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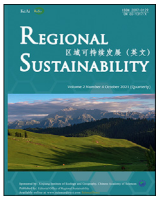

Full Length Article

Motivations, enablers and barriers to the adoption of climate-smart agricultural practices by smallholder farmers: Evidence from the transitional and savannah agroecological zones of Ghana

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ABSTRACT

This paper examined the prioritized climate-smart agricultural practices by smallholder farmers, the motivations of adopting climate-smart agricultural practices, the enablers to the successful adoption of climate-smart agricultural practices, and the barriers to the successful adoption of climate-smart agricultural practices in the transitional and savannah agroecological zones of Ghana. Specifically, we employed ethnographic research using participatory approaches, including two stakeholder workshops and household surveys with 1061 households in the transitional and savannah agroecological zones of Ghana. The weighted average index (WAI) and problem confrontation index (PCI) were used to rank smallholder farmers' perceived enablers to the adoption of climate-smart agricultural practices and the barriers affecting climate-smart agricultural practices, respectively. Results suggest that the majority of the respondents used a suite of climate-smart agricultural practices, including the timely harvesting of produce and storage, emergency seed banking, appropriate and timely weed and pest control, and early planting as practices to build climate resilience. The majority of smallholder farmers primarily employed climate-smart agricultural practices to improve household food security (96.2%), reduce pests and diseases (95.6%), and obtain higher yields and greater farm income (93.2%). Findings also show that secured land tenure system arrangement, understanding the effects of climate change, and access to sustainable agricultural technologies were ranked the first, second, and third most important enablers to the adoption of climate-smart agricultural practices with the WAI values of 2.86, 2.75, and 2.70, respectively. Key barriers to the successful adoption of climate-smart agricultural practices included incidences of pests and diseases (PCI = 2530), inadequate access to agricultural credit (PCI = 2502), high cost of improved crop varieties (PCI = 2334), and limited government support with farm inputs (PCI = 2296). Smallholder farmers need to be better supported through the provision of appropriate institutional and policy arrangements together with improved land management extension advice to overcome these barriers and facilitate the more effective implementation of climate-smart agricultural practices in Ghana.

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1. Introduction

Climate change and variability continue to wreak havoc on socio-ecological processes across sub-Saharan Africa, with agricultural systems particularly vulnerable because of the dependence on rain-fed systems (Niang et al., 2014). Wider institutional and technological weaknesses coupled with higher poverty rates continue to heighten the vulnerability of sub-Saharan Africa to climate change and variability. Ghana, especially northern Ghana, is characterized by high rainfall variability and increasing temperature (Asante and Amuakwa-Mensah, 2015). Mean annual temperature is projected to increase by 0.8 °C by 2020 and 5.4 °C by 2080 across all Ghanaian agroecological zones (Minia and Agyemang-Bonsu, 2008), with the greatest rate of change in temperature likely to occur in the northern-eastern part of the country (Klutse et al., 2020).

Climate extremes including droughts and floods already jeopardize crop development and yields, with negative implications on the livelihoods of vulnerable communities (Government of Ghana (GoG), 2013). The GoG has demonstrated commitment in addressing the threats of climate change through the development of the National Climate Change Policy (GoG, 2013) and the National Climate Smart Agriculture and Food Security Action Plan, which aim at facilitating and operationalizing climate change policy for integration of climate change into food and agricultural sector development policies and programmes (Essegbey et al., 2015).

There has been a greater demand for equitable adaptation interventions and how these can be scaled up to address climate risks (Ford et al., 2015). One of the approaches for dealing with the effects of climate change is the use of climate-smart agriculture, which is defined as any agricultural practice or technology or intervention undertaken to sustainably increase crop yield, build adaptive capacity, and remove or reduce greenhouse gases emission from agricultural activities (FAO, 2013; Lipper et al., 2014; Partey et al., 2018). Climate-smart agriculture seeks to transform the agricultural sector and support food security under a changing climate through a holistic planning of agricultural activities defined through establishing linkages between adaptation and mitigation efforts (Lipper et al., 2014).

Climate-smart agriculture has been embedded in traditional agricultural practices that have been used to buffer the adverse impacts of climate change and variability. Various past studies have demonstrated the effectiveness of using climate-smart agricultural practices to address climate change risks in agricultural systems (Partey et al., 2018; Issahaku and Abdulai, 2020). Common climate-smart agricultural practices employed by smallholder farmers such as conservation agriculture, climate information services, agroforestry practices, and erosion control techniques all aim at addressing the threats of climate change (FAO, 2013; Lipper et al., 2014; Partey et al., 2018). Antwi-Agyei et al. (2021a) found that timely access to accurate climate information services was also necessary for the adaptation practices of smallholder farmers in northern Ghana. In southern Africa, study of Thierfelder et al. (2015) suggested positive effects of maize yield response across diverse agroecosystems under conservation agriculture compared to conventional system. Other studies have reported that smallholder farmers' adoption of climate-smart agricultural practices included water conservation, and that conservation tillage could lead to higher crop revenues which reduced the economic risk in crop production (Sain et al., 2017; Issahaku and Abdulai, 2020). From the prospects of climate-smart agricultural development and promotion, Partey et al. (2018) found that smallholder farmers valued agroforestry, climate information services, and soil and water conservation technologies as highly promising climate-smart agricultural practices for climate change adaptation and risk management among smallholder farmers in western Africa. However, there is a lack of evidence on what explicitly motivates smallholder farmers in climate change vulnerability hotspots to adopt climate-smart agricultural practices. There is also limited empirical evidence on the barriers and enablers that tend to reduce or enhance the effectiveness of climate-smart agricultural practices in vulnerability hotspots.

This paper aims to provide an understanding of what motivates smallholder farmers in the transitional and savannah agroecological zones of Ghana to adopt climate-smart agricultural practices and the key enablers and barriers confronting farming households in their attempt to implement such practices. The research questions guiding this paper are:

(1) What are the prioritized climate-smart agricultural practices by smallholder farmers?
(2) What are the motivations for the adoption of climate-smart agricultural practices?
(3) What are the enablers to the successful adoption of climate-smart agricultural practices?
(4) What are the barriers to the successful adoption of climate-smart agricultural practices?

2. Materials and methods

2.1. Study area

This study was conducted in three regions of Ghana: Bono East region, Northern region and Upper West region (Fig. 1). The regions were selected because of the overall vulnerability to climate change risks (Klutse et al., 2020). These regions are characterized by high degrees of rainfall variability coupled with high incidence of poverty, illiteracy, and low level of infrastructural development (Ghana Statistical Services (GSS), 2015; Klutse et al., 2020). We selected three local assemblies (districts/municipality) due to their overall vulnerability to climate change (GSS, 2015; Klutse et al., 2020) and based on the advice from regional-level agricultural development officers: Kintampo South District (Bono East region), Savelugu Municipality (Northern region), and Lambussie-Karni District (Upper West region). Within each district, we chose three farming communities according to the suggestion from the district agricultural development officers and extension officers. Consequently, Apesika, Ayorya, and Suamire were selected in the Kintampo South District. The Kintampo South District experiences the wet semi-equatorial climate owing to its transitional zone between the wet semi-equatorial and tropical continental climates (GSS, 2014a). Characterized by the double rainfall pattern, its mean annual rainfall is between 1400 and 1800 mm, and the mean annual temperature is between 24 °C in August and 30 °C in March. About 88% of households in the district are engaged in agricultural activities (GSS, 2014a).

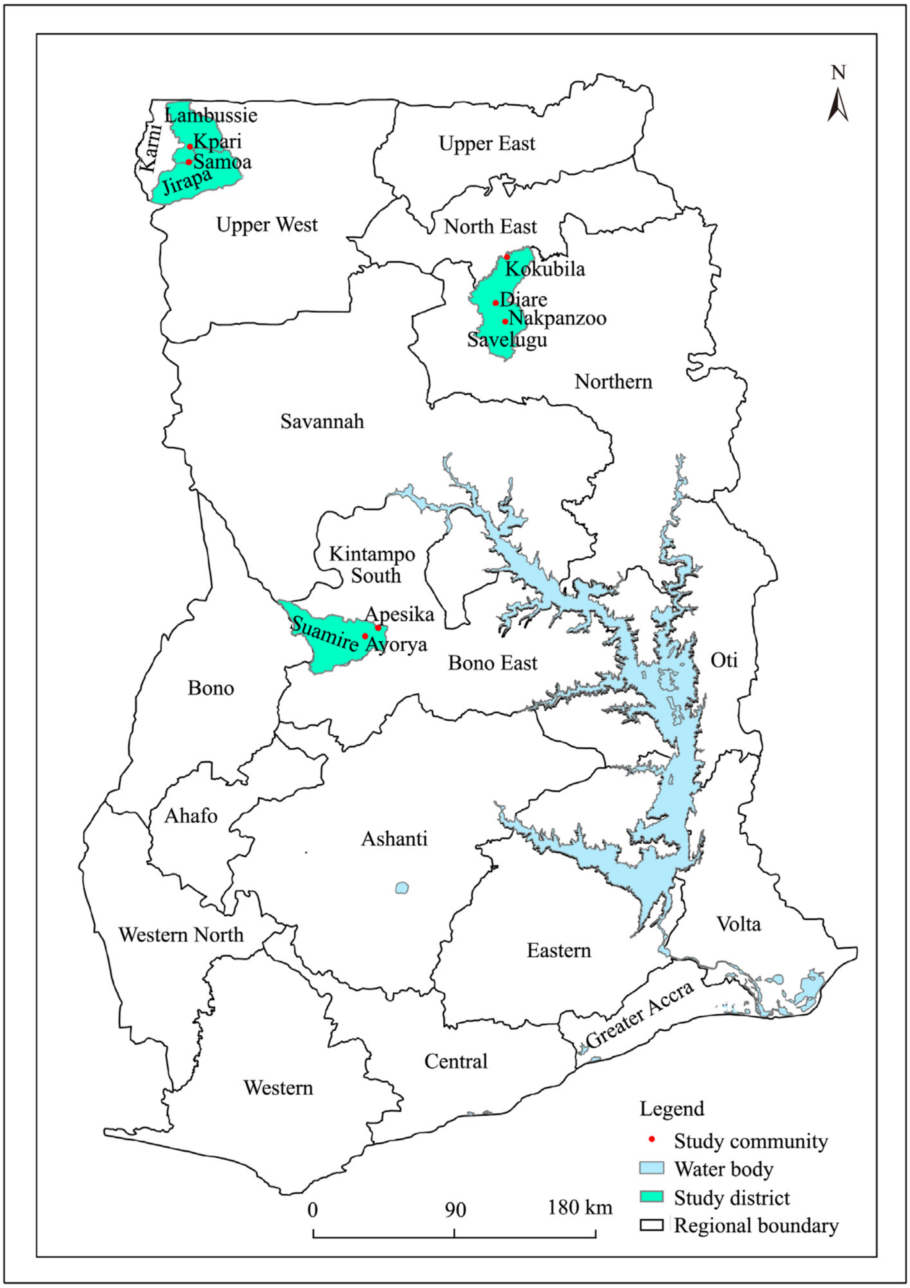

Fig. 1. Location of the study area and the studied communities.

Within the Savelugu Municipality, Nkapandzoo, Diare, and Kukobila were selected. The Savelugu Municipality experiences a single rainfall pattern, with the mean annual rainfall between 600 and 1000 mm. This district is characterized by high temperatures (mean of 34 °C) (GSS, 2014b). Similar to the Kintampo South District, about 89% of households engage in agriculture (GSS, 2014b).

Karni, Kpare, and Samoa are the studied communities selected from the Lambussie-Karni District. This district experiences a single rainy season, which starts in May and ends in September, giving a long dry season usually from October to April. The mean annual rainfall is between 900 and 1100 mm (GSS, 2014c). The district lies in the tropical continental climatic zone with the mean annual temperature between 28 °C and 31 °C. Of the 84% of households engaged in agriculture in the district, 96% are involved in subsistence crop farming (GSS, 2014c).

2.2. Research design and methods

This study used an ethnographic approach to understand the lived experience of smallholder farmers on the motivation for implementing climate-smart agricultural practices and the barriers confronting smallholder farmers in the implementation of climate-smart agricultural practices in vulnerability hotspots. Ethnographic approaches have been employed in climate researches (e.g., Nyantakyi-Frimpong, 2020; Antwi-Agyei et al., 2021a) and their utility was explored in this study. Data collection was conducted in nine studied communities selected from the three studied districts located in Bono East, Northern and Upper West regions from October to December in 2020 (Table 1). Prior to data collection, rapid rural assessments and community engagements were conducted to introduce the purpose of this study to the studied communities. Data were collected using surveys with randomly selected 1061 households with the help of CSPro software (Ponnusamy, 2012) in the three farming communities (Table 2). Data collection was conducted with the assistance of local interpreters. The questionnaire was focused on socioeconomic characteristics of the respondents, the key climate-smart agricultural practices, and the enablers and barriers to the implementation of such practices. The questionnaire also sought answers to the key motivations for employing these agricultural practices. Climate-smart agricultural practices were prioritized using Likert scale (Sullivan and Artino-Jr, 2013) ranging from 1 to 4 (where 1 = never used, 2 = rarely used, 3 = often used, and 4 = used every year). Administration of the questionnaire was done at the respondent's house and typically lasted for 1 hour.

The fieldwork was followed up with two stakeholder workshops held in the Kintampo South District in February 2021 ($n = 30$, where n represents the number of participants) and Lambussie-Karni District in February 2021 ($n = 28$). The workshops were organized to discuss the results obtained from the household surveys. Participants on the workshop were from the government departments including the Ministry of Food and Agriculture, smallholder farmers, and Non-Governmental Organizations. Workshop discussions were focused on the key climate-smart agricultural practices employed by smallholder farmers in the districts, the motivations for implementing the practices, and the barriers and enablers to the climate-smart agricultural practices. Responses from the workshops were analyzed in content and relevant themes were identified from the transcripts.

Table 1
Characteristics of the studied districts (GSS, 2014a, b, c).

Item	Kintampo South District	Savelugu Municipality	Lambussie-Karni District
Agro-ecological zone	Wet semi-equatorial climate	Savannah ecological zone	Tropical continental climatic zone
Average temperature (°C)	24–30	16–42	28–31
Annual rainfall (mm)	1400–1800	600–1000	900–1100
Relative humidity (%)	65	50	47
Major cropping season	March–June	May–October	May–September
Minor cropping season	August–November	Not applicable	Not applicable
Main crops	Yam, cassava, cocoyam, rice, plantain, ground nut, cowpea, and other tree crops such as cashew and mango	Maize, rice, cowpea, groundnut, sorghum, soyabean, millet, and cassava	Maize, rice, sorghum, millet, yam groundnut, and cowpea
Main livelihood activity	Agriculture (crop farming)	Agriculture (crop farming)	Agriculture (crop farming)

Table 2
Characteristics of the studied communities.

Item	Kintampo South District ($N = 395$; 37.2%)			Savelugu Municipality ($N = 351$; 33.1%)			Lambussie-Karni District ($N = 315$; 29.7%)		
	Apesika	Suamire	Ayorya	Diare	Kukobila	Nakpanzoo	Karni	Kpare	Samoa
Total households[a]	775	-	279	1129	-	-	477	144	325
Sampled households	166 (42.0%)	111 (28.1%)	118 (29.9%)	211 (60.1%)	75 (21.4%)	65 (18.5%)	89 (28.2%)	109 (34.6%)	117 (37.1%)
Type of farmers	Predominantly smallholders	Predominantly smallholders	Predominantly smallholders	Predominantly smallholders	Predominantly smallholders	Predominantly smallholders	Predominantly smallholders	Predominantly smallholders	Predominantly smallholders

Note: [a], Data from GSS (2014a, b, c). N represents the number of respondents. -, not available. The percent in parenthesis refers to the percentage of the sampled households in each community.

2.3. Data analysis

In this study, we adopted the Relative Importance Index (RII) to determine the most used climate-smart agricultural practices in the studied communities. The RII is used to assess the degree of usage of climate adaptation practices and arrange them in order of merits (Kassem et al., 2020). Equation (1) was used to calculate the RII:

$$\mathrm{RII} = \sum \frac{W}{A \times N}, \tag{1}$$

where, W is the weight given to an individual statement provided by the respondents, ranging between 1 and 4; A represents the highest response integer (4); and N represents the total number of respondents.

Chi-square analysis was used to determine the association between gender and smallholder farmers' perceived motivations to adopt climate-smart agricultural practices in the studied districts. The Chi-square analysis was conducted using STATA (Sterne, 2009). The level of significance was set at the 95% confidence interval. The formula for computing Chi-square statistic (χ^2) is:

$$\chi_c^2 = \sum \frac{(O_i - E_i)^2}{E_i}, \tag{2}$$

where c is the degree of freedom; O_i is the observed value; and E_i is the expected value.

To identify the key enablers to the implementation of climate-smart agricultural practices, we used a weighted average index (WAI) to rank smallholder farmers' perceived enablers to adopt climate-smart agricultural practices using Equation (3) (Devkota et al., 2014; Ndamani and Watanabe, 2015). Often applied to theoretically expected outcome with different probability outcomes, the WAI was calculated through multiplying the weight of each event with its associated quantitative outcome and, then summing the products of the multiplication together (Devkota et al., 2014). Ranking of the WAI was done by the smallholder farmers on scales ranging from 1 to 5, indicating very low, low, moderate, high, and very high levels, respectively. The frequency (F), importance or weight (W), and score (i) of each enabler to climate-smart agricultural practice were used to calculate the WAI.

$$\mathrm{WAI} = \frac{\sum F_i W_i}{\sum F_i}. \tag{3}$$

The problem confrontation index (PCI) was employed to rank the barriers affecting climate-smart agricultural practices in the studied communities. The PCI in climate change study is defined as a method or an important factor used to evaluate the problem hindering smallholder farmers in adopting a particular climate adaptation or coping strategy (Hossain and Miah, 2011; Uddin et al., 2014). The smallholder farmers ranked their perceived barriers to climate-smart agricultural adoption on a 4-point Likert scale (0, no problem; 1, low problem; 2, moderate problem; and 3, high problem) (Sullivan and Artino-Jr, 2013). Mathematically, the PCI was evaluated as:

$$\mathrm{PCI} = Pn \times 0 + Pl \times 1 + Pm \times 2 + Ph \times 3, \tag{4}$$

where Pn is the number of smallholder farmers who ranked the barrier as no problem; Pl is the number of farmers who ranked the barrier as low level; Pm is the number of smallholder farmers who ranked the barrier as moderate level; and Ph is the number of smallholder farmers who ranked the barrier as high level. The PCI has been used in previous studies, e.g., Hossain and Miah (2011) and Kabir et al. (2019), to rank perceived barriers to climate change adaptation practices.

3. Results and discussion

3.1. Climate-smart agricultural practices

Results indicate that smallholder farmers adopted a wide range of climate-smart agricultural practices to reduce the adverse impacts of climate change on their farming activities. Timely harvesting of produce and storage was ranked the most important climate-smart agricultural practice by the respondents (RII = 0.77; Table 3). Timely harvesting as a climate-smart agricultural intervention is aimed at preventing pests and reducing postharvest losses as well as ensuring that grains are harvested in time for good quality (Shikuku et al., 2015). These considerations are critical in improving the market value of the farm produce and crucially reducing postharvest losses that are often associated with farming activities in Africa (Parfitt et al., 2010; Abass et al., 2014; Affognon et al., 2015). Emergency seed banking (RII = 0.76) was the second most important climate-smart agricultural practice ranked by the respondents due to its ability to provide a buffer against future cultivation planning, improve food varieties, and enhance food security among smallholder farmers. Anuga et al. (2019) acknowledged the centrality of seed banking as a socio-cultural and institutional determinant of climate-smart agricultural adoption decision among smallholder farmers within the Techiman Municipality, Ghana. This practice falls under the knowledge smart practice, one of climate-smart agricultural practices advocated by the World Bank, which is recommended to smallholder farmers as an imperative in their climate change adaptation practices (Keshavarz and Karami, 2014). The relevance of this intervention cannot be underestimated given their vulnerability to floods and droughts (Klutse et al., 2020), as well as the poverty incidence among smallholder farmers in Ghana (GSS, 2015).

Crop rotation (RII = 0.75) was reported as the third most important climate-smart agricultural practice due to its potential to improving or maintaining good physical, chemical, and biological conditions of the soil. This finding compares favorably with other

Table 3
Climate-smart agricultural practices adopted by smallholder farmers in the study area.

Climate-smart agricultural practices	Number of smallholder farmers adopting these practices ($n = 1061$)				RII	Rank
	Never used ($W = 1$)	Rarely used ($W = 2$)	Often used ($W = 3$)	Used every year ($W = 4$)		
Timely harvesting of produce and storage	42	145	564	309	0.77	1
Emergency seed banking	77	190	398	395	0.76	2
Crop rotation	97	141	468	354	0.75	3
Appropriate and timely weed and pest control	48	229	473	310	0.75	3
Early planting	81	209	537	233	0.72	4
Appropriate fertilizer use	91	228	476	265	0.72	4
Appropriate planting methods and spacing	73	238	560	189	0.71	5
Planting early maturing varieties of crops	186	200	496	178	0.66	6
Mixed cropping	208	195	454	203	0.66	6
Planting legumes among crops	240	230	390	200	0.63	7
Use of indigenous or traditional agro-ecological knowledge	231	245	451	133	0.62	8
Cover cropping	268	241	388	163	0.61	9
Appropriate land preparation, with no slash and burn	198	367	355	140	0.61	9
Bush fallowing	293	239	359	169	0.60	10
No burning of residues or biomass on farms	248	372	308	132	0.58	11
Crop diversification	236	377	351	96	0.58	11
Crop residue mulching	357	243	279	181	0.57	12
Zero tillage/minimum tillage	345	241	325	149	0.57	12
Using drought tolerant crop varieties	298	309	351	102	0.57	12
Conservation agriculture	244	388	372	56	0.56	13
Use of pest resistant plant varieties	320	323	287	130	0.56	13
Use of climate information services	241	395	390	34	0.56	13
Water management and water harvesting	385	207	379	89	0.55	14
Mixed farming	505	212	285	58	0.48	15
Agroforestry and woodlot schemes	681	234	128	17	0.38	16
Composting	691	258	88	23	0.37	17
Earth bunding	785	201	64	10	0.34	18
Crop insurance schemes	810	206	33	11	0.33	19
Sprinkler and drip irrigation	870	120	49	21	0.32	20
Tillage by bullock	906	92	35	27	0.31	21
Stone bunding	943	97	18	2	0.29	22

Note: W is the weight given to an individual statement provided by the respondents. RII is the Relative Importance Index.

studies suggesting that the adoption of crop rotation positively influenced the livelihood activities of smallholder farmers in Kenya (Ogada et al., 2020), Vietnam (Luu, 2020), and Guatemala (Sain et al., 2017). Adzawla and Alhassan (2021) suggested that crop rotation is an effective way to improve soil structure and fertility. Other climate-smart agricultural practices reported by the respondents included planting early maturing varieties of crops, agroforestry and woodlot schemes, water management and water harvesting, earth bunding, crop residue mulching, and zero tillage/minimum tillage. Soil and land management practices such as crop residue mulching and zero tillage improve the microclimate, boost soil fertility, and reduce the high intensity of direct sunlight on the crops and soil nutrients (Fagariba et al., 2018).

Climate services and the use of indigenous knowledge information to inform climate change adaptation practices were also reported by the respondents. Smallholder farmers use climate information services and their indigenous traditional knowledge to design and make farm management and crop choice decisions. Indigenous traditional knowledge is an integral part of the agricultural system in northern Ghana where smallholder farmers rely heavily on the happenings around their environment to make important farming decisions (Baffour-Ata et al., 2021). Therefore, the availability and access to timely accurate climate information is critical for the adaptation efforts of smallholder farmers (Antwi-Agyei et al., 2021b). The least important climate-smart agricultural practice considered by the respondents was stone bunding (RII = 0.29), a practice which is related to soil and water conservation where structures are built using stones with 20–30 cm height. It is effective in controlling soil erosion, increasing soil water status, contributing to effective rainwater harvesting, and reducing downward particle transport (Zougmoré, 2003; Zougmoré et al., 2004, 2014). The practice was the least important technique practiced by the respondents due to the labor demands for collecting and transporting the stones used in constructing the bunds (Zougmoré et al., 2014). The results on climate-smart agricultural practices resonate with previous studies suggesting that smallholder farmers in dryland farming systems are employing a host of practices to manage climate risks and sustain livelihood and food security (Fagariba et al., 2018; Williams et al., 2018; Rahut et al., 2021).

3.2. Motivations for the adoption of climate-smart agricultural practices

Table 4 shows that the respondents used a specific climate-smart agricultural practice based on a variety of motivating factors. The majority of the respondents reported that they used climate-smart agricultural practices to improve household food security ($N = 1020$; 96.2%), and increase yields and farm income ($N = 988$; 93.2%). These are important motivating factors as they regulate the decisions of

Table 4
Motivations for the adoption of climate-smart agricultural practices.

Motivations	*N*		Mean	SD	Var.	*P*-value	χ^2
	Yes	No					
Household food security improvement	1020 (96.2%)	40 (3.8%)	0.960	0.191	0.036	0.091	2.86
Reducing pests and diseases	1013 (95.6%)	47 (4.4%)	0.960	0.206	0.042	0.790	0.07
Increasing yields and farm income	988 (93.2%)	72 (6.8%)	0.930	0.252	0.063	0.952	0.00
Controlling erosion and protecting soil	948 (89.4%)	112 (10.6%)	0.890	0.308	0.095	0.690	0.16
Avoiding the effect of droughts on farming	918 (86.6%)	142 (13.4%)	0.870	0.341	0.116	0.673	0.18
Maintaining soil moisture	916 (86.4%)	144 (13.6%)	0.860	0.343	0.118	0.779	0.08
Avoiding the effect of high temperature on farming	901 (85.0%)	159 (15.0%)	0.850	0.357	0.128	0.387	0.75

Note: *N*, the number of the respondents. Number in parenthesis refers to percentage. SD, standard deviation; Var., variance; χ^2, Chi-square test value.

farming households, and determine their source of income and their ability to meet their basic needs. Little emphasis is placed on adapting and mitigating the impact of climate risks on their farm, notwithstanding the fact that some of the productivity practices indirectly enhance agricultural resilience and mitigate greenhouse gases emission. This finding is in keeping with several studies in sub-Saharan Africa where smallholder farmers adopted climate-smart agricultural practices based on their ability to increase household security and improve agricultural yields and on-farm income (Katengeza et al., 2012; Justin et al., 2017; Onyeneke et al., 2018; Myeni et al., 2019; Abegunde et al., 2020). An increase in farm income makes it easier to adopt climate-smart agricultural practices for information disseminated through smallholder farmers' group membership, extension services, and the media. This makes financial empowerment as a crucial consideration in mainstreaming climate-smart agricultural practices by smallholder farmers (Myeni et al., 2019; Abegunde et al., 2020), including improving agricultural yields and sustaining household security (Niang et al., 2014; Sain et al., 2017; Jew et al., 2020). This evidence was corroborated by workshop participants who pointed to the reason for implementing climate-smart agricultural practices.

Findings indicate that farming households are predominantly employing climate-smart agricultural interventions to increase crop yield, ensure food security, and increase household income. The need to reduce pests and diseases on the respondents' farm was also reported ($N = 1013$; 95.6%). Reducing pests and diseases is an important determinant of the yield capacity and market value of the respondents' livelihood activities (Anuga et al., 2019). Both Rochecouste et al. (2015) and Anuga et al. (2019) reported that the incidence of pests and diseases can reinforce the economic and environmental determinants of climate-smart agricultural practices.

Our findings show that gender had no significant influence on the respondents' motivating factor to use a climate-smart agricultural practice in the studied communities ($p > 0.05$; Table 4). Other motivating factors including the need for erosion control and soil protection as well as soil moisture retention are all practices geared towards improvement in the soil to promote crop development and yield. With little or no replenishing of lost soil fertility, the soil in the studied districts has become depleted of nutrients, making it difficult to support plant growth and productivity (Braimoh and Vlek, 2004). Smallholder farmers are therefore employing various climate-smart agricultural practices aimed at maintaining or regulating soil moisture and improving the fertility of the soil.

3.3. Key enablers to the adoption of climate-smart agricultural practices

Table 5 presents the ranking of smallholder farmers' perceived enablers to adopt climate-smart agricultural practices in the studied communities. Among the nine perceived enablers, secured land tenure system arrangement, understanding the effects of climate change, and access to sustainable agricultural technologies were ranked the first, second, and third with the WAI values of 2.86, 2.75, and 2.70, respectively. Access to land and security of tenure is an important determinant of agricultural investment in sub-Saharan Africa (Branca and Perelli, 2020; Tsige et al., 2020), particularly in Ghana (Antwi-Agyei et al., 2015; Asaaga et al., 2020). It determines the extent to which smallholder farmers are willing to invest in agricultural lands. For instance, Antwi-Agyei et al. (2015) observed that households and individuals with access and security of tenure invested in agroforestry practices as an adaptation practice to improve food and livelihood security. This was underpinned by the security of benefiting from such investments in the long-term. Therefore, it is perceived that land tenure security can favorably inform the adoption of climate-smart agricultural practices among smallholder farmers as observed in some studies in sub-Saharan Africa (Asaaga et al., 2020; Tsige et al., 2020).

Knowledge of the impacts of climate change helps smallholder farmers to proactively safeguard their livelihood activities from climate risk (Aryal et al., 2018; Abegunde et al., 2020). Smallholder farmers will initiate adaptation practices only when they can perceive and understand the effects of climate change on their farming operations. This highlights the necessity of awareness creation on the impacts of climate change on agriculture especially among arable smallholder farmers by policymakers, development planners, and the scientific community in supporting the adoption of climate-smart agricultural practices (Nelson and Huyer, 2016). The respondents' priority ranking of these enablers is in keeping with the burgeoning literature reported among sub-Saharan African smallholder farmers in their adoption or otherwise of climate-smart agricultural practices.

Support from local government authorities, support from social group organizations, support from traditional leaders, and access to farmer-based insurance were the lowest ranked enablers, with WAI values of 2.08, 2.08, 2.07, and 1.83, respectively (Table 5). This is interesting as membership of a group provides a social network from which smallholder farmers access farm-related information and provide support to one another (Ojoko et al., 2017). Membership to such organizations bestows a social capital, which could influence public perception (Aryal et al., 2018; Abegunde et al., 2020) and has been reported to positively influence the adoption of climate-smart

Table 5
Enablers to climate-smart agricultural practices.

Enablers	Number of respondents reporting enablers					WAI	Rank
	Very low level	Low level	Moderate level	High level	Very high level		
Secured land tenure system arrangement	178	271	262	223	126	2.86	1
Understanding the effects of climate change	153	264	406	171	66	2.75	2
Access to sustainable agricultural technologies	150	297	392	165	56	2.70	3
Access to financial resources to implement climate-smart agriculture practices	338	259	113	132	185	2.68	4
Access to weather and climate information	236	255	320	193	56	2.60	5
Support from social group organizations	428	323	150	116	43	2.08	6
Support from local government authorities	475	277	129	106	73	2.08	6
Support from traditional leaders	471	288	123	113	65	2.07	8
Access to farmer-based insurance	635	174	101	101	49	1.83	9

Note: WAI, weighted average index. Ranking of the WAI was done by the smallholder farmers on scales ranging from 1 to 5, indicating very low, low, moderate, high, and very high levels, respectively.

agricultural practices among smallholder farmers (Abegunde et al., 2020; Tsige et al., 2020). The decision by the respondents to rank these factors the least enablers should be further explored in line with the GoG planning priorities. During the stakeholder workshops, the participants highlighted the integral role of government support services, finances, social support groups, and timely delivery and access to climate and weather information in enabling smallholder farmers to adopt climate-smart agricultural practices.

3.4. *Barriers affecting climate-smart agricultural practices*

Results indicate that incidences of pests and diseases was the highest ranked barrier affecting climate-smart agricultural practices by the respondents (PCI = 2530) as their presence cause problems by damaging crops and food production, and reducing the market value of the farm produce (Table 6). As an environmental concern, occurrence of pests and diseases influences smallholder farmers' climate-smart agricultural practice decisions as it limits the desirable crop yields and increases the cost of farming through procuring pesticides (Rochecouste et al., 2015; Anuga et al., 2019; Deguine et al., 2021). This challenge was succinctly explained by the smallholder farmers, as well as agricultural extension officers in the studied communities during the community engagement workshops where they expressed various views on the threats of pests and diseases.

Table 6
Barriers affecting climate-smart agricultural practices reported by the respondents.

Barriers	Number of respondents reporting barriers				PCI	Rank
	No problem	Low level	Moderate level	High level		
Incidences of pests and diseases	15	111	383	551	2530	1
Inadequate access to agricultural credit	48	159	216	637	2502	2
High cost of improved crop varieties	24	229	316	491	2334	3
Limited government support with farm inputs	46	211	324	479	2296	4
Destruction of crops by animals (e.g., cattle)	147	135	194	584	2275	5
Bushfires destroying crop residues and biomass	92	196	276	496	2236	6
High illiteracy level of smallholder farmers	34	275	348	403	2180	7
Limited access to agricultural technologies	19	294	436	311	2099	8
Lack of knowledge and education on climate-smart agricultural practices	23	339	429	269	2004	9
Lack of access to productive farm inputs including fertilizers	70	329	400	261	1912	10
Limited access to weather and climate information	77	362	372	249	1853	11
Limited user-friendliness of climate-smart agricultural practices	46	419	408	187	1796	12
Limited access to ready markets and market information	239	259	255	307	1690	13
Unavailability of improved crop varieties	101	432	345	182	1668	14
Shortages of timely labor for climate-smart agricultural practices	197	304	337	222	1644	15
Inadequate agricultural land for climate-smart agricultural practices	249	310	269	232	1544	16
Insufficient organic materials for composting	215	461	192	192	1421	17
Insecure land tenure system to accommodate long duration of observing the effects of climate-smart agricultural practices	214	434	249	163	1421	17
Challenge with bulky nature of manure	267	405	158	230	1411	19
Lack of enforcement by traditional authorities	281	376	258	145	1327	20
Taboos and values of community	506	354	144	56	810	21
Destruction of farms during tribal conflicts	692	207	87	74	603	22

Note: PCI, Principal Confrontation Index.

This was followed by the inadequate access to agricultural credit (PCI = 2502) and high cost of improved crop varieties (PCI = 2334), which influence the adoption and upscaling of climate-smart agricultural practices. The resource intensiveness and long-term orientation of climate-smart agricultural intervention demand adequate access to credit and funds to purchase the necessary inputs. Finance and access to credit facilities provide smallholder farmers with options and further increase household incomes as they empower smallholder farmers to meet the initial financial outlay involved in adopting most climate-smart agricultural practices (Giller et al., 2009; Khatri-Chhetri et al., 2017; Luu, 2020). Among sub-Saharan African smallholder farmers, access to credit enables users of climate-smart agricultural practices to increase their adoption of climate-smart agricultural practices through purchasing more technology, which was hitherto expensive to purchase (Ojoko et al., 2017; Abegunde et al., 2020). Therefore, access to credit has a positive correlation with the adoption of climate-smart agricultural practices (Khatri-Chhetri et al., 2017; Luu, 2020). Recently, advocacy for blended finance where multiple funding modalities from public and private finance sources are explored for agricultural sustainability investment is growing to help overcome the barrier to agricultural credit among smallholder farmers to support agricultural sustainability (Havemann et al., 2020).

Destruction of crops by animals (e.g., cattle) was also reported by the respondents (PCI = 2275). Smallholder farmers have to wait several months for the rains to come, and when crops are planted, they can be destroyed by animals, particularly cattle. Destruction of crops by animals reflects issues pertaining to crop smallholder farmers and Fulani herdsmen conflict in these regions. Smallholder farmers explained how some Fulani herdsmen intentionally bring their animals to eat their farm produce. The activities of bush meat hunters and smokers, the practice of free range of rearing farm animals, and the absence of by-laws to regulate the activities of nomadic herdsmen and cattle rearing in the communities are some of the factors contributing to the destruction of their crops.

Barriers confronting smallholder farmers in adopting conservation agriculture and crop residue mulching are varied, including limited user-friendliness of climate-smart agricultural practices, shortages of labour, and insufficient organic materials for some practices. For instance, in conservation agriculture, there are challenges pertaining to the widespread use of crop residues for livestock feed and fuel, the lack of knowledge about the effectiveness of conservation agriculture, and burning of crop residues (Bhan and Behera, 2014; FAO, 2021). Barriers militating against the adoption of crop residue mulching include trade-offs with livestock fodder, extra labour or cost, and the likelihood of fungal disease (Erenstein, 2002).

Other important barriers reported by the respondents include a lack of knowledge and education on climate-smart agricultural practices, shortages of timely labour for climate-smart agricultural practices, inadequate agricultural land for climate-smart agricultural practices, limited user-friendliness of climate-smart agricultural practices, and limited access to weather and climate information. The lowest ranked barriers reported by the respondents were contextual taboos and values of community (PCI = 810) and the destruction of farms during tribal conflicts (PCI = 603). Taboos and values are embedded in the sociocultural settings of the studied communities and are often conditions over which smallholder farmers have little control (Anuga et al., 2019). For instance, smallholder farmers explained how they are not allowed to go to farms on certain days of the week because of local belief systems. The same applies to the destruction of farms by tribal conflicts, which constitute a major barrier to the adoption of climate-smart agricultural practices in the studied communities, and often occurs when a farmer plants crops on another's land without prior permission (Anuga et al., 2019).

4. Conclusion and policy implications

4.1. Conclusions

This paper examined the key factors that motivate smallholder farmers' decision to implement climate-smart agricultural practices and the challenges they encounter in the transitional and savannah agroecological zones of Ghana. This study is important as it provides critical information to policy-makers in assisting western African smallholder farmers in managing climate risks by implementing appropriate climate-smart agricultural practices. Results indicate that climate-smart agricultural practices can offer opportunities for smallholder farmers to address the threats posed by climate change on agricultural activities. The results suggest that timely harvesting of produce and storage, emergency seed banking, crop rotation, and appropriate and timely weed and pest control are the four topmost climate-smart agricultural practices adopted by smallholder farmers. The overarching aim for the implementation of climate-smart agricultural practices by smallholder farmers is to improve crop yield and livelihood sustainability.

Other motivations reported by smallholder farmers are related to increasing yields and farm income, reducing pests and diseases, controlling erosion and protecting soil, and maintaining soil moisture. Several factors are required for an enabling environment for the adoption of climate-smart agricultural practices. Prominent amongst these are secure land tenure system arrangement, understanding the effects of climate change, and access to sustainable agricultural technologies. Access to financial resource and weather and climate information are also reported as enablers to the implementation of climate-smart agricultural practices among smallholder farmers. Findings highlight that smallholder farmers are confronted with several barriers that impede the adoption of climate-smart agricultural practices. Key factors amongst these barriers include the incidences of pests and diseases, limited government support with farm inputs, inadequate access to agricultural credit, high cost of improved crop varieties, and lack of knowledge and education on climate-smart agricultural practices. Limited access to weather and climate information, shortages of timely labor for climate-smart agricultural practices, unavailability of improved crop varieties, inadequate agricultural land for climate-smart agricultural practices, and limited user-friendliness of climate-smart agricultural practices are also reported as barriers to the successful adoption of climate-smart agricultural practices.

4.2. Policy implications

These findings have several policy implications for agricultural scientists and policy-makers. First, the design of climate-smart agricultural practices should be closely linked to the improvement of household food security and overall farm yield and income. Second, awareness creation on climate-smart agricultural practices is important to improve the understanding of the effects of climate change. There is the need to proactively promote climate-smart agricultural practices through the enhanced awareness creation and education on the benefits to be derived from the implementation of climate-smart agricultural practices. Such awareness creation and education should be integrated within the overall extension delivery services by the Ministry of Food and Agriculture. Third, smallholder farmers should be supported through the provision of credit facilities in order to implement appropriate climate-smart agricultural practices such as improved crop varieties.

To address the effects of pests and diseases as a barrier to the successful implementation of climate-smart agricultural practices, policy-makers need to encourage smallholder farmers to employ various traditional practices and biodiversity-friendly agriculture. Policy-makers need to address land tenure insecurity that tends to derail efforts by smallholder farmers in addressing climate risks through the implementation of policy-makers practices. Customary landholding arrangements that tend to disadvantage certain socioeconomic groups in the implementation of adaptation practices such as agroforestry should be reviewed.

To derive the benefits of policy-makers practices, smallholder farmers whose livelihoods are threatened by climate change will need to be supported through appropriate institutional training and other support mechanisms, including the provision of weather and climate information. Scaling up climate-smart agricultural practices requires appropriate enabling environment including policy and technical frameworks to support smallholder farmers to overcome barriers to the implementation of climate-smart agricultural practices. The Ministry of Food and Agriculture should partner with its regional and local agencies, including the Ghana Meteorological Agency, and Ministry of Environment, Science, Technology and Innovation to foster contextualized climate-smart agricultural training for smallholder farmers within the contexts of the local conditions militating against climate-smart agricultural implementation among smallholder farmers.

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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