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Research article

Assessing the adaptive capacity of smallholder cocoa farmers to climate variability in the Adansi South District of the Ashanti Region, Ghana

Frank Baffour-Ata *, Philip Antwi-Agyei, Louisa Boakye, Lester Simon Nii Aryee Tettey, Muriel Nana Efua Fosuaa Forson, Albright Ewenam Abiwu, Emmanuel Gyenin, Rebecca Naa Merley Larbi

Department of Environmental Science, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana

A R T I C L E I N F O

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A B S T R A C T

This study assessed the adaptive capacity of smallholder cocoa farmers to address the adverse effects of climate variability in the Adansi South District of the Ashanti Region, Ghana. Specifically, the study sought to (i) assess the perception of the smallholder cocoa farmers to climate variability; (ii) determine the perceived effects of climate variability on cocoa production in the district; and; (iii) evaluate the adaptive capacity of the smallholder cocoa farmers to manage climate risks. The study used questionnaire surveys with 150 smallholder cocoa farmers, key informant interviews, and focus group discussions in three selected communities (Afiaso, Tonkoase, and Amudurase). A variety of capital assets (social, financial, human, physical, and natural) were utilized to conceptualize smallholder cocoa farmers' adaptive capacity. Results showed that the smallholder cocoa farmers reported changes in the onset and duration of rains, rising temperatures, and increasing windstorms in the selected communities. The farmers perceived increased incidence of drought and cocoa failure, the prevalence of diseases and pest invasion, and decreased farmer income as the key adverse effects on their cocoa production. Further, findings also revealed that cumulatively, all the selected communities in Adansi South District had a moderate adaptive capacity (0.531). It is recommended that appropriate policies aimed at enhancing the adaptive capacity of smallholder cocoa farmers must be formulated by policymakers to minimize their vulnerabilities to climate risks.

1. Introduction

Sub-Saharan Africa (SSA) continues to be adversely affected by climate variability and extremes [1]. Climate variability is anticipated to make rainfall patterns inconsistent and unpredictable; elevate annual mean temperature by 1.5 °C – 5.2 °C and expand sea level by 34.5 cm by 2090 [2]. This is expected to have adverse implications for food production, especially for developing countries including Ghana [3] where the agricultural sector accounts for about 54% of the country's Gross Domestic Product [2].

Cocoa (*Theobroma cacao*) production which drives the economy of Ghana is progressively imperiled by climate variability [4,5]. As adverse weather events become more persistent, they make some regions and communities less appropriate for the cultivation of

* Corresponding author.
E-mail address: ata.frank@yahoo.com (F. Baffour-Ata).

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cocoa. Lengthened dry spells, reduced precipitation, rising temperatures, and the occurrence of recent diseases and pests can reduce both the quality and yields of cocoa produced [5]. These will lead to a decreased income and uncertainty in the cocoa industry, thereby adversely impacting smallholder farmers whose livelihoods are directly linked to cocoa production. Thus, to build more resilient farming systems and livelihoods, there is a need to assess the adaptive capacity of smallholder cocoa farmers to address the adverse effects of climate variability.

Adaptive capacity refers to the capacity of individuals to adapt to changes in climate or to cope with extremes [6]. For example, enhancing wealth and education, distribution of income, and better health care can be thought of as investments in adaptive capacity [7]. Access to climate information has also been determined to be instrumental in driving the adaptive capacity of communities in addressing climate risks [8,9,10]. These make a community cope better with the variability in climate and other risks thereby reducing its vulnerability [11]. The United Nations Framework Convention on Climate Change (UNFCCC) has established different funds to aid the adaptations to climate change, especially in the Global South [11] and there is enormous evidence to show that smallholder cocoa farmers have been adapting to climate variability in Africa [12,13]. For example, Oluwatusin et al. [12] revealed that cocoa farmers in the Ondo State of Nigeria utilized major adaptation strategies including changing planting dates, sheltering and shading techniques, land and water management practices such as irrigation to reduce the negative ramifications of climate change on their cocoa production. Similarly, Jamal et al. [5] reported that smallholder cocoa farmers in the Central Region of Ghana implemented adaptation measures such as migration, relying on support from family and friends, fragmentation of land, and utilization of drought-resistant hybrids in managing climate risks.

However, there are still unanswered questions as to how climate change adaptation funds can efficiently minimize the vulnerability of communities to climate risks. Research on adaptive capacity has emerged in developing countries with limited research in Ghana [14,15]. Yaro et al. [14] revealed that the adaptive capacity of the Savannah Region in northern Ghana is mainly low as a result of increased poverty levels and the crucial determinants of adaptive capacity in the region were assets, age, gender, education, and perception of climate change. Abdul-Razak & Kruse [15] also found that farmers' awareness of climate change, financial resources, technological abilities, and training are important to enhancing smallholder farmers' adaptive capacity in the Northern Region of Ghana.

These studies provide important evidence on smallholder farmers' adaptive capacity to climate change and variability in Ghana. However, sustained research is required to assess smallholder cocoa farmers' adaptive capacity to climate variability in southern

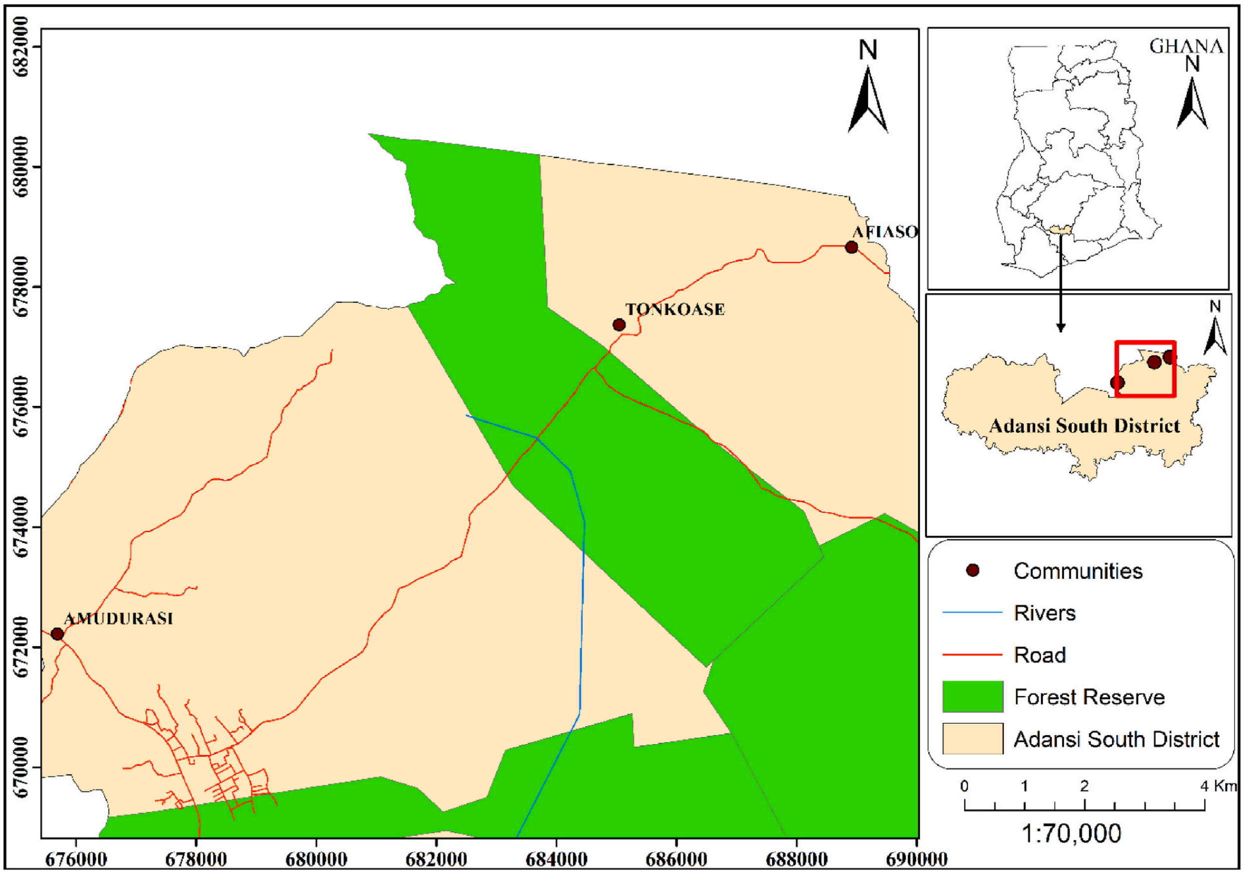

Fig. 1. Adansi South District showing study communities.

Ghana. This is particularly important, considering that, the few adaptive capacity studies in the country have been conducted in northern Ghana. The study is framed around the following specific objectives: (i) to assess the perception of smallholder cocoa farmers to climate variability in Adansi South District; (ii) to determine the perceived effects of climate variability on cocoa production in the study district; and; (iii) to evaluate the adaptive capacity of smallholder cocoa farmers to manage climate risks. An assessment of the adaptive capacity of smallholder cocoa farmers will help policymakers to design relevant policies to minimize the vulnerabilities of smallholder cocoa farmers to climate risks and enhance sustainable development in the country.

2. Materials and methods

2.1. Characteristics of the study area

Adansi South District is found in the South-Eastern section of the Ashanti Region of Ghana and lies within latitude 40″ North and 6° 22″ North and longitude 1° West and 1° 38" West (Fig. 1). With a total land area of 1328.2 km^2, the district is roughly 4% of the total land area of the Ashanti Region [16]. About 334.5 km^2, of this, consists of forest reserves [16]. The district has a mean altitude of about 350 m [16]. The land in the district stretches from flat to a gradually undulating landscape. The district has various streams and rivers with key rivers including Subin, Pra, Fosu, and Muma being the predominant channels.

The district has a good climate with average temperatures spanning between 26 °C and 29 °C [16]. The hottest months within the year in the district are February and March. Adansi South District has a good rainfall distribution trend characterized by 2 rainy seasons with the highest periods recorded from May to June (major rainy season) and October (minor rainy season). The mean annual rainfall is between 1600 mm and 1800 mm [16]. Approximately, 58% of the households in the district are into agricultural activities and most of those households (i.e. 87%) are located in rural areas. The majority of the farming households are involved in crop farming particularly cocoa production with chicken being the predominant animal reared in the district.

Within the Adansi South District, three communities were purposively sampled. These communities were Afiaso, Tonkoase, and Amudurase (Fig. 1). These communities are actively engaged in cocoa farming in the district as proposed by an agricultural extension officer in the district.

2.2. Research design and data collection

The research design employed for this study was cross-sectional. Cross-sectional research design has been utilized in climate variability studies in Ghana including Baffour-Ata et al. [17] and Jamal et al. [5], and hence, its adoption for this study.

2.2.1. Questionnaire surveys

Primary data were collected via questionnaire surveys, key informant interviews, and focus group discussions [18,19,20]. With the help of the lottery approach, one hundred and fifty random household interviews were conducted with smallholder cocoa farmers in their homes or any appropriate place found in the community. The questionnaire contained questions focusing on their demographic characteristics, perspectives on climate variability, and the effects of climate variability on cocoa production and livelihoods. Questions were also asked on their livelihood assets which included human, financial, social, physical, and natural capital assets. The questionnaire surveys were conducted in June 2022 in the local language (Asante Twi) and interviews lasted for about an hour. Ethical issues were considered by seeking their verbal agreement before proceeding with the questions. The respondents' names were also not requested just to ensure the confidentiality of the response.

2.2.2. Focus group discussions (FGDs)

FGDs (one in each community) were conducted to validate the information collected from the household surveys. Questions focusing on the perception of the changing climate and its effects on cocoa production were posed to the focus group participants which were made up of 5 men and 5 women. The reason was to come out with gendered perspectives. The focus group participants consisted mainly of smallholder cocoa farmers who had not taken part in the household surveys. The discussions were audiotaped after soliciting permission from the participants. It was deciphered and interpreted into English later.

2.2.3. Key informant interviews

Comprehensive interviews with individuals (key informants) who had appreciable environmental and climate knowledge of the selected communities were additionally conducted to further validate findings from the questionnaire and FGDs. These individuals were mainly the traditional leaders of the selected communities, Assembly members, youth leaders, and leaders of the cocoa farmers' associations in the community. Six participants were recruited for the key informant interviews. The interviews took place for about 15 min and were also audiotaped and later transcribed with the consent of the interviewees.

2.3. Data analysis

2.3.1. Analysis of quantitative and qualitative data

Quantitative data obtained through questionnaire surveys were evaluated using percentages and frequencies. The computation was done with the help of the IBM Statistical Package for Social Sciences (SPSS) version 25. Data from key informant interviews and FGDs were also assessed using thematic analysis [21].

2.3.2. Analysis of adaptive capacity

The study sought to determine the adaptive capacities of the selected communities in the study district using their capital assets (social, physical, natural, human, and financial). All indicators under the various capital assets were standardized following the United Nations Development Programme's [22] protocol for standardizing indicators for the life expectancy index. This was done to ensure the comparability of the indicators utilized in the formulation of the household adaptive capacity (Equation (1)). This ensured that every indicator was adjusted so that its relative position was between 0 and 1 [23].

$$Indexed\ value(X_i) = \frac{Actual\ value - minimum\ value}{Maximum\ value - minimum\ value} \tag{1}$$

After the indicators had been standardized, it was important to assign appropriate weights to them. An equal weighting method was employed based on the number of capital assets to ensure the homogeneity of the results. The adaptive capacities for the individual capital assets were then determined using (Equation (2)).

$$Adaptive\ capacity = \sum (X_i \times W) \tag{2}$$

Where X_i = indexed value for the indicators of each capital asset.

W = weights based on the number of capital assets $= \frac{1}{5} = 0.2$

The overall adaptive capacities for the individual communities were calculated by finding the averages of the adaptive capacity values for the capital assets.

3. Results and discussion

3.1. Socio-demographic characteristics of respondents

Results indicated that most of the respondents interviewed were men ($n = 82$; 55%) relative to women ($n = 68$; 45%) (Table 1). Several reasons have been attributed to this gender difference including the labor-intensive nature of the work which tends to favor men as well as most farmlands including cocoa farms are owned predominantly by men in SSA [12,24]. In previous cocoa farming studies [5,12,24], the proportion of female respondents has always been small compared with male respondents and this study compares favorably with those studies. Considering age, about 60% of the respondents ($n = 90$) occupied the age group of 41–60 years. This shows that the majority of the respondents were very experienced. Thus, it is not surprising that 93 of the respondents constituting 62% had above 20 years of farming experience.

With education, about 60% ($n = 90$) of the respondents had a basic form of education whilst only 4% had attained a tertiary level of education. This means that most of the farmers had some form of education and this was good considering education is one of the socioeconomic indicators that tend to affect the adaptive capacity of farmers substantially [25]. This is because educated farmers tend to accept new climate change technologies and interventions easily relative to those with non-formal education who normally tend to depend solely on experience [24].

About 79% of the respondents ($n = 118$) accessed agricultural extension services and this was a good socio-demographic characteristic. This is because agricultural extension officers aid farmers in taking farm management decisions and ensure that relevant knowledge is applied to acquire very good results in terms of sustainable farm production and general rural development [26]. This tends to reduce farmers' susceptibilities to climate risks.

Eighty-one of the respondents (54%) accessed climate information whilst 46% did not. Prior studies [10,27] have shown that timely access and utilization of climate information can help smallholder farmers become resilient to climate variability and change.

3.2. Perception of respondents to climate variability

About 147 of the respondents (98%) reported changes in temperature and rainfall patterns in recent years (Table 2). Regarding rainfall, about 61% of the respondents ($n = 91$) disclosed a decrease in rainfall patterns. Most of them ($n = 145$; 97%) also revealed that the duration of rainfall had changed. About 98% of the respondents reported that the onset of the rains had changed with the rains coming late ($n = 138$; 92%) recently as compared to previous years.

In terms of temperature, most of the study respondents (97%) revealed that temperature has been rising. Correspondingly, most of them ($n = 114$; 76%) reported a rise in windstorms but a decrease in floods ($n = 104$; 69.3%). These results were also validated in the FGDs and key informant interviews. For example:

> "*We have been experiencing decreasing rainfall patterns in this community. The timing of the rains is also very difficult to predict now. Last year, for instance, we experienced major rains in September when we normally experience those rains in June*" – (Key informant, Tonkoase, June 2022)

> "*We hardly experience flooding in this district. It was two years ago that the rains were so intense and we had floods in this community. It is rather the temperature that is so high these days*" – (Focus group participant, Afiaso, June 2022).

These results compare favorably with prior research [5,12,28,29] suggesting that smallholder cocoa farmers have perceived

Table 1
Socio-demographic characteristics of respondents.

Variable	Community			Total (n = 150)
	Afiaso (n = 46)	Tonkoase (n = 46)	Amudurase (n = 58)	
Gender				
Males	21 (45.7)	28 (60.9)	33 (56.9)	82 (54.7)
Females	25 (54.3)	18 (39.1)	25 (43.1)	68 (45.3)
Age (years)				
Below 20	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
21–40	6 (13.0)	6 (13.0)	9 (15.5)	21 (14.0)
41–60	27 (58.7)	30 (65.2)	33 (56.9)	90 (60.0)
Above 60	13 (28.3)	10 (21.7)	16 (27.6)	39 (26.0)
Years in Community				
5 and below	3 (6.5)	1 (2.2)	3 (5.2)	7 (4.7)
6–10	0 (0.0)	1 (2.2)	2 (3.4)	3 (2.0)
Above 10	43 (93.5)	44 (95.7)	53 (91.4)	140 (93.3)
Origin				
Native	19 (41.3)	20 (43.5)	32 (55.2)	71 (47.3)
Settler	27 (58.7)	26 (56.5)	26 (44.8)	79 (52.7)
Household size				
1–5	18 (39.1)	23 (50.0)	25 (43.1)	66 (44.0)
6–10	21 (45.7)	12 (26.1)	29 (50.0)	62 (41.3)
11–15	7 (15.2)	11 (23.9)	4 (6.9)	22 (14.7)
Educational level				
Non-formal education	9 (19.6)	5 (10.9)	13 (22.4)	27 (18.0)
Basic	23 (50.0)	31 (67.4)	36 (62.1)	90 (60.0)
Secondary	12 (26.1)	7 (15.2)	8 (13.8)	27 (18.0)
Tertiary	2 (4.3)	3 (6.5)	1 (1.7)	6 (4.0)
Marital status				
Single	5 (10.9)	8 (17.4)	10 (17.2)	23 (15.3)
Married	36 (78.3)	36 (78.3)	46 (79.3)	118 (78.7)
Divorced/Separated	5 (10.9)	2 (4.3)	2 (3.4)	9 (6.0)
Type of farmland tenure system				
Rented	5 (10.9)	9 (19.6)	6 (10.3)	20 (13.3)
Owned	40 (87.0)	36 (78.3)	52 (89.7)	128 (85.3)
Purchased	1 (2.2)	1 (2.2)	0 (0.0)	2 (1.3)
Farming experience (years)				
Less than 5	2 (4.3)	6 (13.0)	1 (1.7)	9 (6.0)
6–10	5 (10.9)	7 (15.2)	11 (19.0)	23 (15.3)
11–20	6 (13.0)	7 (15.2)	12 (20.7)	25 (16.7)
Above 20	33 (71.7)	26 (56.5)	34 (58.6)	93 (62.0)
Access to agricultural extension Services				
Yes	41 (89.1)	36 (78.3)	41 (70.7)	118 (78.7)
No	5 (10.9)	10 (21.7)	17 (29.3)	32 (21.3)
Access to climate information				
Yes	17 (37.0)	21 (45.7)	43 (74.1)	81 (54.0)
No	29 (63.0)	25 (54.3)	15 (25.9)	69 (46.0)
Membership in an organization				
Yes	33 (71.7)	41 (89.1)	42 (72.4)	116 (77.3)
No	13 (28.3)	5 (10.9)	16 (27.6)	34 (22.7)

Numbers in parentheses depict percentages and numbers without parentheses show frequencies.

climate variability through an increase in windstorms, rising temperatures, and decreasing rainfall patterns. Specifically, cocoa farmers in the Ondo State of Nigeria perceived the variability in climate through changes in the timing of rains and increases in temperature [12]. Similarly, cocoa farmers in Alto Beni of Bolivia observed changes in climatic conditions through rising temperatures and extended dry periods [28]. Smallholder cocoa farmers' perceptions of the variability in climate tend to trigger the implementation of adaptation practices and there is a plethora of research [5,13,30] to show that cocoa farmers have been responding to these changes by adopting practices such as changing planting dates, water and land management practices, and the use of drought-resistant varieties.

3.3. Perceived effects of climate variability on cocoa production in the study district

Results indicated that the increased frequency of drought and cocoa failure was the highest perceived effect ($n = 137$; 91%) by the smallholder cocoa farmers (Table 3). This was closely followed by the prevalence of diseases and pest invasion ($n = 135$; 90%). Increased frequency of floods and destruction of cocoa farms was the least perceived ($n = 41$; 27%) by the farmers. These results compare favorably with earlier research such as Agbongiarhuoyi et al. [31] and Raufu et al. [32] suggesting that smallholder cocoa

Table 2
Perception of the respondents to climate variability.

Variable	Community			Total (*n* = 150)
	Afiaso (*n* = 46)	Tonkoase (*n* = 46)	Amudurase (*n* = 58)	
Changes in temperature and rainfall patterns in recent years	45 (97.8)	45 (97.8)	57 (98.3)	147 (98.0)
Increase in rainfall in recent years	38 (82.6)	20 (43.5)	1 (1.7)	59 (39.3)
Decrease in rainfall in recent years	8 (17.4)	26 (56.5)	57 (98.3)	91 (60.7)
Changes in rainfall duration in recent years	44 (95.7)	46 (100.0)	55 (94.8)	145 (96.7)
Changes in the onset of rains in recent years	45 (97.8)	44 (95.7)	58 (100.0)	147 (98.0)
Rains come earlier in recent years	3 (6.5)	3 (6.5)	6 (10.3)	12 (8.0)
Rains come late in recent years	43 (93.5)	43 (93.5)	52 (89.7)	138 (92.0)
Increase in temperatures in recent years	44 (95.7)	44 (95.7)	58 (100.0)	146 (97.3)
Decrease in temperatures in recent years	2 (4.3)	2 (4.3)	0 (0.0)	4 (2.7)
Increase in flooding in recent years	17 (37.0)	17 (37.0)	12 (20.7)	46 (30.7)
Increase in windstorms in recent years	34 (73.9)	42 (91.3)	38 (65.5)	114 (76.0)

Numbers in parentheses depict percentages and numbers without parentheses show frequencies.

Table 3
Perceived effects of climate variability on cocoa production.

Variable	Community			Total (*n* = 150)
	Afiaso (*n* = 46)	Tonkoase (*n* = 46)	Amudurase (*n* = 58)	
Shortening of the cocoa farming season	30 (65.2)	22 (47.8)	31 (53.4)	83 (55.3)
Increased frequency of drought and cocoa failure	42 (91.3)	42 (91.3)	53 (91.4)	137 (91.3)
Increased expenditure on pesticide application	18 (39.1)	9 (19.6)	17 (29.3)	44 (29.3)
Post-harvest losses	40 (87.0)	35 (76.1)	50 (86.2)	125 (83.3)
Prevalence of diseases and pest invasion	41 (89.1)	40 (87.0)	54 (93.1)	135 (90.0)
Increased frequency of floods and destruction of cocoa farms	15 (32.6)	9 (19.6)	17 (29.3)	41 (27.3)
Poor growth of cocoa plants	31 (67.4)	31 (67.4)	19 (32.8)	81 (54.0)
Decreased income of cocoa farmers	45 (97.8)	40 (87.0)	42 (72.4)	127 (84.7)
Destruction of cocoa farm roads and homes	29 (63.0)	28 (60.9)	36 (62.1)	93 (62.0)

Numbers in parentheses depict percentages and numbers without parentheses show frequencies.

farmers have perceived the threats of climate variability on their cocoa farming to include cocoa failure, diseases, and pest infestation, poor growth of cocoa plants just to mention but a few. Some of the focus group participants and key informants also reported these:

> "*I normally spend a lot of money on pesticides to combat the pests that attack my cocoa trees. As a result of that, my income as a farmer is always small and we do not get any subsidies from the government to supplement our income*" – (Focus group participant, Tonkoase, June 2022)

> "*Sometimes, the rains do not come and we experience prolonged drought thereby reducing cocoa production in this community. Cocoa needs a good amount of water to thrive well and attain optimum yield. But when the drought sets in, we lose lots of our cocoa trees. Most of them die*" – (key informant, Amudurase, June 2022).

As reported by the respondents, climate variability tends to affect cocoa production negatively. For instance, concerning the increased frequency of drought and cocoa failure, the farmers remarked that the cocoa trees are very vulnerable to prolonged drought and hence very strong droughts cause decreased cocoa yields and death of cocoa trees. This is because the vascular system of the cocoa trees becomes very stressed during drought conditions. Considering the vascular system is a very crucial part of the plant, more intense and long-lasting droughts push the majority of the cocoa trees beyond their physiological thresholds eventually resulting in their mortalities [33]. Cocoa mortalities and failure could pose another serious ramification including decreased income for cocoa farmers (Table 3).

Pests and diseases have always affected cocoa, particularly the commercially produced ones. Some of the known diseases are swollen shoots and black pods. Swollen shoot disease which is caused by a virus makes the leaves of cocoa trees alter color, the trunk enlarges and the trees die eventually within a few years [34]. The transmission of the virus is favored by changes in climatic conditions [35]. Cocoa pests include vertebrates (e.g., squirrels and rats) and insects (e.g., mealy bugs, aphids, tea mosquito bugs, leaf-eating caterpillars, and ring bark borers) [36]. According to Peprah [36], these diseases and pest infestation tend to reduce cocoa yield in West Africa from 20% to 86%.

3.4. The adaptive capacity of smallholder cocoa farmers in the study communities

The results of the adaptive capacity of the selected communities are presented in Table 4A and 4B , and Fig. 2. The adaptive capacity indices for the various capitals differed among the three selected communities. Social capital is defined as the networks of relationships among people who live and work in a particular society, enabling that society to function effectively. For this study, the indicators used to assess social capital were four, and for each, Tonkoase had the highest index (Table 4A). Social capital has been found to affect the

Table 4a
Adaptive capacity index of the selected communities in Adansi South District.

Indicators	Indexed value		
	Afiaso	Tonkoase	Amudurase
Social capital			
Access to agricultural extension services?	0.192	0.196	0.144
Do you belong to any social group?	0.163	0.183	0.159
Do you belong to any faith-based group?	0.196	0.196	0.193
Do you have access to climate information?	0.129	0.154	0.130
Financial capital			
Do you own any livestock?	0.125	0.113	0.078
Do you have access to credit facilities?	0.067	0.050	0.026
Do you have access to the ready market?	0.183	0.192	0.200
Have you received remittances from family or friends in the last 12 months?	0.013	0.008	0.004
Do you receive agricultural subsidies?	0.000	0.000	0.000
Physical capital			
Do you have access to television?	0.117	0.092	0.122
Do you have access to a radio?	0.133	0.121	0.133
Do you have access to a mobile phone?	0.154	0.183	0.170
Do you have electricity or solar in your house?	0.183	0.188	0.163
Is there a school available nearby?	0.183	0.196	0.196
Do you have irrigation facilities for dry-season farming?	0.050	0.100	0.048
Do you have access to flood/drought emergency systems?	0.025	0.071	0.030
Human capital			
How long to reach the nearest health facility from your house, and how many minutes?	0.158	0.138	0.135
Is anybody in your family chronically ill or disabled?	0.063	0.063	0.059
Has anyone in your family suffered from any climate-related disaster?	0.033	0.025	0.037
Has anyone in your family died due to climate-related diseases in the past 10 years?	0.021	0.008	0.033
Does your family get sufficient food for the whole year?	0.100	0.142	0.126
Natural capital			
Type of farmland tenure system?	0.092	0.085	0.074
Size of farm holding in acres/hectares?	0.063	0.058	0.052
Is access to clean water sufficient for household purposes?	0.200	0.192	0.178
How much does it take to reach the water source?	0.013	0.056	0.019

Table 4b
Overall adaptive capacities of the selected communities.

Major components	Adaptive capacities			
	Afiaso	Tonkoase	Amudurase	Mean
Social capital	0.679	0.729	0.626	0.678
Financial capital	0.388	0.363	0.307	0.352
Physical capital	0.846	0.950	0.863	0.886
Human capital	0.375	0.375	0.391	0.380
Natural capital	0.367	0.392	0.322	0.360
Overall adaptive capacities	0.531	0.562	0.502	0.531

$0 - 0.3 = low$; $x > 0.3$ *but* $\leq 0.7 = moderate$; $x > 0.7$ *but* $\leq 1.0 = high$.
Source: Authors' construct

adaptive capacity of communities to climate variability [37,38]. For instance, agricultural extension services (sometimes called agricultural advisory services) contribute to raising the productivity of farming, boosting food security, and enhancing the livelihoods of rural communities [26]. Thus, increased access to agricultural extension services by smallholder farmers could enhance their adaptive capacities to climate variability. The majority of the smallholder cocoa farmers in the Tonkoase community had access to agricultural extension services (Table 1) and hence one of the possible reasons for its high adaptive capacity index. Furthermore, studies (e.g., Refs. [9,10,27]) have also shown that a crucial means to enhancing the capacity of smallholder farmers to lessen climate risks in food systems is the timely availability and usage of reliable climate information. Therefore, enhanced access and utilization of climate information by smallholder farmers could also raise their capacity to manage the threats of climate variability. This study has revealed that a large number of the smallholder cocoa farmers in Tonkoase received climate information (Table 1).

In this study, financial capital is defined as any economic resource assessed in monetary terms used by smallholder cocoa farmers to buy what they need to make their farming operations efficient. Financial capital has also been documented to influence communities' adaptive capacity to manage the adverse effects of climate variability [39,40]. Afiaso had the highest financial adaptive capacity index of 0.388 (Table 4b) although generally, all three communities recorded a moderate financial adaptive capacity index. The possible reason for Afiaso having the highest could be that, apart from access to ready markets, the community had the highest indices for three

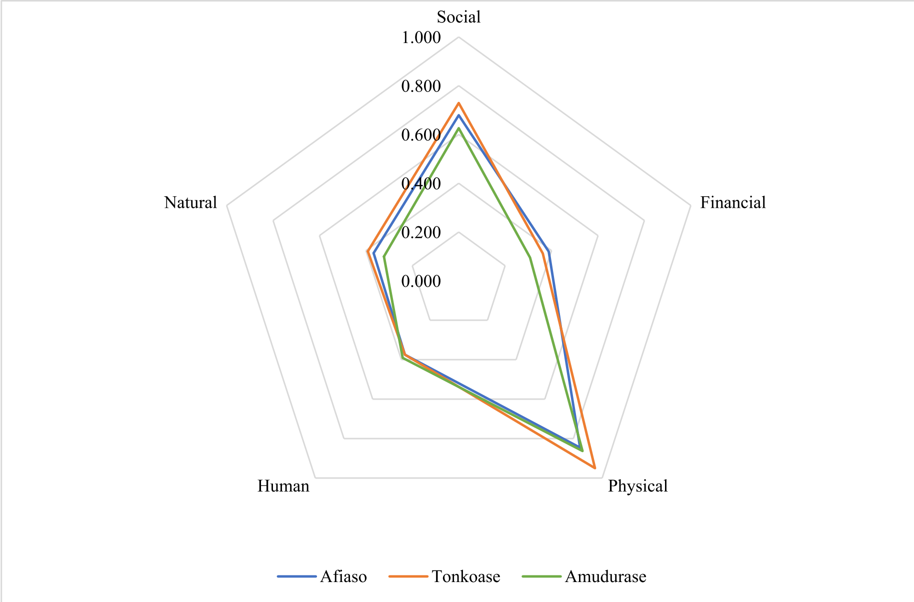

Fig. 2. Overall adaptive capacity for the selected communities in the study district.

of the indicators (Table 4A). Indicators such as access to credit facilities and ready markets influence the adaptive capacity of smallholder farmers. For example, agricultural credits can aid farmers to obtain fertilizers, seeds, and tools that are crucial to their farming activities. Access to ready markets is also key to enhancing the adaptive capacity of smallholder cocoa farmers. This is because, it allows the farmers to efficiently sell more produce, with better quality and at higher prices. Increased access to financial capital by smallholder farmers could boost their ability to reduce climate risks. Nonetheless, all three communities scored a financial adaptive capacity index of zero for access to agricultural subsidies and this is worrying.

Physical capital refers to the substantial assets utilized by farmers to support their farming production. Seven indicators were used to measure physical capital in this study (Table 4A). Tonkoase community recorded the highest physical adaptive capacity index (0.950) (Table 4b). This can be attributed to Tonkoase having the highest indices for five of the indicators (Table 4A). Physical capital has also been reported to affect farmers' capability to manage climate variability and extremes (e.g., Refs. [41,42]). Specifically, Baffour-Ata et al. [10] stated that farmers' access to household information devices (e.g., television, mobile phone, and radio) could influence their timely uptake and usage of climate information which is key to enhancing their adaptive capacity to the threats of climate variability. A flood or drought emergency system is an early warning system and farmers' access to an early warning system has been identified as an efficient tool to minimize their vulnerabilities and enhance consciousness of natural hazards including floods and droughts [43].

Five indicators were used to assess human capital (Table 4A). Human capital is defined as farmer attributes regarded as important in the farming process including good health, knowledge, skills, and education. Research has also shown that human capital affects the adaptive capacity of farmers to climate risks [44,45]. For instance, health is a type of human capital and an input needed to form other types of human capital [46]. An unhealthy farmer is unable to work productively or have the capacity to invest in other forms of human capital which could eventually result in lower farmer income. In this study, though the Amudurase community had the highest index (0.391) in terms of human capital, generally, all three communities recorded a moderate adaptive capacity index for human capital. It is suggested that the smallholder cocoa farmers in the study communities explore ways to enhance their human capital such as improving their access to adequate food and better health facilities to reduce their vulnerability to climate risks.

Natural capital includes a community's stock of natural resources including water, land, etc. Four indicators were employed to assess natural capital in this study. Access to land implies the chance to obtain a reasonable income and accomplish food and nutrition security. Access to land can additionally make way for access to social benefits including education and health care. On the other hand, the absence of secure land may marginalize rural farmers and make them susceptible to the integrated threats of hunger, conflict, and poverty. As a result of this, land tenure security is recognized as key to enhancing rural livelihoods and the adaptive capacity of smallholder farmers [47]. The Tonkoase community had the highest adaptive capacity index for natural capital (0.392). Generally, the three communities registered a moderate adaptive capacity index for natural capital.

Generally, the average adaptive capacity index for the three selected communities in Adansi South District was 0.531 implying a moderate adaptive capacity for the smallholder cocoa farmers. These results highlight the significance of the assessment of smallholder cocoa farmers' adaptive capacity and the need for relevant policies aimed at enhancing the adaptive capacity of smallholder farmers in addressing climate risks.

4. Conclusion and policy implications

This study assessed the adaptive capacity of smallholder cocoa farmers to manage climate risks in the Adansi South District of the Ashanti Region, Ghana. Findings indicated that smallholder cocoa farmers in the three selected communities (Afiaso, Tonkoase, and Amudurase) of the study district perceived climate variability via rising temperatures, changes in rainfall onset and duration, and decrease in rainfall as well as an increase in windstorms. The variability in climate had several implications for cocoa production including an increase in the frequency of drought and cocoa failure, prevalence of diseases and pest invasion, decreased income, and post-harvest losses. Hence, it was important to examine the smallholder cocoa farmers' adaptive capacity to reduce climate threats. The study findings generally suggested a moderate adaptive capacity. Hence, it is important to help the cocoa farmers in the study district to become more resilient to climate variability. The following are suggested: (i) Raising awareness of climate variability and its effect on cocoa production among smallholder cocoa farmers. Raising awareness is imperative as it will aid the farmers and other stakeholders identify the need for adaptation actions. (ii) Appropriate policies aimed at enhancing smallholder cocoa farmers' adaptive capacity in the district must also be formulated by policymakers; and, (iii) Provision of reliable and timely access to climate information. The adaptive capacity of smallholder cocoa farmers could increase significantly with access to climate information and agricultural information from extension officers.

5. Limitations of the study

In adaptive capacity and vulnerability assessment studies, there are many indicators or variables for each capital asset as identified in the literature. However, we limited ourselves to the variables or indicators that could be collected from the field.

Author contribution statement

Frank Baffour-Ata and Philip Antwi-Agyei: Conceived and designed the experiments.

Louisa Boakye, Lester Simon Nii Aryee Tettey, Muriel Nana Efua Fosuaa Forson, and Albright Ewenam Abiwu: Performed the experiments.

Emmanuel Gyenin and Rebecca Naa Merley Larbi: Analyzed and interpreted the data.

Louisa Boakye, Lester Simon Nii Aryee Tettey, Muriel Nana Efua Fosuaa Forson, and Albright Ewenam Abiwu contributed: Reagents, materials, analysis tools or data.

Frank Baffour-Ata, Philip Antwi-Agyei, Emmanuel Gyenin and Rebecca Naa Merley Larbi: Wrote the paper.

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Data availability statement

The authors do not have permission to share data.

Declaration of interest's statement

The authors declare no conflict of interest.

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