RESEARCH ARTICLE

Using climate analogue tools to explore and build smallholder farmer capacity for climate smart agriculture [version 1; referees: 1 approved with reservations]

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Abstract

Background: The phenomenon of climate change (CC) and its attendant challenges in agriculture have been widely document. Climate Smart Agriculture (CSA) focuses on sustainable agriculture intensification for food sovereignty through the adoption of mitigation and adaptation practices. Agriculture provides the livelihood for 70% of rural poor in the developing world, so building farmer capacity in CSA is imperative for food security. Studies show that transformative change must be bottom-up – integrating scientific and ethical dimensions, using participatory research approaches that employ simple comprehensive tools for building participants' capacity to adapt.
Methods: The study uses the "*Climate Change Agriculture and Food Security*" (CCAFS) climate analogue and weather forecasting tools. These participatory learning tools allow participants to interrogate and explore their own geographical and climatic histories and to draw conclusions on climate variability. This study examined smallholder farmers' understanding of CC and their resilience to it. The study consisted of 5 stages – selection of tools, planning and training of teams, meetings with community leaders and community members to select participants, focus group discussions, modelling sessions and community dissemination meetings.
Results: Participants showed awareness of CC, explained in terms of rainfall variability, decreasing rainforest, increasing temperature and excessively long hot days. Farmers illustrated gendered perception of past and present landscapes, time use, past seasonal trends, vulnerabilities and access to key resources. They also observed that natural resources were declining, while population and social infrastructure increased. Participants modelled the shift in seasons and projected possible future scenarios. Finally, participants were willing to adopt climate smart agronomic practices.
Conclusions: After establishing that farmers are aware of CC, follow-on-studies addressing the impediments to adaptation and provision of necessary tools and resources to facilitate adaptation must be carried out. This study can also be replicated among a larger smallholder population for increased capacity to practice CSA.

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Keywords
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Introduction

Smallholder farmers control a significant portion of food production in many developing nations and some of their farming practices contribute to climate change. These practices include poor agronomic practices, indiscriminate use of chemicals, land degradation, poor water resources management, and low capacity for and/or hindrances to adaptive capacity. According to Herrero *et al*., 2010, two thirds of the human population derive their livelihoods from mixed crop-livestock production systems which provide half of the global cereal needs as well as one third of its beef and dairy needs.

Even though GDP growth rate for agriculture increased marginally from 2.8% in 2015 to 3.0% in 2016, the total contribution of agriculture to GDP declined from 20.3% in 2015 to 19.1% in 2016. Of this share, crops cultivation remain the largest contributor, with a share of 14.6% (Ghana Statistical Service, 2017). Ghana's agriculture, in spite of its strategic and economic importance is predominantly small scale and rain fed. Consequently, the current variations and instability in climate and weather patterns are having a negative impact on food production in Ghana. For the last several years, the onset and cessation of rain have varied vastly from the norm, making it difficult for farmers to know exactly when to plant. Furthermore, the total rainfall patterns are also changing with many areas not getting enough rainfall accumulation for significant crop growth and yields.

Since most farms in Ghana are rain fed, information about when the rains start, stop, and how long it lasts is critical for farmers to know when and which crops to cultivate (Mensah *et al*., 2016). In 2015 and 2016 several farmers in the Sunyani Municipality reported heavy losses because there was an unseasonably short and sporadic rain season, causing many crops to fail. It is now very obvious that adaptation measures are needed immediately to assist these farmers keep their families fed.

Meanwhile, the Food and Agriculture Organisation (FAO) 2012 report, "Gender inequalities in Rural Employment in Ghana" indicates that efforts at reducing the number of food-insecure persons in the world has not met the set targets, while at the same time more is being done by citizens of various nations to further destabilize ecological systems, thus further threatening food security. There are intensified efforts to develop and disseminate adaptation and mitigation practices that can counteract the effects of climate change, and possibly slow down the trend of negative human impact on the environment.

While some farming practices contribute to climate change, agricultural systems are very susceptible to climate variability. It therefore stands to reason that stakeholders in this sector, particularly smallholder farmers, be given the capacity to understand the impact of their actions and how to adapt and mitigate them. This can be instrumental in the global adaptation and mitigation of climate change efforts. Altieri & Koohafkan (2008) reported in Enduring Farms that smallholder farmers can be part of the solution "by contributing to climate change mitigation through carbon conservation, sequestration and substitution, and establishing ecologically designed agricultural systems that can provide a buffer against extreme events".

Climate Smart Agriculture which focuses on three important objectives; food security, sustainable and resilient farming systems, and mitigation, is essential in ensuring that global food security targets can be met (Winowiecki *et al*., 2015). Therefore, building smallholder farmer capacity for CSA is a crucial step in the global efforts at adaptation and mitigation in the face of climate change. A modified approach of the Climate Change Agriculture, and Food Security's (CCAFS) analogue and weather forecasting tools were used in this study, which sought to explore smallholder farmers' understanding of climate change, its causes and impacts. Through the interactions, farmers were able to uncover and express their perceptions about climate change, food security, and have a new appreciation of the future uncertainties of climate variability.

The CCAFS climate analogue tools are excellent in helping, mostly illiterate smallholder farmers to clarify their observations and perceptions of climate change. Understanding climate change is an important step in building capacity to adopt adaptation and mitigation strategies. This participatory approach ensures that it is not an external person telling them what to see and believe, but rather, they themselves using the tools, arrive at their own conclusions. The tools help them to articulate the observed evidence of climate variability in various ways.

Additionally, men and women were given separate opportunities to express their perceptions and knowledge and this ensured that each gender is not affected by the presence of the other.

Once that has been achieved, explaining digital models and other theories of climate change is easy for farmers to understand, particularly in areas where the language to explain climate change is very limited. The seasonal food security calendar forecasting tools are also useful in helping farmers understand that the trends are gradual and unpredictable, but they do have a role to play – they are not helpless, thus laying a strong foundation for building the capacity of smallholder farmers in climate smart agriculture.

Methods

Study area

Three villages within the Sunyani Municipality were selected for this study. The selection of the communities was based on the severity of the previous drying season and bushfires they endured. These are Atronie, Nwowasu and Benue Nkwanta. The Sunyani Municipality (SM) is one of the 123 administrative districts in Ghana. It is located between Latitudes 70 20'N and 70 05'N and Longitudes 20 30'W and 2010'W, and has a total land area of 829.3 square kilometres (Mensah *et al.,* 2016). The selected communities are located on the Southern part of the Municipality. Figure 1 and Figure 2 show the political, vegetation and rivers map of the Sunyani Municipality.

Sunyani Municipality is found in the wet Semi-Equatorial Climatic Zone of Ghana, also known as the Transition Zone, which

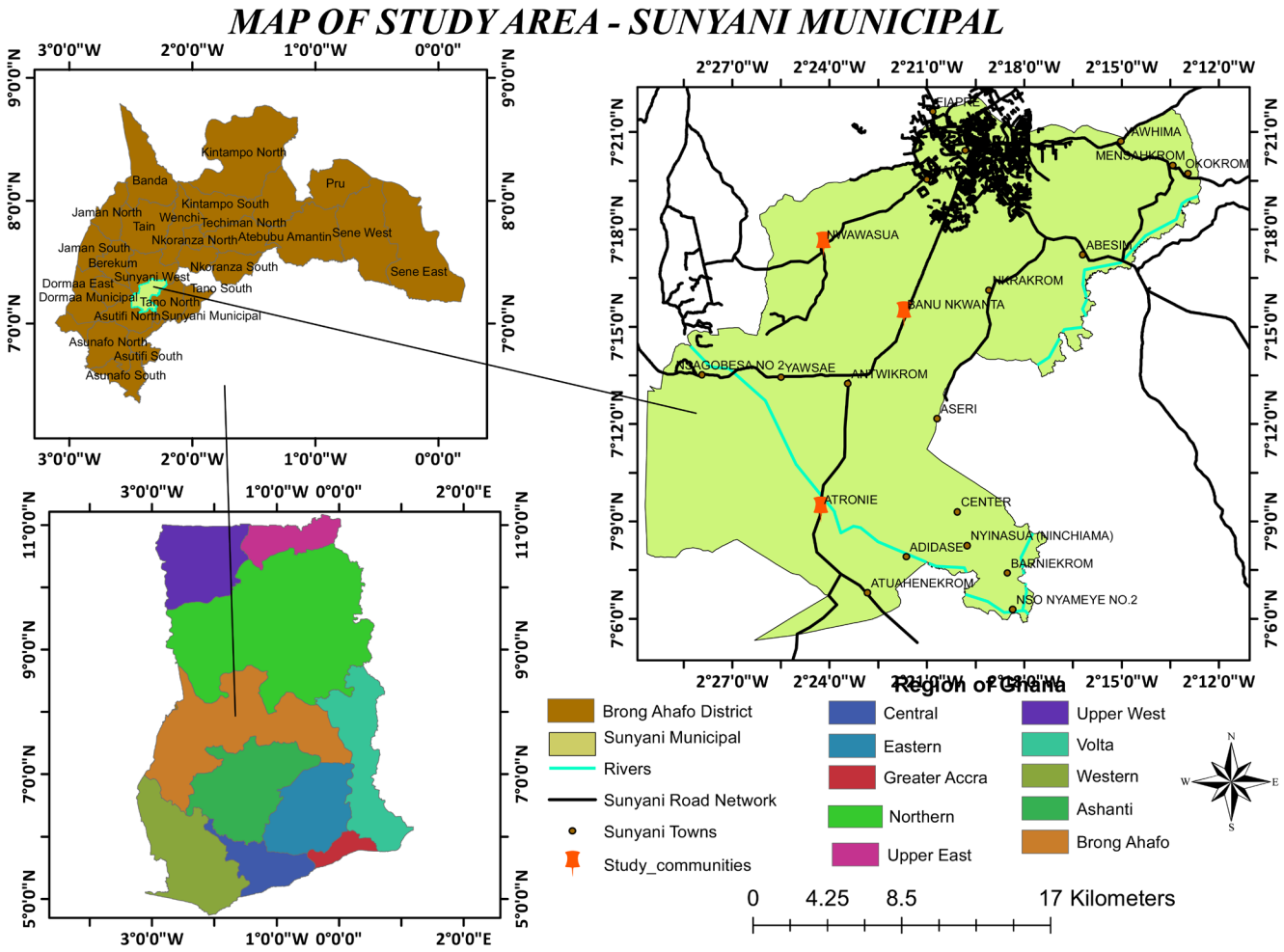

Figure 1. Map of Sunyani Municipality with study area highlighted.

enjoys relatively high temperatures and high humidity with historical mean rainfall averaging about 88.98cm, and mean humidity ranging between 70% and 80% annually (Mensah *et al.*, 2016). There are two rainy seasons: the main season is between March and September, and the minor between October to December. Although it is officially in the Transition Zone, it has areas close enough to the Forest Zone to enjoy a mix of the weather in both regions, (see Figure 3).

Atronie is a small farming community that lies on the major road between Sunyani and Mim (about 23 Km from Sunyani). Since it is on a major road, it enjoys a brisk market and is fairly urban in its outlook. Atronie has a health facility, several schools, including a private basic school, a police post, mosque, several churches, a functional market, business centre, community centre, and a chief who owes allegiance to the Sunyani paramount chief.

Nwowasu, on the other hand, is a typical village about 5.7Km from Atronie, with less than 50 homes and just about 80 households, but with a few more living on farmsteads and cottages further out. The road ends in Nwowasu. The social infrastructure of the village comprises one basic school, a couple of churches, and a Cocoa storage shed.

Benue Nkwanta is closest to Sunyani, just about 10.04 Km from Sunyani. Again, it is also on the main road leading to Mim, but it is a much smaller settlement than Atronie and more spread out. The impression we got was that most of the residents were farm hands or stewards for land owners who hailed from Sunyani. Benue Nkwanta has a basic school, some churches, and a mosque.

Sample

The Sunyani Municipal Department of Agriculture (DOA) has a database of farmers in the area, which served as the population from which a sample was taken for this study. From this population a purposive sample of farmers who agreed to participate in the study was taken at the initial community meetings in each community. A total of 125 farmers from the three communities agreed to participate in the study.

Study design

Participatory research approaches were used in the study with five distinct phases as follows: (a) selection of tools, (b) planning and training of teams, (c) meetings with community leaders and community members to select participants, (d) focus group discussions and modelling sessions and (e) community dissemination meetings. We began by researching for the best

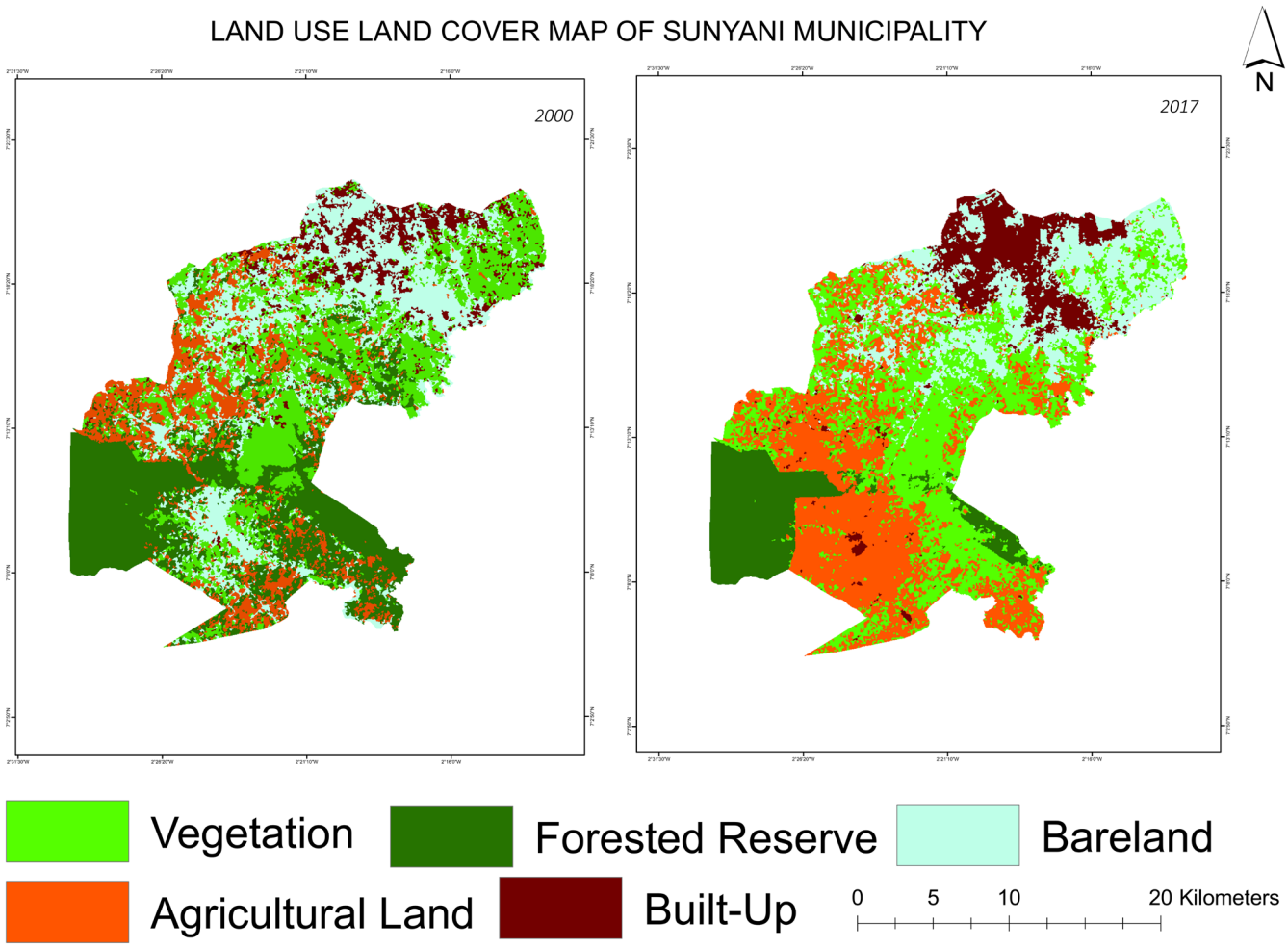

Figure 2. Map showing vegetation and existing crop patterns in the Sunyani Municipality.

methods to be used to learn about the adaptive capacity of the farmers and also help build the capacity of those who had a low capacity. The CCAFS's tools were found to be simple to use but effective in meeting the set objectives. These tools are clearly outlined in the FAO (2013) *Training Guide for Gender and Climate Change in Agriculture and Food Security for Rural Development*. The training guide contains 10 tools listed below:

Tool 1: Village Resources Map

Tool 2: Seasonal Calendar

Tool 3: Daily Activity Clock

Tool 4: Farming Systems Diagram

Tool 5: Capacity and Vulnerability Matrix

Tool 6: Venn Diagram

Tool 7: Institutional Profiles

Tool 8: Changing Farming Practices

Tool 9: Seasonal Food Security Calendar

Tool 10: Climate-Related Risk Management Practices

These 10 tools are further subdivided into the following categories

Climate analogue tools: **Tools 1–5**

Weather forecast tools: **Tool 9**

Tools for understanding catalysing gender-sensitive climate-smart agriculture initiatives: **Tools, 6, 7, 8 and 10.**

Once the tool was determined, a research team was formed comprising the lead researcher who is a lecturer at the University of Energy and Natural Resources (UENR), an agricultural extension officer, national service personnel and two students from UENR. The team met to discuss the tools and assign roles. The extension officer and some other staff from his office were consulted regarding site selection and they recommended the communities based on the severity of draught and significant bush fires they had experienced in the previous year (2015). It was assumed that with these conditions the farmers will be more willing to participate in a study on climate change, and eager to learn about ways to adapt.

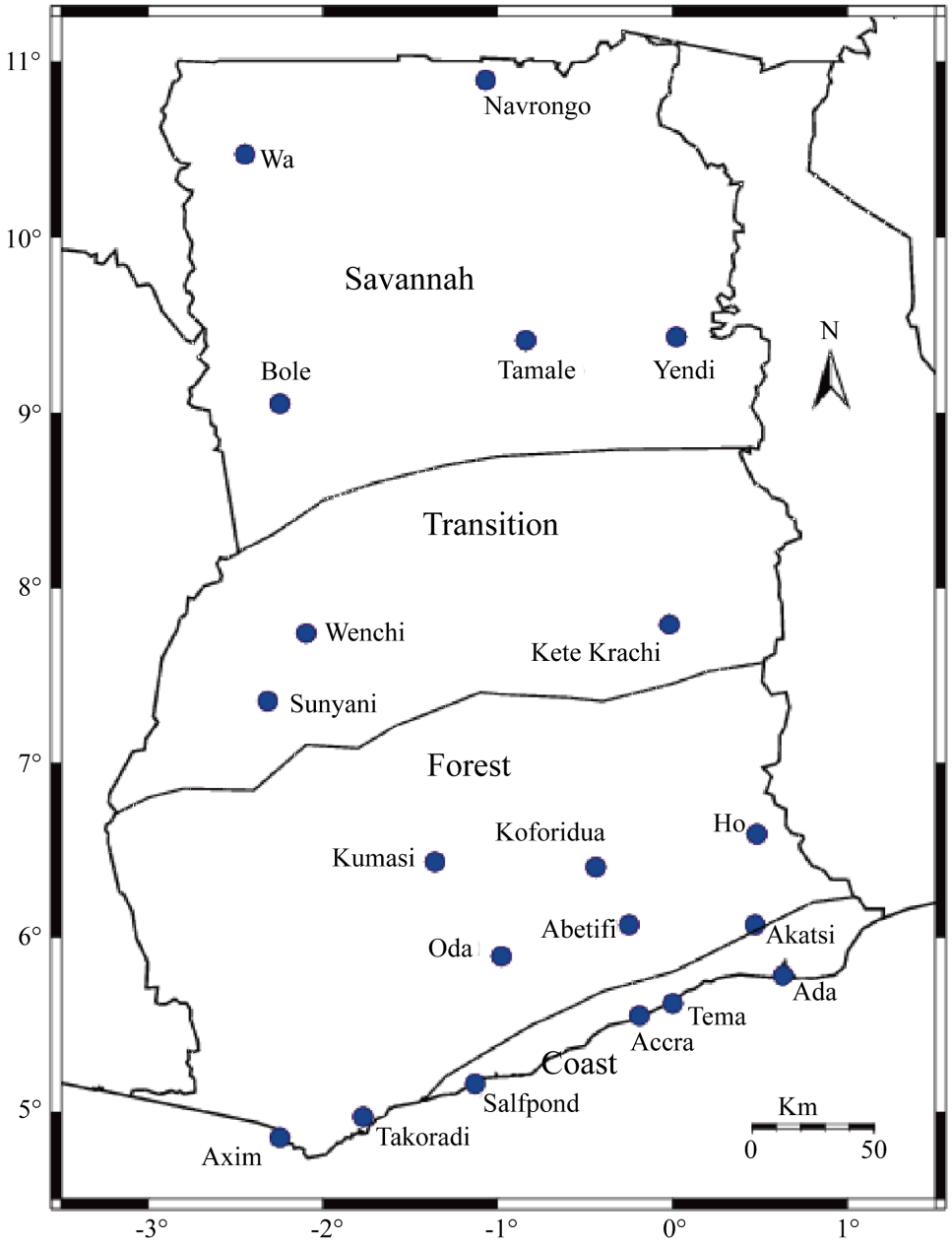

Figure 3. A map of Ghana showing all the GMet Synoptic Weather Stations (blue dots), adopted from Amekudzi *et al.* (2015).

Once the communities were selected, the extension officer made visits to the community leaders to ask for an appointment to meet with them. These initial meetings had two main purposes, to ask for permission and cooperation of the community leaders and to introduce the study to them. At all three locations, the leaders welcomed the team warmly and expressed their support and willingness to participate in the study to be conducted in their villages. Names and contact information were collected from those who indicated verbally that they will be interested in participating in the study.

With the permission of the community leaders, an initial community gathering was organised in all the three locations to explain the study objectives to farmers and community members. The community meetings were also used as an avenue to select participants for the study. After explaining the study objectives and some key terminologies in climate change discourse, volunteers were solicited to participate in a three-meeting focus group discussion over the following several weeks. Some farmers raised their hands to show their willingness to participate, the team then took down their names and contact

information. Some of the terms and vocabulary explained at the meeting included the following: climate change, adaptation, adaptive capacity, food security, mitigation, resilience, risk, carbon sink, stakeholders and vulnerability.

In Atronie 32 people indicated their willingness to participate. The number in Nwowasu was 59, while 35 people volunteered in Benue Nkwanta. All the volunteers were invited to participate in the study and given details of the dates and locations for the focus group discussions. A few individual interviews were conducted at the end of the focus group discussion. The team explained the format of the interviews, the fact that they will be videotaped and shared with the rest of the community, and then asked for volunteers. These were open-ended questions seeking to gather participant's understanding of the process as well as any new knowledge and skills they had acquired. The interviews were mostly open-ended reviews with participants asked to share what they had learnt from the sessions and to provide any further recommendations. These interviews were videotaped.

The tools used in the study were the following:

1. Village resources map
2. Daily activity clock
3. Seasonal food security calendar
4. Capacities and vulnerabilities matrix

The CCAFS tools recommend site visits to a similar ecological zone with more advanced climate smart practices. However, as part of the modification for this study, visits to physical analogue site by farmers were not conducted but attempts were made to help farmers make comparisons of their findings with other farming areas by showing them videos of such comparative sites. Additionally, videos of analogue sites in Kenya were shown as examples.

Village resources map

The first day of the Focus group discussions began with an introduction of the day's activities: the village resources map, the seasonal food security calendar and the daily activity clocks, with leading questions aimed at preparing the participants for the activities. Once that was completed the participants were divided into groups by gender and age (35 years and under were considered the youth group, and those over 36 years were grouped in the 'older' age group) and provided with materials for the activity. The first sessions were held on Friday 6th May in Atronie and Nwowasu, and Sunday 8th May in Benue Nkwanta. In Atronie, 26 participants were present on the first day. They comprised 65% males and 35% females. In Nwowasu 52 participants were present comprising 54% males and 46% females, while the total participants at Benue Nkwanta was 32, made up of 75% males and 25% females. Table 1 presents the attendance at all three villages for the focus group meetings.

For the village resource map activity, the older male and female groups were asked to illustrate on a piece of cardboard a map of their village over 30 years ago, showing key resources while the younger groups were assigned the task of making a current map of their villages. They were asked to create their own legends and symbols. Once the activity was explained to them, the research team allowed the participants to do most of the work but provided constant feedback and clarifications as needed.

Table 1. Number of participants present at each location by gender, and age.

Community/ Date	Participants/age				
	Male		Female		Total
	35 & Under	36 Over	35 & Under	36 Over	
Atronie					
6/5/2016	2	15	0	9	26
13/5/2016	2	15	0	9	26
20/5/2016	0	12	1	10	23
Nwowasu					
6/5/2016	11	17	12	12	52
13/5/2016	7	13	11	8	39
20/5/2016	5	19	13	13	50
Benue Nkwanta					
8/5/2016	6	18	2	6	32
15/5/2016	2	17	1	12	32
22/5/2016	4	13	3	12	32

After the maps were drawn, participants were asked to comment on the changes they could observe between the two maps.

Daily activity clock

This activity was conducted as a precursor to discussing gender issues with the group. The daily activity clock tool is used to show the various activities that people engage in on a daily basis. It is useful in establishing the different roles and responsibilities between men and women. On a cardboard with a pie chart drawn like the face of a clock, men and women are asked to list all activities they engaged in every hour during a typical busy farm and off farm day. This baseline is important in explaining why all must collaborate to ensure CSA is successfully implemented in the communities. The tool can also be used to establish variation in workload for men and women for different seasons of the year.

Seasonal food security calendar

According to the FAO's guide, the seasonal calendar can be used to guide participants in expressing their perception of a typical season's conditions such as incidence and frequency of rainfall throughout the year, the different cycles of food production and other livelihood activities. The seasonal calendar helps to highlight the linkages between climate variability and the various activities and resources that are available throughout the year. Farmer participants were given the task to indicate on a scale of 0-10, with 0 being none and 10 being highest, the availability/frequency of events such as rainfall, land preparation, planting, harvesting etc., throughout 2015.

Capacities and vulnerabilities matrix

Another activity performed by the participants was the capacities and vulnerabilities matrix. Through the capacities and vulnerabilities matrix, the resource needs of men and women can be easily established for a community. The gender analysis embedded in this tool makes it an important activity for long term resource planning in communities. Based on a list of resources that the participants identified, they were tasked to find out what their individual capacities and vulnerabilities were. Men, women, young men and young women all had to do this for themselves separately.

Ethics and consent

Ethical approval was not sought for this study as there were no approval structures in place for this type of study at the time of study commencement. The study is deemed by the researchers to be low risk, as it did not record any identifying information of participants; was not an interventional- or clinical-based study; and used previously developed tools by the Food and Agriculture Organization of the United Nations (FAO) and CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), which can be found here. The study was explained to the community leaders for their approval prior to approaching participants.

Participant consent was sought during the initial community meeting. Potential participants were provided with a letter in the local language describing the study (Supplementary File 1), and those that wished to participate informed their local village authority. This document was read to participants by community volunteers and those who raised their hands when asked were deemed to have given their consent to participate in the study. Written informed consent was not obtained due to the following reasons; i) the participating farmers were mostly illiterate, ii) the information collected from the study was not personal, but rather participant's perception of climatic events and their views about changing farm practices as a result of changing climate. In addition, while participants were encouraged to attend all the focus group sessions, their participation was completely voluntary and they were informed from the outset that they were at liberty to refuse participation in any or all sessions. Furthermore, names and other identifying traits were not included in the results. Where video recordings and pictures were taken, participants' verbal agreement was sought, and they were made to understand that these captured media will be used in disseminating results to the rest of the community and also on other platforms for education purposes.

Data protection: Digital photographs and videos are kept on a local PC as well as on a personal external hard drive of the researcher. These are password protected. The PC is kept in a secured location with limited access to the key researcher only. The personal external hard drive is kept in a locked compartment/room when not in use. The videos and pictures were shared among the communities with participants.

Results

Physical and anecdotal evidence from our study indicated that in 2015 and 2016, onset, cessation, and volume of rainfall varied from the norm. There were no significant rains in March and April in years, and sporadic rains during May to July when farmers finally planted, leading to major crop losses. The minor season rains in 2015 were also sporadic and not significant enough to have made a difference in the losses incurred in the major season.

Village resources map

In all locations, deforestation was evident and shown in the farmers' maps. In addition to the deforestation, the farmer participants also noted the decrease in the wildlife population in the areas. Atronie, according to the participants, had elephant presences just 30 years ago, but they have all been driven away with the disappearing forest. They also pointed out that rivers in their communities were diminishing and that some of them almost dried up in the previous dry season. In all locations, there was a marked increase in human settlements due to increased population, thus creating the need for more forests to be cleared.

Another thing pointed out by the farmers was the decreasing soil fertility. This they attributed to extended use of the same piece of land, indiscriminate use of weedicides, and planting only one crop over several years on the same piece of land. Increased use of agrochemicals was mentioned as a change in agronomic practice in all areas. The farmers testified that the

use of weedicides makes their work easy, since farm labour is expensive and scarce. They admitted that weedicides allowed them to cultivate larger pieces of land than they normally would. These agrochemicals were mostly introduced into the community by vendors, who used mass media to advertise their products.

When asked if they had been trained in the use of agrochemicals, only a few of the participants admitted to having received any form of training. They mostly gained information about these products from the sellers or other farmers. It thus came to light that many of them were using these chemicals indiscriminately. Some were making concoctions of different chemicals while others used too much. Hitherto, the farmers acknowledged that they had not considered the effects these chemicals on their lives and the lives of their clients. Some maintained that the weedicides were a much cheaper way to clear land for cultivation, and they were unwilling to consider giving it up.

Also, in response to a question about possible causes of forest decline, participants stated that clearing forests for food cultivation, lumber and harvesting trees without replanting, and bushfires have all contributed to deforestation. They also indicated that some farmers tend to farm all the way into water bodies, clearing all the vegetation cover along their banks which is causing rivers to dry up.

On the other hand, participants noted that there was more social infrastructure in the villages now than there were thirty years ago. Infrastructure such as schools, churches, wells (boreholes), public places of convenience in all communities, and in Atronie, a clinic, information centre, a vehicle boarding station, a market and mosques were added to the current resources map.

Furthermore, participants reported that there has been increased population with in-migration outweighing out-migration in Atronie and Benue Nkwanta, but Nwowasu recorded more out-migration (however, the population in Nwowasu was still increasing due to high fertility). Atronie and Benue Nkwanta participants attributed the population growth to people coming in to work on farms. Atronie is becoming more urban with more schools and business which in turn bring in more people.

In all the three locations the changes noted have brought some new challenges with profound implications including the following: Drying water bodies have led to difficulty in getting domestic water. However, in all locations deep wells or boreholes had been dug by the government in the last few years. However, at Nwowasu the borehole was not producing anymore water, and the women and children had to descend into a deep valley almost a mile down and a mile up to fetch water.

When asked about the impact of weedicides on their lives, both men and women admitted that the use of weedicides gave them time to attend to other business. They also indicated some physical discomfort and irritation when they applied the chemicals, possibly because they do not use protective clothing while applying these chemicals. In fact, it is not uncommon to see a farmer shirtless and shoeless applying chemicals. They further added that some species of plants and animals are disappearing which they now associate with the use of some agrochemicals. The disappearing species include cocoyam, taro root, snails, mushroom, snakes, and frogs. Some also noticed that worms and other soil organisms were also being killed by the chemicals.

Daily work activity

It became apparent that women were more occupied with activities in a day than men. Both sexes indicated they got up about the same time each morning. However, while the women had a lot to do before they all left for their farms, all the men usually did was their morning ablutions. Similarly, when they returned from the farms, women cooked, washed clothing, utensils, and saw to the children, working until full dark, while the men cleaned up and waited for their food or joined their friends for some relaxation. Many participants agreed that women worked just as hard as or harder than men in the farms. Several of the women who were single testified that they had to do it all alone, so they do not work any less than their male counterparts.

Though the changes impacted all the people in the community, women were most affected, especially with regards to the scarcity of water. They have to now spend considerably more time fetching water. Since the farmers associated the decreasing vegetation cover with decreasing rainfall, the women felt they had to work harder on the farm. They and the children are tasked with irrigation where there's a water body close enough to the farm to water the crops. Since there are no proper irrigation methods in place, they have to use the old-fashioned system of scooping water into a containers and bringing it to the crops, one at a time. Table 2 shows some of the activities that men and women engage in on a typical day.

Seasonal food security calendar

Table 3 below captures participant's perception of availability of the indicated resources from January to December 2015. A scale of 0 to 10 was used, 0 indicating that the event did not happen at all and 10 showing the highest frequency of the event/activity that participants could recall.

Through the seasonal food security calendar, participants were able to visually outline the events and activities that took place the previous year. During the discussion time, questions were asked about historical trends and it was agreed among the participants that several key events were not happening at their historically stipulated times. These changes affect when farmers could conduct farming activities, such as land preparation and planting. For example, onset of rainfall was very late in 2015 causing a delay in land preparation and planting by many farmers. At the same time the intensity of the rain after the onset was low, thus yields were comparatively low.

Because the previous minor season rains were not sufficient, plantain and other crops failed during the harsh dry season, as bushfires also burned many farms. As a result, there was a marked food scarcity in the Municipality in the early part of 2016. In fact, up until June cassava was very hard to find in the Sunyani

Table 2. Daily activities of men and women on a typical farm day.

Time	Men	Women
10:00pm – 5:00am	Sleep	Sleep
5:00am – 6:00 am	Morning ablutions Get ready for the farm	Morning ablutions Fetching water Sweeping, laundry Make up a fire to heat water and breakfast Wash utensils from the night before Bathe and get children ready for school Get ready for farm
6:00am – 7:00am	Walk to farm	Walk to farm
7:00am – 10:00am	Work on farm as needed	Work on farm as needed
11:00am – 12:00pm	Break for refreshment and rest	Break for refreshment Make a fire, prepare something for the family and all working on the farm
12:00pm – 3:00pm	More work on the farm	Work on the farm Gather fuel wood and foodstuffs to take home
3:00pm -4:00pm	Walk home	Walk home Women usually carry the firewood and foodstuffs home
4:00pm – 7:00pm	Wash down Rest and wait to have supper Meet with friends for game or go to church if there is a meeting	Start a fire Get supper on and see if children need any help or have information from school Sweep and clean up kitchen and compound Get dirty utensils cleaned if it is not too dark yet Wash down Go to church if there is a meeting
7:00pm – 10:00pm	Visit with family or friends, smoke or get a drink if nothing is happening in church or the community Help children with homework Relax Watch TV	Help children with homework Get ready for the next day Try to get an early rest if possible Chat with family and friends Relax Watch TV

Table 3. Seasonal food security and farming activity calendar for the Atronie area in 2015.

Event/Activity	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall	0	0	1	2	4	8	2	8	9	8	1	0
Land Prep	1	3	10	1	0	0	2	5	5	0	0	0
Off-farm labour	5	3	2	2	2	1	1	5	5	2	1	1
Food availability	3	2	2	2	2	1	1	8	9	10	9	10
Water availability	1	1	3	3	5	8	9	8	9	8	4	0
Planting	0	0	0	8	10	8	7	8	10	1	0	0
Farm Maintenance	0	0	0	5	5	5	5	5	5	5	5	2
Harvesting	4	2	2	2	1	1	3	4	6	9	10	10

market, and the little available was very expensive, sometimes as much as five times the usual cost during that time of the year.

Capacities and vulnerability matrix

Table 4a and Table 4b show some of the resources and how farmers perceived their own capacities and vulnerabilities.

It can be concluded from the matrix that the participating farmers knew many of their capacities and vulnerabilities. In one of the locations, even though participants were segregated by sex, they were required to fill in the matrix for both sexes. The responses were similar to those done by each sex for themselves alone. Men and women both felt that men had

Table 4a. Men's capacity/vulnerability matrix.

Resources	Capacities		Vulnerabilities	
	Men	**Boys**	**Men**	**Boys**
Physical and material resources • Agricultural implements • Trees • Labour • Water • Land • Seedlings and other inputs • Money/capital • Technologies	• Physically strong • Access to money • Intelligence • Literacy • Networks • Land	Same as men's	• Sickness/ill health • Poverty • Storage challenges • Lack of capacity to adopt new technologies	• Lack of money • Perceived as lacking experience and responsibility • Irresponsibility • Lack of respect • Laziness • Illiteracy
Social – Organisations and Institutions • Unity fun club • Micro credit scheme • Microfinance and banking institutions • Religious institutions • Political parties • Ministry of food and agriculture • COCOBOD • Cocoa spraying gangs • Unit committees	• Money • Physical strength • Patience • Lots of free time • Knowledge • Cell phone access	Same as men's	• Women's empowerment groups • No/poor cell phone reception • No money	• Lack of trust • Lack of knowledge • Discrimination according to age • Lack of time • Mismanagement of time
Motivation and attitudes • Income • Courage • Strength • Future projection • Family responsibilities • Food for family • Contingency plans and savings • Acquisition of properties	• Ability to earn an income • Strength • Marriage • Possession of property	Same as men's	• Laziness • Poverty • Poor health and lack of strength • Frustrations • Drunkenness • Irresponsibility	• Poverty • Lack of strength • Drunkenness • Irresponsibility

more capacities and opportunities than women. However, when further questions were asked, the women acknowledged that some of their vulnerabilities were self-inflicted.

Discussion

Small holder farming contributes significantly to Ghana's socio-economic growth. Research shows that agricultural practices contribute to the global greenhouse gas GHGs emission, at the same time agriculture is also very sensitive to global climate changes occurring in part from the accumulation of GHGs (Lamboll *et al*., 2011). Human survival is dependent on continuous availability of proper nutrition. Consequently, solutions for sustainable agricultural practices that can ensure food security in the face of changing climate is needed. In Ghana and other countries south of the Sahara, agriculture continues to be one of the main means of livelihood for a majority of the people and it contributes significantly to gross domestic products. However, compared to other parts of the world, African countries are not increasing their per capita food production, with many importing staples to supplement local production. This is because for the most part agriculture continues to be practiced as 'business as usual' but the old systems appear ineffective in the face of the changing climate (Herrero *et al*., 2010; Lamboll *et al*., 2011).

In addition to climate change, agricultural systems in many African countries face other pressures as well, such as rapid population growth, bringing about fierce competition for land use, thereby rising incomes and urbanisation. Additionally, the local and national institutions that should be building farmer's capacity to increase food production are not achieving their set goals (Herrero *et al*., 2010).

Tools that can be used to empower local smallholder farmers are very important right now since many of the 'macro-interventions' are not yielding the desired results. This study showed significant differences in farmers' perception of access to resources and responsibilities placed on men and women. Women have less access to resources but have more of the responsibilities

Table 4b. Women's capacities/vulnerabilities matrix.

Resources	Capacities		Vulnerabilities	
	Women	**Girls**	**Women**	**Girls**
Physical and material resources • Agricultural implements • Trees • Labour • Water • Land • Seedlings and other inputs • Money/capital • Technologies	• Access to money • Physically strong • Selling • Borrowing and lending money	Same as women's	• Lack of access to money • Sickness and poor health • Storage challenges • Low rainfall • Laziness • Women's reproductive health challenges • Gender bias • Lack of physical strength • Illiteracy	• Lack of experience • No resources • Laziness • Lack of physical strength • Reproductive health challenges
Social – Organisations and Institutions • Unity fun club • Micro credit scheme • Microfinance and banking institutions • Religious institutions • Political parties • Ministry of food and agriculture • COCOBOD • Cocoa spraying gangs • Unit committees and community task force • Traditional councils • Cooperatives and farmer groups	• Courage • Access to money • Affirmative action – sometimes • Curiosity	Same as women's	• Fear • Lack of self-esteem • Insufficient money • Most decisions made by men alone • Reproductive health challenges • Overburdened with family responsibilities • Shyness	
Motivation and attitudes • Income • Courage • Strength • Future projection • Family responsibilities • Food for family • Contingency plans and savings • Acquisition of properties • To meet personal goals and objectives	• Commitment • Courage • Eager to make profit • Enjoyment in work • Willingness to attend or access resources because of benefits	Same as women's	• Laziness • Depression • Fear • Timidity • Lack of confidence	

in family life. This is in spite of the fact that a significant proportion of small holder farmers among Ghana's rural population are women. According to the FAO 2012 report "*Gender inequalities in Rural Employment in Ghana*", only 27% of small farms belonged to women nationwide, but they constituted 92% of small holder farmers in the rural areas. Thus gender distribution of farm size was very disproportionate in terms of rural to urban distribution. Additionally, female held farms were more market oriented but were less diverse as regards to crops, since the female farmers depend largely on maize production as a cash crop. It is therefore important that any initiative to address food security include males and females as well as other marginalised persons.

The study results on gender disparity in hours spent on domestic labour is consistent with the findings by the FAO report (2012). Both male and female participants of this agreed through the daily activity clock exercise that women spend considerable more time doing domestic chores even though both genders contribute equally in farming and off-farm productive activities. The FAO (2012) report clearly stated that: "65% of men spend from 0 to 10 hours per week on domestic activities, but 89% of women spend 10 hours per week or more… Nearly two thirds of young rural males spend between 0 and 10 weekly hours on domestic work, whereas over a quarter of young rural females spend 50 hours or more on domestic work" (p. 46). There is therefore the need to educate both

men and women about these gender disparities so that they can support each other to increase productivity and thus improve their livelihoods.

Further, the capacities and vulnerabilities matrix helped the participants to appreciate each other's perceptions of self and access to resources. The men in the group expressed the intent to be more careful to ensure that their wives and daughters get the same opportunities as their sons. Some of the men admitted to being helpful in the home and this also challenged those who were not doing so to begin to think about it. They came to understand that fighting climate change was a gender issue, requiring the active participation of both men and women. With follow-up and encouragement, these farmer participants can foster a more equitable family and community life.

Finally, the Consultative Group on International Agriculture Research (CGIAR) has shown that millions of smallholder farmers are responsible for feeding about 1 billion poor people who live on less than $1 a day in developing economies (Herrero *et al*., 2010). Targeting and empowering many smallholder farmers are therefore key steps in ensuring global food security. Government and non-governmental agencies involved in such initiatives must be encouraged to work from the ground up. This can easily be achieved through the use of tools such as the CCAFS analogue tools.

Consent

Verbal consent was obtained from the participants of the one-to-one interviews and focus group discussions for publication of identifying information. For the one-to-one interviews this includes videos and pictures taken during the interviews, and for the focus group discussions this includes audio recordings.

Data availability

Data supporting this paper is available on Figshare: https://doi.org/10.6084/m9.figshare.6024914.v1 (Opare, 2018).

Due to file size constraints some pictures and videos have not been uploaded to Figshare but will be made available upon request from the corresponding author.

Competing interests

No competing interests were disclosed.

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Supplementary material

Supplementary File 1: Participant information letter (English translation).

Click here to access the data.

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? **Amos Apraku**
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The manuscript does an excellent job by demonstrating the role of small-holder farming in the socio-economic development of rural communities in Ghana. It again shows how climate change and its related weather events continue to pose a big challenge to local farmers in the study communities. The paper further highlights how gender stereotypes in household and other community chores continue to place extra burden on women who happen to be at the forefront of small-scale agriculture (especial crop farming) in the study area. The paper proposes Climate Smart Agriculture (CSA) and Climate Analogue Tools as some of the best approaches in lessening some of the negative effects of climate change in rural Ghana and ensuring Food Security/Sovereignty in the country as a whole. Given the topical nature of climate change and agriculture in both policy and development discourses globally, the paper is of high scientific significance both in Ghana and beyond. Again, it is of high importance to national priorities in the areas of rural poverty reduction and the 'Food for Jobs' campaign of the Ghana government. However, the paper will make more impact in both academia and policy if the authors attend to following concerns/suggestions:

- I suggest that the authors clarify the conceptual uncertainty between 'climate change' and 'climate variability'. The two concepts are not the same and cannot be used interchangeably. They should clarify this uncertainty contained in the paper and stick to one - unless otherwise stated.

- Gender, Climate Change, Climate Smart Agriculture, Adaptation, Mitigation, Ethical Approaches and Food Security/Sovereignty are listed as some of the keys words/concepts of the paper; but nowhere in the text are they defined or explained or even contextualized. This needs to be addressed.

- It is not enough to base the selection of communities for a climate change study of this magnitude on only one weather season(2015-2016 farming season). I therefore suggest the authors support the selection of their study communities with more convincing factors/reasons.

- The authors should reconstruct the ecological, social and economic profile(s) of the study communities to properly show a link between such profile(s) and the core variables of the study. Doing this will automatically address my preceding comment/concern.

- The research objectives and or questions are not stated. This leaves readers with no other option than to infer or guess. It again makes it difficult to measure the objectives of the study against the methodology adopted and the results produced thereof. I suggest to the authors to clearly state the

objectives of the study based on which the paper was developed.

- The introduction section is too long thereby denying the paper a separate and proper literature review section. If it is the style of the authors to combine the literature review and introduction sections, then that should be clearly stated. Generally, the literature of the paper is a little bit weak and contains a number of personal assertions. For instance, "Ghana's agriculture.....crop growth and yields.". It is too assertive since it contains no source. This is in the second paragraph of the introduction section. The various IPCC country-specific reports (see https://www.ipcc.ch/) and African Climate Policy Centre (ACPC) reviews can help the authors to revise the literature review component of the paper (see -https://www.uneca.org/acpc).

- The 'methods' section of the paper is far too long and verbose. It needs revision and summary.

- Since the paper is based on a qualitative study, I suggest the authors quote some of the verbatim statements of the respondents in the results section. this would help to add some creed to the paper.

- The discussion section is meant to make sense out of the study findings and not a section for further literature review. I suggest that the authors revise the discussion section of the paper to bring out the locale specific significance of the study based on the findings and move the lengthy literature contained in the discussion to the appropriate section(s) - unless otherwise needed to support and validate a particular argument in the discussion.

- Finally, the paper needs some degree of language editing - focusing on sentence construction to bring out some level of coherence.

- The above mentioned issues are mere suggestions. The authors are the final authority in effecting the necessary changes suggested.

Is the work clearly and accurately presented and does it cite the current literature?
Partly

Is the study design appropriate and is the work technically sound?
Yes

Are sufficient details of methods and analysis provided to allow replication by others?
Yes

If applicable, is the statistical analysis and its interpretation appropriate?
Not applicable

Are all the source data underlying the results available to ensure full reproducibility?
Yes

Are the conclusions drawn adequately supported by the results?
Yes

Competing Interests: No competing interests were disclosed.

I have read this submission. I believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.