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Adaptation strategies of Ghanaian cocoa farmers under a changing climate

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ABSTRACT

Much literature has been devoted to understanding farmers' adaptation decisions in annual cropping systems, but comparatively little is known on adaptation in perennial systems. This paper presents empirical findings on Ghanaian cocoa farmers' experiences of climate change, the coping strategies they have used and the factors that influenced their adaptation decisions. Primary data were collected through a structured survey of 313 households in 20 communities in Dormaa West and Bia East districts of Ghana. The econometric analysis of the data shows that more than 90% of cocoa farmers have been exposed to negative impacts of climate change. This resulted in severe and very severe effects on their cocoa production and livelihood. Yet a fourth of the respondents have not implemented any adaptation strategy. We argue that this is due to the economic superiority of cocoa as a perennial crop vis-à-vis other agricultural (annual) crops. We conclude that there is need for the development of adaptation technologies for current cocoa farmers but also need for more transformational adaptation policies that generate jobs and income generating activities outside cocoa cultivation.

1. Introduction

Theobroma cacao L, (Cocoa) is a tree crop grown in agro-forestry systems in Africa, Latin America and Asia. In this paper, we focus on cocoa farming in Ghana as a case in point. Providing livelihood to more than 800′000 farming families, the cocoa sector is of importance for Ghana's national economy (Asamoah and Owusu-Ansah, 2017). Agroforestry systems are increasingly being appreciated for their multiple regulating functions that can help mitigate impacts of climate change including microclimatic cooling, water retention, soil improvement, atmospheric moisture regulation and carbon sequestration (Ellison et al., 2017; Sheil, 2018). Ghana's REDD+ (Reducing Emissions from Deforestation and forest Degradation) strategy is largely focused on the cocoa forest landscape and has the potential to support these multiple co-benefits if well designed and implemented (Saeed et al., 2018).

Apart from the climate change mitigation potential of forests and agroforests in particular, it is important to understand the climate adaptation decisions of the farmers who are managing the agroforest landscapes. Most studies on farmers' adaptation decisions focus on annual crops, while comparatively little empirical research has been done on perennial crops such as cocoa trees (Gunathilaka et al., 2018). Given that perennial crops require long-term management strategies and create path-dependencies for farmers, adaptation decisions need to be taken with great care.

Cocoa trees start fruiting four years after planting and are most productive at an age of 8 to 25 years (Daniels et al., 2012). Recent studies show that cocoa suitability will decrease with climate change in vast areas of the West African cocoa belt (Laderach et al., 2013; Laderach et al., 2011; Schroth et al., 2016). This projection is associated with overall rainfall variability, extreme temperatures and long drought periods which are assumed to continuously increase by 2050. These climatic events can intensify the risk of crop failure given that very few producers have irrigation facilities (Amin et al., 2015; De Pinto et al., 2012). Since Ghanaian cocoa farmers generate about 70 to 100% of their income from cocoa (Afriyie, 2017; Ntiamoah and Afrane, 2008), any yield decline can significantly affect them. This in turn obviously is an obstacle to addressing Sustainable Development Goal (SDG) one, which is to end poverty in all its forms everywhere (United Nations, 2015). However, it is important to understand that the producer price for cocoa in Ghana is set by the Ghana Cocoa Board (COCOBOD) each year. Hence, farmers are not subject to world market price fluctuations (Asante et al., 2017).

From the literature on annual crop farmers in developing countries, it is well-known that they are among the hardest hit by climate-induced risks (Bwalya, 2010; USAID, 2012). Crop failures due to climate-related

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risks can worsen farmers' income status, health and livelihood (Meze-Hausken et al., 2009). Vulnerability is a result of low or poor adaptive capacity, often due to extensive poverty and overdependence on rain-fed agriculture (Addisu et al., 2016; Atinkut and Mebrat, 2016; Castells-Quintana et al., 2018). Farmers with low adaptive capacity are mostly unable to recover from yield and income losses after risk exposure (Noujeima et al., 2013). Thus understanding farmers' adaptation decisions and barriers to adaptation within their socio-economic context is key to improve future adaptation policies for climate change (Bryan et al., 2013). However, little research has been devoted to understanding variation of perceptions of climate change between households with different socio-economic backgrounds (Adu et al., 2018).

The paper seeks to contribute to understanding the perceptions of climate change especially among farmers of perennial crops. Two main research questions serve as structure for the paper. The first concerns how cocoa farmers perceive climate change, both in terms of changes of weather patterns and livelihood impacts. We investigate whether these perceptions differ between farmers with varying socio-economic backgrounds to understand if some sections of the local societies are more affected by changing weather patterns than others.

The second major research question is which adaptation options cocoa farmers choose and which underlying household characteristics, social capital indicators or institutional factors impact adaptation uptake or function as barriers to adaptation. A better understanding of these relationships is expected to contribute to the knowledge base on perennial farming systems, which in turn is key for the development of targeted policies that can contribute to achieving the sustainable development goals (SDGs) one and thirteen. Goal thirteen aims at combatting climate change and its impacts (United Nations, 2015).

The remainder of this paper is structured as follows: in section 2, we develop our hypotheses on adaptation decisions based on existing literature, section 3 describes the study area in Ghana, section 4 presents results and sections 5 and 6 discuss and conclude respectively.

2. Theoretical framework

Moser and Ekstrom (2010) developed a phases model to explain the process of taking adaptation decisions. Several definitions of adaptation exist that emphasize different aspects (Biagini et al., 2014). For the purpose of this paper, we understand adaptation in the sense of adjustments made by individuals in reaction to real or expected climate stimuli in view of moderating damages. The Moser and Ekstrom model suggests that adaptation can be subdivided into three major phases: (i) understanding the problem, (ii) planning options, and finally (iii) managing the options that were selected and implemented. In empirical research, the first phase is often referred to in terms of farmers' perceptions of climate change, i.e. whether individuals can discern a long-term change from the day to day variability of local weather (Hansen et al., 2012). The hypothesis is that farmers' perceptions of climate change impact their adaptation decisions (Atinkut and Mebrat, 2016). The more severe or more threatening the impacts of climate change are perceived to be, the more likely it is that farmers will move to the second phase and plan for adaptation options. Households that take a positive adaptation decision, in the third phase select an adaptation strategy that suits their needs and circumstances.

Building on the adaptation literature we investigate relationships between the three main stages and livelihood characteristics, in particular household characteristics. The left side of Fig. 1 presents an adapted version of the phases model in which we highlight that pathways diverge in the decision phase. While some may decide to adapt and proceed to the implementation phase, others who decide not to adapt continue to observe and evaluate their livelihood options under the changing environmental conditions. The right side of the Figure shows the livelihood characteristics we use in our analyses. We use the term livelihood in a general sense. The independent variables were chosen based on previous empirical literature as put forward in the sections below.

As depicted by the arrows between the two sides of the Figure, we divide the analysis into three parts. The first concerns the relationships between households' characteristics and perceptions of climate change. The second part of the analysis investigates, why some cocoa farming households choose to adapt while others don't. In the third part we investigate which adaptation strategies the households have implemented and whether there are associations between the strategies and household characteristics.

2.1. Household characteristics and perceptions of climate change

Empirical studies on farmers' perceptions of climate change often investigate whether farmers have observed changes in temperature or rainfall patterns (Alauddin and Sarker, 2014; Kabir et al., 2017). In some cases, they also report farmers' self-assessments of the degree to which they are affected by climate change (Alam, 2015; Jin et al., 2015). Previous research supports the hypothesis of a positive relationship between consciousness of climate change impacts and adoption of adaptation strategies in Ghana (Antwi-Agyei et al., 2018) as well as in many other developing countries (Alam, 2015; Alauddin and Sarker, 2014; Jin et al., 2015; Kabir et al., 2017). However, comparatively few studies have investigated whether perceptions of climate change differ between households with different socio-economic backgrounds (Adu et al., 2018). We contribute to this literature by investigating whether there are significant differences in households' perceptions of climate change effects and their socio-economic background, in particular their education level, gender of the household head, and indicators of wealth. The hypothesis is that more wealthy, male headed and better educated households have better preconditions to cope with climate change and thus perceive the effects of climate changes as less severe.

2.2. Adaptation decisions

In the second phase of the adaptation process, households decide whether to adapt or not. Factors which previously have been found to influence this decision can be grouped into the categories of household characteristics, social capital, and institutional factors (Alauddin and Sarker, 2014). For the specific agro-forestry context we add characteristics of the perennial crop to this list (see right side of Fig. 1).

2.2.1. Household characteristics

Among the household characteristics, age of the household head, per se, is expected to have a negative impact, given that younger farmers are likely to be more willing to test new methods and innovations (Ali and Erenstein, 2017). However some studies relate age to farming experience, which in turn is expected to increase the likelihood to adapt (Alemayehu and Bewket, 2017; Jin et al., 2015).

Education is expected to have a positive impact on adaptation because better educated farmers are likely to have a better understanding of climate change impacts and corresponding adaptation strategies (Alauddin and Sarker, 2014; Alemayehu and Bewket, 2017; Khanal et al., 2018).

Household size is also expected to be a positive determinant of adaptation, given that larger households are more likely to have surplus labour, which can be invested in off-farm income generating activities (Alauddin and Sarker, 2014; Ali and Erenstein, 2017). Jin et al. (2015) argue that vulnerability to climate change impacts is gender biased. However, there are mixed findings on whether adaptation strategies differ by gender. While some find no effect of gender, others find that men and women indeed choose different adaptation strategies, although some of these effects may be mediated by gender related differences in other socio-economic variables such as education (Ahmed et al., 2016; Ali and Erenstein, 2017).

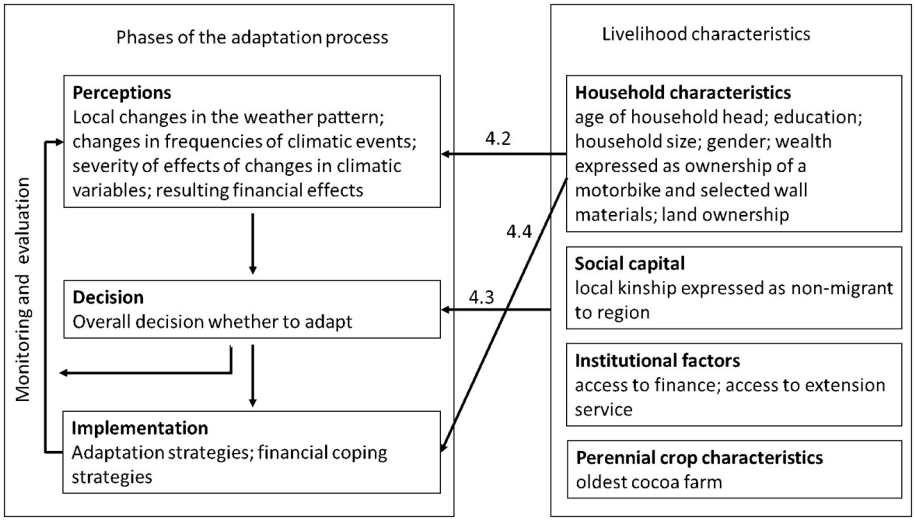

Fig. 1. Conceptual framework.

Many empirical findings point to positive impacts of wealth, measured through indicators such as livestock or land, on adaptation (Alam, 2015; Alauddin and Sarker, 2014; Gunathilaka et al., 2018; Khanal et al., 2018). One reason is that adaptation often requires costly investments which poorer households may not be able to finance. Another reason is that testing new adaptation strategies can involve taking significant risks. Wealthier households are likely to have better financial preconditions to take these risks (Ali and Erenstein, 2017). For the case study context in Ghana, we use ownership of a motorbike and material of the wall as indicators of relative wealth.

Land ownership, as opposed to land lease, is expected to motivate farmers to invest in long-term management and this is likely to be positively associated to adaptation (Alam, 2015; Alemayehu and Bewket, 2017; Ali and Erenstein, 2017).

2.2.2. Social capital

Social capital generally refers to social bonds, social cohesion and trust in individuals' networks. Such networks can function as a source of information on adaptation strategies, but also as a safety net in times of need. Community members who are native are expected to have a higher degree of kinship which is expected to be beneficial for social capital (Chaudhury et al., 2017).

2.2.3. Institutional factors

Access to credit is expected to facilitate implementation of adaptation strategies. However, there is mixed empirical evidence with some studies finding that credit supports adaptation (Bryan et al., 2013; Khanal et al., 2018), while others find no such effects (Ali and Erenstein, 2017).

Finally, access to extension services, as key channel for information on technologies and strategies, has often been found to be positively associated to adaptation (Alam, 2015; Alemayehu and Bewket, 2017; Bryan et al., 2013; Khanal et al., 2018).

2.2.4. Perennial crops

The findings on the factors discussed above are mostly derived from studies on annual cropping systems. Comparatively little research has been devoted to adaptation in perennial cropping systems, which often require high initial investments and create path dependencies (Gunathilaka et al., 2018). In Ghana, there is growing interest in cocoa farming despite declining yields and the challenges associated with the changing climate. Asante et al. (2017) argue that the interest in cocoa is due to the benefits of having a fixed producer price and because cocoa currently outperforms all other cropping options in terms of income. Similarly, Adégnandjou and Barjolle (2018) in their study on farmers' adaptation strategies to climate change and their implications in the Zou department of South Benin found that farmers in Benin are moving into arboriculture as an adaption strategy to minimize risk and raise income.

Our hypothesis is thus, that farmers with older, more mature cocoa farms are less likely to adapt, mostly due to the paucity of good alternatives. By contrast, farmers with younger cocoa farms are more likely to choose adaptation strategies in order to support their cocoa trees or to diversify their income before the trees reach maturity.

2.3. Adaptation strategies and household characteristics

The third step of the phases model addresses the implementation of adaptation strategies. Previous empirical studies have identified large variation in such strategies and point to social differentiation within communities in terms of capacities to adapt (Hirons et al., 2018). Given the growing body of literature on novel financial adaptation options, e.g. rainfall index insurance, we investigate whether informal financial coping options are present in the case study area and if so, which sections of the local society make use of these options. The rational is that if such informal mechanisms exist, then care needs to be taken to assess how the advent of novel formal insurance would interact in terms of synergies and tradeoffs with the more traditional informal insurance solutions.

3. Study area and data collection

This study was conducted in the Dormaa West district (Brong-Ahafo Region) and Bia East district (Western Region) of Ghana. The geographical locations of the study areas are presented in Fig. 2. These two districts were selected based on their relevance as main cocoa growing areas. On average, the districts have a population of 6 persons per household living in compound houses made of either brick or mud with roofing sheets. The main economic activity in the districts is agriculture (including small scale poultry, livestock farming, hunting, fishing etc.), which employs about 90% of the active population (Ghana Statistical Service, 2017a, 2017b). Cultivators in the two districts engage in the cultivation of cash crops (i.e. cocoa, oil palm, cashew, citrus) and food crops (i.e. plantain, cassava, cocoyam, maize and some vegetables). The food crops are normally intercropped with cocoa during the first four years before the cocoa trees start to bear fruit. Other economic activities include oil palm extraction and different forms of petty trading. Both areas have two seasons; the wet season occurring between April and

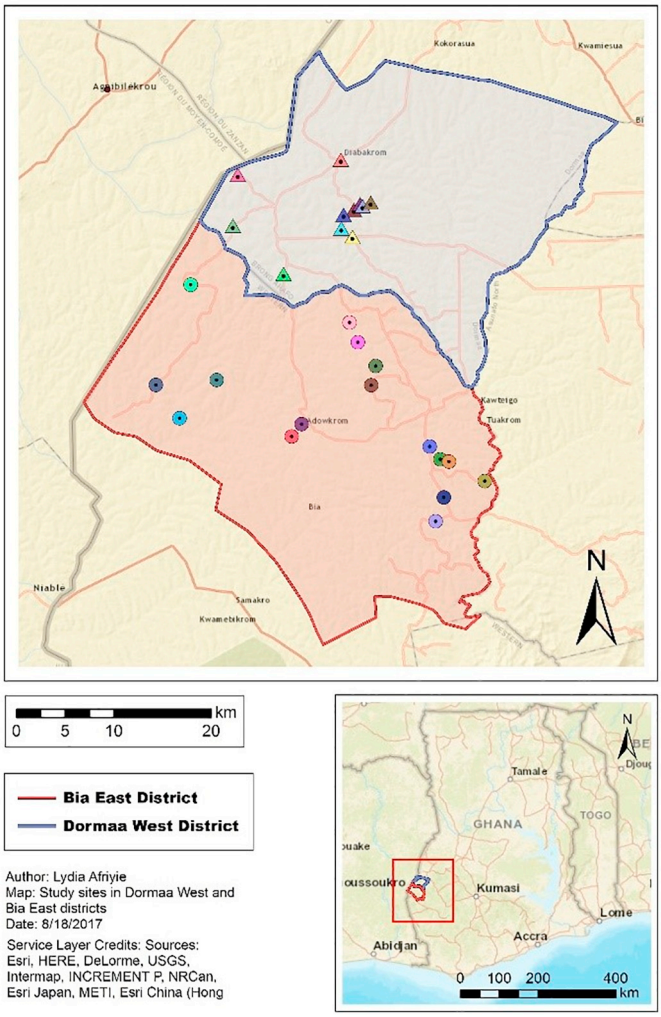

Fig. 2. Study sites in Dormaa West and Bia East districts of Ghana.

November and the dry season between December and March (Ghana Statistical Service, 2017a, 2017b).

Dormaa West district (DWD) is located within the wet semi-equatorial climate zone. It has a mean annual rainfall between 1250 mm and 1750 mm and temperature ranging from 26.1 °C to 30 °C (Ghana Statistical Service, 2014b). The district has an estimated total area of 381 km^2. DWD is prone to dry spells which have negatively affected cocoa production and yield in the area. Bia East district (BED) is within the moist semi-deciduous forest zone with a mean annual rainfall between 1250 mm and 2000 mm and temperature from 25.5 °C to 30 °C (Ghana Statistical Service, 2014a). It has an estimated total land area of about 783 km^2. BED has favorable climatic conditions, good soil and vegetation cover, making it a promising destination for migrant farmers (Ghana Statistical Service, 2017a).

3.1. Data collection

Data used for this study were collected from 20 selected communities in the two districts (see SM Table 1 and Table 2 for detailed information). These communities have been demarcated into zones for the purpose of the cocoa rehabilitation exercise of the Cocoa Health and Extension Division (CHED) in various cocoa districts of Ghana which aims to treat and rehabilitate diseased and overaged cocoa farms (Andoh, 2017). The sample of communities were drawn without replacement from the CHED's database of cocoa farmers in the two districts (the data is available upon request at the respective district office). Likewise, the list of individual farmers was also drawn from the biophysical data received from the CHED. A total of 313 cocoa farmers were randomly selected and interviewed in early 2017 using a structured set of questionnaires with an average response time of 45 min. Questions addressed comprised: (1) socio-economic characteristics of respondents; (2) respondents' perceptions and experiences of climatic change; (3) implemented and planned adaptation strategies (the survey is available in SM Table 3).

[Fig. 2 about here].

3.2. Data analysis

Descriptive statistics on the respondents' socio-economic background are presented in Table 1. We cross-tabulate data on household characteristics and respondents' answers on perceptions and experiences of risks in order to test for significant associations using the Fisher's test. The same procedure is later applied to test for associations between coping strategies and household characteristics.

In order to explain farmers' decision not to adapt, a logistic regression model was employed. The dependent variable takes the value 1 if the respondent has not taken any adaptation action and 0 otherwise. The logistic regression model,

$$ln\left(\frac{P_i}{1-P_i}\right) = \beta_0 + \beta_1 X_1 + ... + \beta_n X_n$$

expresses the relationship between the log of the odds ratio and the explanatory variables. The odds ratio here is the probability of the occurance of the non-adaptation decision, P_i, to the probability of the occurance of an adaptation decision, $(1 - P_i)$. The coefficients, B, express the change in log of the odds ratio. While the coefficients value is difficult to interpret directly, we are interested in the coefficients' signs. In our case, a positive coefficient indicates that the probability of a non-adaptation decision becomes more likely with an increase in explanatory variable's value.

4. Results

4.1. Socio-economic background

Table 1 provides descriptive statistics on the respondents' socio-economic background, their cocoa farming businesses and selected indicators of wealth. Wall-wealthy stands for walls made of either stone, burnt bricks, cement or sandcrete. Walls of the dwellings not in this category were made of either mud, mud bricks, wood or bamboo.

Only a few of the respondents in our sample were female cocoa farmers. While female-headed households are often associated with high poverty rates (Kim and Choi, 2013; Rajaram, 2009), this does not necessarily hold true for Ghana (Afriyie, 2017; Asamoah and Owusu-Ansah, 2017). A possible explanation is that while males by default are the household heads in Ghanaian tradition, a female can become household head when her husband is deceased or when she is divorced. Another explanation could be the matrilineal inheritance system allowing an unmarried-first-born female whose parents are deceased to inherit.

The average household size in the sample is significantly larger than the national average of 5 persons in 2010. Differentiating by region also reveals that households sampled in Brong Ahafo are significantly larger than the corresponding regional average (5) of rural households in 2010. The same holds true for households sampled in the Western Region, where the regional average size of rural households was 4.5 in 2010 (Ghana Statistical Service, 2013).

The share of income derived from the cocoa sector in our sample corresponds to similar values reported in other studies (Ntiamoah and Afrane, 2008). Recent studies have also reported an income share of 67% from cocoa which corresponds to our results (Ghana Statistical

Table 1
Descriptive statistics of the survey data.

Variable	Specification of dummy variables	Mean	Std. Dev.	Min.	Max.	Freq.	Percent	N
Socio-economic background								
Household-head						257	82.11	313
Age		50.80	11.22	24	90			313
Gender	Male					228	72.84	313
Female household head						43	13.74	313
Education	No_education					93	29.71	313
	Primary					141	45.05	313
	Secondary					72	23.0	313
	Tertiary					7	2.24	313
Household size		8.13	3.63	1	26			313
Migrant	Migrant					166	53.04	313
Microfinance	Accessed finance					124	39.62	313
Extension	Accessed extension service					278	88.82	313
No adaptation	No strategy applied					82	26.89	305
Cocoa business								
Number of farms		2.02	0.98	1	9			313
Total_farm_size (ha)		5.35	4.05	0.61	25.5			313
Cocoa income share		68.53	16.68	10	100			313
Ownership	Self-owned					264	84.35	313
Tree type	Shaded					31	9.90	
	Full sun					99	31.63	
	Light shade					183	58.47	
Oldest	Oldest cocoa farm	23.65	11.34	3	60			313
Indicators of wealth								
Wall-wealthy						92	29.39	313
Motorbike						96	30.67	313

Table 2
Respondents' perceived changes in the climatic variables during the past 20 years (n = 313).

Climatic variables	Percent of respondents (frequency)			
	Increased	No change	Decreased	Don't know
Rainfall variation	99.7 (312)	–	0.32 (1)	–
Drought	99.4 (311)	0.32 (1)	0.32 (1)	–
Extreme temperature	97.8 (306)	1.92 (6)	0.32 (1)	–
Pest infestation	78.0 (244)	16.3 (51)	5.75 (18)	–
Flooding	–	34.8 (109)	57.2 (179)	8 (25)

Service, 2015; Vigneri and Kolavalli, 2018).

Aneani et al. (2011) reported an average working experience of 19.6 years among Ghanaian cocoa farmers and an average farm size of 3.0 ha which both are significantly lower than the corresponding average values in our sample, but within a reasonable range. The farm ownership structure recorded in this study was similar to that reported by Asamoah and Owusu-Ansah (2017) where the majority of respondents own their cocoa farms. Compared to census data the percentage of households in the category wall-wealthy in our sample (29.39%) is significantly lower than in the larger Brong Ahafo Region (47.59%) (Ghana Statistical Service, 2012). This seems plausible because Brong Ahafo, apart from cocoa farming, also harbours industries and government workers. Moreover, some respondents reported to have built houses of one type in their home town yet live in a different type of house in their cocoa farming villages. This could account for the variation in the numbers.

We argue that overall our sample is representative for the regional cocoa growing sub-population and differences between our sample averages and census averages are likely to be due to the inclusion of non-cocoa farmers in the latter.

4.2. Farmers' perceptions and experiences of climate change

Respondents were asked whether they have heard about local changes in the weather pattern. The data reveal that 91% of the respondents had indeed heard about such changes. When asked to mention the three most important changes experienced in cocoa production, rainfall variation (60.1%), drought (51.8%) and pest infestation (47.9%) ranked as the top three. In addition, a set of climate events were read out to respondents and they were asked to indicate whether the frequency of these events had changed during the past 20 years. Results are reported in Table 2. Out of the 313 farmers, only one person reported a decrease in rainfall variation whilst the remaining 99.7% reported an increase. Likewise, nearly all respondents perceived an increase in droughts and extreme temperatures. There was more variation in the perceived changes of pest infestation frequencies, with 16% reporting no change and almost 6% reporting a decrease in frequency. In addition, 78.0% reported an increase in pest infestation. The perception of flooding events is quite different – no respondent indicated an increase of such events. The majority rather stated that flooding has decreased.

Table 3
Perceived severity of effects of changes in climatic variables (n = 313).

Climatic variables	Percent of respondents (frequency)				
	Very severe	Severe	Not severe	No effect	Don't know
Rainfall variation	79.9 (250)	18.5 (58)	1.3 (4)	0.3 (1)	–
Drought	80.8 (253)	17.6 (55)	1.3 (4)	0.3 (1)	–
Extreme temperature	62.9 (197)	35.1 (110)	1.0 (3)	0.6 (2)	0.3 (1)
Pest infestation	36.4 (114)	41.2 (129)	21.1 (66)	1.0 (3)	0.3 (1)

Table 4
Respondents' perception of likelihood of occurrence of future climatic events (n = 313).

Climatic variables	Percentage of respondents (frequency)				
	Very likely	Likely	Somewhat likely	Not likely	Don't know
Rainfall variation	77.6 (243)	6.4 (20)	1.9 (6)	0.3 (1)	13.7 (43)
Drought	75.4 (236)	9.3 (29)	1.3 (4)	0.6 (2)	13.4 (42)
Extreme temperature	53.4 (167)	31.0 (97)	1.9 (6)	0.3 (1)	13.4 (42)
Pest infestation	35.8 (112)	33.9 (106)	24.9 (78)	2.9 (9)	2.6 (8)
Flooding	0.0 (0)	1.6 (5)	5.8 (18)	90.1 (282)	2.6 (8)

They based their perception on the understanding that forest and trees facilitated rainfall and regulated temperatures in the past. They also believe that forest clearance and tree removal in the area have altered the rainfall pattern and exposed extreme sunshine and temperature on cocoa trees.

Farmers were further asked to indicate how severely they are affected by changes in rainfall variation, frequencies of drought, extreme temperature and pest infestations. Again, there was little variation in the first three categories with most respondents mentioning that they are severely or very severely affected (Table 3). Explanations for the category not severe included leaf desiccation, abnormal leaf deciduousness, abnormal colour of pods etc. Those that experienced severe effects stated changes like poor flowering of cocoa, delayed fruiting, low bean quality, low yield, holes in cocoa trees and pods, high need for investment in pesticides etc. Respondents who experienced very severe effects mentioned death of young and sometimes old cocoa trees, premature ripening of pods, pods rot etc.

Results of the cross-tabulations of household characteristics and respondents' answers on perceptions and experiences of risks are reported in the supplementary material (see SM Table 5). Households with walls made of material indicating relative wealth were significantly more likely to find effects of extreme temperature and pest infestations very severe than severe. For owners of a motorbike it was vice versa. In addition, female headed households were significantly more likely to find effects of rainfall variation, droughts and extreme temperature severe rather than very severe. The data also point to significant associations between respondents' education and their perception of the severity of effects, but the pattern is not clear.

Moreover, for nearly all respondents (97%), the climatic changes resulted in financial effects. Although the responses seem surprisingly uniform, differentiating by respondents' socio-economic background reveals a significant association (5% level) between education and financial effects (see SM Table 6). It indicates that the respondents with middle or tertiary education were more likely not to have experienced financial effects. However, the indicators of relative wealth (wall material, ownership of a radio or motorbike and female household head) did not reveal similar findings.

Respondents were further asked how likely they think it is that such climatic events will occur in the future. Results are presented in Table 4. Three-fourths of respondents assume that it is very likely for rainfall variation and drought to occur in the future. Future extreme temperature and pest infestations are assessed to be likely or very likely by the majority of respondents. By contrast, flooding is assessed to be unlikely by nearly all respondents.

4.3. Implemented and planned adaptation measures

In an open question, respondents were asked to indicate which strategies they use to deal with the effects of the climatic change. The responses were categorised into nine different groups. They are presented in Table 5 in descending order of frequency. In total, 305 respondents provided information on their coping strategies. Several answers were possible. About a fourth of the respondents indicated that they have not implemented any adaptation strategy yet. Equally, many indicated that they are adapting to climate change through changes in farm management within the cocoa farm.

The data reveal that households with walls made of stone, brick or cement/sandcrete are more likely to choose crop diversification, rely on food crops and petty trading as coping strategy (see SM Table 7). At the same time, they are less likely to choose general farm management as a coping strategy. Owners of a motorbike were found to be more likely to choose basic farm management and loans as coping strategies but less likely to choose crop diversification. Loans were also more likely to be chosen by respondents with tertiary education than by respondents with less education. Female headed households were more likely to choose petty trading and a decrease in living expenses as coping strategies.

To investigate whether there are informal financial coping strategies, respondents were asked whom they consult in case they experience financial effects of climate change. As can be seen from Table 6, the majority of respondents do not have an informal or traditional insurance that they can call on in times of financial hardship. Only 26% reported that for pest infestation, they received support in a form of pesticides from the government, which in a follow-up question they deemed as very helpful.

Table 5
Adaptation strategies farmers have used in the past.

Adaptation strategy	Percentage of respondents (frequency)	Interpretation of measures
None	27 (82)	
Basic farm management/farm diversification	27 (82)	Irrigating young cocoa farms, increasing fertilizer /pesticide application, mulching to reduce direct impact of heat on cocoa, slashing old cocoa and replanting with hybrid, chemical spraying
Rely on food crops	18 (55)	
Crop diversification	11 (33)	Mixed cropping with cashew, cashew plantation, oil palm cultivation
Petty trading	9 (28)	On- and off-farm income generating activities e.g. sale of farm animals, oil palm extraction, cocoa purchasing, selling alcohol, selling food
Loan (diverse sources)	7 (21)	Cocoa purchasing clerks, neighbours (100% interest) and micro-finance companies
Extension advice	4 (12)	
Cut down expenses	2 (7)	Saving on food and other basic expenses
Casual labour	1 (2)	Palm wine tapping, work as mason or farm labourer
Rely on other cash crops	1 (2)	Already existing oil palm plantation

Table 6
Financial coping strategies of respondents ($N = 313$).

Institutions to call on	Percent of respondents (Frequency)			
	Rainfall variation	Droughts	Extreme temperature	Pest infestation
No one	92 (288)	92 (288)	93 (291)	68 (213)
Family	6 (18)	6 (18)	6 (18)	4 (14)
Church	1 (2)	1 (2)	1 (1)	1 (1)
Farmer association	1 (3)	1 (3)	1 (2)	1 (4)
Governmental support	1 (2)	1 (2)	1 (1)	26 (81)
Tribal group	(0)	(0)	(0)	(0)
Traditional council	(0)	(0)	(0)	(0)

4.4. Factors influencing farmers' adaptation decision

About three-fourths of the respondents have implemented some adaptation strategy while one fourth of the respondents have not implemented any such strategy. Table 7 presents logistic regression results, for the choice not to implement an adaptation strategy. The explanatory factors in this model are derived from the literature discussed in section 2. Descriptive statistics on these variables are presented in Table 1. As can be seen from Table 8, the coefficient for ownership of a motorbike is negative and significant. The negative sign is in line with our hypothesis that wealthier households are more likely to adapt (or in terms of the model less likely to choose not to adapt). The coefficient for age of the oldest cocoa plantation is positive and significant. This is also in line with our hypothesis that farmers with more mature cocoa farms are less likely to adapt, due to a lack of alternatives. The coefficients of the other explanatory variables are non-significant. The pseudo R-squared is very low, indicating that this theory-driven model has poor explanatory power.

Table 7
Logit results for choice not to adapt.

VARIABLES	(1)
	No adaptation
Age	0.020
	(0.014)
No_education	0.396
	(0.295)
Household size	−0.054
	(0.043)
Gender	0.328
	(0.334)
Motorbike	−0.678*
	(0.360)
Total_farm_size	−0.027
	(0.038)
Ownership	−0.639
	(0.406)
Migrant	−0.365
	(0.302)
Microfinance	−0.339
	(0.298)
Extension	−0.311
	(0.442)
Oldest	0.023*
	(0.013)
Constant	−1.081
	(0.865)
Observations	305
Pseudo R-squared	0.0627
Log likelihood	−166.41585
LR chi2(11)	22.26
Prob > chi2	0.0224

Standard errors in parentheses.
*** $p < .01$, ** $p < .05$, * $p < .1$.

5. Discussion

5.1. Perceptions of climate change

The analysis of respondents' perceptions of past climate change revealed that nearly all have noted an increase of rainfall variation, drought and extreme temperatures during the past 20 years. Most respondents have been severely or very severely affected by these changes and estimate that these changes are likely or very likely to carry on in the future. At this point it is important to mention that asking several questions about perceptions of climate change could cause bias, because the questions may lead respondents to recall certain events and thereby influence the response. The findings confirm results based on qualitative research from Ghana's main cocoa growing area by Asante et al. (2017) and are in line with very similar results of a study conducted in Brong Ahafo and Upper West regions of Ghana (Abdoulaye et al., 2017). Studies conducted in Northern Ghana by Ndamani and Watanabe (2016) and Kusakari et al. (2014) also present similar results as does a study conducted in Benin (Adégnandjou and Barjolle, 2018).

The differentiation of perceptions of climate effects in general and financial effects of climate change in particular revealed that better-off households measured by motorbike ownership perceived effects of extreme temperature and pest infestations as severe rather than very severe. A possible explanation could be that relatively wealthier households, in particular measured by motorbike ownership, on average have significantly larger cocoa farms. However, their average share of income from the cocoa sector is not different from that of others. Respondents with secondary or tertiary education were less likely to have experienced financial effects of climate change. This may be due to the fact that cocoa's contribution to total income is significantly lower among households with tertiary education. However, the data do not reveal strong and consistent patterns of association between respondents' socio-economic background and their perceptions and exposure to climatic changes.

5.2. Adaptation strategies

Given the perceived intensity of climatic changes and their severity, it is surprising that a fourth of the respondents have not implemented any adaptation strategy yet. The most frequent adaptation measures chosen by those who take action are related to improvements in the cocoa farm. There is no indication of a major shift from cocoa cultivation to other farming activities. These results on farmers of perennial cocoa trees are very different from the findings of Ndamani and Watanabe (2016) from a study site in Ghana, north of the cocoa growing area, where more than 50% of the respondents used crop diversification strategies in response to climate variabilities. However, the overall set of adaptation strategies to lessen the effects of climate change is similar in both studies. Abdoulaye et al. (2017) conducted a study on adaptation strategies in the Brong Ahafo and Upper West Regions of Ghana. In their sample only 0.4% of respondents have not implemented any adaptation strategy. A possible explanation is that cocoa farming, being a perennial crop with the fixed producer price is preferred by many despite declining yields, because it outperforms all other cropping options in terms of income (Asante et al., 2017). If cocoa production is in fact a major stronghold to farmers in the study area, this could explain why households who do invest in adaptation strategies mostly choose on-farm options rather than diversifying with annual crops or investing in off-farm options. Concerning the choice not to adapt at all, one reason could be that for some Ghanaians (superstitious believers) preparing oneself for future misfortune is like calling for the calamities on oneself (Acka and Owusu, 2012).

The logistic regression model has a moderate overall fit. The data do

not, in large, confirm the hypotheses on factors found in the literature on adaptation decisions. However, the positive coefficient on the age of the oldest cocoa farm in the logistic regression reveals that farmers with older cocoa plantations are more likely not to implement an adaptation strategy. Once a cocoa plantation is matured, it provides regular income and is seen as a sustainable investment that can be passed on to the next generation (Asante et al., 2017) due to its perennial nature. Moreover, few low-cost adaptation options are available for matured cocoa plantations.

This suggests that cocoa farmers may be pursuing a maximin strategy in times of climate change, i.e. they choose the option with least expected losses given the rather pessimistic expectations about future climate developments. In this case, abstaining from adaptation investments may indeed be rational.

However, our findings on the perennial cocoa trees may be specific to the Ghanaian context with fixed producer prices. Tea, for example, is also a perennial crop that is traded on the global market. Gunathilaka et al. (2018) investigate 50 Sri Lankan tea estate managers' climate adaptation strategies and find that all have taken some form of adaptation action in the areas of crop diversification, soil conservation and shade tree management. Research on rice farmers in Nepal found that roughly a fourth of the farmers had not taken adaptation measures. The main factors impacting adaptation were education and rice yields of both adapters and non-adapters (Khanal et al., 2018).

The investigation of differences in adaptation strategies based on respondents' socio-economic background mainly revealed associations between financial adaptation strategies and indicators of wealth and higher education. This is in line with results from a study conducted in Ethiopia which also found associations between adaptation and respondents' socio-economic background i.e. education, wealth status, off-farm employments and extension service (Addisu et al., 2016). An unexpected finding was that only very few households rely on informal transfer networks in times of hardship. This could be due to the declining nature of the extended family system in Ghana which used to help kinsmen share their risks and support each other (Soundaffects, 2010). Another reason could be that the informal risks sharing among kinsmen becomes less effective when there is a cumulative risk (Meze-Hausken et al., 2009; Mobarak and Rosenzweig, 2012), and for that matter farmers have to deal with their financial burden on their own (Acka and Owusu, 2012). Related to health insurance in Ghana, Strupat and Klohn (2018) argue that such informal networks have recently been crowded-out by the introduction of formal insurance. Whether there was a diffusion effect from the health sector that may have led to an erosion of other informal insurance networks unfortunately cannot be tested with our dataset.

6. Conclusion and policy recommendations

Agroforestry systems can play important roles in climate change mitigation. However, climate change adaptation decisions of the farmers managing these systems need to be understood in order to design supportive policies. This paper seeks to contribute to filling the knowledge gap on adaptation in perennial agroforestry systems by investigating Ghanaian cocoa farmers' perceptions and experiences of climate change and analysing their adaptation strategies. The results show that farmers are very aware of climate change and its effects. Most of them have personally experienced severe effects of climate change and expect that rainfall variability, droughts and extreme temperature will occur in the future. While these findings are largely in line with studies from other regions of Ghana, cocoa farmers' adaptation choices prove to be starkly different because many cocoa farmers choose not to implement an adaptation strategy. A logistic regression model was applied to explain farmers' non-adaptation choices based on explanatory factors derived from the literature on household characteristics, social capital, and institutional factors. Moreover, we added age of the oldest cocoa plantation as an explanatory factor to capture a specificity of the perennial cropping system.

We argue that the comparatively sparse involvement in adaptation observed in our sample of cocoa farmers is due to the economic superiority of cocoa vis-à-vis other agricultural (annual) crops. The annually fixed producer price provides income security and the perennial nature of cocoa trees is seen as an advantage by farmers. This market situation creates a form of management “stickiness”, in which farmers, due to the paucity of viable alternatives, remain in cocoa production despite increasing climate-change related problems in cocoa cultivation.

Our main conclusion is that cocoa farmers' climate adaptation decisions are different from the patterns of adaptation that are typically found in studies on farmers cultivating annual rainfed crops. We suggest that the observed differences are likely attributable to the security provided by the fixed producer price and the perennial nature of cocoa. This should be considered in future national studies on adaptation.

The finding that cocoa farmers in our sample are only moderately involved in adaptation activities does not mean that there is no need for adaptation. Given that the West African sub-region is among the most vulnerable areas to the changing climate, adaptation is imperative (Intergovermental Panel on Climate Change, 2007; Ndamani and Watanabe, 2016). Schroth et al. (2016) argue that adaptation is needed at several levels reaching from cocoa variety selection, over shade tree selection to regional policies. Ideally such adaptation measures should be effective and should come at low-cost. The management “stickiness” merely provides more time to test and disseminate novel adaptation strategies, before the effects of climate change lead to a race-to-the-bottom in the cocoa sector. Allowing farmers to take time to gain confidence in new technologies may be favorable, given that fear over devastating losses in case of technology failure is known to be a reason for non-adaptation (Castells-Quintana et al., 2018).

Cocoa insurance, in particular rainfall insurance, could be an option to enable farmers to gain some payouts in extreme events. Moreover, credit facilities could be made available to farmers at the beginning of the cocoa season to enable farmers to purchase farm inputs that will enhance their yield. In addition, the use of shade trees in cocoa could be made attractive through REDD+ (Reducing Emissions from Deforestation and Forest Degradation as well as enhancement of carbon stocks) initiatives and benefit sharing agreements. Aside that, current reforms on tree tenure that seek to transfer full ownership rights to farmers and landowners should be brought to full force (Antwi et al., 2018; Ministry of Lands and Natural Resources, 2016). Tree integration could reduce heat stress and improve the microclimatic condition of the cocoa farm, thereby increasing their lifespan and productivity. Economically, fruit trees could also provide food for the household and reduce the impact of cocoa yield failure on livelihoods (Hoogendijk, 2012).

If cocoa cultivation remains comparatively attractive, there may be an incentive for in-migration into this area in the next decades. Diao et al. (2019) suggest that the development of an agri-food sector in rural areas may be a way forward in Ghana which has not undergone an industrial revolution that could absorb large labor fluxes. An agri-food processing sector could help diversify farmers income, create a bridge between the rural and urban economies, and make adaptation of the Ghanaian economy more transformational rather than simply relying on an existing sector (Castells-Quintana et al., 2018). Absorbing labor in less-climate sensitive food processing opportunities could also prevent further forest conversion for cocoa production which has been a problem in the past (Wessel and Quist-Wessel, 2015).

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Declaration of Competing Interest

None.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.forpol.2020.102115.

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