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Building resilience to shocks of climate change in Ghana's cocoa production and its effect on productivity and incomes

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ABSTRACT

Climate change is happening and cocoa producers are aware of its causes as well as its effects on their farms. However empirical evidence has revealed that a small number of farmers adopt climate change adaptation technologies to build resilience to the shocks meted out to them by climate change. In this paper, using data from Ghana, we employ propensity score matching to control for selection bias and to analyse adoption of adaptation technologies, its determinants as well as impact on cocoa productivity and incomes. The results showed that most cocoa farmers do not adopt climate change adaptation technologies and for those who adopt some technologies, diversification of income sources was the major innovation. Also, eight factors including gender, age of respondent, involvement in other economic activities, farm size, membership of a farmer association, access to extension service, access to credit as well as annual income from cocoa production were found to significantly influence adoption of climate change adaptation technologies. Finally, cocoa farmers who adopted climate change adaptation technologies recorded significantly higher farm productivities and incomes vis-à-vis non-adopters. To build resilience, cocoa farmers are encouraged to join farmer based organizations and extension officers should be supported to be able to reach out to farmers to educate them on climate change resilience technologies.

1. Introduction

One of the key challenges that cocoa farmers have experienced in recent times is the issue of climate change, especially with unpredictable rainfall and rising temperature [34]. In the 21st century, the rate of increase in temperature in Africa is projected to be faster than the average for the globe. In West Africa for instance, this is expected to occur even about a decade earlier than other regions of the world. Towards the end of the 21st century, West Africa's temperatures are forecasted to increase by 3–6 °C far above the baseline for the latter part of the 1900s [12,34,36].

Ghana's weather conditions over the last two decades have been very unstable and unpredictable. Because of this, estimations are that average annual temperature will increase by 1–3 °C and 1.5–5.2 °C by the 2060s and 2090s respectively [34]. While predictions for temperature figures are possible, because of severe variabilities experienced over the past years, predictions for rainfall trends in the long-term is very difficult [34,36]. That is, projected ranges for rainfall variability are quite huge and this makes long-term rainfall projections to be very uncertain than those of temperature [12,34]. The mean amount of rainfall in most of Ghana's cocoa growing areas is projected to fall by 12 mm, with most of the changes expected to take place after 2030 [34]. Ghana will however experience a rise in rainfall before seeing an insignificant decline in rainfall amounts in most of her cocoa growing areas [34,35]. From the foregoing, it is clear that climate change is real and a threat to the future of Ghana's cocoa industry if steps are not taken to mitigate the harmful effects of climate change. This is because, climate change is one of the factors that drives the sustainability and the resilience of food systems [45].

Climate change is happening, and Ghana's cocoa farmers are well aware of its causes and the threats it poses on their farms. However, empirical evidence has revealed that only few of the farmers adopt some form of adaptation technologies [15,20]. Meanwhile adoption of adaptation technologies is an integral aspect of building resilience in the face of climate change [54]. The reasons for the few adopters of adaptation technologies in Ghana's cocoa production are unknown and should be a

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course for concern to stakeholders in the cocoa industry given the aforementioned unpleasant projections for climate variables and with Ghana poised to regain her status as the world's leading producer of cocoa. Also, [42] suggested that future researchers should look at income differential between small-scale farmers who adapt to climate change and those who do not adapt to climate change as this may provide information about the benefits derived from taking steps to adapt to climate change. This paper addresses two main questions, viz. what factors influence cocoa farmers' adoption of climate change adaptation technologies and what is the impact of adoption of climate change adaptation technologies on cocoa farm productivity and farmers' incomes? This paper contributes to empirical literature in two ways, viz. it provides insights into why a small number of farmers adopt climate change adaptation technologies to build resilience to the shocks meted out to them by climate change and also provides evidence of income differential between small-scale farmers who adapt to climate change and those who do not adapt to climate change. The rest of the paper is organized as follows. The next section reviews literature on adoption of adaptation technologies. Section three presents the research methodology employed in the study. Section four presents the results and discussion and in the final section, we present the conclusions and recommendation.

2. Literature review

Adaptation is defined as interventions which are embarked upon so as to manage the losses or take advantage of the opportunities presented by a changing phenomenon [42]. According to [10], climate change adaptation implies taking action to minimize the adverse effects or to exploit the positive effects of climate change. [41,43] suggested that agricultural adaptations primarily consist of two (2) types of modification in production systems. The authors argued that the first technology is increased diversification which comprises engaging in production activities that are resistant to temperature stress and drought tolerant. The second technology primarily dwells on crop management practices directed at ensuring that critical crop growth stages do not coincide with extremely harsh climatic conditions. Most agricultural systems practiced in Ghana and in most sub-Saharan African countries serve as climate change adaptation technologies and can help the farmer to build resilience to adverse effects of climate change if they are planned and managed well with the broader landscape in mind [31]. For instance, to reduce the susceptibility of cocoa to high dry season temperatures, the use of shade trees in cocoa farms will be an appropriate adaptation technology [48].

[30] explained that the use of fertilizers and pesticides and insuring agricultural crops are potential adaptation technologies to climate change. Adaptation technologies specific to tree crops, such as cocoa, include shade management technologies, crop diversification, farm size technologies, soil fertility management, land preparation technologies as well as lining and pegging technologies [15]. In building resilience to effects of climate change, technologies identified by [15] in rural Ghana included coping strategies related to land preparation, soil fertility improvement, lining and pegging, farm size and shade management. [42] grouped adaptation technologies into on-farm and non-farm technologies. The on-farm adaptation technologies identified in the study included shade management, farm size technologies, soil fertility management, land preparation technologies, crop diversification as well as lining and pegging technologies. Non-farm technologies broadly included alternative livelihood sources for the cocoa farmers in the face of climate change outside of the farm sector and included working on other people's farms, trading in agricultural commodities and agricultural processing. [42] also reported that for farmers who adopted some form of adaptation technologies, age, gender, education and membership of farmer based organizations (FBOs) were statistically significant determinants of choice of adaptation technologies to climate change and variability.

According to [20], climate adaptation technologies employed by farmers to build resilience include intensification of pesticide and fertilizer application, planting of improved cocoa varieties, provision of shade with trees as well as diversification of income sources. Extension contact, marital status, gender, family size, involvement in non-farm activities, level of education, experience of farmer, access to credit as well as cocoa income were also reported as drivers of choice of adaptation technologies. [6] reported that farmers who practiced climate smart agriculture (CSA) recorded a 29% increase in their incomes compared to non-practitioners. The factors identified to influence adoption of CSA practices in cocoa production included location of farm, land tenure, residential status, farmer's age as well as contact with agricultural extension officers. According to [1], current yields of cocoa in the mid (712 kg $ha^{-1}yr^{-1}$) and wet (849 kg ha^{-1} yr^{-1}) regions were significantly higher than yields in the dry regions (288 kg $ha^{-1}yr^{-1}$). With cocoa farmers in the wet regions mostly depending solely on cocoa production, those in the dry regions diversified their sources of income by cultivating other crops apart from cocoa as well as engaging in non-farm activities. [1] added that two shade cocoa agroforestry systems were identified in the study areas and included medium shade cocoa agroforestry system and low shade cocoa agroforestry system. The dry regions were characterized by abundance of the medium shade cocoa agroforestry system and was related to adapting to marginal changes in amounts of rainfall and temperature. With no observable differences in the mid and dry regions, the low shade cocoa agroforestry system recorded appreciable higher yield in the wet regions.

3. Research methodology

3.1. Data collection

The study mainly used cross-sectional data collected from cocoa farmers in the Western and Brong-Ahafo Regions of Ghana. We employed the formula advanced by Taro Yamane in the determination of the sample size. The formula is given as:

$$n = \frac{N}{1 + Ne^2} \tag{1}$$

where n = desired sample size, N = the finite size of the population, e = maximum acceptable margin of error as determined by the researcher and 1 = a theoretical or statistical constant. According to the Ghana Living Standard Survey 6 (GLSS 6), in 2014, there were 794,129 cocoa farmers in Ghana [27]. With this population, with a 5% margin of error, the sample size for the study was calculated to be approximately 400.

Multi-stage sampling technique was employed in selecting the respondents in the two regions. Given that at least 50% of Ghana's cocoa is grown in the Western region [10], in the first stage, three districts were selected from the Western region out of 22 districts/municipalities and one from the Brong-Ahafo Region out of 21 districts/municipalities based on the level of cocoa production [26]. These districts were Sefwi Akontombra, Sefwi Wiawso and Sefwi Bibiani-Anhwiaso-Bekwai districts/municipalities from the Western Region and Berekum Municipality from the Brong-Ahafo Region. In the second stage, four communities were randomly selected from the main cocoa growing areas in each district/municipality with help from COCOBOD's Agricultural Extension workers working in the districts/municipalities [26]. These communities included Akontombra, Ntimkrom, Abrahamkrom and Asantekrom from Sefwi Akontombra district, Asafo, Boako, Punikrom and Kokokrom from Sefwi Wiawso municipality, Sefwi Bekwai, Atronsu, Asawinso and Subri from Sefwi Bibiani-Anhwiaso-Bekwai District and finally, Koraso, Senase, Kato and Biadan from the Berekum Municipality [26]. The final stage was the random selection of 25 cocoa farmers from each community, also with the help of a list of cocoa farmers obtained from COCOBOD's Agricultural Extension Workers operating in the respective communities.

The disadvantage with the current design is that each farmer in the population does not have an equal probability of inclusion as it was not a self-weighting one. As a result, the unweighted sample mean is a biased and inconsistent estimator of the population mean. Consequently, to control for selection bias, before the sample data is used to calculate estimates for the population, it is weighted to ensure that each group of farmers is properly represented, making the sample data representative of the population [17]. To obtain the sampling weights, the probability that each farmer was selected is first computed. This probability is given by the product of the probability that the district/municipality of a farmer in his/her region was selected, the probability that the community of the farmer in his district/municipality was selected and the probability that the farmer was selected in his/her community. Weight is the opposite of probability and therefore is given by the reciprocals of sampling probabilities. That is, the rule here is to weight according to the reciprocals of sampling probabilities because households with low (high) probabilities of selection stand proxy for large(small) numbers of households in the population. After computing the sampling probabilities, the probability that a farmer was selected depends on his/her community of residence is tested. The weight of each farmer is not taken into account if the aforementioned test is rejected. In this study, two variables, viz. description of the community in which farmer lives-rural or urban, as well as number of cocoa farmers living in a farmer's community of residence (proxies for characteristics of community in which farmer lives), were used as explanatory or independent variables whereas the probability that a farmer was selected was the dependent variable in a linear regression. The hypothesis of dependence of selection of farmer on community of residence was rejected as the estimated coefficients were not significant. As a result, the weight of each farmer was not taken into account. The test results are presented in Table 5.

The main data collection instrument used was a structured questionnaire. The questionnaire was divided into three sections. The first section consisted of questions on the socio-economic characteristic of cocoa farmers in chosen districts. The second section consisted of questions on climate change and its adaptation technologies as well as some determinants of adoption of adaptation technologies. Finally, the last section was made up of questions on inputs employed in cocoa production and the outputs produced.

3.2. Analytical framework

3.2.1. Method of analysing adaptation technologies employed in cocoa production

The study employed descriptive statistics in presenting socioeconomic characteristics of the respondents as well as adaptation technologies employed in Ghana's Cocoa production. The adaptation technologies were measured as dummy variables. That is, out of individuals that adopted some technologies, the number of farmers adopting a particular adaptation technology was determined. Basically, frequency tables, mean and standard deviation were the specific descriptive tools employed.

3.2.2. Method of analysing factors influencing adoption of adaptation technologies

The framework employed to examine determinants of adoption of at least one adaptation technology in Ghana's cocoa production is the adoption behaviour model where individual cocoa farmers respond differently to new technologies. A cocoa farmer may/may not respond fully/partially to using the entire adaptation package or may not respond at all. Cocoa farmers who normally respond do so either slowly or rapidly. The adoption model representing adoption behavior employed in this study, follows the threshold theory of decision-making [32] proposed. That is, individuals with choices to make have reaction thresholds, which are determined by a multiplicity of factors. Choices of this nature are usually modeled as:

$$y_i = \beta_i x_i + u_i \tag{2}$$

where, y_i is equal to one if at least one adaptation technology is adopted by the farmer and zero otherwise. That is, $y_i = 1$ if $x_i \geq x^*$ and $y_i = 0$ if $x_i < x^*$ and x^* is a critical value representing the joint effect of independent variables at the threshold level.

The decision to adopt an adaption technology by a cocoa farmer is binary so a farmer may/may not adopt any of suggested adaptation technologies. The model is binary which involves estimating and examining the likelihood of adoption of adaptation technologies, y, as a function of independent variables, x. For this study y_i therefore takes a value of 1 if a cocoa farmer adopts at least one adaptation technology, and 0 if he/she does not adopt any of them. The estimation of such qualitative response model allows us to estimate the conditional probability that y_i assumes one of the specified values. Thus, the probability that a given cocoa farmer will adopt at least one adaptation technology, $\beta_i x_i > x^*$ ($y_i = 1$) is given as:

$$P_i = Prob(y_i = 1) = F(\beta^{'} x_i) \tag{3}$$

The probability that a cocoa farmer will not adopt any of the adaptation technologies, is therefore, given as:

$$1 - P_i = Prob(y_i = 0) = 1 - F(\beta^{'} x_i) \tag{4}$$

where, y_i is the observed response of the *ith* observation of the response variable y and x_i is a set of explanatory variables of the *ith* respondent. The function F may take the form of a normal logistic or other probability functions. The logit model was employed to analyse the factors influencing adoption of adaptation technologies by Ghana's cocoa farmers. The model, $F(\beta^{'} x_i)$, uses a logistic cumulative distribution function to estimate P_i as follows [44]:

$$P(y = 1) = \frac{e^{\beta^{'} x}}{1 + e^{\beta^{'} x}} \tag{5}$$

$$P(y = 0) = 1 - \frac{e^{\beta^{'} x}}{1 + e^{\beta^{'} x}} = \frac{1}{1 + e^{\beta^{'} x}} \tag{6}$$

The probability model [28] shows a regression of the conditional expectation of y on x, given:

$$E(y/\ x)\ =\ 1[F(\beta^{'} x)\ ] + 0[1 - F(\beta^{'} x)] = F\ (\beta^{'} x) \tag{7}$$

Because of the non-linear nature of the model, the parameters do not represent the marginal effects of the respective independent variables and therefore the marginal effects had to be estimated differently. The marginal effects were obtained by taking the first derivative of equation (5) with respect to x_{ij}. This resulted in the equation:

$$\frac{dP_i}{dx_{ij}} = \left[\frac{e^{\beta^{'} x}}{(1 + e^{\beta^{'} x})^2}\right]\beta = F(\beta^{'} x)[1 - F(\beta^{'} x)]\beta \tag{8}$$

The maximum likelihood method of estimation is employed in estimating the parameters. The logit and the probit models give similar marginal effects but the logit model is much more attractive and preferred by most economists because of its mathematical convenience. Empirically, the logit model was specified as follows:

$$y = \beta_0 + \beta_i x_i + \varepsilon_i \tag{9}$$

where $y =$ Adoption of at least one climate change adaptation technology, measured as a dummy (1 for adoption of at least one climate change adaptation technology and 0 otherwise), x_i are the factors influencing adoption of at least one climate change adaptation technology and and ε_i is the error term. Table 1 presents the explanatory variables employed in the study.

Table 1
Variables employed in the study and their a priori expectations.

Variable	Description and Measurement	A priori Expectation	Source
x_1	Age of respondent, measured in years	–	[20,42]
x_2	Experience, measured in number of years in cocoa farming	+	[20]
x_3	Engagement in other economic activities, measured as a dummy (1 for cocoa farmer engaging in other economic activities and 0 otherwise)	+/−	[19,33, 39]
x_4	Gender, measured as a dummy (1 for males and 0 otherwise)	+/−	[11]
x_5	Marital status, measured as a dummy (1 for married and 0 otherwise)	+	[16]
x_6	Educational level, measured in number of years of schooling	+	[58]
x_7	Household size, measured in number of people living with cocoa farmer	+	[5,57]
x_8	Access to extension services, measured as a dummy (1 for yes and 0 otherwise)	+	[24,51]
x_9	Access to credit, measured as a dummy (1 for yes and 0 otherwise)	+	[8,24]
x_{10}	Annual income from cocoa, measured in Ghana Cedis	+	[4,50, 56].
x_{11}	Membership of a farmer association, measured as a dummy (1 for member and 0 otherwise)	+	[7]

3.2.3. *Method of analysing impact of adoption of climate change adaptation technologies*

Cocoa farmers are considered to have adopted a climate change adaptation technology if they responded yes to the question, 'do you practice any cultural practice aimed at building resilience to the effects of climate change'? Propensity score matching (PSM) was employed in analysing the impact of adoption of an adaptation technology on the productivity and incomes of cocoa farmers. PSM is chosen over other impact evaluation/assessment techniques because it assumes that all important household characteristics determining adoption of adaptation technologies to build resilience to climate change effects are observable. If we use ϕ to represent the impact of adoption of at least one climate change adaptation technology on one of the outcome variables, say cocoa productivity, then:

$$\phi = Y_1 - Y_0 \tag{10}$$

where Y_1 and Y_0 denote productivity of the cocoa farmers when they adopted a climate change adaptation technology and the counterfactual respectively. The Average Treatment Effect (ATE) of adoption of a climate change adaptation technology can be calculated as:

$$ATE = E(\delta) = E(Y_1 - Y_0) \tag{11}$$

where $E(\ .)$ represents the average or expected productivity. The impact of treatment on productivity of the cocoa farmers who adopted at least one climate change adaptation technology.

(treated) can be estimated as:

$$ATT = E(Y_1|D=1) - E(Y_0|D=1) \tag{12}$$

where ATT represents Average Treatment effect on the Treated and denotes adoption of a climate change adaptation technology indicator which equal to one (1) if the farmer adopted climate change adaptation technologies and zero (0) otherwise. $E(Y_0|D=1)$ is the mean productivity of treated in the absence of the treatment (i.e counterfactual productivity)? In the case of non-adopters of any of the climate change adaptation technologies (untreated or control), their average productivity can be estimated as:

$$ATU = E(Y_1 - Y_0|D=0) \tag{13}$$

where, ATU is the Average Treatment effect on the Untreated. Estimating ATT and ATU is determined by the levels of counterfactuals of cocoa farm productivity and incomes of the control and treated groups. That is, $E(Y_0|D=1)$ and $E(Y_0|D=0)$ as stated above. In a non-experimental study such as ours, it is not possible to evaluate the counterfactual productivities and incomes of the treated and control groups. It is possible to use the productivity and income of non-adopters as a counterfactual for adopters. However, according to [46], because of selectivity bias, the estimate of ATT may be biased.

In what follows, we present how selection bias may result in bias estimates of ATT when using productivity of untreated respondent as counterfactual for the treated farmers and how to correct for this bias. Let us represent the change in productivity of the treated and the control as:

$$\Delta = E(Y_1|D=1) - E(Y_0|D=0) \tag{14}$$

By expanding and rearranging, we have:

$$\Delta = E(Y_1|D=1) - E(Y_0|D=1) + E(Y_0|D=1) - E(Y_0|D=0)$$

$$\Delta = ATT + E(Y_0|D=1) - E(Y_0|D=0)$$

$$\Delta = ATT + SB$$

$$ATT = \Delta - SB \tag{15}$$

where SB is selection bias which arises as a result of unobservable factors that determine treated and control groups of respondents. If $SB = 0$, then

$$ATT = E(Y|D=1) - (Y|D=0) \tag{16}$$

However, if $SB \neq 0$, it implies there is selection bias indicating that the estimate of ATT cannot be the expected difference in the average observed productivity of the treated and untreated. It is possible that hardworking farmers may be the ones who adopted climate change adaptation technologies, thus $SB \neq 0$. Hence farmers who adopted at least one climate change adaptation technology may have larger productivities even if they did not adopt the technologies compared to non-adopters. Because of this, estimates of the mean productivity and income of the control group will not be a perfect comparison for the counterfactuals of the adopters in evaluating the effect of adoption of adaptation technologies on cocoa productivity and income. [46] therefore proposed usage of PSM to correct for the presence of confounding factors.

The PSM is a two-step procedure. First, either logit or probit model is used to estimate the probability (propensity score) of adoption of at least one climate change adaptation technology, using observable characteristics which influence adoption of climate change adaptation technologies. As explained above, we specify the logit model as:

$$P(X) = P(D=1|\ \ X) = F(\beta_1 X_1 + \ldots \beta_i X_i) = F(X\beta) = e^{X\beta} \tag{17}$$

where $F(.)$ represents the probability of adoption which must range from zero to one, X denoting a vector of observable characteristics influencing adoption and β representing the parameter which is the coefficient of X.

The above model is used to predict the propensity score of adoption of at least one climate change adaptation technology. Given that the propensity score is a balancing score, the probability of adoption of a climate change adaptation technology conditional on X will lead to distribution of farmers' covariates X, such that these covariates will be the same for treatment and control groups. Assuming all information relevant to adoption of a climate change adaptation technology and cocoa farm productivity are observable, then the propensity score will produce valid matches which can be used to estimate impact of adoption of a climate change adaptation technology on productivity and incomes at the second stage. With the predicted propensity scores, the treated and untreated groups of respondents are matched as follows:

$$ATT = [(E(Y_1|D = 1.E(P(X)) - E(Y_0|D = 1.E(P(X))] \quad (18)$$

where $E(P(X))$ represents expected propensity score distribution and $E(Y_1|D = 1, P(X), E(Y_0|D = 1$ have their usual meanings.

In this study, ATT is estimated using key matching algorithms, viz. Nearest Neighbour, Radius, and Kernel Matching methods. In practice, more than one algorithm is employed for comparison purposes to ensure the ideal ATT is estimated. PSM follows two assumptions. These are conditional independence and common support (balancing) assumptions. By assumption of conditional independence, all covariates must not depend on adoption. That is, selection of cocoa farmers into control and treated groups must be based only on observable factors (X) influencing the propensity score. The assumption of common support states that adoption is influenced by pre-adoption factors. This assumption scraps the notion that prediction of adoption is perfect ($D = 1$) given covariates X.

[49] has recommended an assessment of the matching quality which requires the re-estimation of propensity score of matched adopters and matched non-adopters. The matching procedure is expected to balance the covariates very well if the $pseudo - R^2$ after matching is fairly low, while the probability of the F-statistics is not significantly different from zero.

4. Results and discussion

4.1. Socioeconomic characteristics of cocoa farmers

The socioeconomic characteristics of the respondents are presented in Tables 2 and 3. The gender differences showed that over 70% of the respondents were males (Table 2). The implication is that.

Ghana's cocoa production is dominated by males. This finding corroborates with results reported by similar studies in Ghana and Nigeria [3,6,42]. The age categorization revealed that 69.25% of the respondents were at least 36 years old, indicating that generally, most cocoa farmers are old and few youths are involved [37] (Table 2).

Table 2
Characteristics of cocoa farmers interviewed.

Variables	Categories	Frequency	%
Gender	Male	303	75.8
	Female	97	24.2
Age in years	15–35	30	7.5
	36–60	277	69.25
	>60	93	23.25
Educational level of farmer	No formal education	51	12.7
	Primary school	60	15.0
	Middle school/JSS/JHS	208	52.0
	SSS/SHS	33	8.3
	Training college/ Tertiary	48	12.0
Farming experience (years)	<5	56	14.0
	5–10	72	18.0
	>10	272	68.0
Marital status	Married	345	86.3
	Single	55	13.7
Household size	<5	83	20.8
	5–10	230	57.5
	>10	87	21.7
Association membership	No	334	83.5
	Yes	66	16.5
Access to extension	No	299	74.8
	Yes	101	25.2
Access to credit	No	285	71.3
	Yes	115	28.7
Engage in other economic activities	Yes	175	43.7
	No	225	56.3
Adoption of Adaptation technologies	Yes	166	41.5
	No	234	58.5

Source: Survey, 2018

Table 3
Characteristics of adopters and non-adopters of climate change adaptation technologies in cocoa production (Test of Equality of Means).

Variable	Adopter	Non-Adopter	t-value
Age of farmer (Years)	47.2	51.70	−4.12***
Educational level (years)	8.46	5.74	3.11*
Farming Experience (years)	16.11	11.31	2.15**
Farm size (ha)	3.45	1.43	0.11**
Number of extension visits	4.24	1.17	0.09**
Credit (Gh')	540	211	2.41***
Household size	9.01	6.24	0.44*
Capital (Gh')	842	357	2.74***
Off-farm income (Gh')	650	245	1.75**
Annual farm income (Gh')	1012	581	3.41***
Land productivity (kg/ha)	341	245	2.41**

Note: The asterisks indicate levels of significance. *** is significant at 1%, ** is significant at 5% and * is significant at 10%.
Source: Survey, 2018

Table 3 also presents a significant difference between the ages of adopters and non-adopters of climate change adaptation technologies with the ages of non-adopters being relatively higher than those of adopters. This means that the youth will be better adopters of climate change adaptation technologies. In fact, the few number of youth involved in cocoa production should therefore be a concern for stakeholders in the cocoa industry given Ghana's strive towards becoming the world's leading producer of cocoa again and the fact that earlier studies have reported similar results [1,10,20,42].

Over 50% of the respondents were educated up to at least the Junior High/Middle school level and very few of them (12.7%) had no formal education (Table 2). We also find in Table 3 that there exist a significant difference between the educational level of adopters and non-adopters of climate change adaptation technologies. That is, generally, while adopters had up to Junior High/Middle school education, non-adopters ended in the primary school. The implication is that, generally, most cocoa farmers have at least some level of formal education. This corroborates the findings of similar earlier studies [6,20,42]. In terms of experience, most of the respondents (68%) had been producing cocoa for not less than ten years, indicating the great level of experience the farmers have. This is expected since most farmers operate old cocoa farms and few youth venture into cocoa production [10]. Also worthy of note is the significant difference in the experience levels of adopters and non-adopters of climate change adaptation technologies, making experience expected to have a positive influence on adoption of climate change adaptation technologies (Table 3). The high experience level found in this study is in line with the findings of [6,20].

Given the old age of most cocoa farmers, it is not surprising that almost all of them (86.3%) are married. If married farmers have children, they will likely be able to adopt some adaption technologies since they will have cheap family labour. This compares well with similar results reported by [20,42]. The findings of household size revealed that most of the cocoa farmers in the study area (79.2%) had at least five people living in their household (Table 2). This is expected as most of them are married and given that they have children, at least their children will add to their households. Also, household sizes of adopters were found to be significantly different from those of non-adopters of climate change adaptation technologies (Table 3). The above finding are consistent with household sizes reported by [6,20] that cocoa farmers generally, have large family sizes. According to them, large family sizes supply labour to the farm given the many labour activities undertaken in cocoa farms especially when it comes to practicing recommended productivity enhancing technologies such as climate change adaptation technologies.

Most of the respondents (83.5%) did not belong to any farmer association and this can negatively affect their chances of being able to adopt adaptation technologies. This is because information on most climate change adaptation technologies aimed at building resilience to climate change effects are disseminated through farmer groups. This finding however disagrees with those of [34] that most cocoa farmers belonged to farmer associations. A greater percentage of the respondents (74.8%) too did not have access to extension service and this is very unpalatable given the key role expected to be played by agricultural extension officers in disseminating information on climate change adaptation technologies from researchers to the farmers [15]. We also find in Table 3 that the number of extension service received by adopters of climate change adaptation technologies is significantly higher than those received by the non-adopters. The few number of cocoa farmers having access to extension service confirms similar reports by [34] and [20] even though it disagrees with those of [6] which stated that 64% of sampled cocoa farmers had access to extension service.

Generally, only 28.7% of the sampled cocoa farmers had access to credit. What this means is that even if farmers are taught climate change adaptation technologies, due to the capital intensive nature of these technologies, they will struggle to practice them because of inadequate funds. Table 3 also reveals that for those who had access to credit, the amount received by adopters of climate change adaptation technologies was significantly higher than those received by non-adopters. This finding is in consonance with the results of [10] as well as [20] that most cocoa farmers do not have access to credit. We also find in Table 2 that, apart from cocoa production, 43.7% of the respondents engaged in other economic activities comprising cultivation of other crops and engagement in non-agricultural activities. Generally, farmers engaged in other economic activities as a diversification strategy aimed at helping them build resilience to climate change effects on cocoa production [34].

Generally, off-farm income, annual incomes and productivities of adopters of climate change adaptation technologies were found to be significantly higher than the non-adopters (Table 3). The productivity estimated in this study compares well with the productivity reported by [10]. According to [10], Ghana's productivity is low compared to countries like Cote d'Ivoire and Indonesia, which have annual yield rates estimated at 600 kg and 1000 kg per hectare, respectively. Furthermore, the results in Table 3 report that adopters of climate change adaptation technologies own significantly higher cocoa farms than non-adopters. This finding corroborates similar findings reported by [14]. Finally, this study found that only 41.5% of cocoa farmers in the study area adopted one or more climate change adaptation technologies to help them build resilience to climate change's effect on their cocoa production. This confirms Denkyirah et al.'s. (2017) report that only few cocoa farmers adopt some form of climate change adaptation technologies. This unpleasant development should be a course for concern for stakeholders in the cocoa industry given that climate change is happening and given its potential to negatively affect cocoa farm productivity.

4.2. Adaptation technologies employed in Ghana's cocoa production

Climate change is happening and cocoa farmers in the study area are aware of its presence as well as its devastating effects on the productivity of their farms. To build resilience to climate change effects, some cocoa farmers in the study area adopted one or more adaptation technologies. These technologies are presented in Table 4. As explained in the preceding section, generally, over 57% of the respondents did not adopt any of the adaptation technologies or innovations. For those who adopted one or more adaptation technologies, 67.5% diversified their income sources, indicating that diversification of income sources was the major technology or innovation employed by cocoa farmers in the study area to help build resilience to the devastating effects of climate change. This was followed by 60.8% of the respondents who rather intercropped their cocoa trees with other crops like, plantain, cassava and maize. This finding is consistent with [20] that found crop diversification and diversification to non-farm activities as the major adaptation technologies employed by cocoa farmers in the Brong-Ahafo Region of Ghana. Table 4 also shows that only 12% of the respondents adopted farm rehabilitation using grafting, indicating how uncommon this adaptation technology was in the study area. This result however disagrees with [20] that rather found planting of improved cocoa varieties to be the adaptation technology least adopted by cocoa farmers to mitigate the harmful effects of climate change. In fact, Solidaridad, an international civil society organization and Cocoa Research Institute of Ghana have mentioned grafting as a path for cocoa productivity and argued that the government should not be so hindered by the possibility of spreading Cocoa Swollen Shoot Virus as cautioned by earlier proponents of the technology [10,34].

Table 4
Adaptation technologies to climate change effects in cocoa production.

Adaptation technologies	Frequency	Percentage
No adaptation	234	58.5
Planting of improved cocoa varieties from certified source	48	28.9
Increasing fertilizer application	66	39.8
Increasing pesticide and fungicide application	88	53.0
Diversification of Income Sources	112	67.5
Agroforestry	70	42.2
Intercropping with other crops	101	60.8
Farm rehabilitation using grafting	20	12.0
Pruning practices	77	46.4
Weeding 4–6 times per year for young cocoa	41	24.7
Leaving cleared weeds to mulch on prepared lands	16	9.60

Note: Respondents were asked to tick multiple responses.
Source: Survey, 2018

4.3. Factors influencing adoption of adaptation technologies in cocoa production

Table 5 presents the results of the logit model representing the factors influencing adoption of at least one climate change adaptation technology by cocoa farmers in the study area. The significance of the likelihood ratio statistic at 1% suggests the robustness of the model. Table 5 also shows that eight variables including gender, age of respondent, involvement in other economic activities, farm size, membership of a farmer association, access to extension service, access to credit as well as annual income from cocoa production were found to be significant. The marginal effect of gender is positive and significant at the 1% level. It suggests that men will 15.3% more likely adopt at least one climate change adaptation technology than women (Table 5). The implication is that, generally, male cocoa farmers easily adopt climate change adaptation technologies as compared to female ones. This could be due to the intensive and laborious nature of adopting most climate change adaptation technologies which is too much for women to bear. The reason may also be that female farmers have higher health risk when they come into contact with pesticides and other chemicals [23]. The likelihood of men to adopt at least one climate change adaptation technology is consistent with the findings of similar recent studies [20, 42].

The marginal effect of age is negative and statistically significant at the 1% level. Its magnitude means that increasing the age of the cocoa farmer by one year will decrease his/her probability of adoption of a climate change adaptation technology by 0.6% (Table 5). The implication is that old cocoa farmers hardly adopt recommended technologies. This is because older cocoa farmers are very conservative and always prefer sticking to primitive or crude technologies and therefore will hardly adopt newly introduced or recommended technologies. Some of the farmers think they have enough experience in cocoa production and do not really need to employ any recommended climate change adaptation technology. Also, younger cocoa farmers will more likely invest in long-term projects because they are more energetic than older ones [2]. The negative effect of age on the probability of adoption corroborates the findings of [20] as well as [55]. It however contradicts the findings of [6] in which positive effects were reported.

Table 5
Logistic regression coefficients and marginal effects of factors influencing adoption.

Variable	Coefficient	Std. Err	z-statistic	Marginal Effect	P-value
Constant	−3.59	1.047	−3.43		0.001
Gender	1.152	0.048	3.18	0.153	0.001***
Age of respondent	−0.045	0.002	−2.69	−0.006	0.007***
Involved in other economic activities	1.449	0.040	4.78	0.192	0.000***
Formal education	0.047	0.005	1.23	0.006	0.219
Household size	0.070	0.008	1.20	0.009	0.229
Farm size	0.147	0.007	2.61	0.019	0.009***
Member of an FBO	0.758	0.044	2.28	0.101	0.022**
Access to extension	1.656	0.055	4.03	0.220	0.000***
Cocoa farming experience	0.001	0.001	0.51	0.001	0.613
Access to credit	0.135	0.044	0.41	0.018	0.085*
Marital status	−0.213	0.048	−0.59	−0.028	0.553
Annual income from cocoa	0.087	0.029	0.45	0.064	0.000***
Number of Observations	400				
Log likelihood	−167.8				
LR chi^2 (11)	59.06				
Prob> chi^2	0.000				
Pseudo R^2	0.1496				
Selection of farmer depends on community description (rural or urban)	0.0124	0.021			
Selection of farmer depends on community farmer population	0.0014	0.0215			

Note: The asterisks indicate levels of significance. *** is significant at 1%, ** is significant at 5% and * is significant at 10%.
Source: Survey, 2018

Involvement in other economic activities comprised undertaking either other farm activities apart from cocoa production or non-farm activities. Farmers basically engaged in other economic activities as a diversification technology aimed at building resilience to adverse climate change effects on cocoa production. For those who diversified into other agricultural production activities, they either grew food crops or other cash crops. Other cash crops normally grown apart from cocoa include oil palm, plantain, cassava and peppers [34]. The variable representing involvement in other economic activities is positive and significant at the 1% level. The marginal effect revealed that engagement in other economic activities apart from cocoa production will lead to a 19.2% increase in the likelihood of adoption of at least one climate change adaptation technology (Table 5). This implies that cocoa farmers who do not rely solely on cocoa production stand a greater chance of being able to adopt recommended climate change adaptation technologies. This is because, the income obtained from engagement in other economic activities can be channeled into supporting adoption of recommended climate change adaptation technologies as well as help farmers take up any agricultural activity that is deemed costly [33]. This finding however disagrees with [19] as well as [20]. They argue that involvement in other economic activities will rather decrease their probability of adoption since the farmer invests resources in other economic activities other than practicing climate change adaptation technologies.

Farm size is positively related to the probability of adoption of a climate change adaptation technology and statistically significant at the 1% level. Its marginal effect means that an increase in farm size by 1 ha will increase the probability of adoption of a climate change adaptation technology by 1.9% (Table 5). This is because cocoa farmers know that, with large farms, their risk are higher and they will lose so much in the event of a climate change shock. Owners of large farms will therefore do all they can to mobilize resources with which they can practice recommended climate change adaptation technologies in their cocoa farms to help them build resilience in the face of climate change. This result is consistent with those of [20,55] even though it is not in agreement with those of [53].

The variable for belonging to a farmer association has a positive relationship with the likelihood of adoption of a climate change adaptation technology and this is significant at the 5% level. The marginal effect suggests that belonging to a farmer association will lead to a 10.1% increase in the probability of adoption (Table 5). This is expected because belonging to a farmer group exposes farmers to recommended climate change adaptation technologies whose adoption has the potential to help them build resilience to the shocks climate change brings. This is because information on most agricultural productivity enhancing technologies are disseminated through farmer based organizations [7] and therefore not belonging to any farmer group means a decline in one's probability of becoming aware of recommended technologies let alone adopt them to help mitigate the negative effects of climate change. This finding is in line with similar results reported by similar recent researchers [6,42].

The effect of access to extension service by the sampled cocoa farmers was positively correlated with the probability of adoption of at least one climate change adaptation technology and this was significant at the 1% level. The magnitude of the marginal effect has it that having access to extension will cause a 22% rise in the likelihood of adoption of a climate change adaptation technology (Table 5). This agrees with the findings of recent similar studies [6,20,55] and is not surprising given the key role played by agricultural extension agents in disseminating information on recommended agricultural productivity enhancing technologies [24]. Added to this is the fact that farmers become aware of climatic conditions and their effects on crop productivity when they have access to agricultural extension service [29]. Agricultural extension agents are therefore reliable source of information to farmers [52].

Access to credit had a positive effect on probability of adoption of at least one climate change adaptation technology and was statistically significant at the 10% level. The marginal effect reveals that having access to credit will result in a 1.8% increase in the chances of a cocoa farmer adopting a climate change adaptation technology (Table 5). This is expected because credit adds to the financial resources available to the cocoa farmer and gives him/her the opportunity to meet the financial demands of adopting newly introduced productivity enhancing technologies [24]. Previous studies have also shown that farmers' ability to build resilience to adverse effects of climate change is positively influenced by access to credit [21,25] and generally, use of improved recommended technologies from research institutes relies on accessibility and availability of credit [18]. The positive effect of credit on probability of adoption found in the current study concurs with similar results reported by [20] as well as [55].

Finally, annual income from cocoa production was positively related to the probability of adoption of at least one climate change adaptation technology and was statistically significant at the 1% level. The marginal effect implies that an increase in annual income of a cocoa farmer by one Ghana Cedi will increase his/her probability of adopting climate change adaptation technologies by 6.4% (Table 5). An increase in annual income means farmers have enough money to take care of traditional production operations as well as meet the financial demands of adopting climate change adaptation technologies that will help them build resilience in the face of shocks of climate change. This finding corroborates the findings of previous similar studies that found that cocoa income had a positive impact on capacity of farmers which influenced their adoption of new technologies [56]. According to [10] as well as [59], cocoa income contributes at least 70% to the annual income of cocoa farmers, indicating the key role cocoa income plays in helping farmers to meet the financial demands of adopting climate change adaptation technologies. The current study's results however disagree with those of [20] who argued that with increase in cocoa income by one Ghana cedi,[1] the farmer will less likely adapt to climate change. According to them, the farmer may use his/her cocoa income for non-farm activities other than climate change adaptation, since he/she might perceive climate change to have minimal impact on his/her farming activities.

4.4. Impact of adoption of climate change adaptation technologies on productivity and income

The propensity scores used to match each adopter of a climate change adaptation technology with similar non-adopters (control) on cocoa farm productivity and cocoa income was estimated using the logit model. The independent variables used in the logit model are those explained in the previous section.

The study employed Nearest Neighbour, Radius and Kernel based matching algorithms for the matching. Fig. 1 (a, b and c) presents the density distributions of the estimated propensity scores for adopters and non-adopters for each of the aforementioned matching algorithms. These histograms illustrate the number of respondents who are on support (have matches) and those off support (do not have matches). The three figures show that there is evidence of overlap in the distribution of the propensity scores of both adopters and non-adopters of at least one climate change adaptation technology. In each histogram, the bottom half presents propensity scores distribution for non-adopters and the upper half presents those of adopters.

Table 6 presents the results of the propensity score matching on the impact of adoption of at least one climate change adaptation technology on cocoa productivity and incomes. Interestingly, similar results were obtained in all matches. For the nearest neighbour matching algorithm, the impact of adoption of a climate change adaptation technology on cocoa productivity was an increase of about 9.51 kg/ha and this was statistically significant at the 1% level. For the radius matching algorithm, the impact was an increase of about 12.45 kg/ha and this was statistically significant at the 10% level. Similarly, for the kernel based matching algorithm, the impact of adoption was a rise in cocoa productivity of about 10.81 kg/ha. [9] analyzed the drivers of yield in Ghana's cocoa production and found that non-climate change adaptation technologies such as planting of poor cocoa varieties have negative impacts on cocoa yield. According to them, this can reduce cocoa yield by 28.1 kg/ha. Also according to [60], adoption of improved cocoa varieties increases cocoa yields by at least 45%.

In the case of cocoa incomes, for the nearest neighbour matching algorithm, farmers who adopted at least one climate change adaptation technology saw an increase in their incomes of about Gh¢96.11 and this was statistically significant at the 1% level. For the radius matching algorithm, adopters of a climate change adaptation technology saw their incomes increased by Gh¢101.6 and this was significant at the 5% level. Finally, for the Kernel-based matching algorithm, the impact of adoption on cocoa incomes was an increase of about Gh¢90.25 and this was significant at the 1% level. The matching methods gave similar results and generally, the implication is that adoption of at least one climate change adaptation technology really leads to an increase in the incomes of cocoa farmers. This is because variability and change in climate alter the development of pests, diseases and cocoa pods that affect cocoa trees, resulting in low crop productivity that influence farm income but with adoption of climate change adaptation technologies, yields are higher which leads to higher incomes [3]. The findings of this study corroborates similar findings reported by previous similar studies that adoption of climate change adaptation measures such as improved seed varieties, use of organic manure and increased farm size have significant positive impacts on cocoa farm net income [9,38,40]. Also, according to [13], adaptation through on-farm management practices has statistical significance and positive effects on incomes of households. The results from a study by [22] also showed that climate extremes adaptation significantly improved both farm productivity and net revenues from smallholder farms.

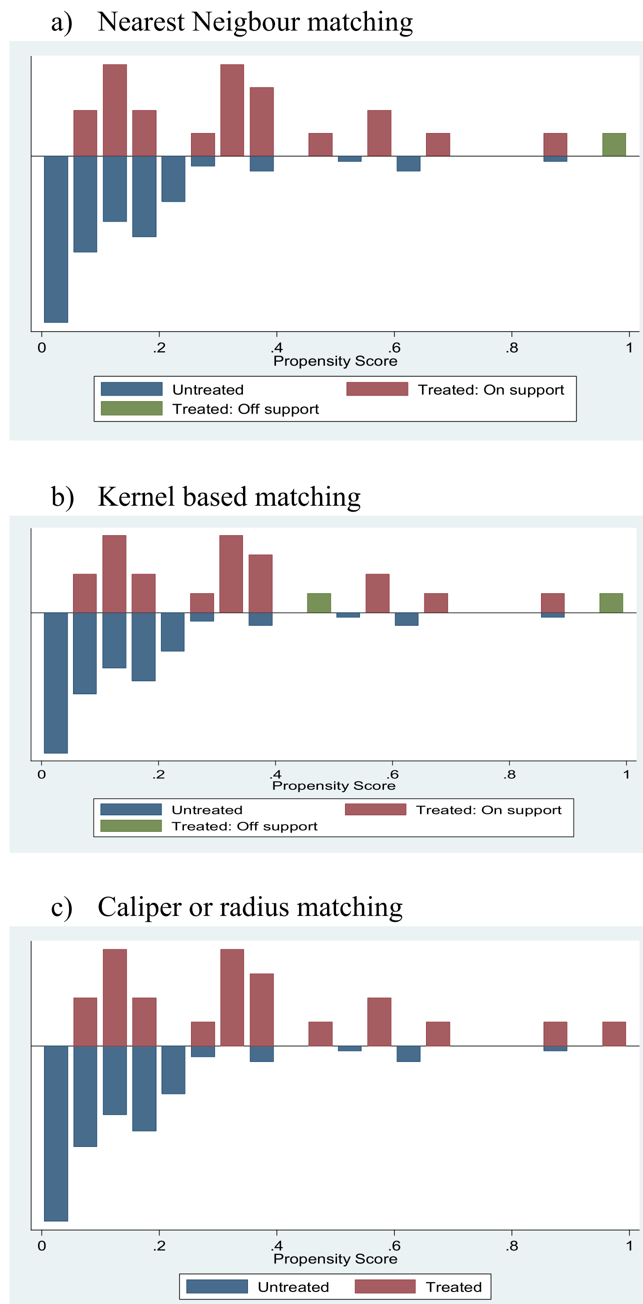

Fig. 1. Distributions of the estimated propensity scores for adopters and non-adopters.

In fact, all the matching techniques gave similar estimates of the effect of adoption of climate change adaptation technologies on cocoa farm productivity and incomes (Fig. 1). From the foregoing, the propensity score matching analysis results showed that cocoa farmers who adopted at least one climate change adaptation technology recorded significantly higher farm productivities vis-à-vis non-adopters. Adopters of climate change adaptation technologies also had higher farm incomes than non-adopters.

Table 7 presents results from covariate balancing tests before and

[1] 1US$ = Gh’5.70.

Table 6
Propensity score matching results of impact of climate change adaptation technologies adoption on productivity and income.

Outcomes/ Matching algorithm	Adopters (N)	Non-Adopters (N)	ATE	ATU	ATT
Productivity					
Nearest Neighbour	158	230	20.312	10.802	9.51*** (0.451)
Radius	162	198	30.415	17.965	12.45* (0.742)
Kernel-based matching	159	227	55.421	44.611	10.81* (0.884)
Cocoa income					
Nearest Neighbour	149	218	120.22	24.11	96.11*** (2.453)
Radius	152	213	111.28	9.68	101.6** (5.174)
Kernel-based	145	199	146.37	56.12	90.25*** (4.157)

Note: The asterisks indicate levels of significance. *** is significant at 1%, ** is significant at 5% and * is significant at 10%. *ATE* = Average Treatment Effect, *ATU* = Average Treatment effect on untreated and *ATT* = Average Treatment effect on the treated and standard errors are in parenthesis.
Source: Survey, 2018

after matching which give the indication of matching quality. The results show substantial reduction in absolute bias for all the outcome variables for the three matching algorithms. As indicated in Table 7, the mean bias after matching lies below the 20% level suggested by [47]. This indicates that the variables were significantly balanced as a result of the propensity score matching procedure. In addition, the $pseudo- R^2s$ after matching are fairly low with none of the F-statistics being significantly different from zero, suggesting that the proposed specification of the propensity score is fairly successful in terms of balancing the distribution of covariates between the two adopters and non-adopters [49].

5. Conclusions

Empirical evidence has revealed that only few cocoa farmers adopt some form of adaptation technologies that are expected to help them build resilience to the adverse effects of climate change. This study analyzed the determinants of adoption of at least one climate change adaptation technology as well as productivity and income differential between small-scale cocoa farmers who adapt to climate change and those who do not adapt to climate change. Indications are that generally, most cocoa farmers do not adopt any of the climate change adaptation technologies. For those who adopted one or more adaptation technologies, diversification of income sources was the major technology employed.

The study revealed that men will more likely adopt any of the climate change adaptation technologies than women. This could be due to the intensive and laborious nature of adopting most climate change adaptation technologies which is too much for women to bear. Generally, old cocoa farmers hardly adopt recommended technologies. This is because they are very conservative and will always prefer sticking to primitive or crude technologies. Cocoa farmers who do not rely solely on cocoa production stand a greater chance of being able to adopt any of the recommended climate change adaptation technologies. This is because, the income obtained from engagement in other economic activities can be channeled into supporting adoption of recommended climate change adaptation technologies as well as help farmers take up any agricultural activity that is deemed costly. Increasing farm size will increase the probability of adoption of a climate change adaptation technology. This is because cocoa farmers know that, with large farms, their risks are higher and they will lose so much in the event of a climate change shock and therefore will do all they can to mobilize resources with which they can practice recommended climate change adaptation technologies in their cocoa farms to help them build resilience in the face of climate change.

Membership of a farmer association will likely increase adoption because it exposes farmers to recommended climate change adaptation technologies whose adoption has the potential to help them build resilience to the shocks climate change brings. This is because information on most agricultural productivity enhancing technologies are disseminated through farmer based organizations. Having access to extension has the effect of increasing adoption of a climate change adaptation technology because of the key role played by agricultural extension agents in disseminating information on recommended agricultural productivity enhancing technologies. Access to credit increases the chances of a cocoa farmer adopting at least one climate change adaptation technology because it adds to the financial resources available to the cocoa farmer and gives him/her the opportunity to meet the financial demands of adopting newly introduced productivity enhancing technologies. Also, an increase in annual income of a cocoa farmer will likely increase his/her adoption of any of the recommended technologies because, it implies farmers have enough money to take care of traditional production operations as well as meet the financial demands of adopting climate change adaptation technologies that will help them build resilience in the face of shocks of climate change. Finally, cocoa farmers who adopted at least one climate change adaptation technology recorded significantly higher farm productivities and incomes vis-à-vis non-adopters. This presents good news to Ghana's cocoa farmers about what can be done to help build resilience to adverse effects of climate change.

Ghana's cocoa production still has a great future notwithstanding climate change threats provided recommended adaptation technologies are adhered to by the farmers. Cocoa farmers, especially females, should be empowered by the Ministry of Food and Agriculture through extension education and social networks to adopt adaptation technologies to enable them build resilience to the negative effects of climate change. Instituting a price policy by government to ensure higher income from cocoa for farmers will significantly increase adoption of adaptation technologies by cocoa farmers. Cocoa farmers should however not rely solely on cocoa production but should engage in other income generating activities as well as a diversification technology, as this will make available enough funds to support meeting the demands of adopting climate change adaptation technologies aimed at building resilience in

Table 7
Indicators of matching quality before and after matching.

Matching algorithm	Outcome indicator	R^2 Unmatched	R^2 matched	P-value Unmatched	P-value Matched	Mean absolute bias unmatched	Mean absolute bias matched	Absolute bias reduction
Nearest Neighbour	Productivity	0.204	0.024	0.000	0.345	22.4	8.3	62.8
	Income	0.204	0.022	0.000	0.305	7.6	13.2	45.7
Radius	Productivity	0.204	0.018	0.000	0.511	22.4	6.7	70.2
	Income	0.204	0.019	0.000	0.431	7.6	12.2	42.3
Kernel based	Productivity	0.207	0.024	0.000	0.216	22.4	6.2	70.2
	Income	0.204	0.022	0.000	0.305	7.6	13.2	45.3

Source: Survey, 2018

the event of climate change shocks. Also, training more extension personnel to ensure more access to extension service by farmers may foster effective adaptation through adoption of adaptation technologies. Agricultural extension officers should also be supported financially by the government and development organizations to be able to reach out to all cocoa farmers to educate them on climate change resilience technologies. Cocoa farmers are encouraged to join farmer based organizations to enable them have access to and use information required for successful adoption of climate change adaptation technologies.

Author statement

The authors declare that they have no competing interest.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.techsoc.2020.101288.

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