binomial distribution. In this case, the determinants of the number of adaptation measures that cocoa farmers were using, which is nonnegative integers: 0, 1, 2, 3, 4, 5,... was modelled. Negative binomial regression was chosen because the distribution rejects the underlying assumptions of Poisson regression that emphasise the equality of variance and mean. Specifically, the specification of the Negative Binomial model begins with a Poisson specification:

$$\Pr[Y = y] = \frac{e^{-\mu}\mu^{y}}{y!} \quad y = 0,\ 1,\ 2,\ 3,\ldots, \quad (2)$$

$y$ denotes the number of climate change adaptation methods that a farmer uses. The basic assumption of Poisson distribution is the equality of both mean ($\mu$) and variance. After running the data with Poisson regression in STATA 13 software, the goodness of fit test rejects the hypothesis of Poisson distribution. Therefore, Negative Binomial distribution was used. The conventional specification of the Negative Binomial regression model is in line with the Poisson–gamma mixture distribution, with a mean of 1 and scalar parameter $v$ (Cameron and Trivedim 2013; Hilbe 2014). This is as specified as follows:

$$\Pr\left(Y = \frac{y_i}{\mu_i}, \alpha\right) = \frac{\Gamma(y_i - \alpha^{-1})}{\Gamma(y_i + 1)\Gamma(\alpha^{-1})}\left(\frac{\alpha^{-1}}{\alpha^{-1} + \mu_i}\right)^{\alpha^{-1}}\left(\frac{\mu_i}{\alpha^{-1} + \mu_i}\right)^{y_i} \quad (3)$$

where $\mu_i = t_i\mu$ and $\alpha = \frac{1}{v}$.

The estimated model is of the form:

$$\mu_i = \exp\left(\ln(t_i) + \varpi_k \sum_{k=1}^{24} \boldsymbol{x_{ik}}\right) + u_i \quad (4)$$

where $\boldsymbol{x_{ik}}$ are as defined in Table 1.

#### 2.3.4 Instrumental variable Probit regression

The need to model the influence of climate change adaptation on the decision to rehabilitate cocoa farms compels some econometric procedures in the form of Two-Stage Probit regression due to the potential endogeneity of the climate change adaptation index. It should be noted that the conventional Probit model only produces unbiased estimators when endogeneity is not a problem within the specified model. In this study, Two-Stage Probit model was estimated as follows:

$$R_i = \gamma + \varepsilon_i \sum_{k=1}^{20} \boldsymbol{x_{ik}} + \zeta Y_i + e_i \quad (5)$$

$$\boldsymbol{Y_i} = \boldsymbol{\alpha_1} + \boldsymbol{\beta_k} \sum_{\boldsymbol{k}=1}^{20} \boldsymbol{x_{ik}} + \boldsymbol{\pi_s} \sum_{\boldsymbol{s}=1}^{4} \boldsymbol{V_{ik}} + \boldsymbol{u_i} \quad (6)$$

Equation (5) presents the Probit regression model for the decision to rehabilitate cocoa farms with $R_i$ being the dependent variable coded as 1 for those that rehabilitated and 0 for those who did not rehabilitate. $Y_i$ is the endogenous independent variable that represent indicators of adaptation to climate change. In this analysis, the two forms of indicators that were used in estimating equations (1) and (2) were utilised. The major issue in estimating Two Stage Probit model is identification of instrumental variables, which must be correlated with $\boldsymbol{Y_i}$ but not correlated with $R_i$. Equation (5) was estimated with instrumental variables defined as perception of too much rainfall in the previous year, delay in rainfall commencement in the previous year, delay in rainfall stopping in the previous year and cocoa being grown as primary crop. The description of the independent variables in equations (5) and (6) is presented in Table 1. Estimation of equation (5) in STATA 13 generated the Wald test of exogeneity (athrho = 0), which if statistically significant indicates that climate change adaptation indicator is truly endogenous, and estimation of a standard Probit regression would have produced inefficient and biased estimators.

# 3 Results and discussion

Table 2 shows the demographic characteristics of the cocoa farmers. It shows that in line with previous studies, the majority (70.11%) of the farmers were male (Asamoah et al. 2013); Cocoa Research Institute of Ghana (CRIG) and The World Cocoa Foundation (WCF 2017). Male dominance in cocoa agriculture is a reflection of the tediousness of several agronomic practices that are involved and relatively low access to production resources by women. Educational attainments were also very low with the majority only having primary education, while 20.63% did not have any form of formal education. The role of education in promoting receptiveness of farmers to new production technologies has been highlighted in the literature Cocoa Research Institute of Ghana (CRIG) and The World Cocoa Foundation (WCF 2017). Cocoa farmers' household sizes were also high with an average of eight members per household. In some instances, cocoa farmers would see large family size as a way of promoting their farming activities due to the

**Table 1:** Description of explanatory variables

| Symbol | Variable name | Description |
|---|---|---|
| $x_1$ | Monthly income | Monthly income in Ghanaian Cedes |
| $x_2$ | Formal education | Formally educated = 1, 0 otherwise |
| $x_3$ | Cocoa farming experience | Number of years farming experience |
| $x_4$ | Adult number | Number of adult members |
| $x_5$ | Under 5 number | Number of children under the age of 5 years |
| $x_6$ | Extreme high temperature | Noticed extremely high temperature last year = 1, 0 otherwise |
| $x_7$ | Extreme low temperature | Noticed extremely low temperature last year = 1, 0 otherwise |
| $x_8$ | Delay in rainfall start | Noticed delay in rainfall commencement last year = 1, 0 otherwise |
| $x_9$ | Delay in rainfall stop | Noticed delay in rainfall stopping last year = 1, 0 otherwise |
| $x_{10}$ | Member sick in cocoa season | Yes = 1, 0 otherwise |
| $x_{11}$ | Missed regular cocoa spraying | Yes = 1, 0 otherwise |
| $x_{12}$ | Missed regular farm clearing | Yes = 1, 0 otherwise |
| **Mode of farm ownership** | | |
| $x_{13}$ | Rented farm | Yes = 1, 0 otherwise |
| $x_{14}$ | Lease farm | Yes = 1, 0 otherwise |
| $x_{15}$ | Sharecropping | Yes = 1, 0 otherwise |
| $x_{16}$ | Others | Yes = 1, 0 otherwise |
| $x_{17}$ | Number of cocoa farms | Number of separate cocoa farms managed by farmers |
| $x_{18}$ | Cocoa land area | Acres of cocoa farm cultivated |
| $x_{19}$ | Number of time head sick | Number of times head was sick during cocoa season |
| $x_{20}$ | Farming as primary occupation | Yes = 1, 0 otherwise |
| $V_1$ | Too much rainfall | Noticed too much rainfall last year = 1, 0 otherwise |
| $V_2$ | Storming rainfall | Noticed storming rainfall last year = 1, 0 otherwise |
| $V_3$ | Too low rainfall | Noticed too low rainfall last year = 1, 0 otherwise |
| $V_4$ | Cocoa as primary crop | Cocoa is the main crop grown = 1, 0 otherwise |

**Table 2:** Socioeconomic characteristics of cocoa farmers in Ahafo Ano North district

| | Freq. | Percent |
|---|---|---|
| **Gender** | | |
| Male | 265 | 70.11 |
| Female | 113 | 29.89 |
| **Per capita income** | | |
| <200 | 298 | 78.84 |
| 200 < 400 | 45 | 11.90 |
| 400 < 600 | 12 | 3.17 |
| 600 < 800 | 11 | 2.91 |
| ≥800 | 12 | 3.17 |
| **Age of cocoa farmers** | | |
| <30 | 14 | 3.70 |
| 30 < 40 | 60 | 15.87 |
| 40 < 50 | 76 | 20.11 |
| 50 < 60 | 126 | 33.33 |
| 60 < 70 | 69 | 18.25 |
| ≥70 | 33 | 8.73 |
| **Educational levels** | | |
| None | 78 | 20.63 |
| Primary | 185 | 48.94 |
| Secondary | 94 | 24.87 |
| Tertiary | 21 | 5.56 |
| **Cocoa growing experience** | | |
| <10 | 104 | 27.51 |
| 10 < 20 | 96 | 25.40 |
| 20 < 30 | 99 | 26.19 |
| 30 < 40 | 41 | 10.85 |
| ≥40 | 38 | 10.05 |
| **Household size** | | |
| <5 | 53 | 14.02 |
| 5 < 10 | 213 | 56.35 |
| 10 < 15 | 75 | 19.84 |
| ≥5 | 37 | 9.79 |
| **Other household member sick** | | |
| No | 91 | 24.07 |
| Yes | 287 | 75.93 |

availability of child labour for several farming activities, especially during the peak labour demand time when hired labour may be very scarce (Luckstead et al. 2019).

Table 2 shows that majority of the cocoa farmers (60.31%) were 50 years or older. Also, with 19.57% being younger than 40 years, cocoa farming is gradually seeing injection of youths. The results also show that 27.51% of the farmers had less than 10 years of growing cocoa, while 10.05% had grown cocoa for more than 40 years. Specifically, one of every three cocoa farmers was between 50 and 60 years old. The notion of ageing cocoa farmers had been raised as a serious concern bedevilling future cocoa productivity in Ghana (Löwe 2017). Although unemployment is very rife in rural areas, agriculture is disdained by the growing population of rural youths, who often prefer to migrate to cities in search of greener means of livelihood. The future of the Ghanaian cocoa industry is therefore being seriously threatened as a result of the ageing of the majority of cocoa farmers. While the average age of the farmers was 52 years, it has been noted that life expectancy in Ghana is just 62 years (Löwe 2017).

The results in Table 2 further show that majority of the farmers (78.84%) were earning less than GhC 200 (US $50) monthly per capita income, while only 3.17% earned GhC 800 or more. This is a reflection of the grave socioeconomic deprivation among cocoa farmers, despite their huge annual contributions to Ghana's economic growth and development (Asamoah et al. 2013). International Cocoa Initiative (ICI) (2017) noted that Ghanaian farmers earn between less than US 0.5 from cocoa due to the low scale of operation and low productivity. It has been noted that the productivity of cocoa farming varies from as low as 400 kg/ha under low technology to 650 kg/ha under medium technology (Cocoa Research Institute of Ghana (CRIG) 2010). It had been asserted that about 10% of Ghanaian cocoa farmers specifically attain a yield of 1,400 kg/ha given that they operate on more advanced cocoa production technology (CRIG 2010).

Table 3 shows the observed changes in some weather parameters. It reveals that in 2015, high temperature, too stormy rainfall and too much rainfall were largely perceived by cocoa farmers. Depending on the time of the month, high temperature can have positive or negative impacts on cocoa production. In some instances, insufficient rainfall could lead to the death of young cocoa trees, while excessive rainfall could facilitate the falling of some cocoa trees or promote the incidence of some diseases like black pod. Barry Callebaut (2008) submitted that cocoa requires a favourably humid tropical climate with 'well-distributed rainfall and stable high temperatures.' Projections of future increases in global temperature hold some significant dangers for cocoa productivity due to the expected rise in cocoa trees' evapo-transpiration, which could also constitute some water demand stressors for cocoa plants, especially in the events of droughts (Läderach et al. 2013).

## 3.1 Adaptation and coping methods used by cocoa farmers

Table 4 shows the adaptation methods being used by cocoa farmers against climate change. It shows that some farmers have resorted to the diversification of their cocoa farming activities into other non-farm businesses (44.18%) and other crops that may be more resistant to vagaries of weather (70.63%). Diversification is a way of

**Table 3:** Perceived trends of changes in some weather parameters

| Observed weather parameters | 2014 | 2015 | Trend | | | |
|---|---|---|---|---|---|---|
| | | | Upward | Downward | Same | Do not know |
| Extremely high temperature | 72.75 | 64.29 | 30.95 | 10.85 | 24.60 | 33.60 |
| Extremely low temperature | 47.88 | 46.03 | 32.54 | 8.73 | 21.43 | 37.30 |
| Too much rainfall | 54.50 | 61.90 | 27.78 | 13.49 | 23.02 | 35.71 |
| Too low rainfall | 53.70 | 47.62 | 23.28 | 13.23 | 26.72 | 36.77 |
| Delay in rainfall commencement | 60.85 | 52.12 | 25.66 | 1.06 | 26.98 | 46.30 |
| Delay in rainfall stopping | 45.50 | 43.12 | 22.49 | 8.47 | 30.69 | 38.36 |
| Too stormy rainfall | 58.99 | 64.29 | 26.98 | 9.79 | 29.89 | 33.33 |
| Thicker cloud covers | 56.61 | 53.44 | 22.49 | 8.99 | 33.86 | 34.66 |

exploring some alternative means of livelihood in the event of pertinent income risks. Codjoe et al. (2013) noted that crop diversification implies farmers' engagements with the planting of crops that have shown commendable resistance to drought which also serves as a form of insurance against rainfall instability and its associated variability. More specifically, however, farmers had to resort to devoting more time in cultivating food crops at the expense of climate-risk prone cocoa.

Many of the adaptation methods are related to farming activities and include re-spray of cocoa pods in cases where there were rains after application of pesticides (50.79%), deliberate wetting of young cocoa plants during the dry season (43.92%) and commitment to regularly spray cocoa pods (74.87%). Timeliness of spraying cocoa is a major issue for government agencies those implement Ghanaian mass spraying project However, there have been some delays in cocoa agrochemical spraying, thereby compelling affected farmers to be engaged in self-supplementary cocoa spraying (Naminse et al. 2012; Akosa 2001; Abankwa et al. 2010).

**Table 4:** Adaptation measures employed by cocoa farmers against climate change

| Methods of adaptation | Freq | % |
|---|---|---|
| **Diversification** | | |
| Diversify into other crops | 267 | 70.63 |
| Diversify into non-farm activities | 167 | 44.18 |
| **Farming practices/operation enhancement** | | |
| Invest in cocoa drying machine | 148 | 39.15 |
| Re-spray of cocoa | 192 | 50.79 |
| Reduce time interval for spraying | 177 | 46.83 |
| Irrigation of young plants | 166 | 43.92 |
| Planting hybrid seeds | 271 | 71.69 |
| Regular cocoa spraying | 283 | 74.87 |
| Change planting and harvesting time | 272 | 71.96 |
| **Weather monitoring** | | |
| Monitor weather change by indigenous knowledge | 224 | 59.26 |
| Monitor weather change through Media | 226 | 59.79 |

Table 4 also shows that 71.69% were planting hybrid cocoa varieties to cope with weather vagaries. Hybrid cocoa plants take a shorter time to reach maturity, while the productivity is also higher than those of old cocoa stocks. Some farmers were also changing the time of planting cocoa (71.96%). Planting time becomes very critical when the pattern of rainfall changes. In a situation where rainfalls become unstable, the inability to change planting time would result in planting crops' exposure to severe environmental and water stressors. Several authors have raised concerns over expected negative impacts of high temperature and reduction in the volume of rainfall on cocoa productivity and expansion of its land areas in Ghana (Okoffo et al. 2017; Laux et al. 2010). The general agronomic rule of thumb is that in absence of functioning irrigation, variability in spatial and/or temporal rainfall portends significant negative consequences for crop productivity (Intergovernmental Panel on Climate Change 2014).

## 3.2 Determinants of climate change adaptation

Table 5 shows the results of OLS and Negative Binomial Regression as presented in equations (1) and (2), respectively. It should be reemphasised that the OLS was carried out with index of adaptation that was computed with PCA as the dependent variable. The Negative Binomial regression was carried out with the count of the number of adaptation methods of each farmer as the dependent variable. The results from the two models show that the data were properly fitted by the models, going by statistical significance of the Likelihood Ratio Chi Square ($p < 0.01$). In the two models, the parameters of cocoa farming experience, number of children under 5, perception of extremely high temperature, perception of too low rainfall, perception of delay in commencement of rainfall and cultivation of cocoa as primary crop are statistically significant ($p < 0.05$). However, in the OLS regression model, perception of delay in rainfall stop and delay in regular farm clearing schedules showed statistical significance ($p < 0.05$), while the parameter of rented farm is significant in the Negative Binomial regression model ($p < 0.05$).

The results show that farming experience is with a negative sign in the two models and statistically significant ($p < 0.05$). This implies as the number of years of cultivating cocoa increases, the indicators of climate change adaptation decrease. In some previous studies, the farming experience had been hypothesised to have a positive influence on climate change adaptation given the expectation that accumulated experiences can facilitate substantial effectiveness and diversity of implemented adaptive measures (Maddison 2006; Nhemachena and Hassan 2007; Denkyirah et al. 2017). The results are contrary to those reported by Denkyirah et al. (2017). In the context of climate change adaptation, understanding the influence of farming experience is very critical. Well-experienced farmers are expected to be aged, and this may influence their ability to take some proactive decisions against climate change.

The results further show that as the number of children below the age of 5 years increases in a farming household, climate change adaptation indices increase. The need to understand the impact of child dependency within cocoa farming households motivated the separation of the number of children from that of adults. More importantly, some previous studies had found a negative

**Table 5:** Determinants of adaptation to climate change

| | Ordinary least square | | Negative binomial | |
|---|---|---|---|---|
| **No. of adaptation methods/indicator of adaptation** | **Coef.** | ***Z* stat** | **Coef.** | ***Z* stat** |
| Monthly income | $-8.28 \times 10^{-6}$ | −0.28 | $-4.34 \times 10^{-6}$ | −0.50 |
| Formal education | −0.0337653 | −0.08 | 0.0406557 | 0.32 |
| Cocoa farming experience | −0.0174054** | −2.20 | −0.0057635 | −2.48** |
| Adult number | 0.0330895 | 1.14 | 0.0086331 | 1.05 |
| Under 5 number | 0.0947507** | 2.38 | 0.0272935** | 2.39 |
| Extreme high temperature | 0.4452777** | 1.97 | 0.1340115** | 1.96 |
| Extreme low temperature | 0.1112304 | 0.49 | 0.0231334 | 0.34 |
| Too much rainfall | 0.0906391 | 0.41 | 0.0156434 | 0.24 |
| Storming rainfall | 0.0415459 | 0.55 | 0.0098236 | 0.47 |
| Too low rainfall | 0.9400425*** | 4.21 | 0.2558276*** | 3.86 |
| Delay in rainfall start | 0.5163758** | 2.43 | 0.129692** | 2.03 |
| Delay in rainfall stop | 0.4510006** | 2.03 | 0.0898556 | 1.37 |
| Member sick | −0.0650131 | −0.29 | 0.011186 | 0.17 |
| Missed regular cocoa spraying | −0.0400568 | −0.15 | −0.0101448 | −0.12 |
| Missed regular farm clearing | 0.6310387** | 2.41 | 0.1504692* | 1.88 |
| **Mode of farm ownership** | | | | |
| Rented farm | 0.5932407 | 1.53 | 0.2260377 | 2.01 |
| Lease farm | −0.3842001 | −0.62 | 0.0283378 | 0.16 |
| Sharecropping | 0.1817199 | 0.70 | 0.0087742 | 0.12 |
| Others | 0.2871855 | 0.61 | 0.036067 | 0.26 |
| Number of cocoa farms | −0.0451512 | −0.52 | 0.0046695 | 0.18 |
| Cocoa land area | 0.0042248 | 0.61 | 0.0005515 | 0.28 |
| Number of time head sick | 0.0149878 | 0.27 | −0.0069385 | −0.43 |
| Farming as primary occupation | −0.1604202 | −0.57 | −0.0193252 | −0.24 |
| Cocoa as primary crop | 0.7863547*** | 2.89 | 0.1981916*** | 2.56 |
| Constant | −1.845527** | −2.23 | 1.336523*** | 5.50 |
| ln alpha | | | −2.434359 | |
| alpha | | | 0.0876539 | |
| Number of observations | 378 | | 378 | |
| LR $chi^2$ (26) | 7.26*** | | 120.05*** | |
| Pseudo $R^2$/Adj. $R^2$ | 0.3017 | | 0.0575 | |
| Breusch–Pagan/Cook–Weisberg test | 0.76 | | | |

***Statistically significant at 1%, **Statistically significant at 5%, *Statistically significant at 10%.

relationship between household size and the ability to adopt innovative farming (Denkyirah et al. 2017). The result of this study shows that farmers with more children under the age of 5 years had higher indicators of climate change adaptation.

The results also show that perception of higher temperature, too low rainfall and delays in commencement of rainfall are with a positive sign and showed statistical significance ($p < 0.05$) in the two estimated models. However, in the OLS model, delay in rainfall stopping is a positive sign and statistically significant ($p < 0.05$). These results are attesting to the notion that perception of climate changes can facilitate positive actions towards mitigation of its impacts. The ability to properly understand the prevailing trends in weather by farmers is a prerequisite for timely adaptation (Neil Adger et al. 2005; Tesso et al. 2012). The changes that are needed to mitigate adverse impacts of climate change are only going to be effectively undertaken when the farmers are equipped with accurate perceptions (Oluwatusin 2014; Nhemachena and Hassan 2007; Maddison 2006). Ehiakpor et al. (2016) found that perception of climate variability positively influenced adaptation among cocoa farmers in Ghana. In another study, Jiri et al. (2015) also reported a positive correlation between climate change perceptions and adaptation.

The result also showed that in the two models presented in Table 5, the farmers who were growing cocoa as a primary crop had significantly higher indicators of climate change adaptation ($p < 0.05$). This gives some indications that those farmers who concentrated on cocoa cultivation had more drive to undertake several adaptation methods. It also reveals that farmers who depended on cocoa as a major source of livelihood cannot trivialise the need to take some adaptive measures against climate change. It had been emphasised that cocoa is among the most sensitive crops to changes in temperature and precipitation (Schroth et al. 2016; Läderach et al. 2013).

Table 5 also shows that in the results for the OLS model, the farmers who rented land had significantly higher climate change adaptation indicators. This underscores the role of the land tenure system in climate change adaptation. Cocoa farmers on rented land would have made some upfront payment on the rented land or a bidding agreement exists on the amount of money expected to be paid at the end of the season. This implies they must be able to circumvent all climatic obstacles to achieve maximum yields from their rented cocoa farms. In a previous study, Fagariba et al. (2018) found that the land tenure system was one of the major constraints to climate change adaptation among cocoa farmers.

## 3.3 Determinants of farmers' decision to rehabilitate cocoa farms

Table 6 presents the results of instrumental variable Probit regression. It reveals the results in Panels A and B for cases where adaptation indicators were the PCA indices and number of adaptation methods, respectively. The results are quite similar except for few cases where the levels of significance vary. The results show that adaptation indicators increase the probability of the farmers choosing to rehabilitate cocoa farms ($p < 0.01$). This is expected because the farmers who are utilising many adaptation methods may not give too much thought on climate change issues that are affecting cocoa productivity.

The results in Table 6 also indicate that as the monthly incomes of cocoa farmers increased, the probability of rehabilitating cocoa farms significantly decreased ($p < 0.05$). These results are also emphasising the role of income in cocoa farm rehabilitation.

The results show that the parameters of rented land and sharecropping variables were statistically significant at 10 and 5%, respectively. The results indicate that farmers who were cultivating rented cocoa farmland had a higher probability of rehabilitating cocoa farms when compared with those who own their cocoa farms. However, the farmers who were on sharecropping arrangements had a lower probability of rehabilitating cocoa farms. Peyton (2018) also reported that sharecroppers were very reluctant to make investments in rehabilitating old farms. Therefore, this result indicates that sharecropping discourages cocoa farm investment via rehabilitation (Roth et al. 2017).

Table 6 further reveals that as the number of adult members in farming households increases, the probability of rehabilitating cocoa farmland increases. This may have resulted from labour intensiveness of rehabilitation processes, which in most cases requires uprooting of old cocoa trees and cutting down the old stock. This result buttresses that of Roth et al. (2017) who reported that rehabilitation of cocoa farms was being delayed due to the ageing of cocoa farmers, high cost of uprooting cocoa trees, inadequate finance and inadequate knowledge of modern agroforestry technologies

The results also show that the farmers who perceived high and low temperature had a lower probability of accepting to rehabilitate their cocoa farms. It should be noted that cocoa farming is highly susceptible to variations in temperature. These results are therefore in line with expectations. In addition, as the number of times, the farmers who were sick during cocoa season increase,

**Table 6:** Determinants of farmers' decision to rehabilitate cocoa farms

| | A | | B | |
|---|---|---|---|---|
| | **Coef.** | **Std. Err.** | **Coef.** | ***z*** |
| Adaptation indicator | 0.467905*** | 6.45 | 0.296191*** | 6.39 |
| Monthly income | −0.0001069** | −2.34 | −0.0001081** | −2.16 |
| Formal education | 0.245382 | 1.38 | 0.228552 | 1.20 |
| Cocoa farming experience | −0.0007513 | −0.11 | 0.0013451 | 0.19 |
| Adult number | 0.0459103* | 1.71 | 0.0498021* | 1.74 |
| Under 5 number | −0.0144866 | −0.47 | −0.0210437 | −0.64 |
| Extreme high temperature | −0.5739904*** | −3.25 | −0.6252772*** | −3.33 |
| Extreme low temperature | −0.286911* | −1.69 | −0.3238359* | −1.78 |
| Too much rainfall | −0.1591519 | −1.00 | −0.1722028 | −1.02 |
| Storming rainfall | −0.0326303 | −0.49 | −0.0358055 | −0.49 |
| Member sick | −0.0070566 | −0.04 | −0.0381148 | −0.21 |
| Missed regular cocoa spraying | 0.1753195 | 0.83 | 0.1931315 | 0.86 |
| Missed regular farm clearing | −0.1813694 | −0.87 | −0.1570291 | −0.72 |
| Number of cocoa farms | 0.0344356 | 0.51 | 0.0141598 | 0.20 |
| **Mode of farm ownership** | | | | |
| Rented farm | 0.6187055* | 1.80 | 0.6348572* | 1.71 |
| Lease farm | 0.4141236 | 0.92 | 0.3849979 | 0.80 |
| Sharecropping | −0.4807** | −2.46 | −0.4619218** | −2.20 |
| Others | −0.3015251 | −0.85 | −0.255462 | −0.69 |
| Cocoa land area | −0.0076545 | −1.36 | −0.007382 | −1.23 |
| Number of time head sick | −0.0792829* | −1.81 | −0.080738* | −1.70 |
| Farming as primary occupation | −0.0091849 | −0.05 | −0.0377428 | −0.19 |
| Constant | 0.6808467** | 2.02 | −1.241423*** | −3.59 |
| Athrho | −0.4929058*** | −2.63 | −0.3947375* | −1.66 |
| ln sigma | 0.4867126*** | 13.37 | 1.154758*** | 31.72 |
| Rho | −0.4565197*** | −3.08 | −0.3754372*** | −6.08 |
| Sigma | 1.626959*** | 27.46 | 3.173255*** | 30.46 |
| Number of obs | 378 | | 378 | |
| Wald $chi^2$ (21) | 100.05 | | 103.03 | |
| Prob > $chi^2$ | 0.0000 | | 0.0000 | |
| Wald test of exogeneity (/athrho = 0) | 6.94*** | | 2.75* | |

***Statistically significant at 1%, **Statistically significant at 5%, *Statistically significant at 10%.

the probability of rehabilitating cocoa farms decreases. This is expected given the labour intensiveness of cocoa rehabilitation. This also underscores the fact that it will take a healthy farmer to undertake many of the farming activities in cocoa production.

# 4 Conclusion

Understanding the drivers of climate-smart cocoa production is essential for devolving some policies to ensure the sustainability of cocoa agriculture in Ghana. Given on-going agitations on the impact of climate change on cocoa productivity, the future seems very bleak when the implications of climatic changes on the adoption of environmentally benign production system through rehabilitation and renovation of old cocoa farms are properly factored into the equation. This study provides a vital contribution to knowledge by econometrically linking some essential climate change adaptation indicators of cocoa farmers to their ultimate decision to rehabilitate their old cocoa farms. The results have highlighted some fundamental issues in respect of climate change adaptation and the possibility of engaging in climate-smart cocoa farming through old farm rehabilitation. Specifically, there are some policy implications arising from this study. First, the enhancement of cocoa farmers' climate change adaptation will promote involvement in cocoa farm rehabilitation. This implies that farmers' ability to adapt to changes in climate will foster their willingness to invest in old cocoa farms through rehabilitation. Therefore, there is a need to facilitate climate change adaptation among old cocoa farmers by undertaking some comprehensive assessment of their resource endowment and receptibility to changes. The findings have also indicated that adequate perception of climate change would facilitate adaptation and engagement with cocoa farm rehabilitation. The policy implications of promoting awareness and ability of cocoa farmers to adequately perceive climatic changes cannot be overemphasised. Such efforts would facilitate the rehabilitation of cocoa farms because the farmers are well able to understand changes in climatic parameters. In addition, the findings have underlined the role of the land tenure system in promoting climate change adaptation and farm rehabilitation decisions among cocoa farmers. Specifically, the proper definition of land ownership rights would enhance sustainable cocoa production with cocoa farm renting arrangements holding a higher potential.

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**Author contribution:** ASO conceptualised the study, analysed the data and wrote the report.

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