Energ. Ecol. Environ. (2021) 6(3):271–284
https://doi.org/10.1007/s40974-020-00181-3

ORIGINAL ARTICLE

Climate change resilience: lessons from local climate-smart agricultural practices in Ghana

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Received: 24 March 2020 / Revised: 24 July 2020 / Accepted: 27 July 2020 / Published online: 2 September 2020

Abstract The need to adapt to the changing climate is one of the important concerns of our time. However, the use of local ecological knowledge (LEK), which farmers have built up over the years to adopt climate-smart agriculture (CSA) practices, has been less explored by researchers and policy scientists. Leveraging on LEK, this study explores various local CSA practices, their benefits and management constraints and suggests ways to improve local CSA practices to enhance farmers' resilience to climate change (CC). We conducted eight focus group discussions (FGD) in eight farming communities in the Western region of Ghana. The data from the FGD was complemented by secondary data from sources such as peer-reviewed journal articles, organisational websites, and quarterly reports. The study found that farmers used LEK to identify key local CSA practices, including agroforestry, cover cropping, crop rotation, mulching, and mixed cropping. However, some of their farming practices are not consistent with sustainable agricultural practices. Key issues that need immediate attention include (i) limited access to agricultural inputs prevented farmers from adopting CSA, (ii) land tenure issues adversely affected access to arable land for farming, (iii) inadequate agricultural training for farmers on CSA practices, (iv) limited access to agricultural information on CSA options, and (v) high labour-intensive activities for some CSA practices. We maintain that governmental efforts to improve local CSA, and in the context of increasing resilience of farmers and local communities, need to engage relevant stakeholders and communities to formulate and develop an effective climate-smart agricultural action plan. The policy implications of these findings and recommendations for future research are also discussed and documented.

Keywords Climate resilience · Climate-smart agriculture · Local ecological knowledge · Focus group · Ghana

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1 Introduction

Climate Change (CC) affects many aspects of our lives. The IPCC (2011) reports that CC is the result of natural internal processes (Vijayavenkataraman et al. 2012) or external forces, or persistent anthropogenic changes (Rapp 2014) in the atmospheric composition or land use. CC has been observed in changing rainfall pattern, temperature, and weather events. Its implications include global warming and extreme weather events, to which agriculture, the primary source of livelihood in many parts of the global south, is particularly vulnerable (United Nations 1992; McBride 1995; Nicholson 2001; IPCC 2007; Ziervogel et al. 2008; IPCC 2011; Arbuckle et al. 2013). Data from a recent study depict an increase in aridity in several land areas, which has been associated with the changing global climate since 1950 (Dai 2013). The vulnerability of the food production systems implies that the increasing global population will face food security challenges. The recent UN population prospects reveal that 70 per cent more food will be needed to feed an estimated 9.1 billion people by 2050. The feasibility of expanding the global food supply system to meet the growing need for food has been undermined by CC. CC poses challenges to crop yields in many parts of the world

(Challinor et al. 2007; Kang et al. 2009; Hatfield et al. 2011; Roudier et al. 2011; Asseng et al. 2013; Adhikari et al. 2015) whereas the greenhouse gases (GHG) that are emitted by some agricultural practices exacerbate the CC effects. Accordingly, a myriad of innovations have been introduced to promote the resilience of the global food supply system to CC and mitigate the effects of the agricultural systems on the environment. The innovations cover sustainable and ecological-friendly energy supply systems and Climate-Smart Agriculture (CSA). Within the sustainable energy technologies literature, a number of sustainable energy innovations exist that are both energy-smart and climate-smart and can improve agricultural technology and productivity (Bella et al. 2020; Fagiolari and Bella 2019; Santos et al. 2020). These innovations include wind mills, solar collectors, carbon-based materials for solar cell technology/photovoltaic panels, Zn/air batteries for electricity, and power generators. In addition to these non-exhaustive list of examples, this mix of technologies can add value to crop production near the source of raw materials. While progress has been made at the global level, for example sustainable Zn/air batteries for electricity to agriculture (Santos et al. 2020), energy conservation in agricultural buildings (Bella et al. 2020) and energy/power technologies to agriculture (Piana et al. 2019), the wide application of the innovations in African countries is limited (Oyedepo 2012) mainly because of their associated cost constraints.

Meanwhile Africa countries experience the highest impact of CC, particularly in the agricultural sector, although they contribute the least to global GHG emissions. The effects are severe on farmers since their livelihoods depend on farming activities (Owusu 2007; Lwasa 2011; Sissoko et al. 2011; Chinsinga and Chasukwa 2012; Juana et al. 2013; Thornton and Herrero 2015; Green and Raygorodetsky 2010). Given this context, innovations for addressing the effects of CC on agricultural systems must not only be holistic but also account for the economic prowess of the user population. The proposed innovative solutions should also address the doubled-pronged objective of promoting the agricultural sector's adaptation to CC and minimising the sector's tendency to exacerbate the effects of CC. Based on this, the Food and Agriculture Organisation (FAO) recommends CSA approach to manage agriculture for food security in the face of changing climate. Thus, CSA will enhance agricultural productivity, increase food production, improve the quality of the environmental, increase income, increase adaptive capacity, and reduce CO_2 emissions from agricultural activities. The approach has gained currency in the scientific and policy communities. Many agricultural-focused development partners are also promoting CSA in their regions of operation. However, many innovative CSA practices and sustainable agricultural technologies that take place in African countries are less reported in the conventional literature (See: Patel et al. 2020; Lei et al. 2016; Simons and Leakey 2004). In Central and West Africa, for example, it has emerged that coco-agroforestry can integrate forest with crops and provides farmers with agroforestry tree products (AFTPs) such as timber and fruits for household consumption. Moreover, Lei et al. (2016) note that farmers in South Africa and Ethiopia use a variety of drought adaptation strategies, including modifying planting dates, adopting new crop varities, and seasonal migration to adapt to and mitigate the effects of climate change. Many other countries in sub-Saharan Africa have developed policies to address their vulnerability to CC. For example, in line with the United Nations Framework Convention on Climate Change (UNFCC) guidelines, Ghana, Tanzania, Uganda, Liberia, Kenya, and Lesotho have prepared a national adaptation plan (NAP) to address their vulnerability to CC. Ghana has also implemented a CSA action plan to develop climate-resilient agriculture and food systems for all agroecological zones as well as developed human resource capacity for CSA. These initiatives have paid dividends in terms of livelihoods improvement, farmers' resilience and cutting emissions to some extent. However, the implementation has not yet been explored in some communities in Ghana (Naaminong et al. 2016) while several others are reluctant to adopt them citing reasons of cost and less suitability to local conditions. This suggests that CSA practices must be user-friendly and suited to local economic conditions, and therefore requires an exploration of the CSA practices of farmers with the aim of identifying a bundle of practices that suit the local contexts. This bottom-up approach to promoting CSA practices may lead to wider-scale adoption and contribute to local CC adaptation.

Based on the foregoing, this study examines CSA practices in the local context of Ghana, highlighting the key CSA practices that farmers have prioritised, their benefits, challenges, and possible remedial actions. To a large extent, the results of the study may increase the value of LEK and efforts needed by authorities in addressing pertinent issues in local CSA practices. Although the assessment is limited to Ghana, the results could have significant policy relevance and practical application for countries elsewhere, whose experiences on local CSA practices are similar to that of Ghana.

2 The value of LEK in CSA practice in sub-Saharan Africa

LEK has a key role to play in minimising the impact of CC in Africa. In the past, local communities have had a number of coping strategies that have been neglected and untapped by policy communitarians and development practitioners (Vermeulen et al. 2012; Mapfumo et al. 2016; Duruigbo et al. 2011; Ajani 2013; Ayeri et al. 2012). There are currently an increasing appeal for the use of LEK in CC measures. Previous studies have also highlighted the benefits of LEK in the mitigation and adaptation of CCs in local communities (Nyong et al. 2007; Leonard et al. 2013; Ajani 2013). For example, Leonard et al. (2013) posit that local communities are knowledgeable in managing their natural resources and providing useful information that shapes their natural environment. This points to the fact that the local community's capablities in managing their natural resources should not be underestimated. Again, during the international conference of parties to the UN Framework Convention on CC, the International Indigenous Peoples Forum on Climate Change (IIPFCC) suggested that it is time to acknowledge the fundamental role of LEK for enhancing CC adaptation and mitigation (Mavhura et al. 2013). The Intergovernmental Panel on Climate Change (IPCC) even proposed that LEK could play an instrumental role in understanding the nature and approaches to adaptation that are cost-effective, participatory, and sustainable. Mapfumo et al. (2016) draw the attention of scholars, governments and development partners to the need to build adaptive capacity by improving LEK, information, and improved technologies to address emerging impacts of CC on local communities.

Despite the progress made in some of the African countries on climate change policy on agriculture, gaps remain, resulting in a slow rate of CSA adoption and implementation (Nciizah and Wakindiki 2015; Nyasimi et al. 2017; Mango et al. 2018; Senyolo et al. 2018; Makate 2019). The slow implementation of CSA may increase vulnerability or increase the cost of adaptation at a later stage, if not adequately addressed. However, the measures undertaken by authorities have still poorly explored the insights from LEK of farmers, which they have built up over the years. Moreover, studies that account for the value of LEK in CSA practices in Africa are less common in conventional literature (Duruigbo et al. 2011; Rankoana 2016). In achieving the sustainable development goals (SDGs) through CC mitigation, ending poverty, food security, and promoting sustainable agriculture, local-specific climate change adaptation strategies need to be implemented (Manning et al. 2015; Chandra et al. 2017; Makate et al. 2019; Chandra et al. 2017). This study aims to identify local CSA practices, their benefits, challenges, and way forward that could position farmers to keep up with the changing climate, using Ghanaian communities as a case study.

3 Method

3.1 Study area

The study was conducted in the rain forest zone in Ghana. Eight communities from the Western Region of Ghana were covered in the study—Jomoro, Ellembelle, Nzema, Adum Banso, Sankor, Mpohor, Domunli, and Obrayebona. The communities are among those that receive the highest amount of rainfall (up to 2200 mm) in Ghana and are endowed with arable land (Fig. 1). The Western region of Ghana is bordered to the north by the Western North region, to the east by the Central region, and to the west by La Cote d'Ivoire. The southern part is covered by the Gulf of Guinea. The region is endowed with numerous natural resources, such as cocoa, gold, bauxite, manganese, oil, timber, wildlife, rubber, coconut, oil palm. These resources contribute enormously to the socio-economic development of the region, and the country as a whole. The selection of the communities was supported by the Agricultural Extension Agents of the Ministry of Food and Agriculture (MoFA), Ghana. The selection criteria were: (i) communities' sustainable farming practices; (ii) communities have received training in the past on sustainable farming, such as CSA and; (iii) willingness to participate. The communities do not differ in terms of economic activities as they were predominantly agrarian. During the offseason, farmers switch to temporal jobs, such as retail business, carpentry, and trading in the local market to ensure a constant flow of income.

3.2 Data collection

The study relied on both secondary and primary sources of data. This allowed for triangulation to improve validity, and a coherent justification of the results. In this study, qualitative data were collected using focus group discussion (FGD) (McQuarrie and Krueger 1989) with farmers who were purposively sampled (Tongco 2007). The FDGs were conducted from September 12, 2018 to December 31, 2018. Data from the FDGs was recorded on a digital voice recorder and written in a field notebook to serve as a backup. An advantage of FGDs is that it allows interaction between participants and highlights their views and lived experiences (Powell et al. 1996). It also provides interaction between participants and highlights the language they use about an issue, and their values and beliefs about a situation (Kitzinger 1994). During FGD, participants were allowed to pose questions among themselves, brainstorm, re-evaluate, and reconsider their understanding of their locally specific experiences on CSA practices. The rationale behind the FGD was explained to the participants.

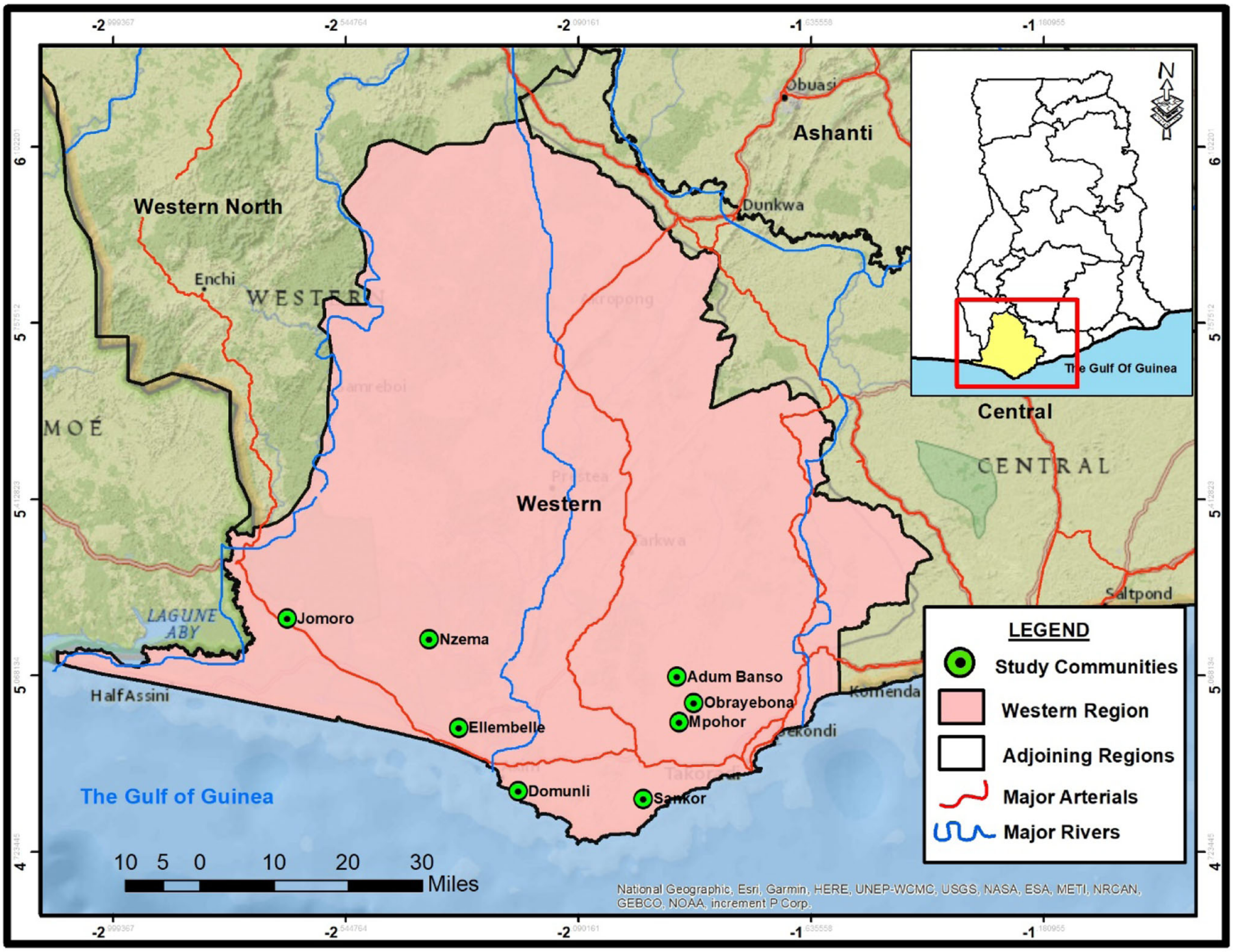

Fig. 1 Map of Ghana showing the eight communities Source. Author´s construct

Table 1 List of sample guiding questions used in the FGD

What are some of the local CSA practices?
How do you practise CSA locally?
How have you benefited from local CSA practices?
Why do you practice local CSA?
How do you protect the environment during farming?
What are the barriers against local CSA practices?
What do you think are required to enhance the local CSA practices?

Each session was conducted for 1–2 h. Participants reached their opinion through discussion with community leaders. Most participants were well represented, which encouraged diversity in opinions. The participants (farmers) were identified with the support of the district Agricultural Extension Agents. The guiding questions for the FGDs were evaluated for validity by the Agricultural Extension Agents and subject matter specialists. In the secondary data sources, Internet-based databases, such as Google Scholar, SCOPUS for peer-reviewed journals, and organisational reports from institutions such as Ghana's Ministry of Food and Agriculture (MoFA), Ghana's Forest Commission, and the FAO. Data was also gathered through the researchers' observation, which was guided by the following themes (a) farming practices, (b) existing CSA practices, (c) location/scale of CSA practice, (d) factors for limiting CSA use, and (e) land degradation.

3.3 Data analysis

The study used key guiding questions in the FGD, as already indicated in Table 1. Moreover, the focus group sessions were recorded, and participant reactions were noted. Following the responses of the participants, the research applied content analytical technique to unearth the emerging issues and themes from the interview transcripts as well as understanding the research problem, and to

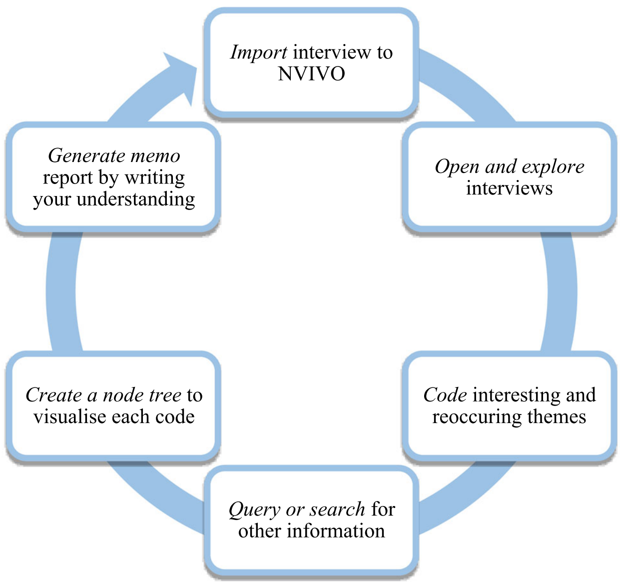

Fig. 2 Process of identifying themes from interview transcripts

address the research questions (Hsieh and Shannon 2005). The data were transcribed, coded, and analysed using computer-aided qualitative data analysis software (CAQ-DAS), called NVIVO 10. NVIVO 10 is a professional software designed to allow researchers to achieve more reliable coding in a shortest possible time, and to identify patterns of ideas during compiling, disassembling, and reassembling phase. Figure 2 shows the process of identifying themes from interview transcripts.

3.4 Ethical consideration

Research ethics were duly observed in the study. The purpose was to safeguard the validity and worth of the results. The research sought permission from the participants before the FGDs were held. The participants were informed that participation in the study was voluntary and their responses would be used solely for the intended purpose. Participants could withdraw their consents anytime they wished, in which case the data obtained from him/her would be discarded. In reporting the results, the anonymity of the respondents was protected. An opportunity was provided for each participant to ask questions, and to share his/her views. Addressing the participants' right to full disclosure, we explained the purpose of the study, the nature of the research before the FDGs commenced. Finally, it was ensured that participants retained the right to refuse to participate in the interview.

Table 2 General information about local communities and focus group participants

Communities	Duration (h/min)	Female	Male	Total
Jomoro	1.40	6	9	15
Ellembelle	1.45	3	10	13
Nzema	1.50	2	13	15
Adum Banso	1.38	3	10	13
Sankor	1.40	4	11	15
Mpohor	2.00	7	9	16
Domunli	1.45	5	6	11
Obrayebona	1.53	4	12	16
		34	80	116

4 Results

The general information about the communities and focus group participants is summarised in Table 2. It was observed that due to the limited number of female participants, the males' responses could overshadow the female counterparts. Therefore, additional discussion time with females was spent. The logic behind such low female respondents was due to the limited interest in farming activities. The overall age of focus group participants ranged from 30 to 62 years, and most of them had been engaged in farming for over 7 years.

Table 3 shows the key local CSA practices in the study communities in the Western region of Ghana. It also outlines the key reasons for adopting the CSA and the measures required to improve these practices. In general, it emerged that many of the farmers had a positive attitude towards local CSA practices. The comments on local CSA from the eight focus groups are described in the next section. Overall, a total of five key local CSA practices emerged from the discussions.

4.1 Key local CSA practices and experiences

4.1.1 Agroforestry

Majority of the farmers in the study area commonly practised plantations farming cultivating cash crops such as teak, rubber, and oil palm. The plantations were mostly combined with food crops in the first three years of plantation. Some farmers, particularly from Mpohor, Nzema, and Domunli communities, stated that the importance of growing tree crops was the huge economic return from it. For instance, farmers who cultivated oil palm could continue to harvest after 30 years. Similarly, the teak plantations were crucial to farmers because of its high demand in the internal market. The framers were aware of the profound ecological roles the trees on the farms. They mentioned that the tress absorb carbon dioxide from the

Table 3 CSA practices and the measures required to improve their adoption from farmers' perspectives

Key practices	Some observed benefits narrated by farmers
Agroforestry	It has a favourable microclimate, windbreak for houses and crops and reduces erosion in the medium to long term; leaves and fruits from trees are used to feed the animals
Cover cropping	It reduces erosion, improves soil fertility, and reduces weeds on the farm
Crop rotation	It improves soil organic matter, controls weeds, reduces pests and diseases, and generates income from other crops
Mulching	The mulching conserves soil, prevents surface erosion, reduces weed on the field, and supports plant growth.
Mixed cropping	It produces crop varieties, controls pests and diseases, and controls weeds on the farm
What is needed to improve these practices: key farmers' responses	
Training and sensitisation about the sustainable farming practices that enhance income generation, food security, and environmental conservation	
Provision of knowledge on management requirements (e.g. how to apply fertilisers and spraying)	
Provision of high economic value of seedlings, farming equipment, crop requirement, and affordable pesticides	
Provision of farming equipment (e.g. spaying machines) and farming machinery (e.g. tractors and slashers)	
Monitoring farming practices by extension agents in a continuous manner	

Source Developed by the author, based on the results of this study

atmosphere, and the oxygen they release could support human and animal lives. Moreover, they remarked that the trees provide favourable microclimate, reduce erosion in the medium to long term, and increase carbon sequestration. Among many important comments, one of the farmers during the discussion reported that:

> agroforestry helps the community a lot because the branches of the trees are collected for firewood. Fruits and leaves are used to feed animals, and timber for building our houses.

Another farmer remarked that:

> As far as I know, the combination of trees with crops helps the environment because it sustains the soil water content during the dry season.

One of them noted that:

> Planting trees with crops is an investment for him and the children in the future.

Due to agroforestry practice by farmers, it has discouraged the use of fire on the farm because setting fire on the farm might burn trees too.

One farmer had a major concern:

> Farmers who have no trees on their farms practiced slash and burn farming practice, which have negative environmental consequences.

4.1.2 Crop rotation

We learned through the FGD that most farmers were aware of the benefits of crop rotation. The farmers from Jomoro, Sankor, Mpohor, and Adum Banso communities revealed that they used the crop rotation technique to mitigate the adverse effects of changing climate. According to them, it is effective for the control of pests and diseases. Many farmers from all the FDG reported that they rotated corn and soybean, and this practice provided their households with regular income at different times of the year. Farmers who practised crop rotation remarked that the practice has reduced their reliance on inorganic fertiliser. The leguminous crops they cultivated fixed nitrogen into the soil and helped to forestall nutrient leaching. Although some of the farmers practised crop rotation, it was generally difficult for them to follow appropriate steps of sustainable agriculture due to the general limited knowledge. The farmers who adopted crop rotation recommended to the other farmers to leave crop residues on the farmers to improve the soil moisture and nutrients. Doing so did not adversely affect plant growth.

A farmer expressed that:

> Crop residue left on the farm decomposes, which increases soil organic matter. One could use maize residue, grass, residues from plantain crops or other crops to increase soil moisture and reduce erosion.

Improper implementation of crop rotation has led some of the farmers to incur losses. Although information about the planting techniques was available, it was difficult for some of the farmers to access it. Crop rotation requires investment in the different planting seasons, which puts a financial burden on the farmers. A farmer narrated that:

> I practised crop rotation over the years, and it requires money in different planting techniques for each unique crop. This is because each crop needs a different budget.

4.1.3 Cover cropping

Many of the farmers from Jomoro, Sankor, Mpohor, and Obrayebona communities reported that cover cropping was not a common practice. They cited limited market, for crops such as soya beans, as the main reason. Farmers who practised this method argued that it helps to control erosion, prevent weeds, and improve soil productivity because leguminous crops fix nitrogen into the soil. Cover crops suppress weeds in plantation, such as oil palm, teak, rubber, and increase organic matter in the soil. It was observed that cover cropping has the tendency to reduce erosion and increase carbon sink. Farmers explained that this practice is one of the effective adaptation techniques against changing weather.

According to a farmer:

> The method is easy and convenient, and we do not have the problem of weeds invading the farm.

4.1.4 Mixed cropping

Mixed cropping or intercropping was one of the commonly practised local CSA practices in all the eight communities. Farmers preferred to combine root/tuber-cassava, and cereals maize with oil palm and teak, which were cultivated on large scale. Mixed cropping improves the soil fertility, especially if it involves legumes. Although, mixed cropping could not lead to higher yields, it produced a variety of crops for the family, controlled pests, diseases and weeds. Most farmers mentioned that due to the rainfall anomalies, it was important to practise mixed cropping. This is because if there was a shortage of water or nutrient, the resistant crops forestalled the occurrence of complete failure. According to a farmer:

"The crops form canopy, which prevented sunlight to the weeds, therefore limiting their strength to grow."

Regarding the control of pests, one farmer said:

> Because of variety of crops that are grown, each crop is attracted to birds or insect that feed on pests.

4.1.5 Mulching

Mulching was also one of the commonly practised local CSA techniques in the various communities. Generally, the farmers applied mulch because of the benefits it provided to the soil. The farmers disclosed that mulching conserves soil, prevents surface erosion, reduces weed on the field (Table 4), and saves people from buying unauthorised weedicide or herbicides, which negatively affected their health and farm productions. Farmers used creeping crops, grasses, weeds, small branches, and crop residues for mulching. However, one of the challenges was the competing demand for weeds to feed animals and be used as firewood for cooking. It was also a challenge to transport mulch materials to the farm or plantation. Regarding the benefit of mulch, one farmer noted: Table 5 shows the key local CSA practices from the various communities. Farmers reported that despite their contribution to sustaining their lives and protecting the environment, there are a myriad of barriers against their adoption. Table 6 shows the constraints the farmers faced in their attempts to adopt the CSA practices.

> I apply mulches from my farm residue, such as maize. During the hot temperature, the mulches protect the soil from losing excess water in the soil.

4.2 Constraints of local CSA practice

To end poverty, achieve food security, and promote sustainable agriculture in the face of climate change, farmers, institutions and policymakers should adopt and strongly encourage local-specific climate change adaptation strategies. Despite the opportunity for improving and upscaling these CSA practices, there were still a number of constraints as reported by the farmers. These constraints are grouped into five main themes and are discussed in this section of the paper.

4.2.1 Lack of climate-smart agricultural inputs

Most farmers indicated that they did not have access to tree seedlings to practise agroforestry. The most significant concern from the farmers was lack of equipment and tools for the preparation of land and rasing of seedlings. Moreover, farmers who were interested in CSA practices such as agroforestry could not purchase tree seedlings due to financial constraints. According to farmers, government or benevolent organisations should support them to acquire the seedlings to adopt agro-forestry. Moreover, many of the farmers were could not practise manure management and adopt crop varieties on their farm due to financial

Table 4 Perceived reasons why farmers adopt local CSA

Communities	Perceived reasons				
Jomoro	Pest/disease control	Improvement in soil moisture	Weed control	Improvement in soil fertility	Income generation
Ellembelle	Reduction in run-off	More harvest	Income generation	Cheap	Limited labour
Nzema	Income generation	Improvement in soil moisture	Prevention of erosion	Food security	Crop diversification
Adum Banso	Water retention	Income generation	Prevention of pest/disease	Higher yield	Trees provide shades
Sankor	Reduction in erosion	Prevention of pest/disease	Income generation	Weed control	Trees for windbreaks
Mpohor	Pest/disease control	Improvement in soil moisture	Maintaining trees on the farm	Improvement in soil fertility	Income generation
Domunli	Weed control	Soil fertility	Income generation	Improvement in soil moisture	Food security
Obrayebona	Food security	Weed control	Water retention	Improvement in soil fertility	Income generation

Source Developed by the author, based on the results of this study

Table 5 Local CSA practices from the communities

	Jomoro	Ellembelle	Nzema	Adum Banso	Sankor	Mpohor	Domunli	Obrayebona
Local CSA								
A			✔	✔		✔	✔	
B	✔				✔	✔		✔
C	✔			✔	✔	✔		
D	✔	✔	✔	✔	✔	✔	✔	✔
E	✔	✔	✔	✔	✔	✔	✔	

A = agroforestry; *B* = cover cropping; *C* = crop rotation; *D* = mulching; *E* = mixed cropping

Source Developed by the author, based on the results of this study

Table 6 Constraints limiting CSA practice in the communities

Key issues	Local communities visited							
	Jomoro	Ellembelle	Nzema	Adum Banso	Sankor	Mpohor	Domunli	Obrayebona
A	+++	+++	+++	+++	+++	+++	+++	+++
B	–	++	–	++	–	++	–	–
C	++	+++	++	++	++	++	++	++
D	+++	+++	–	++	++	+++	–	+++
E	+++	+++	+++	+++	++++	+++	+++	+++

Source Developed by the author, based on the results of this study

A = lack of climate-smart agricultural inputs; B = lack of land tenure system; C = lack of agricultural training; D = limited information about CSA options; E = labour-intensiveness

+ = the extent of key issues reported during the discussion and brainstorming; ' +++' High; ' ++' Medium; '-' Low constraints. Given this context, the affected farmers could plant a few trees on their farms. Other planted fruit trees in their homes, which supplied them food and yielded incomes through the sale of the fruits. The limited access to CSA-specific farm equipment and tools led to inappropriate local CSA practices. A farmer expressed his sentiments about the limited availability of farm machinery:

> I have been tilling and weeding my land with simple tools, such as hoe and cutlass, due to the lack of farm machinery, such as tractors, therefore, I cannot cultivate large scale.

4.2.2 Land tenure security problems

Traditional authorities and family heads own most arable land in Ghana. Farmers mentioned that to acquire a parcel of land for agricultural purposes, one needs to obtain permission from the allodial title holders. Some landowners also prevented the farmers from planting trees that could occupy the lands for a long time. Although trees enhance biodiversity, air quality, and absorb greenhouse gases, planting of trees with crops requires permission from the landowners. This makes it difficult to adopt CSA practices such as agro-forestry. The farmers who did not own land had requested the District Assemblies and MoFA to dialogue with the landowners to allow them to adopt CSA practices on their lands. Due to land right and difficulty to access arable land, females were often deprived. This appears to be a recurring problem in Ghana. It was understood that land is predominantly owned by men. The problems for women have worsened, since women have limited income, due to limited access to credit facilities to rent or purchase land. Moreover, a farmer who has been farming on rented land suggested to the government to secure a vast portion of land for interested people, since a lot of young people were willing to engage in agriculture. According to a farmer:

> We are not financially resourced to own our land. In fact, most of our family members have moved to the cities for their daily bread. Also, for the youths, farming is not attractive because of land litigations and the high cost of the lease or hire.

4.2.3 Insufficient agricultural training

Farmers have not received adequate agricultural training to address local farming problems. Some of the farmers argued that inter-cropping food crops with trees could lead to total crop failure. We recorded that improper implementation of these CSA practices could cause much more harm than good. Generally, the farmers had limited knowledge on sustainable agricultural practices, particularly CSA. However, there was no clear understanding of the CSA concept among farmers. Also, many of the farmers lacked training on the various choices of CSA that could be suitable for their local conditions. This underscores the need for continuous education in the subject area. There was the need to have an extension agent in the farming communities to assist them with sustainable farming practices, such as planting distances, choice of crops or tree types, and agroforestry practices to improve food security, however, the extension agents were limited in number and capacity. The limited number extension agents and their training capacity could undermine the farmers' ability to implement the CSA practices. A farmer expressed that:

> There are many challenges facing farmers, for example, the extension agents do not come often to inspect our farms to understand whether farmers do the right things or not. There is no training for us to improve our skills. The farmers are many and we need more extension agents as soon as possible.

4.2.4 Limited information about CSA options

Many farmers did not have access to appropriate information, whereas others indicated that they were unable to fully utilise the existing information. Farmers also raised concerns about their limited agricultural information from institutional sources on CC and CSA options that are available to the local communities and asked for CSA experts to visit and properly educate them to adopt these practices. It was recognised that successful adaptation requires knowledge about available options. Failure to support farmers had forced some farmers to use agro-chemicals uncontrollably to increase crop yield. For example, most farmers lacked limited information on the appropriate application of fertiliser, which is known to reduce carbon emissions. Sometimes, farmers placed the fertiliser either very close to the plant or far away from it, which led to depletion. Farmers applied fertiliser inappropriately, and information obtained from government extension agents and NGOs was limited. It was observed that farmers continued to engage in major tillage practices, using disc plough, which could have adverse implications for soil conservation. According to a farmer who reported on the limited information about CSA:

> We have limited or no access to information to support our farming work, the information that comes in are difficult to absorb due to our low level of education in this area. For example, market information, sustainable farming practices, and the application of

fertilizers are often difficult to practice due to illiteracy.

4.2.5 Labour-intensiveness

Most farmers used labour-intensive methods to practise farming. This has undermined the adoption of appropriate farming practices. For example, agroforestry was more labour-intensive and inefficient, compared to mixed cropping. Labour peaks occurred at harvest time, weeding, and land preparation. According to them, their inability to adopt modern tools was due to poverty, low levels of education, and limited awareness of the importance of improved agricultural tools. It was observed that modern tools could be one of the important assets for adopting and adapting new CSA practices to respond to changing climate. In the absence of modern tools, many farmers largely depended on human labour for cultivation, harvesting, agriprocessing, and transport. Family members were mostly unwilling to provide labour, and majority of them have migrated to the urban areas which adversely affected CSA practices. A farmer expressed that:

> I have to pay people money when I am not fit to work on my farm. Farming without appropriate tools is time-consuming and causes an adverse physical effect on my bodies, such as body pain and headaches.

5 Discussion

Rainfall variability and increasing temperature due to CC are making farmers in Ghana vulnerable (Naaminong et al. 2016). For example, in an earlier study, many farmers revealed that temperature has increased and the rainfall pattern become erratic (Kemausuor et al. 2011). Generally, farmers are aware of these climatic changes, and they are adopting strategies, such as irrigation, mixed cropping, crop rotation, and mulching to adapt to the effects of climate change in Ghana (Kemausuor et al. 2011; Limantol et al. 2016). A similar trend has been observed for the entire sub-Saharan Africa (Kotir 2011; Singh and Singh 2017; Patel et al. 2020). The agricultural sector is most vulnerable to the observed changes in the climate.

Meanwhile, the agriculture is the backbone of the economy and employs more than half of Ghana's labour force. It is therefore important to adopt climate-resilient measures for the continuous growth of the agricultural sector. Generally, it is suggested that CSA is one of the CC resilience strategies that enhance productivity, reduce hunger, and safeguard the environment. In the environment, for example, it could serve as a carbon sink, increase carbon sequestration, reduce farmers' reliance on inorganic fertilisers, increase organic matter in the soil, prevent surface erosion, and increase food security, however, the adoption rate is minimal, particularly in Africa (Branca et al. 2011).

The current study indicates that farmers have mainstreamed LEK into CSA practices. Farmers used their LEK to prioritise key local CSA practices, such as agroforestry, cover cropping, crop rotation, mulching, and mixed cropping. The local practices help the farmers to sustain their livelihoods and contribute immensely to the sustainability of ecological system. Despite the various benefits of local CSA practices, there are still some key challenges, which include the lack of skills on the part of farmers, high cost of their implementation, their labour intensiveness, unavailability of requisite inputs and climate constraints. The key challenges are consistent with those that were reported by Nkomoki et al. (2018).

Regarding agroforestry, during the juvenile stage of the tree crops, farmers inter-planted food crops to provide regular incomes. Moreover, the farmers adopted cover-cropping to control weeds and reduce the cost of weeding the farms. Cover cropping also added nutrients to the soil and optimised the use of land. Previous studies have proven that the best intercropping or mixed cropping techniques make a profound impact on the yield (Nchanji et al. 2016). Similarly, mixed cropping with leguminous crops prevents soil water loss, reduces run-off and maintains soil fertility, and helps in recycling of nutrients. These crops can coexist without competing for space or nutrients (Samedani et al. 2015). Early scholars have demonstrated that the tree crops on farms sequester carbon (Lemade and Bouillet 2005; Brahene 2013). For instance, Lemade and Bouillet (2005) compared different planted ecosystems and found a high rate of carbon sequestration for oil palm. Moreover, oil palm plantation not only sequesters carbon, but also enhances biodiversity and soil organism population. Despite the merits of agro-forestry, it is often hampered by land tenure insecurity. Most prospective investors in agriculture and farmers are discouraged due to challenges of the land tenure system in the country. The government has no absolute control over lands in Ghana. The ownership of lands by traditional authorities and families often undermine investments. Some farmers work on rented land, therefore, they could not adopt agro-forestry practices, neither could they use the land to secure loans from final institution for investments purposes (Johnson et al. 2018). Although, some local CSA practices are labour-intensive, a reflection of smallholder farmers in Ghana shows that they provide wealthy environmental services. The reason was that farmers have limited income to hire machine to work on their farms. We observed that the machinery (e.g. tractors) that were available at the

Agricultural Departments had been broken for a very long time. Therefore, even if farmers were willing to pay for the services of the machinery, they could not have access. This could undermine the adoption of sound agricultural practices. Mulching was one of the commonly practised techniques in the study areas. Although it is one of the best CSA practices, farmers complained about its management. It was also a challenge to carry mulch to the farms or plantations. Mulching has been previously cited as necessary for the control of weeds, prevention of erosion, addition of sol nutrients, and maintenance of soil moisture (Jabran 2019a, b).

Some farmers still practiced maximum tillage in the study areas, which have adverse effects on the environment. The practice is inconsistent with the Ministry of Food and Agriculture's minimum-tillage or zero-tillage policy, 2010. In eastern Kenya, Karuma et al. (2014) found that soil moisture content was significantly low if the land is tilled with disc plough. Therefore, continuous ploughing (and harrowing) could adversely affect the soil moisture content, which could ultimately undermine the efforts of promoting CSA practices. Most agricultural land is being degraded by farmers due to limited knowledge of sustainability principles. Moreover, previous research pointed out that there is widespread degradation due to unsustainable farming practices, such as logging, slash and burn, and land rotation, leading to wastage of agricultural land (Table 7). Given this context, there is the need for the Agricultural Department in the communities to educate farmers on the possible effects of these sustainable practices.

Table 7 High forest zone land area outside forest reserves

Region	Land area (m ha)	Area off-reserve (m ha)
Ashanti	2.44	2.08
Central	0.95	0.76
Western	2.25	1.57
Eastern	1.89	1.71
Brong Ahafo	0.99	0.77
Total	8.5	6.92

Source Naaminong et al. (2016)

Table 8 Potential stakeholders and their roles

Stakeholders	Potential roles
Farmers	Test and evaluate solutions
	Adopt sustainable agricultural practices
Private sectors	Develop and deliver CSA technologies
	Create favourable conditions for increasing agricultural productivity
	Provide easy access to products, mechanisation, and knowledge that help farmers on investment and risk management
NGOs/Development Organisations	Train private sector on agricultural productivity and marketing
	Promote environmentally sustainable agriculture
	Participate in prospecting and promotion of appropriate inputs for CSA
	Organise activities that are in line with CSA practices
Finance institutions	Develop financial services that support farmers and interventions
	Fund and protect the investments of farmers
Extension agents	Provide information on identification, development, and implementation of CSA techniques
	Support communication and promote CSA practice
Research institutions	Implement development outreach activities and technical support to CSA farmers, and private sectors, such as agro-dealers and agribusinesses men and women
	Promote policy and institutional change
	Team up with local extension services to provide training and advice on CSA practices
	Conduct new research where necessary
Policymakers	Create an enabling environment for CSA practice through regulations, policy frameworks, and other measures that ensure CSA practices and food
	Support formulation of appropriate policies
	Provide amenities, such as transportation and storage facility to farmers
	Create incentives for farmers to adopt an environmentally sound practice

Source Adapted from Khatri-Chhetri et al. (2019), Zougmoré et al. (2019), and Mujeyi (2020)

Many studies have examined farmers' vulnerability to CC in African countries (Kemausuor et al. 2011; Kotir 2011; Limantol et al. 2016) and accordingly recommended CSA practices to enhance farmers' resilience to CC. The government could do more to foster the adoption of CSA in the farming communities and also work with stakeholders to promote access to funds to enhance the adoption and upscaling of CSA technologies for total agricultural development in the communities. Prior studies have noted the important role of stakeholders in promoting CSA practices. Table 8 shows a summary of some potential roles of relevant stakeholders to reshaping unsustainable farming practices in the local communities in the face of CC.

6 Conclusion and policy implications

The overarching purpose of the study was to explore various local CSA practices, their benefits and, management constraints and suggests ways to improve local CSA practices to enhance farmers' resilience to climate change (CC). The research points to the value of LEK in CSA practices and as an important source of information for improving the adaptation capacity of farmers to climate change. Farmers used their LEK to prioritise agroforestry, cover cropping, crop rotation, mulching, mixed cropping as their key local CSA. These key local CSA practices were in line with Khatri-Chhetri et al. (2017) and Naaminong et al. (2016), who outlined a myriad of CSA practices and technologies that could respond to the principle of sustainable agriculture. This study indicates that farmers' adaptive capacity and resilience to CC will not yield any positive result if the following obstacles exist, including lack of climate-smart agricultural inputs, land tenure problems, lack of agricultural training, inadequate agricultural information about CSA options, and labour-intensiveness of CSA practices. Despite the contribution of local CSA to sustaining lives in the rural community, some farming practices such as tillage and slash and burn were not consistent with sustainable agricultural practices in the farming sector. Therefore, the LEK and modern science could succeed in promoting CSA practices by addressing the aforementioned challenges. This will contribute to the sustainable development goals (SDGs), such as climate action, poverty reduction, and eradication of hunger among people. Besides, the wide adoption of CSA in the communities and beyond will help farmers to increase their adaptive capacity. Therefore, developing and enforcing CSA mechanisms to deal with the changing climate, and its effects must be a high priority for government and relevant stakeholders in the agricultural sector. The study findings are limited to the eight communities in the Western region of Ghana and therefore could not represent the views of farmers elsewhere. Based on the findings, the ensuing recommendations could enhance farmers' resilience to CC and could help in achieving CSA goals:

1. Incorporating LEK in modern scientific knowledge could contribute to modern science through natural resource management and by minimising the possible effects of CC. Policymakers should, therefore, redirect policy towards climate dialogue to local communities where LEK is used to identify appropriate coping and adaptive strategies to enhance CC resilience, increase productivity and reduce emissions;
2. In order to ensure the proper adoption of climate-smart agriculture in the communities, national and local authorities must engage more with the communities to jointly formulate and implement the CSA Action Plan for all agroecological zones;
3. Farmers should establish farmer cooperative to encourage sharing of knowledge, and easy access to extension, credit facilities and other support services from the government and benevolent organisations;
4. It was realised that although LEK is yielding positive outcomes at the communities, the idea is not promoted. Therefore, future research should continue to explore the ecological values of LEK, and the fundamental role it plays in CC adaptation. Further research is needed in other communities to unearth local CSA practices to have a national database of CSA. This will help to develope the CSA technologies and management, and other innovations that could enhance resilience and address CC. This will further improve food security. This study is a qualitative research, therefore, further study is required to assess and quantify local CSA practices and experience in a broader context.

Acknowledgements We wish to express our profound gratitude to the anonymous reviewers for their valuable comments, which helped us to improve the earlier version of the manuscript.

Authors' contributions HM contributed to the study conception and design. HM, DKA, SAT, and OA performed material preparation, data collection, and analysis. The first draft of the manuscript was written by HM. DKA, SAT, and OA reviewed the first draft manuscript. All the authors read and approved the final manuscript.

Funding Not applicable

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