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Improving the effectiveness of agricultural extension services in supporting farmers to adapt to climate change: Insights from northeastern Ghana

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ABSTRACT

The importance of extension services in helping smallholder farmers to address the many challenges of agricultural production cannot be over-emphasized. However, relatively few studies have been conducted that investigate how the capacities of agricultural extension agents can be built to more effectively assist smallholder farmers in managing climate risks and impacts. As climate change is a key threat to smallholder food production, addressing this issue is increasingly important. This paper aims to identify how agricultural extension agents in Ghana can better support smallholder farmers in navigating and addressing the effects of climate change on food production. It asks: (i) what are the sources of information used by agricultural extension agents in Ghana's Upper East region? (ii) what are the capacity building needs of agricultural extension agents for effective communication of climate information for building resilient agricultural systems? (iii) what are the key barriers to successful extension outcomes for climate change adaptation? The paper uses a mixed methods approach including three regional stakeholder workshops, expert interviews and surveys with 32 agricultural extension agents in northeastern Ghana. Results addressing question (i) indicated that radios and television are the dominant sources of climate information for agricultural extension agents in the Upper East region. Findings targeting question (ii) identified capacity building needs such as developing extension agents' technical skills, improving communication skills, improving knowledge and use of climate smart agricultural interventions such as soil moisture conservation methods, and training on information communication technologies (ICT) to deliver extension advice on climate change. Other needs included developing skills in field demonstration and project monitoring and evaluation. Addressing question (iii), key barriers confronted by agricultural extension agents in the delivery of extension on climate change included lack of transportation facilities for extension agents, lack of appropriate extension materials, high agricultural extension agent to farmer ratios, and inadequate funds to implement adaptation practices. Wider barriers reducing the effectiveness of extension efforts included farmer resistance to change and complex land tenure arrangements that do not allow investment. Periodic workshops should be organised for agricultural extension agents on the use of ICT to deliver extension services, whilst encouraging the use of audio-visuals in extension delivery. These efforts should be supported by regular assessments of extension agents' capacity building needs.

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1. Introduction

Agriculture contributes 27% of Ghana's Gross Domestic Product (GDP), as well as providing employment for about 60% of the labour force, especially those living in rural communities (Institute of Statistical, Social and Economic Research, 2014). Smallholder farmers dominate Ghana's agriculture sector, with an estimated 90% of farms being ≤ 2 ha. Smallholder farmers operate family-owned farms and use traditional subsistence methods, exposing them to significant climate risks when seasonal changes and droughts linked to climate change occur. Agriculture is the most vulnerable sector to climate change impacts because of its over-dependence on rain-fed systems. It is one of the key priority sectors identified by the Ghana government in its Nationally Determined Contribution submitted under the Paris Climate Agreement (Republic of Ghana, 2015). This signifies the important role of the agricultural sector in meeting the adaptation and mitigation commitments set out by the Ghana government to address climate change.

Ghana has witnessed significant increases in temperature and varied rainfall patterns and recent studies suggest the country's climate has become progressively drier over the last century and prone to drought conditions (Abbam et al., 2018; Asante and Amuakwa-Mensah, 2015). Using a 2010 baseline, Ghana's Environmental Protection Agency has projected that rainfall is expected to decrease across all agro-ecological zones by an average 18.6% by 2080, while temperature is expected to increase on average by 3.9 °C by 2080 (Republic of Ghana, 2015). Extreme climate events including droughts and storms have also been projected to increase across all agro-ecological zones. These projections will have significant implications for millions of farming households, who depend on rain-fed agricultural systems and other agro-based activities for their livelihoods and food security. This necessitates more concerted efforts in combating climate change effects, involving all actors within the agricultural sector.

Farming households in Ghana and across sub-Saharan Africa are employing a host of production practices aimed at reducing the adverse impacts of climate change on their livelihoods. For instance, they are planting early maturing varieties and drought-tolerant crops, practising crop diversification; and changing land management practices in efforts to adapt to the changing climate (see Antwi-Agyei and Nyantakyi-Frimpong, 2021; Williams et al., 2019; Bawakyillenuo et al., 2016). Farmers nevertheless need to overcome many barriers to implement such adaptation practices, including a lack of financial resources, lack of local involvement in policy decision making and inadequate information on climate change characteristics and other climate information (Antwi-Agyei et al., 2015a; Yiran and Stringer, 2017). Adapting to climate change thus requires a change in behaviour, knowledge, skills and capacities of people to help build their resilience (Nnadi et al., 2013). Normally such learning is facilitated through both informal and formal institutions.

In many countries, extension services represent one such example of a formal institution that plays a critical role in supporting small-scale agriculture and in achieving national and household food security (Rickards et al., 2018). Agricultural extension services have been shown to build farmers' agricultural knowledge and skills, disseminate new technology and change farmers' attitudes (Khan et al., 2012) as well as promote community development through human and social capital development, facilitate access to markets and work with farmers towards sustainable natural resource management (Bonye et al., 2012; Swanson, 2008).

Danso-Abbeam et al. (2018) observed that participation in agricultural extension programmes by farmers in Ghana's northern region led to improved welfare through increases in farmers' income. Donkor et al. (2016) demonstrated the critical role of agricultural extension in promoting the adoption of soil improvement technologies, highlighting that access to extension services significantly enhanced the adoption of chemical fertilizers.

In the context of climate change, agricultural extension has a responsibility to increase awareness of the best available local adaptations that can be used to manage climate risks (Afsar & Idrees, 2019), whilst at the same time assisting farmers to avoid maladaptation (Antwi-Agyei et al., 2018; Juhola et al., 2016). Whilst existing studies demonstrate the significant role played by extension services in promoting farmers' welfare and productivity and empowering them to address climate change effects, significant knowledge gaps remain relating to the capacity building needs of extension officers themselves. Focus has been largely on supporting farmers to adapt, without empirically assessing how agricultural extension agents can be more effective. In relation to climate change, it is also unclear how extension capacity gaps feature in the wider landscape of factors that combine to create barriers to successful adaptation outcomes.

For agricultural extension agents to help smallholders to effectively manage and adapt to climate change, it is vital to understand the capacity building needs of the agricultural extension agents to fulfil this important mandate. Capacity building includes efforts to "generate knowledge, skills and expertise in order to enhance analytical capacity that may assist in increasing agricultural productivity and sustenance" (IFPRI, 2005, p.3). This paper aims to identify how agricultural extension agents in Ghana can better support smallholders in navigating and addressing the effects of climate change on food production. It asks: (i) what are the sources of information used by agricultural extension agents in Ghana's Upper East region? (ii) what are the capacity building needs of agricultural extension agents for effective communication of climate information to support agricultural adaptation? (iii) what are the key barriers to successful extension outcomes for climate change adaptation?

2. The role of extension services in food production and climate change adaptation

In the 1970s, extension evolved as a government policy response to the World Food Crisis when there was a need to boost the production of staple food crops (Benson and Jafry, 2013). In general, the role of agricultural extension is educational, with agents providing and disseminating information to farmers, providing institutional support and helping meet their needs (Maponya & Mpandeli, 2013). Efforts have included the transfer of appropriate technologies (primarily for crop and livestock production systems) from central research units to smallholders (Gebrehiwot, 2015).

Mustapha et al. (2012) mentioned three ways that extension officers could help in supporting adaptation to climate change: (i) facilitating and implementing policies, and programmes, (ii) providing information and guiding management of new methods of farming, and (iii) developing capacity. Existing literature shows that agricultural extension services play a role in educational programs that enhance the capacity of farmers in addressing climate change effects (see Rickards et al., 2018; FAO, 2003). Extension services have also created awareness on issues of climate change whilst seeking ways to build the resilience and adaptive capacities of vulnerable individuals and communities in managing climate change effects (FAO, 2003). Different approaches have been used in delivering extension education to farmers around the world, including farmer-field schools, flyers, radio messages, and field demonstrations (Anyadike, 2009).

Climate change will induce extreme climate events and sudden onset disasters as well as new vectors of human and livestock diseases, with many of these hazards interacting with one another (Yiran and Stringer, 2016). Extreme drought and flood events closely linked to climate change will cause severe local hardship but do not attract the attention of the international community. Boosting the capacity of smallholder farmers in vulnerable communities to manage such climate risks will become ever more crucial, and extension efforts must be directed towards educating farmers about their adaptation options to enhance resilience and response capacities (IPCC, 2007). Another role of extension, critical for climate change adaptation, is to link farmers to transport agents, markets, and input suppliers, as well as to other different actors within the rural sector (Ferris et al., 2014), particularly private and public institutions that disseminate adaptation technologies, and funding programs for adaptation investments (Mustapha et al., 2012).

Ozor & Nnaji (2011) indicated that extension services should emphasise the re-training of extension staff to acquire new professional skills and competencies in climate risk management, setting up emergency management units in extension agencies, and building resilience capacities of vulnerable people. Wojcik et al. (2014) highlight the importance of engaging extension staff in long-term professional development aimed at improving their training in climate education, as well as preparing them to effectively communicate climate change information to farmers who may be extremely vulnerable to climate change. Nevertheless, little is known about agricultural extension agents' capacity needs, the barriers they face, and the solutions that can help them to become more effective in supporting smallholders. This paper addresses this important gap.

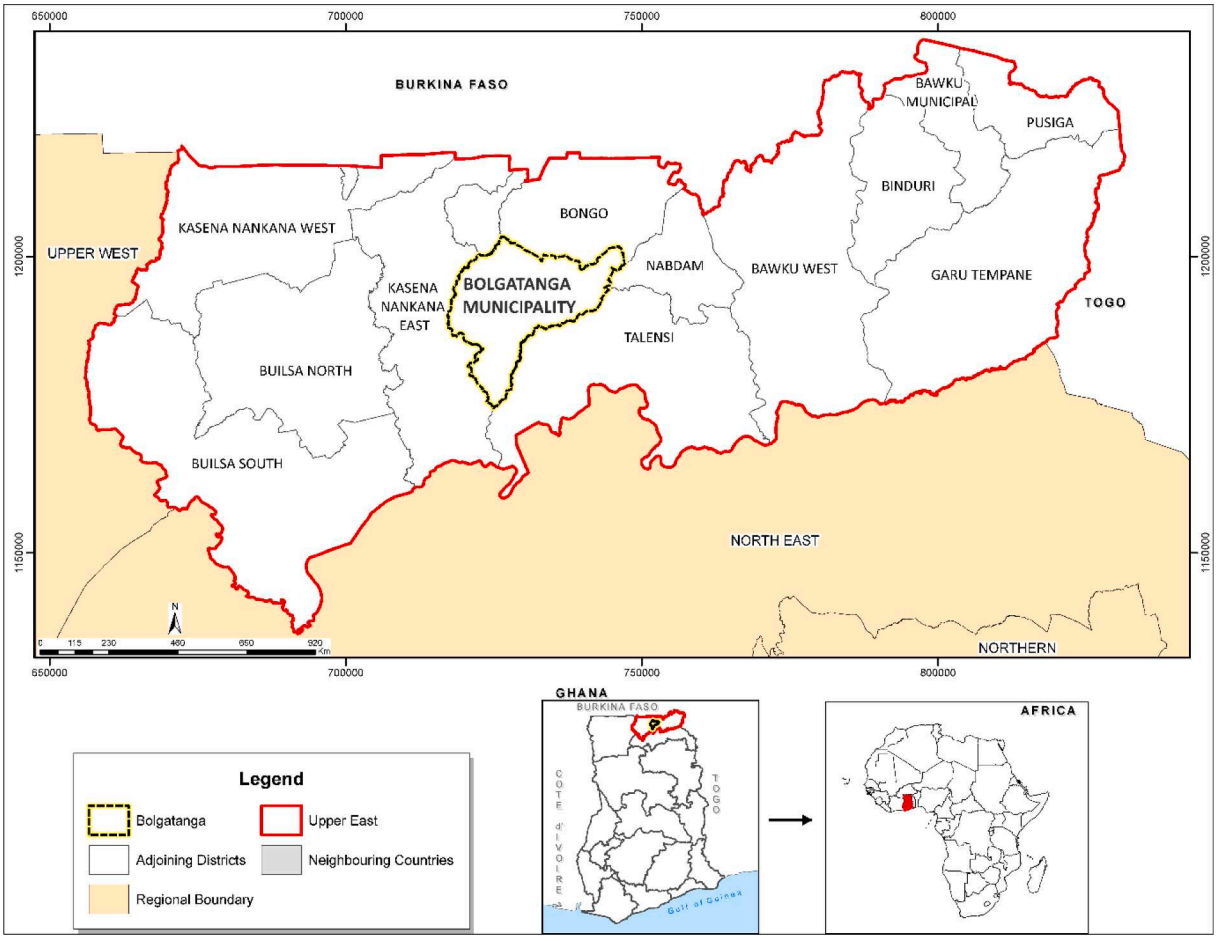

Fig. 1. Map of the Upper East showing the Bolgatanga municipality and adjoining districts.

3. Research methodology

3.1. Study area

Ghana's Upper East region is located in the northeastern corner of the country, has a population of 1,046,545 people, and Bolgatanga as its capital (GSS, 2013). Upper East region occupies 8,842 km^2 and lies between longitude 0° and 1° West, and latitudes 10° 30′N and 11°N (Fig. 1) (GSS, 2013). The land is relatively flat with hills to the southeast and the east. The natural vegetation is savannah woodland and the most common drought resistant and economic trees are the shea nut (*Vitellaria paradoxa*), dawadawa (*Parkia biglobosa*) and baobab (*Adansonia digitata*). The Upper East region was selected for this study based on its high vulnerability to climate change (Issahaku et al., 2016; Antwi-Agyei et al., 2012).

Climate in the region is characterised by one rainy season from May/June to September/October with mean annual rainfall between 800 mm and 1,100 mm (GSS, 2013). Rainfall is variable in duration, as well as spatially. The region experiences frequent droughts, exposing farmers to climate change impacts (Issahaku et al., 2016). It is also characterised by a long spell of dry season from November to mid-February, accompanied with cold, dry and harmattan winds (Issahaku et al., 2016; Nkrumah et al., 2014). Temperatures during this period can move as high as 35 °C during the day and as low as 14 °C during the night (GSS, 2013). Several recent ensemble models have confirmed temperature increases of 1.0 °C since 1960, at an average rate of 0.21 °C per decade (Republic of Ghana, 2015). The savannah area including the Upper East region will experience higher increased temperatures than the south, alongside more uncertainties in rainfall patterns. Using meteorological data from 1954 to 2014, Issahaku et al. (2016) reported that daytime and night-time temperatures have been increasing in the Upper East region at a rate of 0.30% and 0.25%, respectively per decade. In the Savannah agroecological zone, it is projected that rainfall will reduce on average between 2.8% and 10.9% by 2050 (Republic of Ghana, 2015).

Although the region has 15 districts, the majority of the population is found in Bolgatanga Municipality. Agriculture, hunting and forestry are the main economic activities. The main food crops grown are guinea corn, millet, maize, groundnut, sorghum and beans (GSS, 2014). Poultry production and livestock rearing are also vital agricultural livelihood activities (GSS, 2014). In terms of agricultural extension, each district has an officer who is in-charge of extension activities in the district and monitors the activities of the agricultural extension agents. The extension officer trains the agricultural extension agents on new farming innovations, technologies and interventions. The agricultural extension agents are responsible for delivery of extension services in terms of innovations, and technologies to farmers within a particular operational area consisting of a number of communities.

3.2. Research methods

To elicit information on the capacity building and training needs of agricultural extension agents to effectively communicate climate information to smallholder farmers, a mixed methods approach was used, including stakeholder workshops, questionnaire surveys and expert interviews. Stakeholder workshops were used to identify the capacity building needs of agricultural extension agents as well as barriers to successful extension outcomes. Three regional workshops were held at Bolgatanga (in September 2019, n = 26 participants); Navrongo (in September 2019; n = 27 participants), and a final one at Bolgatanga (in February 2020, n = 39 participants). Stakeholders for these workshops were purposefully selected and included regional and district directors of agriculture, district agricultural extension officers, agricultural extension agents, civil society organisations, NGOs, and academic researchers. Discussions at these workshops focused on the climate information landscape in the Upper East region and identified the capacity building needs of agricultural extension agents in supporting smallholder farmers to address climate change. Workshop participants also deliberated on the sources of climate information for agricultural extension agents in the Upper East region.

A questionnaire survey was administered with 32 agricultural extension agents drawn from all the districts within the Upper East region (Fig. 1). Purposive non-probabilistic sampling was used to select 32 agricultural extension agents who were part of the 39 stakeholders attending the third stakeholders' workshop at Bolgatanga. The survey aimed to understand the capacity building needs of agricultural extension agents to assist farmers to effectively manage the risks associated with climate change, and contained questions related to knowledge, learning needs and demographic factors (including gender, age, level of education, marital status, year of extension and number of communities serving). Questions asked extension agents about their understanding of the causes of the changing climate and the sources of climate information they use.

Expert interviews were conducted to further provide information on the barriers to successful extension services in managing climate risks. Such interviews provided an opportunity to triangulate most of the issues raised in the stakeholder workshops and questionnaire surveys. In all, 20 expert interviews were conducted between October 2019 and February 2020. Experts were purposefully selected based on their longstanding and comprehensive knowledge on climate change adaptation issues in Ghana. These experts were not the same people who attended the stakeholders' workshops, though they did cover the same stakeholder groups. All participants in the research gave their consent to participate and were informed that their participation would not be compensated in monetary terms. They were also informed that they could withdraw from the interviews, workshops and the survey at any time during data collection.

Qualitative data from stakeholder workshops and expert interviews was coded and analyzed thematically using content analysis to draw out the key themes emerging from these discussions (Creswell, 2014). Quantitative data from the questionnaire surveys was subjected to analysis using the SPSS 21 software package for descriptive statistics (frequency counts and percentages).

4. Results and discussion

4.1. Demographic characteristics of respondents

The demographic characteristics of the agricultural extension agents are presented in Table 1. The vast majority of the respondents (94%) were male. In Ghana, males dominate agricultural extension services and this could be attributed to the fact that structural barriers may have restricted their access to the educational levels required to become an extension agent. Women have also traditionally worked on post-harvest activities and different processes within the value chain, as well as bearing large responsibilities for domestic and caring duties (Okpara et al., 2019). The low representation of female farmers in the extension services could disadvantage female farmers from accessing extension advice particularly in the Upper East region, where cultural norms make it difficult for a female farmer to talk to a male extension officer (Lamontagne-Godwin et al., 2017). Close to half (47%) of the respondents were aged between 20 and 30 years. All respondents had formal education at the tertiary level while 66% were married. About 56% of the agricultural extension agents had < 5 years of extension experience, with 6% having > 20 years of extension experience. About 9% of the respondents served > 20 communities while 44% served between 6 and 10 communities.

4.2. Agricultural extension agents' understanding of climate change drivers

Efficient delivery of extension services to farming communities requires that extension officers have good knowledge and understanding of the drivers of climate change. This could inform some of the adaptation interventions and technologies that are delivered to smallholder farmers. The perceived drivers of climate change by agricultural extension agents are presented in Table 2. All the respondents reported that deforestation was a major cause of climate change. A large majority (94%) of them mentioned charcoal harvesting, poor farming practices (84%), increased release of greenhouse gases (88%), population growth (84%) and overexploitation of natural resources (91%) as major causes of climate change. Nearly three quarters (72%) of the respondents indicated that the use of nitrogen-containing fertilizers and conversion of forests into agricultural lands (69%) greatly influence the occurrence of climate change. This suggests that extension officers in the study attributed climate change to anthropogenic causes and that they have a good understanding of both distal and proximal drivers presented in the wider literature (IPCC, 2019). Findings agree with others including de Koff and Broyles (2019) who observed that the majority (about 62%, n = 100) of extension advisors in Tennessee, United States understood climate change to be caused by both natural changes and human activities. In China, Wei et al. (2014) reported that about 74.8% of health professionals at the Centre for Disease Control and Prevention indicated the emission of greenhouse gases was the cause of climate change.

Workshop participants across all stakeholder groups also reported that apart from natural causes, emissions of CFCs, bush burning, overgrazing, energy production and transportation are important contributors. In addition, they considered that any activity that could exacerbate warming of the climate should be tackled with all seriousness, and that there is a need for a holistic approach and discipline, from policy to grassroots, to tackle climate change and its related issues.

Table 1
Demographic characteristics of agricultural extension agents in the Upper East region.

Category	Frequency (N = 32)	Percentage
Sex		
Male	30	93.8
Female	2	6.3
Age (in years)		
20–30	15	46.9
31–40	9	28.1
41–50	5	15.6
>50	3	9.3
Level of education		
Tertiary	32	100.0
Marital status		
Single	11	34.4
Married	21	65.6
Years of extension		
1–5	18	56.3
6–10	7	21.9
11–20	5	15.6
>20	2	6.3
Number of communities served		
1–5	10	31.3
6–10	14	43.8
11–20	5	15.6
>20	3	9.3

Table 2
Perceived causes of climate change by agricultural extension agents.

Perceived causes	Yes		No		Don't know	
	N	%	N	%	N	%
Deforestation	32	100.0	0	0	0	0
Charcoal harvesting	30	93.8	2	6.3	0	0
Poor farming practices	27	84.4	5	15.6	0	0
Increased release of greenhouse gases	28	87.5	2	6.3	2	6.3
Population growth	27	84.4	5	15.6	1	3.1
Overexploitation of natural resources	29	90.6	3	9.4	0	0
Increased livestock farming	13	40.6	16	50.0	3	9.4
The use of nitrogen-containing fertilizers	23	71.9	4	12.5	2	6.3
Conversion of forests into agricultural lands	22	68.8	10	31.3	0	0
Act or will of God	3	9.4	18	56.3	11	34.4

4.3. Sources of climate information for extension agents in the Upper East region

Understanding the sources of information used by agricultural extension agents is critical in helping them to effectively deliver extension activities to farmers to address climate risks. In dryland farming systems, access to timely and accurate climate information is considered a climate smart intervention that could be used to manage climate risks by smallholder farmers (Hansen et al., 2019; Singh et al., 2018; Vincent et al., 2017). During workshop sessions, agricultural extension agents highlighted the key sources from which they obtain climate information, including radios, social media, televisions, the Ministry of Food and Agriculture, ACCU weather App and text messages. Extension agents indicated that radios and televisions remain their main sources of climate information. One agricultural extension agent remarked:

> "*We rely so much on radios and televisions for information on the weather. Ghana Meteorological Service provides forecasts for every day and this is what we rely on for our extension work*" (Agricultural Extension Agent, Bolgatanga, September 2019).

Another stated:

> "*Even though we may obtain climate information from other sources including social media, radios and televisions continue to dominate when it comes to access to climate information in this region. Accessing climate information through radios and televisions is free and one can get this information as long as he/she has radio or television sets*" (Agricultural Extension Agent, Bolgatanga, September 2019).

The use of radio as a source of climate information is quite popular amongst both extension agents and farmers in rural communities in Ghana. One of the key advantages in using radios is that information is indeed delivered free of charge. Our findings compare favourably with Ogunlade et al. (2014) who reported that radio, including community radio, was ranked first as the main source of climate and agricultural information by a sample of extension officers selected randomly in Ghana.

Workshop participants including extension agents and subsequent expert interviews confirmed that the Ministry of Food and Agriculture also provides climate information delivered via text messages on regional agricultural extension agents' platforms. According to the agricultural extension agents, the key disadvantage with delivery of climate information via text message is that the information passes through several units before reaching them. This makes such information untimely and not usable by smallholder farmers to inform critical farming decisions including when to plant and apply fertilizers. Safdar et al. (2014) also reported that the most frequent source of climate information and agricultural information for agricultural extension agents in Pakistan was from the agricultural department, closely followed by radio.

4.4. Capacity building needs for agricultural extension agents to address climate change

Understanding capacity building needs of agricultural extension agents is critical in planning and designing efficient training outreach programs on climate-resilient agriculture. Agricultural extension agents and other stakeholders from civil society

Table 3
Capacity building needs of agricultural extension agents in the Upper East region.

Needs	Yes		No	
	N	%	N	%
Climate smart agricultural interventions including soil moisture conservation methods	32	100	0	0
Weather forecast skills on climate change	31	96.9	1	3.1
Pest control skills to reduce pest attack	30	93.8	2	6.3
Use of information communication technologies (ICTs)	27	84.4	5	15.6
Programme planning for climate change issues	30	93.8	1	3.1
Recording and reporting climate change impacts	32	100	0	0
Communication skills	28	87.5	4	12.5
Field demonstration skills	29	90.6	3	9.4
Project monitoring and evaluation in extension	29	90.6	3	9.4

organisations and NGOs generally agreed that climate change was a major challenge to achieving food security within the Upper East region, especially because agriculture is predominantly rain-fed, with patterns and amounts of rainfall determining the productivity of crops. The need to build the capacity of agricultural extension agents and understanding of the barriers to effective extension services was acknowledged by all stakeholder groups at the workshops. Both agricultural extension agents and other stakeholders agreed there was a need to develop the capacity of agricultural extension agents to be able to effectively assist farmers to manage climate risks to their livelihoods. All of the agricultural extension agents (n = 32) in the questionnaire survey reported the need to receive training on climate smart agricultural interventions such as soil moisture conservation methods, and noted limited current knowledge on how to record and report climate change impacts (Table 3). A district director of agriculture stated:

> "*In addressing climate change effects on crop production, extension agents should be able to help farmers on sound and adequate soil moisture conservation practices. This is due to the nature of the soils and how these have been depleted over the years because of continuous farming on the same piece of land*" (District Director of Agriculture, Expert Interviews, Bolgatanga, October 2019).

Building farmers' capacity on the use of climate smart agricultural practices including soil conservation is critical because of the high vulnerability of farming households in the region to climate change. Climate smart agricultural technologies provide opportunity for farmers to increase food production whilst increasing adaptive capacity and mitigating climate change risks and extension agents are important in designating information on climate smart technologies (Olorunfemi et al., 2020). The Upper East region is poorer and drier than many other parts of the country, and the people depend on subsistence agriculture. The region is one of the most climate-stressed regions in Ghana (Abbam et al., 2018). Soils are shallow and low in fertility, have low organic matter content, and are predominantly coarse textured (GSS, 2013).

The vast majority (97%; n = 31) of respondents to the survey also mentioned that they needed training on effective interpretation of weather forecasts to then share with farmers. One agricultural extension agent remarked:

> "*Agricultural extension agents are at the forefront of communicating climate information and innovations in agriculture to farmers to address the threats posed by climate change, yet, many of them lack the knowledge on climate change to be effective agents of change*" (Agricultural Extension Agent, Stakeholder Workshop, Bolgatanga, September 2019).

Another extension agent stated:

> *"Farmers need climate information to address climate change effects, yet, most of the agricultural extension agents do not understand the various terminologies used in communicating climate information to farmers. How can we then help these farmers?* (Agricultural Extension Agent, Stakeholder Workshop, Navrongo, September 2019).

The above views were expressed by several extension agents and aptly reflect the general opinion of extension agents, as well as district directors of agriculture. Interpreting and communicating climate information are key to the successful delivery of extension services. Other stakeholders within the agricultural value chain across the Upper East region share similar sentiments. A district director of agriculture provided another characteristic remark during an expert interview:

> "*How can we expect agricultural extension agents to help farmers to address the adverse impacts of climate change on their livelihoods when the agricultural extension agents themselves lack the necessary skills and tools needed to effectively help these farmers? Agricultural extension agents need to have a fuller understanding of the causes and effects of climate change to be able to proffer the appropriate adaptation practices to farmers*" (Expert Interview, Bolgatanga, February 2020).
>
> "*Agricultural extension agents are the link between farmers and research institutes and therefore are quite critical in ensuring the smooth flow of research innovations to farmers. They act as conveyer belts for the flow of information to farmers. They play a significant role in ensuring that farmers receive important information and advice for their farming operations. It is therefore important that extension agents are provided with the necessary training and equipped with the appropriate resources to deliver on this mandate*" (Community Leader, Bawku West, October 2019).

The above narrations give credence to the statement that agricultural extension agents are key stakeholders in the fight against climate change in dryland farming systems. Extension agents support two-way communication flows between researchers and farmers and are therefore central players within the agricultural institutional landscape.

Agricultural extension agents also reported the need to develop technical skills for effective extension delivery. Climate change issues are complex and most technical institutions where most of the agricultural extension agents are trained do not teach them about climate change. Therefore, the need exists to periodically run workshops and in-service training for agricultural extension agents on climate change issues. This finding agrees with those from other studies including that by Sulaiman & Mittal (2016), suggesting that agricultural extension agents need to have sound technical knowledge relevant to crops and enterprises in the specific context and functional skills related to communication.

Most of the survey respondents (88%; n = 28) highlighted communication skills as crucial in helping agricultural extension agents to effectively discharge their mandate. An agricultural extension agent indicated:

> "*We need to be trained on modern forms of communicating climate information to farmers in order to help them address climate risks. The old mode of communications is sometimes failing us. Indeed, most of us [extension agents] are less skilled in the use of modern communication approaches including social media to reach out to our farmers. The other thing is even if extension agents are able to use social media, will farmers be able to understand and appreciate such messages?*" (Agricultural Extension Agent, Stakeholders' Workshop, Navrongo, September 2019).

Previous studies (including Mustapha et al., 2012; Prokopy et al., 2015; Ali et al., 2018) suggest that agricultural extension agents' communication skills are a strategic asset for enhancing the adaptive capacity of farmers. Chowdhury et al. (2014) suggest that

training workshops on communication approaches can be organized for extension officers and advisors who provide support to farmers to manage climate risks.

Improved capacity in the use of information communication technologies (ICT) was also considered important by the majority of the survey respondents (84%; n = 27) as well as other stakeholder groups during the workshops. The use of ICT can improve extension service delivery. For instance, ICT can support climate change adaptation through digital farm mapping and keeping of agricultural records. Previous studies (including Balaji et al., 2007; Meera et al., 2012; Ali et al., 2018) suggest that ICT can boost the quality of extension efforts because it can be used as an education and learning medium to promote practical and important adaptation strategies to farmers. In Nigeria, Omotesho et al. (2012) reported that agricultural extension agents demonstrated low levels of access to ICT.

Agricultural extension agents further expressed the desire to build their capacities in project monitoring and evaluation in extension (91%; n = 29). Monitoring and evaluation skills could help agricultural extension agents to track the impact of the various extension interventions they undertake. This will help improve the delivery of future projects aimed at building the resilience of smallholder famers to address climate risks in vulnerability hotspots. This finding is in agreement with previous studies indicating that project monitoring and evaluation helps to track implementation of adaptation strategies by farmers systematically, and also measure the effectiveness of the adaptation strategies (see Cerdán-Infantes et al., 2008; Bours et al., 2013). Monitoring and evaluation form the basis for the modification of climate change adaptation strategies and can be used to assess the quality of the strategies suggested to the farmers, as well as playing a key role in identifying and avoiding potential maladaptation.

Extension delivery often involves field demonstrations on farmers' fields. Field demonstration skills can be used to develop farmers' thinking skills and facilitate adaptation strategies such as terracing. Field demonstration skills can also increase the curiosity and enhance the reasoning abilities of the farmers (see Ozor & Nnaji, 2011; Singh & Grover, 2013; Yegbemey et al., 2014) suggesting that this approach is a useful way to enhance farmers' interest in an adaptation strategy. The effectiveness of such demonstrations depend largely on the ability of the agricultural extension agents to use locally relevant materials to enhance understanding by smallholder farmers, and to communicate effectively. This requires special training in delivering this kind of approach and 91% of survey respondents felt agricultural extension agents should be trained and better supported to deliver appropriate demonstration exercises.

4.5. Barriers to successful extension services delivery for climate change adaptations

This section focuses on both extension agents and farmers to answer the third research question: what are the key barriers to successful extension outcomes for climate change adaptation? Survey respondents and other stakeholders at the workshops reported a number of barriers confronting agricultural extension agents' efforts at assisting smallholder farmers to address climate risks in the Upper East region. Six key barriers were identified: (i) lack of transportation facilities for extension agents, (ii) lack of appropriate extension materials, (iii) high agricultural extension agents to farmer ratio, (iv) inadequate funds to implement climate change adaptation practices, (v) farmers' resistance to change, and (vi) complex land tenure arrangements that do not allow investment.

4.5.1. Lack of transportation facilities for agricultural extension agents

One of the key barriers to effective extension delivery is the lack of resources including transport. Most farming communities are located far from the district capital where most of the extension agents tend to live. Hence, extension agents require transport to get to these communities. Unfortunately, many of the extension agents do not have their own means of transport. The Ministry of Food and Agriculture provided motorcycles to some of the extension agents to make them more mobile but the majority remain without transport. This affects effective delivery of extension services as captured by this remark by a district director of agriculture:

> "*Not all the agricultural extension agents got the motors that were distributed by Ghana's Ministry of Food and Agriculture. Majority of the extension agents do not have means of transport to our farming communities and this reduces the number of times we can visit such communities*" (District Director of Agriculture, Expert Interviews, February 2020).

Related to a lack of transport is the poor quality of the road networks in most of the farming communities who are in most urgent need of extension advice to address climate risks. "*Most of our roads are unmotorable and this makes it difficult to visit such communities. The roads to most of the farming communities are in a bad state such that even when one has the means of transport, they struggle to use these roads to visit farmers."* (Agricultural Extension Agent, Bolgatanga, February 2020). Other stakeholders shared similar sentiments.

> "*Our roads are one of the biggest challenges to extension delivery in this region. Extension agents need to regularly visit their operational area or communities. However, bad road networks make it difficult for extension agents to do that. The roads virtually become unmotorable especially during the rainy season, when we need the extension agents the most to advise us on farming practices*" (Community Leader, Interview, Talensi District, February 2020).

These narrations point to a worrying situation because the majority of the extension officers are unable to reach vulnerable communities to provide advice, which undermines the delivery of information to support effective adaptation to climate change. Such findings are in consonance with previous studies in the East Akim and Atiwa districts of the Eastern region of Ghana, indicating that the majority of agricultural extension agents do not feel motivated to perform their duties due to lack of transport to the farming communities (Baah et al., 2009). Similarly, Belay and Abebaw (2004) reported that the majority of agricultural extension agents in southwestern Ethiopia pointed out that inadequate transportation facilities was impeding their efforts in promoting and disseminating information on modern agricultural technologies. Belay and Abebaw (2004) also highlighted the country's poor road network as a major challenge interlinked with the inadequate transportation facilities.

4.5.2. Lack of appropriate extension materials

Climate change is a complex and abstract concept and this sometimes poses challenges to smallholder farmers in appreciating and understanding their vulnerability to climate change. Agricultural extension agents need to be fully resourced with audio-visuals to deliver extension advice that farmers can understand. An extension agent remarked: "*even we, the extension agents, sometimes struggle to appreciate the complexity of climate change and how to effectively communicate the same to smallholder farmers*." Our assessment of the causes of climate change illustrates this point, alongside the varied emphasis placed on different drivers by different agricultural extension agents. It is not appropriate for agents to use the same materials used to train them on climate change adaptation with the farmers. High levels of illiteracy within the Upper East region make it difficult to communicate with farmers through written means. This suggests alternative materials are needed. Our finding that there is a lack of appropriate extension materials supports those in previous studies, and forms another barrier that hinders the promotion, dissemination and adoption of agricultural technologies (see Belay and Abebaw, 2004; David & Cobbah, 2008).

4.5.3. High agricultural extension agent to farmer ratios

High extension agent to farmer ratios lead to increased workloads for extension agents. When agricultural extension agents are given too many farming communities to handle, the frequency of visits becomes lower, more irregular and this potentially reduces the effectiveness of extension advice. Our results show that about 25% of extension agents surveyed in this study were responsible for extension delivery in 11 or more communities (see Table 1). A district director of agriculture reflects on this in this remark:

> "*Our agricultural extension agents are sometimes over-burdened with too many communities to serve. They become less effective whilst trying to satisfy the many communities and farmers they serve. For effective extension delivery to address the threats posed by climate change, the number of communities served by each extension agent should be carefully looked at to ensure that extension agents are not exhausted and over-burdened*" (District Director of Agriculture, Expert Interview, November 2019).

Increased workload leads to a lack of time that could potentially constrain extension agents' efforts to acquire knowledge and competencies to promote extension for climate change adaptation, especially in vulnerable dryland farming systems like those in the Upper East region. Our findings share similarities with those reported across other parts of Africa. For example, Ifejika Speranza et al. (2009) found that the ratio of frontline extension workers to farmers in Kenya was about 1:1000 compared to the desired level of 1:400. Chinseu et al. (2019) noted from their survey of 300 farmers in two districts in Malawi that despite 93% of their respondents identifying that they had a designated extension officer working in their section, only 25% of respondents said they were visited every month, 22% received one visit in the whole cropping season and 18% reported no contact with agricultural extension agents. The implications of this for the uptake of climate change adaptation strategies is worrying, because without the necessary technical understanding of adaptations such as conservation agriculture, farmers are unlikely to utilise the necessary techniques to manage climate risks.

"In our section, the extension worker just came to introduce CA and

4.5.4. Inadequate funds to implement adaptation practices

Inadequate funds to initiate climate change adaptation is a major barrier to the implementation of climate change adaptation practices and has been mentioned in relation to Ghana as well as other developing countries many times in the literature (Antwi-Agyei et al., 2015a; Bryan et al., 2009). This issue presents a key challenge to the success and effectiveness of extension outcomes, and was recognised by a workshop participant from a civil society organisation who remarked:

> "*Poverty levels in these communities are so high and smallholder farmers are only subsistence farmers who normally produce enough to feed their families. They are often left with nothing to sell to raise funds to implement adaptation measures that may require financial investments*" (Participant, Stakeholders' Workshop, February 2020).

This means that even if extension agents have received extensive capacity building and training, and have been equipped with the necessary communication and ICT tools, they cannot guarantee the uptake of the techniques they espouse due to this broader resourcing challenge. Previous studies note the same, and suggest that smallholder farmers are faced with inadequate funding to carry out adaptation strategies suggested by agricultural extension agents (Swanson, 2008; Ebenehi et al., 2018).

Most climate change adaptation practices including the use of early maturing varieties of crops, and planting improved varieties such as drought tolerant varieties, require financial commitment on the part of smallholder farmers. However, poverty is prevalent in the Upper East region (), compounded by other non-climate stressors including a lack of credit facilities that could facilitate adaptation measures. This makes it difficult for farmers to accept and implement adaptation measures and other agricultural innovations and interventions that can help reduce their vulnerability. Most adaptation initiatives are also donor funded and NGO led; making it difficult to sustain such practices after donor support has ended (Yakubu, et al., 2019). This suggests that consideration needs to be given to all stakeholders within the agricultural system, as building the capacity of extension agents alone is insufficient to guarantee the desired adaptation outcomes.

4.5.5. Farmer resistance to change

Agricultural extension agents highlighted that farmers are sometimes reluctant to accept new technologies and innovations that can help them to address climate change effects. They are used to their old ways and methods of farming. One stakeholder indicated that:

"*One of the major barriers to effective extension is the unwillingness on the part of smallholder farmers to accept new innovations and technologies aimed at building the resilience of farmers to climate change. Our farmers sometimes want to hang on to the old ways of doing farming*" (Community Leader, Talensi District, October 2019).

There are new improved varieties of crops and other farming practices (such as when to plant and apply fertilizers), which when properly applied in line with agricultural extension agents' advice, can reduce the vulnerability of farming households to climate change. Yet, because of social beliefs and values, many smallholder farmers find it difficult to do away with old practices (Meijer et al., 2015). For instance, Meijer et al. (2015) reported that the uptake of agricultural technologies is greatly influenced by both extrinsic and intrinsic variables that shape the behaviour, knowledge, attitudes and perceptions of adopters of innovation. Resistance to change is also related to a general lack of confidence in science by smallholder rural farmers largely due to farmers' bad experiences with past climate forecasts and other innovations that might have not met farmers' expectations (Kabobah et al., 2018). Kiptot and Franzel (2015) suggested that extension agents feel discouraged when some farmers they have trained do not take up the adaptation practices.

4.5.6. Complex land tenure arrangements as a barrier to extension services

Another key barrier impeding the work of agricultural extension agents in helping farmers to manage climate risks relates to cumbersome land tenure arrangements in the Upper East region.

"*We have a complex land tenure arrangement in this region, which sometimes becomes a disincentive for farmers in the implementation of key adaptation practices including soil conservation and management practices, planting of trees etc. This is particularly so for migrant and female farmers in this region*" (Workshop Participant, Stakeholder Workshop, Bolgatanga, September 2019).

Another stakeholder remarked:

"*How do you expect a farmer who knows he/she can lose title to the land any time to invest resources in long-term climate change adaptation practices? Most farmers who have no tenure security resort to using short-term soil and land management practices which may not be helpful for climate change adaptation*" (Agricultural Development Officer, Expert Interview, February 2020).

The Upper East region has complex land tenure systems that serve as dis-incentive for investments into the agricultural sector (Obeng-Odoom, 2014; Yaro, 2010). For instance, although females can generally access farmland, they cannot own land and these sociocultural barriers often tend to slow the implementation of adaptation measures. This is particularly important for adaptations such as tree planting and soil erosion control measures that demand considerable investments and which have a longer return on investment period. A gender-sensitive approach can help to tackle challenges of land degradation as well as reducing climate risks (Okpara et al., 2019). This finding agrees with previous studies in the Upper East region, suggesting that complex land tenure systems prevent certain socioeconomic groups including females and migrants from implementing appropriate adaptations (Nyantakyi-Frimpong, 2020; Antwi-Agyei et al., 2015b).

Formalisation of land rights (including women's land rights) increases their bargaining power and decision-making (Meinzen-Dick et al., 2019) and provides an opportunity for landholders to access credit, which can be invested in adaptation practices to reduce poverty. Complex land tenure systems are one of the biggest challenges in extension services delivery because farmers who rent lands are unable to adopt certain adaptation strategies suggested to them by extension agents (Donkor & Owusu, 2014).

5. Conclusion: Improving extension delivery to address climate change and the way forward

This paper sought to identify the major knowledge gaps and capacity building needs of agricultural extension agents in order for them to more effectively support smallholder farmers in navigating and addressing the effects of climate change. Results revealed that agricultural extension officers in the study area have good knowledge on the key drivers of climate change. Results indicated that radios and televisions remain the main sources for climate information for agricultural extension officers in the Upper East region. Findings further indicated that agricultural extension agents felt that they needed capacity building to enable them to successfully deliver extension services in relation to climate change. Capacity needs include training on effective interpretation of weather forecasts and its onward communication to farmers, using climate smart interventions such as soil moisture conservation methods and developing technical skills for effective extension delivery. Other skills identified to be in need of development include those in field demonstration, project monitoring and evaluation, as well as programme planning for climate change issues. The use of ICT to deliver extension advice on climate change was also identified as a key capacity building need. Our analysis showed that agricultural extension agents are confronted with range of barriers beyond their control that impede the successful delivery of extension services and which cannot be addressed through capacity building and training alone. Key barriers included lack of transportation facilities for extension agents, lack of appropriate extension materials, high agricultural extension agents to farmer ratios, and inadequate funds to implement adaptation practices. Other barriers included farmer resistance to change because of attachment to old farming practices, and complex land tenure arrangements that do not incentivize or support investment.

It is recommended that the central government and development partners should commit more human, financial and logistical resources to agricultural extension delivery in Ghana to boost agricultural productivity and address climate risks, including investments in road networks. However, improvements in extension alone are insufficient to guarantee the desired adaptation outcomes on the ground. Farmers should therefore be educated and supported to accept innovation and technologies that can help them to manage climate risks. Periodic workshops should be organised for agricultural extension agents on the use of ICT to deliver extension services, as well as undertaking regular assessments of their training needs. Additionally, regular capacity building workshops on climate change should be organised for extension officers to build their capacity to help smallholder farmers to address climate risks in dryland farming systems. One of the key barriers identified in the study was the lack of effective communication of climate information

and forecasts to aid farmers in making strategic farming decisions. In this regard, it is important that agricultural extension agents are fully trained in the use of appropriate audio-visuals to aid understanding of climate change issues by smallholder farmers. There is also a need for agro-meteorological advice on climate information to enable farmers to make strategic cropping and land management decisions.

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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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Author contributions

P.A-A conceived and designed the research as well as collecting the data. P.A-A and L.C.S. analysed the data. P.A-A and L.C.S co-wrote the paper.

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