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Building the resilience of smallholder farmers to climate variability: Using climate-smart agriculture in Bono East Region, Ghana

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ABSTRACT

The concept of climate-smart agriculture (CSA) emerges from a requirement to come up with advanced solutions towards the intricate and combined objectives of enhancing crop yields, ameliorating resilience, and encouraging a low-emissions agricultural sector. This study examines how smallholder farmers are building their resilience to climate variability using CSA practices in the Bono East Region, Ghana. Specifically, the study sought to: (i) assess the trends of temperature and rainfall for the period 2011 to 2021; (ii) identify and rank CSA practices used by the smallholder farmers for resilience building in agricultural systems; and; (iii) determine the barriers militating against smallholder farmers' implementation of the prioritized CSA practices. Standardized rainfall and temperature anomalies integrated with Sen's slope were used to determine the temperature and rainfall trends. One hundred and fifty random household surveys in five selected communities (Benkai, Fiaso, Traa, Awurano, and Bomini) accompanied by five key informant interviews were used to collect field data. The CSA practices identified by the farmers and the barriers opposing the implementation of these practices were ranked using the Relative Importance Index (RII) and Weighted Average Index (WAI) respectively. Results showed that rainfall was inconsistent and temperature rose from 2011 to 2021 in the study area. Results also revealed that the key CSA practices implemented by the farmers were appropriate fertilizer application (RII = 0.758), mixed farming (RII = 0.735), and crop diversification (RII = 0.717). However, in the implementation of these CSA practices, the farmers were confronted with key barriers including increased occurrences of diseases and pests (WAI = 1.173), restricted access to agricultural technologies (WAI = 1.100), and excessive price of improved crop varieties (WAI = 1.067). The study concludes that the resilience of smallholder farmers in Ghana can be built through the effective implementation of the aforementioned CSA practices.

1. Introduction

Agriculture is a key sector of the world's economy contributing to about 4 % of the global Gross Domestic Product (GDP) and in some developing nations, accounting for at least 25 % of the GDP [1]. The development of agriculture can help elevate incomes,

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minimize poverty, and enhance food security for about 80 % of the world's poor who inhabit rural communities and work mostly in farming [1].

Nonetheless, agriculture-driven growth, food security, and minimization of poverty are at risk of conflicts, high incidences of diseases and pests as well as accelerating climate variability, particularly in sub-Saharan Africa (SSA) [2]. Enhanced climate variability could additionally decrease the yields of food crops, particularly in SSA's most food-insecure countries thereby impacting food systems, triggering elevated food prices, and increasing hunger [2].

In Ghana, the agricultural sector employs at least 50 % of the nation's labor force [3]. However, smallholder farmers encounter numerous barriers such as high post-harvest losses, the absence of market information on the prices of livestock and crops as well as low productivity levels caused by increasing climate variability [4]. Climate variability presents a significant threat to the socio-economic development of Ghana where rain-fed agricultural systems provide livelihoods to millions of households. About 80 % of Ghanaian farmers are smallholders who play a crucial role in the production of food [5]. The majority of smallholder farmers rely solely on rainfall, making their livelihoods more susceptible to the adverse impacts of rainfall variability. For instance, the majority of farmers follow the traditional calendar for the cultivation of crops, however, climate variability changes the anticipated patterns of the weather and enhances the risks of crop failures as a result of extreme events including floods and droughts [6]. Furthermore, smallholder farmers in Ghana generally lack access to timely and reliable climate services that are key to farm management decisions including the preparation of farmland, the application of fertilizers, irrigation, planting, and harvesting of crops [7]. This will disproportionately affect the attainment of the United Nations Sustainable Development Goals (SDGs), particularly goals relating to food security and poverty. Therefore, there is a need to build the resilience of smallholder farmers in Ghana to manage the adverse effects of climate variability through social, economic, and technological strategies.

Climate resilience is generally considered to be the ability to recover from or mitigate vulnerability to climate-related shocks such as floods and droughts [8]. For this study, resilience is defined as being present in situations where major changes and variability in the climate (such as drought) result in insignificant loss of crop yield in a particular community [9]. The critical focus of enhancing climate resilience is to reduce the climate vulnerability that communities, states, and countries currently have concerning the numerous effects of climate change [10]. Presently, efforts to build climate resilience encompass social, economic, technological, and political strategies that are being implemented at all scales of society [11]. Addressing climate resilience from local community action to global treaties, is becoming a priority, although it can be argued that a significant amount of the theory is yet to be translated into practice [12].

Climate resilience is related to climate change adaptation efforts and one such adaptation strategy that aids smallholder farmers in managing agricultural systems effectively to climate variability is the adoption of climate-smart agriculture (CSA) [13]. CSA (or climate resilient agriculture) is an integrated approach to managing landscapes to help adapt agricultural methods, livestock, and crops to the effects of climate change and variability and, where possible, counteract it by reducing greenhouse gas emissions from agriculture, at the same time taking into account the growing world population to ensure food security [13]. It aims at achieving three objectives including sustainably increasing incomes and productivity, adapting to changes in climate, and minimizing the emissions of greenhouse gases. Thus, the emphasis is not simply on carbon farming or sustainable agriculture, but also on increasing agricultural productivity (Table 1). CSA lists different actions to counter future challenges for crops and plants. Concerning rising temperatures and heat stress, e.g., CSA recommends the production of heat-tolerant crop varieties, mulching, water management, shade houses, boundary trees, and appropriate housing and spacing for cattle [14]. CSA aims to help farmers build and improve resilience to the negative effects of climate variability and change on their harvests and livelihoods [15]. By incorporating these solutions and new technologies into their post-harvest practices, farmers can then transition from their traditional ways to a more sustainable and climate-resilient post-harvest process and gain long-term benefits. In terms of controlling insects and pests, CSA practices can help reduce the use of pesticides which can be harmful to the environment and human health. For example, crop rotation can help reduce pest pressure by breaking pest cycles. Additionally, intercropping can help reduce pest pressure by creating a more diverse environment that is less attractive to pests [15]. Despite these pros, CSA has its disadvantages including enhanced utilization of chemicals

Table 1
Important variables for CSA.

Variable	Brief explanation	Key questions
Adaptation	CSA emphasizes the need to adapt agricultural practices to changing climatic conditions. This includes changes in crop and livestock management and land use practices	What are the barriers to the adaptation of climate-smart agriculture?
Mitigation	CSA aims to reduce greenhouse gas emissions from agriculture, through practices such as conservation agriculture, agroforestry, and improved livestock management.	Does CSA impose climate change mitigation requirements on agriculture?
Resilience	CSA aims to build resilience in agriculture systems, helping them to withstand the impacts of climate change. This includes measures such as improving soil health, water management, and diversifying crops and livestock.	What are the possible approaches to climate-resilient agriculture?
Sustainable intensification	CSA seeks to increase agricultural production while maintaining or improving ecosystem services, such as soil fertility, water quality, and biodiversity.	How is CSA related to sustainable agriculture?
Knowledge and innovation	CSA relies on the use of new and innovative technologies and practices, as well as the sharing of knowledge and innovation between farmers, researchers, and other stakeholders.	How can CSA be promoted?
Gender equity	CSA recognizes the importance of addressing gender inequalities in agriculture and promoting the participation of women in decision-making and the development and adoption of climate-smart practices.	How can gender be mainstreamed in climate-smart agricultural initiatives?

Source: Palombi & Sessa [19].

by farmers, irregular distribution of water, reliance on organic fertilizers, and increased food miles [15]. Furthermore, there are also some limitations associated with CSA practices for controlling insects and pests. For example, some CSA practices may not be effective in controlling certain pests or may require more labor than conventional methods. Nonetheless, the advantages of adopting CSA tend to outweigh the disadvantages and thus there have been several attempts to mainstream CSA into core government policies, expenditures, and planning frameworks. As a result of this, CSA has received considerable research attention globally and in SSA (e.g. Refs. [16–18]).

For instance, studies including Khatri-Chhetri et al. [20] and Antwi-Agyei et al. [6] have indicated that the implementation of CSA practices by smallholder farmers has the potential to achieve the objectives of CSA. Khatri-Chhetri et al. [20] reported that rural farmers in different rainfall zones of India preferred to use CSA technologies such as harvesting rainwater, laser land leveling, and crop insurance because of their significant implications on food crop production and livelihoods. Laser land leveling is a process of flattening the land surface using a laser-guided machine [20]. It is a more precise and efficient way of preparing the land for irrigation and sowing than traditional methods [20]. Similarly, Antwi-Agyei et al. [6] revealed that smallholder farmers in savannah and transitional agroecological zones of Ghana used CSA practices including crop rotation, emergency seed banking, and timely harvesting of produce and storage to enhance household food security, secure higher yields and income as well as minimize the high rate of diseases and pest infestation. Furthermore, Antwi-Agyei et al. [6] reported that conservation agricultural practices including cover cropping, irrigation, zero or minimum tillage, and mulching can make smallholder farmers resilient to the adverse impacts of climate change and variability. Despite this evidence, the current rate of implementation of CSA practices by smallholder farmers in Ghana is still fairly low (i.e., 30 % of smallholder farmers in Ghana use CSA practices) [6].

Thus, there is a dearth of empirical evidence on how smallholder farmers in Ghana can build their resilience to climate variability through the adoption of CSA practices. In addition to that, the barriers confronting Ghanaian smallholder farmers in the implementation of CSA practices have not been adequately discussed in the literature. This is critical considering the effectiveness of the adoption of CSA practices by smallholder farmers is largely contingent on the barriers they face. For this reason, there is a need for sustained research to identify the CSA practices utilized by farming households for resilience building in agricultural systems in the Bono East Region, Ghana. This study aims to: (i) assess the trends of temperature and rainfall for the period 2011 to 2021 in the study area; (ii) identify and rank the CSA practices used by smallholder farmers in the study area; and; (iii) determine the barriers faced by the farmers in utilizing the CSA practices. We hypothesized that smallholder farmers in the Bono East Region of Ghana implement CSA practices for resilience building in agricultural systems. However, they are also confronted with barriers to their adoption and implementation of CSA practices in the study region.

Findings from this study provide useful information that will help policymakers formulate relevant policies that aim at reducing the vulnerabilities of smallholder farmers to the adverse impacts of climate variability. This will sustainably enhance agricultural

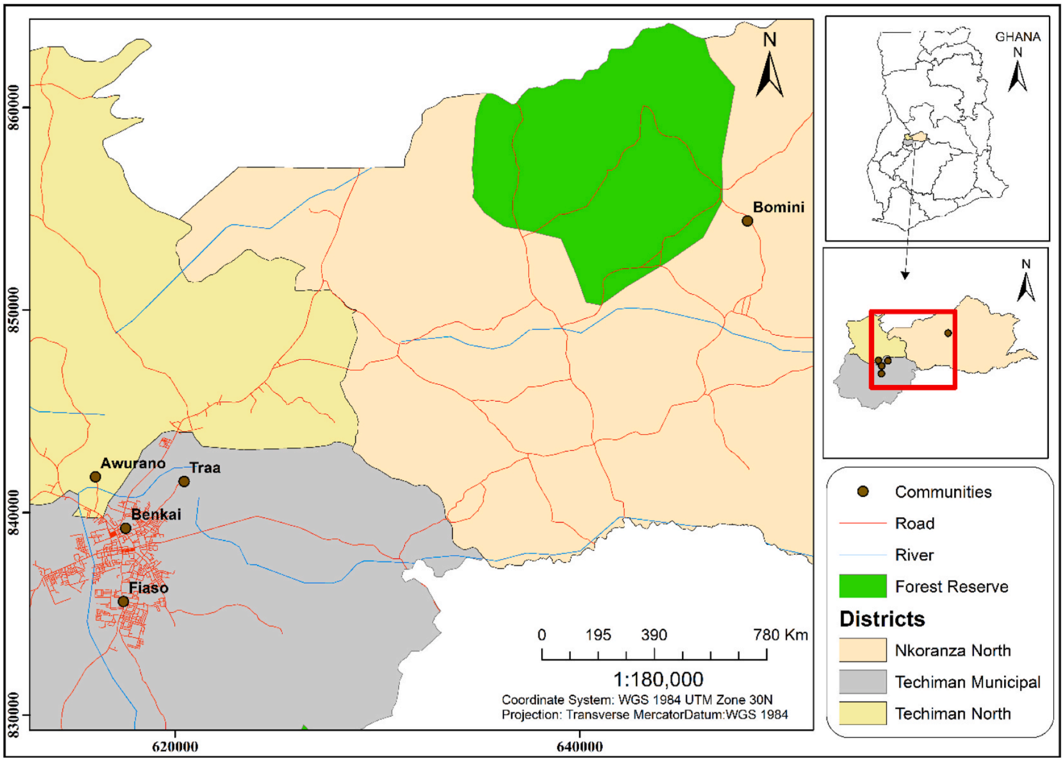

Fig. 1. Bono East Region showing the study communities.

productivity and income for food security. Furthermore, the findings provide valuable lessons on how CSA can contribute to building the resilience of agricultural and food production systems to climate variability. It is hoped that findings from this study will impart significant information for future studies on climate change and variability in the study region. Overall, it is anticipated that the findings will contribute to the accomplishment of the SDGs including Goal 1 (No poverty), Goal 2 (Zero Hunger), and Goal 13 (Climate Action).

2. Materials and methods

2.1. Description of the study area

The Bono East Region experiences a wet season between July and November and a dry season between December and April [21]. The mean annual precipitation in the region ranges between 1260 mm and 1660 mm [21]. The temperatures in the region can change between 40 °*C* during the day and 14 °*C* at night [21]. The region's vegetation is predominantly made up of forests. The major economic activity in the region is agriculture where dominant crops such as beans, maize, cassava, cocoyam, rice, and plantains are cultivated. Some fishing activities occur along the region's side of Lake Volta.

Within the region, three districts including Nkoranza North, Techiman Municipal, and Techiman North were chosen based on the expert advice from agricultural extension officers found at the regional office. They suggested these districts because of their active agricultural activities. Within the districts, five communities including Benkai, Fiaso, Traa (Techiman Municipal), Awurano (Techiman North), and Bomini (Nkoranza North) were also selected due to their significance for the production of food crops in the selected districts (see Fig. 1).

2.2. Research philosophy and design

The research philosophy employed for this study was pragmatism. This is because pragmatism is relevant in solving practical problems and involves an integration of multiple research methods [22]. The research design used in this research was cross-sectional [23]. Time series analysis, a statistical methodology appropriate for longitudinal research design [24] was also used to assess the temperature and rainfall trends in the study area from 2011 to 2021.

2.3. Collection of rainfall and temperature data

The temperature and rainfall data from 2011 to 2021 were taken from the Ghana Meteorological Agency (GMet) in Accra, Ghana. The data were grouped into months and hence were assessed into mean annual data using Microsoft Excel Version 2016.

2.4. Field data collection

Data from the field were obtained via household surveys and key informant interviews. Thirty household surveys were conducted in each community. This was done to obtain a sample size of 150 respondents. This was done with the lottery technique where households in each community were assigned a number, after which the numbers were selected at random to obtain the total number of households. A good maximum sample size is usually around 10 % of the population as long as this does not exceed 1000 [25] and according to the district's agricultural extension officers, there are about 1500 smallholder farmers in the selected communities, hence the choice of the sample size. Administration of questionnaires was then conducted in person with farmers (i.e., either men or women) who were heads of their households. The questionnaire entailed three sections with the first section being the socioeconomic characteristics of the respondents. The second section was on the CSA practices (i.e., the use of traditional agroecological knowledge, sprinkler, and drip irrigation, appropriate fertilizer use, crop rotation, intercropping, mixed farming, crop diversification, and changing of planting dates) implemented by the farmers and the last section was on the barriers militating against the adoption of the CSA practices. The aforementioned CSA practices were adopted for this study based on expert advice from the agricultural extension officers in the study region. The questionnaires were administered in the native language (Bono Twi) in June 2022.

Key informant interviews authenticated the issues that were brought out in the household surveys. Key informant interviews are qualitative in-depth interviews with people who know what is going on in the communities. The purpose of key informant interviews is to collect information from a wide range of people including community leaders, professionals, or residents who have first-hand knowledge about the community [26]. For this research, a mean number of five participants was used for the key informant interviews in each community. These included assembly members, youth leaders, and agricultural extension officers stationed in each community. The leaders in each community were also interviewed. The interviews which were conducted in the native language lasted for about 30 min and the discussions were taped and later transcribed with the agreement of the participants.

The Humanities and Social Sciences Research Ethics Committee (HuSSREC) of the Kwame Nkrumah University of Science and Technology reviewed and provided the ethical approval for this study. Ethical issues were focused on the agreement of the respondents and the confidentiality of the response. Most of the smallholder farmers in the study communities had non-formal education thus an oral agreement was obtained from the respondents. Key informants' and farmers' names were kept anonymous. They were assured that direct quotes that could be used in the write-up would also be anonymous.

2.5. Data analysis

Standardized anomalies were computed from the rainfall and temperature data. Standardized anomalies describe climate variability over larger areas more accurately than absolute climatic data, and they give a frame of reference that allows more meaningful comparisons between locations and more accurate calculations of climatic trends [27]. The means and standard deviations for each variable were computed for 11 years (2011–2021). The computation of the standardized anomalies followed two steps: in the first stage, we computed the anomaly of each variable by subtracting the overall mean from the yearly means of each variable [28]. This is illustrated in equation (1) below:

$$A_i = M_i - \mu_{in} \tag{1}$$

Where A is the yearly anomaly, M is the yearly mean, μ is the overall mean and i indicates whether rainfall or temperature. The second step of the computation involves dividing the anomaly of each year by the overall standard deviation (Equation (2)). Standardizing the yearly anomaly by the overall standard deviation helps to eliminate the effects of wide dispersions on the anomaly index [29].

$$SA_i = \frac{A_i}{SD_i} \tag{2}$$

Table 2
Socio-demographic characteristics of the smallholder farmers.

	Gender		
Variables	Males ($n = 89$)	Females ($n = 61$)	Total ($n = 150$)
Age (years)			
Below 20	4 (4.5)	0 (0.0)	4 (2.7)
21–40	38 (42.7)	26 (42.6)	64 (42.7)
41–60	36 (40.4)	26 (42.6)	62 (41.3)
Above 60	11 (12.4)	9 (14.8)	20 (13.3)
Household size			
1–5	50 (56.2)	28 (45.9)	78 (52.0)
6–10	35 (39.3)	32 (52.5)	67 (44.7)
11–15	4 (4.5)	1 (1.6)	5 (3.3)
How long have you lived in the community?			
Below 10 years	19 (21.4)	8 (13.1)	27 (18)
10–20	22 (24.)	13 (21.3)	35 (23.3)
Above 20 years	48 (53.9)	40 (65.6)	88 (58.7)
Educational level			
Non-formal	25 (28.1)	35 (57.3)	60 (40.0)
Basic	40 (44.9)	22 (36.1)	62 (41.3)
Secondary school	11 (12.4)	2 (3.3)	13 (8.7)
Tertiary	13 (14.6)	2 (3.3)	15 (10)
Type of farmland tenure system			
Rented	60 (67.4)	39 (63.9)	99 (66.0)
Inherited	26 (29.2)	20 (32.8)	46 (30.7)
Purchased	3 (3.4)	2 (3.3)	5 (3.3)
Farming experience (years)			
Below 10	17 (19.1)	7 (11.4)	24 (16.0)
10–20	34 (38.2)	20 (32.7)	54 (36.0)
Above 20	38 (42.7)	34 (55.7)	72 (48.0)
Do you receive government subsidies?			
Yes	16 (18.0)	6 (9.8)	22 (14.7)
No	73 (82.0)	55 (90.2)	128 (85.3)
Do you get weather and climate information?			
Yes	87 (97.8)	55 (90.2)	142 (94.7)
No	2 (2.2)	6 (9.8)	8 (5.3)
Source of weather and climate information			
Media	88 (98.9)	50 (82)	138 (92.0)
Village elders	0 (0.0)	2 (3.2)	2 (1.3)
Friends and relatives	1 (1.1)	9 (14.8)	10 (6.7)
Access to a ready market			
Yes	66 (74.2)	46 (75.4)	112 (74.7)
No	23 (25.8)	15 (24.6)	38 (25.3)
Access to extension services			
Yes	73 (82.0)	43 (70.5)	116 (77.3)
No	16 (18.0)	18 (29.5)	34 (22.7)
Access to irrigation facilities			
Yes	31 (34.8)	32 (52.5)	63 (42.0)
No	58 (65.2)	29 (47.5)	87 (58.0)

Numbers in parentheses indicate percentages while numbers without parentheses indicate frequencies.

Where *SA* is the yearly standardized anomaly and SD is the overall standard deviation.

Sen's slope estimator was used to evaluate the slope of the trends [30]. The advantage of using Sen's slope estimator is that it tends to yield accurate confidence intervals even with non-normal data and heteroscedasticity (non-constant error variance) [30]. A 95 % confidence interval was set. The variation in temperature and rainfall was evaluated using the Coefficient of Variation (CV) [31]. The CV is useful because the standard deviation of data must always be understood in the context of the mean of the data. Thus, CV is calculated using the formula in equation (3):

$$\mathrm{CV} = \frac{Standard\ deviation}{mean} \tag{3}$$

Descriptive statistics involving percentages and frequencies were used to assess the household survey data. RII was used to rank the CSA practices [6] (equation (4)). RII analysis allows identifying most of the important criteria based on participants' replies and it is also an appropriate tool to prioritize indicators rated on Likert-type scales.

$$\mathrm{RII} = \frac{sum\ of\ weights\ (W1 + W2 + W3 + W4)}{A\ X\ N} \tag{4}$$

Where W = weights given to each factor by the respondents and range from 1 to 4 where '1′ is less important and '4′ is extremely important; A = highest weight (i.e., in this case, = 4); and; N = total number of respondents. The higher the RII, the more important the CSA practice.

The weighted Average Index (WAI) was utilized to rank the barriers militating against the smallholder farmers' implementation of CSA practices [32]. A WAI is sometimes more accurate than a simple average. In a WAI, each data point value is multiplied by the assigned weight, which is then summed and divided by the number of data points. For this reason, a WAI can improve the data's accuracy. Equation (5) was used to calculate WAI.

$$\mathrm{WAI} = \frac{\sum FaWa}{\sum Fa} \tag{5}$$

Where F = frequency of perceived barrier; W = weight; a = score of each barrier. The scales ranged from 1 to 2 where they indicated "no problem" and "Yes problem" respectively.

The computations for CV, RII, and WAI were done using the Microsoft Excel version 2016. Content analysis was used to analyze the key informant interviews [33]. Content analysis is a research tool used to determine the presence of certain themes, words, or concepts within some given qualitative data [33]. The major advantage of using content analysis in qualitative data analysis is that it focuses on the specific communication message and the message creator [33]. Relevant quotes from the key informant interviews were used to emphasize the interviews.

3. Results and discussion

3.1. Socio-demographic characteristics of farmers

Out of the surveyed farmers, about 59 % were men while the remaining were women (Table 2). This is consistent with a report by the Food and Agriculture Organization of the United Nations [34] which reported that about 60 % of farmers who conduct agricultural activities in Ghana are men. This is because men tend to have access to farm labor, tools, extension services, and financing for their farms relative to women in Ghana [34]. About 43 % of the farmers belonged to the age group of 21–40 years. This was closely followed by the age category of 41–60 years ($n = 62$). This could explain why 48 % of the farmers had more than 20 years of farming experience. This is in line with the findings of GSS [21] indicating that almost 60 % of the population in the Bono East Region is between the ages of 15–64 years (conventionally referred to as the labor or productive age group) and hence can be harnessed for productive work including farming. About 59 % of the farmers had lived in the selected communities for more than 20 years indicating that a greater number of them had a detailed understanding of the past and present climatic conditions of the communities. Roughly 41 % of the farmers had obtained elementary education and 40 % of them had non-formal education. This is alarming because illiteracy and low levels of education tend to hinder rural development and food security. It threatens agricultural productivity and limits opportunities to enhance livelihoods since farmers may not be able to accept the key climate-smart technologies needed to build their resilience to the changes in climate [6]. This is because they may not have the knowledge or skills to understand the benefits of these technologies. An agricultural subsidy is a government incentive given to farmers to boost their income, manage the provision of farming products, and affect the market price and provision of such products [35]. The majority of the farmers ($n = 128$) reported not receiving government subsidies. This is serious and needs government intervention since supporters of farm subsidies have argued that such programs stabilize agricultural commodity markets, aid low-income farmers, raise unduly low returns to farm investments, aid rural development, compensate for monopolies in farm input supply and farm marketing industries, and help ensure national food security [36]. Consistent with previous studies including Baffour-Ata et al. [7] and Antwi-Agyei et al. [37], a greater number of the farmers ($n = 142$) obtained weather and climate information with a large number of them ($n = 138$) receiving the information from the media (i.e., radio and television shows). This is impressive considering studies have shown that farmers' access to timely and reliable climate services can help build resilient food systems in Ghana (e.g. Refs. [7,37]). About 75 % of the farmers reported having access to ready markets. Good access to ready markets is vital for farmers to be productive and profitable [38]. This is because, with ready markets, smallholder farmers would sell more products and expand their enterprises, thus solving household poverty.

3.2. Rainfall and temperature changes in the study area

Fig. 2A and B shows the standardized anomalies of rainfall and temperature over the given period in the study area. Positive anomalies indicate that the observed rainfall or temperature values are higher than the baseline whilst negative anomalies indicate that the observed rainfall or temperature values are lower than the baseline. Concerning rainfall, it changed from 2011 to 2021 with an insignificant increasing trend ($p > 0.05$). This is corroborated by a positive magnitude of Sen's slope (i.e., 5.550). The maximum annual rainfall for the study period was 1502.7 mm whilst the minimum annual rainfall was 868 mm (Fig. 3A). The variation in rainfall in the study area was about 16 %. Similarly, temperature followed the same pattern with an increasing insignificant trend ($p > 0.05$). The positive Sen's slope also showed that temperature increased in the study area from 2011 to 2021. The minimum and maximum mean annual temperatures from 2011 to 2021 were 31.6 $^{\circ}C$ and 32.4 $^{\circ}C$ (Fig. 3B). These results are consistent with a report by the Environmental Protection Agency [39] which states that Ghana will continue to experience increases in temperature and variable rainfall patterns across all agroecological zones by 2050 and 2080.

Rising temperatures and erratic rainfall patterns have considerable implications for food production and farming activities in the study area. For instance, rising temperatures may benefit some specific crops and allow some farmers to cultivate new crops that grow well in hotter climatic conditions [31]. However, rising temperatures could also be challenging for some farmers to grow their conventional crops. This may shift ideal growing conditions to higher latitudes where the soil may not be as fertile, resulting in less land available for productive farming. Furthermore, rising temperatures could also result in rapid evaporation, resulting in more shortages of water and droughts [40]. The altering rainfall patterns accompanied by increased amounts are becoming more frequent in most parts of Ghana [41,42], and these could directly destroy crops, resulting in reduced yields. Increased amounts of rain could also initiate floods which could drown crops [43]. Floodwaters can also aid in the transportation of manure, contaminants or pollutants, and sewage from lawns, roads, and farms, and more toxins or micro-organisms could find their way into our food [44]. The ongoing discussion highlights the need for farmers particularly smallholders to undertake CSA practices to reduce climate risks to their farming activities and livelihoods.

3.3. CSA practices implemented by the smallholder farmers

Results from our study revealed that the smallholder farmers employed a variety of CSA practices to address the impact of climate

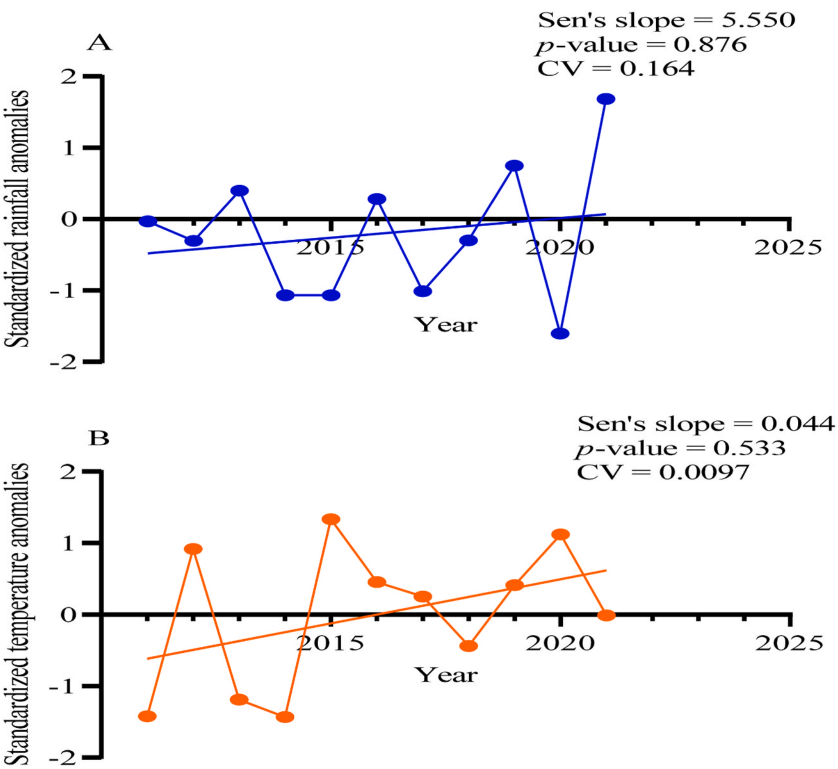

Fig. 2. Standardized rainfall (A) and temperature (B) anomalies in the study region.
Source: Ghana Meteorological Agency

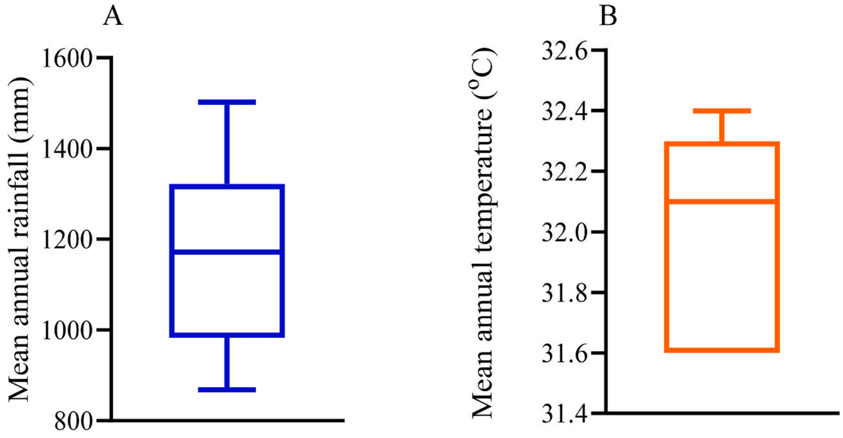

Fig. 3. Box-and-whisker plot for rainfall (A) and temperature (B) in the study region.

variability on their farming activities (Table 3). Appropriate fertilizer use with an RII of 0.758 was ranked as the highest preferred CSA practice in the selected communities. The farmers reported applying fertilizers including NPK (Nitrogen, Phosphorus, and Potassium), sulfate of ammonia, and muriate of potash on their farms. For instance, some of the respondents said:

> "*I have been applying NPK to my five-acre maize farm and of late I harvest more than 30 bags of 100-kilogram bags of maize*" – (Male farmer, Bomini, June 2022).

> "*It seems like the farmers are very happy applying fertilizers such as NPK and muriate of potash on their farms. This is because they have been reporting increased yields of crops and more production of food*" – (Key informant, Traa, June 2022).

Although farmers acknowledged the difficulty in using fertilizers appropriately, they contended that appropriate fertilizer use is the most important CSA practice given that it ensures a higher rate of recovery of nutrients applied to crops and hence leads to improved crop yields [45,46]. Furthermore, the smallholder farmers stated that they had been taught and trained on the 4 R s (right source, right time, right rate, and the right place to apply the fertilizer) by agricultural extension officers and have been seeing improved results through increased crop yields and income. Despite the benefits derived by the farmers through appropriate fertilizer use, most of them bemoaned the increasing costs of fertilizers. They were of the view that their capacity to buy fertilizers has also been adversely influenced by the depreciation of the Ghanaian Cedi versus the United States Dollar, particularly in the year 2022 [47]. Since Ghana imports almost all of the fertilizer it consumes, the government must subsidize the majority of the fertilizer market. This study has revealed that most smallholder farmers do not receive agricultural subsidies (Table 2) and we suggest that the government comes out with policy measures to address this.

Mixed farming with an RII of 0.735 was ranked second by our study respondents. Mixed farming is a farming system whereby the farmer cultivates crops and rears animals on the same piece of land [48]. The smallholder farmers in the study area mostly kept ruminants such as goats and sheep as well as poultry and cultivated crops such as maize, plantain, cocoyam, and cassava as part of their mixed farming systems. It was observed that the residues from crop production were utilized as feed for the livestock whereas the animal dung was returned to the crop fields as manure. Mixed farming is increasingly being adopted among smallholder farmers because of its ability to ensure feed availability for livestock during periods of climatic shocks [49,50]. Additionally, mixed farming ensures that farmers can meet the nutrient requirement of their crops since manures from their livestock complement fertilizers that they can acquire with their limited resources [51]. For instance, one key informant validated this by reporting that:

> "*I have realized the majority of the farmers in this community adopt mixed farming as a CSA practice. Most often, they integrate cereals such as maize and livestock including sheep and goats. According to the farmers, this practice helps to offer the highest return on farm business, as the by-products of the farm are properly utilized*" – (Key informant, Awurano, June 2022)

Table 3
CSA practices adopted by smallholder farmers in the study area.

CSA practices	Never used	Rarely used	Often used	Used every year	RII	Rank
Appropriate fertilizer use	21	62	60	312	0.758	1
Mixed farming	11	96	90	244	0.735	2
Crop diversification	7	116	99	208	0.717	3
Crop rotation	10	106	39	256	0.685	4
Intercropping	12	116	114	168	0.683	5
Changing planting dates	21	50	174	144	0.648	6
Sprinkler and drip irrigation	55	156	45	8	0.440	7
Use of traditional agroecological knowledge	107	12	39	96	0.423	8

Crop diversification was ranked as the 3rd highest CSA practice by the smallholder farmers in the study area (RII = 0.717). Crop diversification refers to the addition of new crops or cropping systems to agricultural production on a particular farm taking into account the different returns from value-added crops with complementary marketing opportunities [52]. For instance, the surveyed smallholder cassava farmers added crops such as yam and beans to their farms. Also, the farmers preferred to diversify their crops because it can be used as a tool to increase farm income, generate employment, alleviate poverty, and conserve soil and water resources [53]. For example, one of the farmers reported that:

> *"Generally, I am a maize farmer, but I have been integrating it with vegetables and fruits on the same farmland. I must admit that diversifying my crops has helped to reduce my financial risks that were related to unfavorable weather"* – (Female farmer, Fiaso, June 2022).

It is important to highlight that the CSA practice was also highly adopted by smallholder farmers in the transitional and savannah agroecological zones of Ghana [6].

Contrary to the findings of Baffour-Ata et al. [54] who indicated the significant role of traditional agroecological knowledge in farmers' adaptation to the changes in climate, the smallholder farmers in the study area ranked the utilization of indigenous knowledge as the least CSA practice adopted. The low importance attached to the use of indigenous knowledge may be because of the innovations necessary to make traditional knowledge relevant to the fight against climate variability [55,56]. Furthermore, another possible reason could be that most of the smallholder farmers accessed weather and climate information (Refer to Table 2) although studies including Baffour-Ata et al. [7] and Antwi-Agyei et al. [37] have advocated for the integration of traditional agroecological knowledge and climate information services to build resilient agricultural systems.

3.4. Barriers to the implementation of CSA practices in the study area

Table 4 shows that the respondents' usage of CSA practices largely depended on the barriers they faced in implementing these practices. The smallholder farmers ranked increased occurrences of diseases and pests as the greatest barrier (WAI = 1.173) followed by limited access to agricultural technologies (WAI = 1.100). These were the two key barriers identified by the farmers as limiting their adoption and use of CSA practices in the study area. This is in line with the findings of Antwi-Agyei et al. [6]. The major challenge posed by increased pests and disease incidence was the reduction in desired crop yield coupled with the increased cost of production through the purchases of pesticides [57]. This was further emphasized by a key informant:

> "*When compared to now, there used to be fewer pest infections, but new pests and diseases are attacking our crops and lowering yields*"- (Key informant, Bomini June 2022).

Furthermore, the smallholder farmers reported other challenges faced by increased occurrences of diseases and pests including the contribution to food shortages and harming their poor rural communities. The pests cause direct harm to the farmers through bites, stings, diseases, and general annoyance. The increased incidence of diseases and pests has been aggravated by climate variability. Climate variability affects rainfall and temperature, which happen to be the two leading determinants of where pests spread their diseases [58]. Many insect pests increase in population in warm and humid environments [58]. However, too much moisture can restrict growth by washing away insect eggs and larvae from the host plants [59]. This dilemma has forced insects to move to moderate regions with more stable heat and rainfall levels [59]. That means vector-borne diseases will come into contact with healthy crops and human populations, giving rise to the expansion of the range of diseases [59].

Secondly, limited access to agricultural technologies was regarded as the second highest barrier to farmers' adoption and subsequent use of CSA practices. It was observed that the lack and/or limited access to agricultural technologies such as improved seeds prevented farmers from using such CSA practices even though they were willing to pay for such improved technologies [60,61]. The adoption of agricultural technologies for sustainable farming systems is a challenging and dynamic issue for farmers, extension services, agri-businesses, and policymakers [62]. Inadequate levels of education, access to advice, and pressures on financial resources for some farmers slow the adoption of some agricultural technologies, particularly those in rural communities [62].

The 3rd highest-ranked barrier was the high cost of improved crop varieties and limited government support with farm inputs (WAI

Table 4
Barriers to the adoption and implementation of CSA practices in the study area.

Barriers	Yes	No	WAI	Rank
Increased incidences of pests and diseases	174	2	1.173	1
Limited access to agricultural/farming technologies	152	13	1.100	2
High cost of improved crop varieties	142	18	1.067	3
Limited government support with farm inputs	142	18	1.067	3
Lack of knowledge and education on climate-smart agricultural practices	140	19	1.060	5
High illiteracy of smallholder farmers	130	24	1.027	6
Unavailability of improved crop varieties	98	40	0.920	7
Insufficient organic materials for composting	96	41	0.913	8
Inadequate access to agricultural credits	92	43	0.900	9
Limited access to weather and climate information	90	44	0.893	10
Bushfires destroying crop residues and biomass	34	72	0.707	11

= 1.067). In most developing countries including Ghana, the majority of smallholder farmers use traditional crop varieties, which give low yields and may be vulnerable to drought, heat, diseases, and other stresses. Modern improved varieties offer much higher yields, better quality, and more stable production [63]. The new varieties are suitable for rainfed agriculture in areas where rainfall is erratic [63]. However, the farmers were hindered by their high costs considering they were smallholders. Further, the farmers also complained about limited government support with farm inputs. Farm inputs are the resources for a farm that require upfront purchases necessary to begin production [64]. These are items such as fertilizer, pesticides, seeds, weaned animals, feed, and any other production input. The economic importance of smallholder farmers in Ghana is not reflected by their earnings which are meager and vulnerable to shocks [65]. One problem is that smallholder farmers lack the capital to acquire high-quality seeds, fertilizer, and crop protection products, all of which help boost yields. Loans from the capital market come with high interest rates. This means smallholder farmers cannot plan and maximize production, and instead live from cycle to cycle, saving seed from one harvest to grow the next.

The least important barrier ranked by farmers in our study area was the destruction of crop residues and biomass by bushfires. Contrary to the findings of Dapilah et al. [66], bushfires were not a significant barrier to farmers in the study area. This may be due to the increase in awareness about bushfires across the country by government agencies such as the National Disaster Management Organization (NADMO). This was also highlighted by another key informant.

> "*I'm not too surprised that the farmers perceived bushfires as the least important barrier. Recently, there has been proper education and awareness creation by NADMO on the dangers of bushfires in this community. Hence, the burning of debris by farmers has all reduced drastically. Also, I have realized the smallholder farmers are playing their part in preventing/managing those that are accidentally triggered*" – (Key informant, Fiaso, June 2022).

4. Conclusion and policy implications

This study assessed how smallholder farmers are building their resilience to climate variability through the adoption of CSA practices in the Bono East Region, Ghana. Findings showed that rainfall has been changing while temperature has been rising in the study area. Studies (e.g. Refs. [67,68]) have shown that climate variability could reduce agricultural productivity thereby having significant effects on the income and livelihoods of smallholder farmers. CSA is embedded in sustainable and resilient agriculture, thus, it is imperative to build the resilience of smallholder farmers through the adoption of CSA. Findings indicated that the farmers used key CSA practices including appropriate fertilizer application, mixed farming, and crop diversification. However, they were confronted with key barriers such as increased occurrences of diseases and pests, limited access to farming technologies, high cost of improved crop varieties, and limited government support with farm inputs.

These findings have considerable policy implications. Ghana is experiencing inconsistent rainfall and rising temperature trends which threaten farming productivity and growth. The country's economy is susceptible to climate variability because the economy is highly dependent on rain-fed agriculture and most of the farmers are smallholders. To achieve food security goals within the context of enhanced climate variability, tenable enhancements in agricultural productivity through the implementation of CSA practices and technologies must be incorporated into Ghana's climate change policies and strategies. Key CSA practices as identified in this study should be prioritized by smallholder farmers in their farming practices to boost household food security and enhance their income and livelihoods. Appropriate policies should be put together by policymakers or strengthened to address the barriers and facilitate the implementation of CSA practices. For instance, the best thing we can do to fight the spread of pests and diseases is to improve our monitoring systems. Early warning technologies that allow the detection of diseases in plants within days of contamination must be developed to allow farmers, researchers, and officials to make informed decisions promptly. Also, since climate variability promotes insect growth and migration through rising temperatures and rainfall, enabling foreign diseases to reach fresh populations, it is important to enhance surveillance efforts and look for more natural and eco-friendly solutions to reduce health risks from pests in agriculture. Furthermore, subsidizing improved crop varieties by the government of Ghana for smallholder farmers has the potential to address the barrier of the high cost of improved crop varieties. This can be done directly by reducing the cost. Lastly, several factors including research and development efforts, better education and training of farmers, the shift in the focus of advice, quicker and cheaper means of disseminating and sharing information, availability of financial resources, pressures from consumers, non-government organizations, the media, and the public, in general, could contribute towards facilitating the adoption of sustainable agricultural technologies.

5. Limitations of the study and future research directions

The study did not assess the socioeconomic or institutional factors affecting the smallholder farmers' adoption or implementation of the prioritized CSA interventions in the study area. Hence, it is suggested that future studies take into consideration the determinants of smallholder farmers' adoption or implementation of CSA practices. Furthermore, the study was limited to five communities in the Bono East Region of Ghana and hence cannot be used to represent the perceptions of other smallholder farmers in other regions of Ghana. It is therefore recommended that future research considers other regions to explore the local CSA interventions and practices required to continually build the resilience of smallholder farmers in Ghana to address the adverse impacts of climate change and variability and enhance food security in the country.

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Declaration of competing interest

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

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