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Local level impacts of climatic and non-climatic factors on agriculture and agricultural land-use dynamic in rural northern Ghana

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This study investigated the local level impacts of climatic and non-climatic factors on the agricultural land-use dynamic in rural northern Ghana. Data was collected by means of household questionnaires and interview. The data collected relates to farmer's knowledge about climate change, response to the impact of climate change, dynamics in the area cultivated for crops, and the climatic and non-climatic factors that affect agricultural land-use dynamics. The data collected was subjected to simple descriptive statistics and chi-square tests. Farmers indicated that the weather patterns have affected their cropping activities. Delay in the start of rainfall, fluctuation and cessation before the growing season ends have affected them. Also, inadequate access to farm inputs has affected them. In the face of unfavourable conditions, the farmers may respond by increasing or decreasing the land area cultivated for some crops, they may continue to cultivate their crops, or they may abandon the crop(s) for the season. Jobs outside of the farm are being taken up to support household needs. Climate change has been interacting with non-climatic (socio-economic) factors, and a holistic approach would be the best to address the local or regional change. Intensification of research within the study region and nearby regions would improve preparedness for future local/regional change.

Keywords: climate change, impact, response, agricultural land-use, northern Ghana

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Introduction

The rainfall pattern in the northern savannah of Ghana is gradually becoming unpredictable. The three northern regions (northern, upper east and upper west) have a much higher incidence of poverty than other regions of Ghana (Dietz *et al.*, 2002; GSS, 2007; Osei-Assibey, 2014; Cooke *et al.*, 2016). About 30-40 per cent of the total land area of Ghana, most of which is concentrated in the northern drier part of the country, has been reported to be experiencing some form of land degradation (EPA, 2003; Agyemang *et al.*, 2007; Dittoh *et al.*, 2015). The Upper East Region (UER) of Ghana has experienced a series of changing climate impacts, such as shifts in seasons and irregular climatic conditions. Lack of reliability of rainfall is seriously impacting the farmers (van de Geest & Dietz, 2004; Dittoh *et al.*, 2015; Antwi-Agyei *et al.*, In Press) and this is associated with inter-annual variability of both the distribution and total amounts of rainfall (van de Geest & Dietz, 2004). This makes agricultural planning very difficult, as being able to predict the beginning of the rainy season, the intensity, duration, and periods of drought, is important to the farmers. According to Braimoh (2004), the onset of rainfall is always unpredictable, with the first rains usually torrential, and only a small quantity percolating into the soils. A shorter and more unpredictable rainy season, in terms of both amount and timing, have been reported by residents of UER (Dietz *et al.*, 2004; Badmos *et al.*, 2015; Limantol *et al.*, 2016; Nyadzi, 2016; Nyuor *et al.*, 2016; Dickinson *et al.*, 2017).

With respect to rural livelihood and agricultural activities, climate change/variability seems to be the most discussed issue about environmental change adaptation. Quality and quantity of land and water resources available for production in agriculture and other climate-dependent sectors such as forestry and fisheries are affected by the changing climate (Darwin, 1999; Kankam-Yeboah *et al.*, 2011; Yaro, 2013). Climate change is adding more stress to already threatened habitats, ecosystems and species in Africa. Species migration may be triggered, resulting in habitat reduction. Overexploitation of land resources, increase in population, desertification and land degradation poses additional threats (UNDP, 2006). Up to 50 per cent of Africa's total biodiversity is at risk due to reduced habitat and other human-induced pressures (Boko *et al.*, 2007).

The impact of climate change varies for different locations. For example, crop yield is expected to increase in higher latitudes of Europe and North America, but in other areas changes in temperature and water availability are expected to result in reduced yields, particularly in the tropical regions where temperature is already at, or exceeding, optimal conditions for plant growth (Parry *et al.*, 2004; Challinor *et al.*, 2006; Boko *et al.*, 2007; Christensen *et al.*, 2007; Dawson & Spannagle, 2009). Change in climatic pattern can also alter the spatial allotment of agroecological zones and distribution style of plant diseases, habitats, and pests which can have notable effects on agriculture and food production (FAO, 2007; Kurukulasuriya & Mendelsohn, 2008; Regniere, 2012; Mohammed *et al.*, 2013; Kaczmarek *et al.*, 2016). The impacts of climate change are unavoidable, even if we reduce emissions now. Understanding the depth and magnitude of climate change impacts on livelihoods is essential in proffering efficient adaptation strategies, particularly at the grassroots.

Interestingly, some studies have indicated that climate change is not the main driving force triggering environmental change adaptation. Studies conducted on drivers of adaptation strategies in Senegal and Burkina Faso show that climate change was not the main driver (Barbier *et al.*, 2009; Mertz *et al.*, 2009). Mertz *et al.* (2009) reported that marginal changes in conditions of market, supply of labour, subsidies, availability of seed, supply of energy, etc., may lead low economic resilience farmers to markedly change their strategies, irrespective of the climatic parameters. Thus, knowing the manner in which non-climatic factors impact on livelihoods would also be important when designing adaptation strategies.

In this paper, we explored the impacts of climatic and non-climatic factors on agricultural activities and agricultural land-use change in the Vea catchment, northern Ghana. The manner in which climatic and non-climatic factors affect agricultural activities at the local level and their responses were further discussed. This paper tried to answer these research questions: (i) what is the level of knowledge of farmers about climate change; (ii) what are the responses of farmers to the impacts of climate change/variability; (iii) what change has occurred in the area cultivated for major crops; (iv) what are the climatic factors that affect agricultural land-use dynamics in the study area; and (v) what are the non-climatic factors that affect agricultural land-use dynamics in the study area?

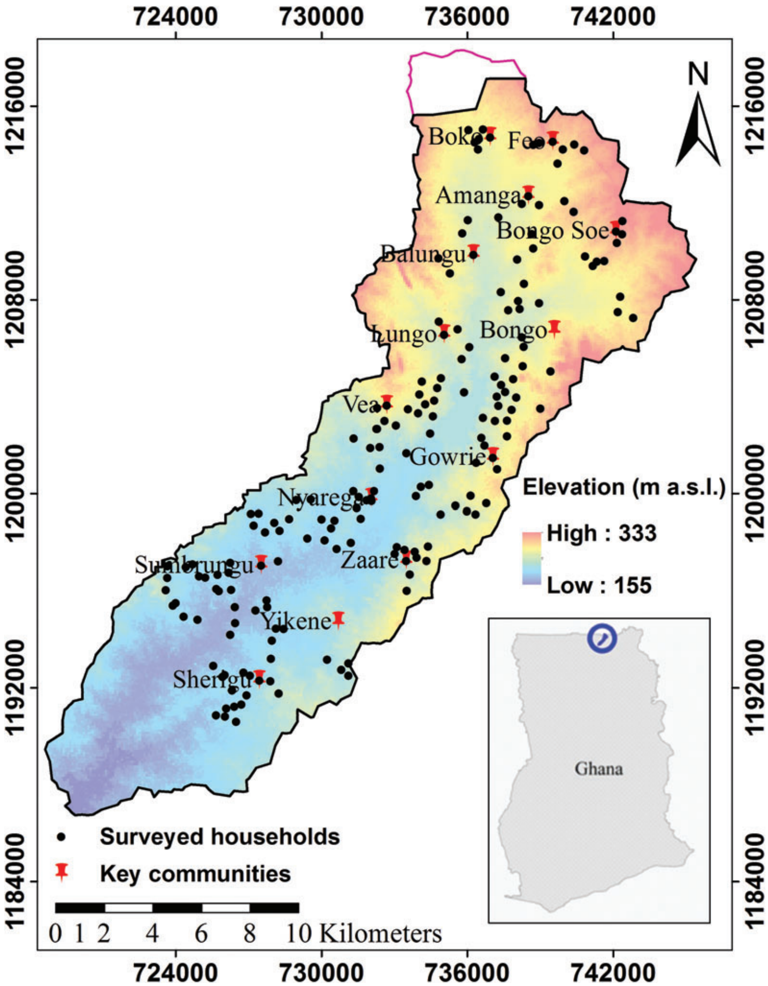

Figure 1. *Map of study area. The top pink boundary represents Burkina Faso section of the catchment.*
Source: **Digital Elevation Model obtained from United States Geological Survey (n.d.).**

Study Area

This study was conducted in the Vea catchment (Figure 1), a sub-catchment of the White Volta River. The catchment lies in both Burkina Faso and Ghana, with a total area of 8 and 293 km^2 respectively. This study was conducted within the Ghanaian section of the catchment, in the Bongo and Bolgatanga districts in the UER. The UER of Ghana is located on the northeast corner of Ghana, between latitudes 10° 30′ N to 11° 8′ N and longitudes 1° 15′ W and 0° 5′ E. The region is directly bordered by Burkina Faso to the north and Togo to the east. The major part of northern Ghana, including the UER, belongs to the West-African semi-arid Guinea Savannah belt, with the exception of a small swathe of land in the very northeast part of the region around Bawku that belongs to the Sudan Savannah (Adu, 1972). Analysis of 40 years rainfall has averaged 1 044 mm/annum, which is suitable for a single wet season crop (IFAD, 2007). About 60 per cent of the annual rain falls between July and September

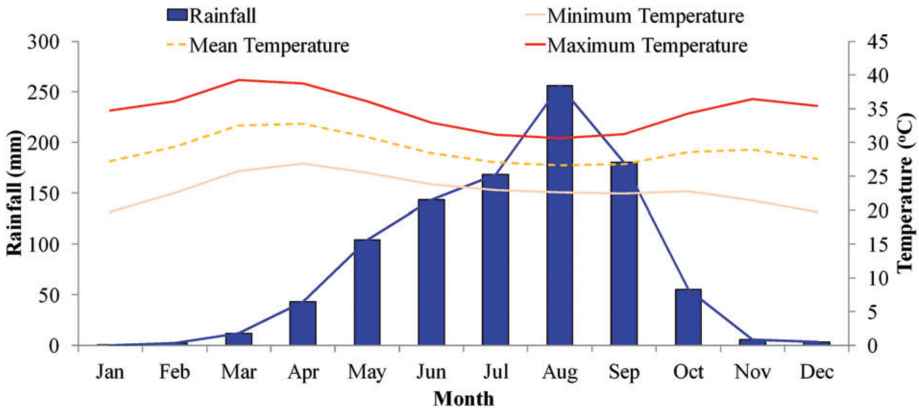

Figure 2. *Average rainfall, minimum and maximum temperature between 1985-2010 of Bolgatanga, Upper East Region, Ghana.*
Source: **Ghana Meteorological Agency (2011).**

(Figure 2). Temperatures in the region are high, with the hottest month being around March - April, and August being the coolest month (Mdemu, 2009).

About 70 per cent of the economic active population (≥15 years old) are involved in agricultural practices, followed by service and sales workers, and craft and related trades workers which constitute of 10 per cent each (GSS, 2012). Crop production is carried out both in the rainy season (rain-fed) and dry season (irrigated), but the larger part is concentrated in rainy season. Millet (*Pennisetum* spp.) and guinea corn (*Sorghum* spp.) are the most important grain staples cultivated in the upper regions of Ghana, while maize (*Zea mays*), millet and guinea corn are important across the northern region (Dietz *et al.,* 2004; Gyasi *et al.,* 2008).

The crops cultivated in the study area include millet (short seasoned millet - naara - and long seasoned millet – zia), guinea corn (kimulga), cowpea (tier), groundnut (suka), maize (kayene) and rice (mui). Millet is the least risky with regard to climate-induced fluctuations in yield, followed closely by guinea corn and maize, making all of them important for food security (Dietz *et al.,* 2004; Derbile, 2010; Stanturf *et al.,* 2011; Darko & Atazona, 2013). Manure application is the major source of nutrients for rain-fed crop production, while fertilizer may be applied to rice (*Oryza* spp.) and maize. Dry season farming activity is made possible in the region due to the availability of two major irrigation projects (Vea and Tono). Rice and vegetables (fruit and leafy) production are mostly carried out during dry season. Common types of livestock reared in this part of the country include cattle, sheep, goats, fowls, guinea fowls, pigs, and donkeys.

Methodology

Data collection and analysis

This study commenced in 2013, and, at that time, the most recent census of Ghana (2010), was yet to provide community-level household information. However, district-level data from the 2010 census was available, with Bongo and Bolgatanga district having 15 188 and 26 706 households respectively (GSS, 2012). Using GIS, the area occupied by the districts (1 188 km^2) was generated. The total area occupied by the district was combined with the area of the catchment that falls within Ghana (293 km^2) and the total households in Bongo and Bolgatanga district (41 894) to extrapolate the total number of households in the catchment (Equation 1). The extrapolated number of households (10 333) within the catchment was used as the population from which the sample size was determined (Equation 2) based on random sampling technique (Krejcie & Morgan, 1970).

$$hh = \left(Hh^{*} a\right)/A \tag{1}$$

in which, 'hh' is the number of households within the catchment, 'Hh' is the total number of households in the district, 'a' is the area occupied by the catchment (km^2), and 'A' is the total area occupied by the district (km^2).

$$s = \frac{X^2 \times N \times P \times (1-P)}{\left(d^2 \times (N-1) + X^2 \times P \times (1-P)\right)} \tag{2}$$

in which, 's' is the sample size, 'X' is the table value of chi-square for 1 degree of freedom at the desired confidence level, 'N' is the population size, 'P' is the population proportion, and 'd' is the degree of accuracy.

This study was conducted under a larger integrated project in West Africa, and concurrently, other household surveys were ongoing in the study area. Hence, to reduce research fatigue on the respondents, the sample size was reduced from 371 to 186 by expert judgment. Surveyed communities were identified by georeferencing an optimum accessibility map of Bongo and Bolgatanga districts produced by the Centre for Remote Sensing and Geographic Information Systems (CERSGIS), University of Ghana. A shapefile of the study area was then overlaid on the georeferenced map. The sample was distributed randomly across the catchment, from upper, mid and lower parts of the catchment. No households existed in the lowest part of the study area because it is a forest reserve. Data used in this study was collected from farmers by means of household survey questionnaire and interview. Self observation was done to validate some of the responses made by the farmers. A household consists of people who rely on the same income. People who stayed temporarily with a particular household, probably because of absent parents/guardians or for other reasons, were not considered as part of the household. Household members who were away on seasonal migrations were considered as members. In situations where compound houses existed (i.e. more than one household), data was collected from the head of the compound about his own household. However, when the compound head was absent, data was collected from the household of the first person of contact. Data collected included household characteristics and possessions, land-use data, knowledge about climate change, change in area cultivated for crop(s), impacts of climatic and non-climatic factors, and adaptation challenges and responses. Qualitative data were also collected from farmers, key informants and agricultural extension officers. Descriptive statistical analysis was used to summarize the collected data into frequencies and percentages. The association between crop types and the farmer's perceived change in area cultivated for the crop was tested using chi-square (Equation 3).

$$X^2 = \Sigma \left[(O_{r,c} - E_{r,c})^2 / E_{r,c} \right] \tag{3}$$

in which, 'X^2' is the chi-square, '$O_{r,c}$' is the observed count at level 'r' of variable 'A' and level 'c' of variable 'B', '$E_{r,c}$' is the expected count at level 'r' of variable 'A' and level 'c' of variable 'B'.

Table 1. Descriptive statistics of selected household variables.

Household Variables	Minimum	Maximum	Mean	Std. Error of Mean	Std. Deviation
Age of household head	18	90	56	1	17
Household size	2	18	8	0	3
Size of labour (≥15 years)	1	13	5	0	2
Number of bicycles	0	9	2	0	1
Number of hoes	2	20	6	0	3
Number of machetes	0	8	2	0	1
Number of mobile phones	0	10	2	0	2
Total land area cultivated (sq. m)	1 474	44 874	12 957	579	7 895
Land area cultivated per capita (sq. m)	184	14 958	1 912	110	1 505
Number of cattle	0	21	3	0	4
Number of donkeys	0	8	1	0	1
Total farm income (Cedis)	71	5 959	1 074	71	967
Per capita farm income (Cedis)	14	1 029	158	11	146

Notes: n = 186. All values are in nearest whole number. Farm income is estimated from crop.

Results and Discussion

Socio-economic characteristics of surveyed household

The descriptive statistics of some selected household variables are presented in Table 1.

Level of knowledge of farmers about climate change

Eighty per cent of respondents claimed that they have been involved in discussions, or have heard people discussing, the issues of climate change. Those farmers that were visited confirmed that the climate has changed (99.5 per cent), and it has affected their crops (98 per cent) and livestock (89 per cent). From the climate parameters (i.e., rainfall, temperature, wind, and drought) presented to the households, 79 per cent and 88 per cent claimed that temperature and drought periods respectively have been on the increase, and 84 per cent claimed that the wind was becoming stronger. The trend is slightly different for rainfall, though: the majority (52 per cent) claimed that rainfall is reducing, but a considerable number (27 per cent) claimed it is increasing, while 20 per cent claimed that it is fluctuating.

In the course of the focus group discussion, farmers claimed that the local spatial variability of rainfall has increased, as compared to the past. Nearby locations that used to have similar rainfall patterns are experiencing variation. Also noted by the farmers was that they experience high air temperatures in the months of the year that are supposed to be cooler. Other impacts of climate change mentioned included: grass and water shortages for animals, low egg production by guinea fowls due to the delay in the availability of fresh grasses, increases in market prices due to scarcity, and a drop in income generated from animals sales due to poor performance.

Farmers' responses to the impacts of climate change/variability

The manner of response to a situation can be associated with capacity and available resources. The crops cultivated in this part of the country are highly traditional to the people; they claim the crops were passed to them by their ancestors. Farmers still cultivate their crops, even in the face of unfavourable environmental conditions, due to having no other options. Also, the area cultivated for some crops may be increased or decreased to cope with current environmental change. Some crops may be completely abandoned in a growing season due to unfavourable environmental conditions. Other

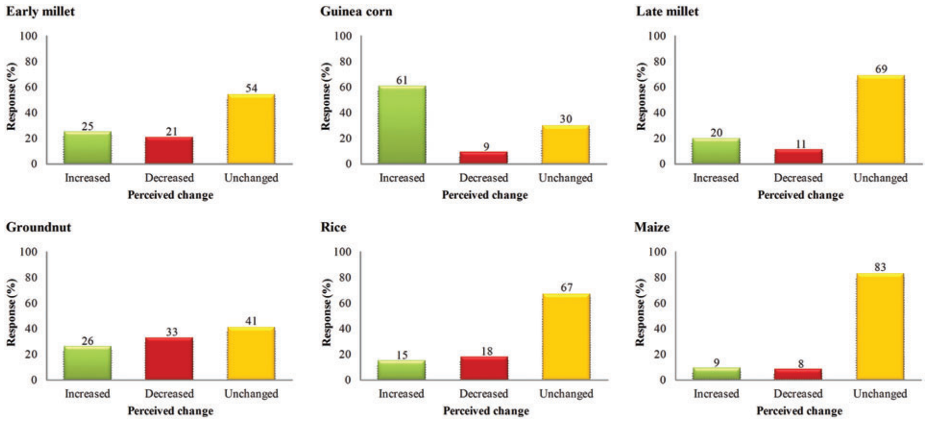

Figure 3. *Perceived change in area cultivated for crops in the past 5 years ($p < 0.01$).*

responses include: following the pattern presented by the rainfall, seeking alternative food sources like tree fruits, borrowing seeds to replant when initial planting was affected by drought, planting crops that can better survive, taking the animals to where they can get enough grass to feed on, seeking alternative livelihood sources (trading, metal works, art and craft), making bounds to conserve water in their farms, and seeking advice from agricultural officers.

Change in area cultivated for major crops

Six major crops were selected: early millet, guinea corn, late millet, groundnut, rice and maize. With the exception of guinea corn, most farmers claimed that they have not increased nor decreased the area cultivated for the crops (Figure 3). On the other hand, 60.8 per cent of sampled households claimed that the area cultivated for guinea corn has increased as compared to unchanged (30.1 per cent) or decreased (9.1 per cent). The chi-square test of association between crop types and a farmer's perceived change in the area cultivated for the crop showed significance (chi-square = 232.737; df = 10; $p < 0.01$), implying that there is relationship between crop types and changed land area cultivated for the crop.

Climatic factors that affect agricultural land-use dynamics

The pattern of rainfall reported as having affected crop production includes: delay, fluctuation and cessation before the end of season. The cropping system practiced by the local farmers is mostly for subsistence, hence the time each crop is cultivated is calculated to keep the farming household surviving through a particular time of the year. As presented in the cropping calendar of UER (Figure 4), traditional cereals (early millet, guinea corn and late millet) are the first round of crops cultivated by the farmers. These traditional cereals ranked highest in the crop preference of the farmers (Figure 5), explaining why more plots and total land area is cultivated for the traditional cereals than for other crops (Table 2) and the importance of the traditional cereals in their diet. As the first round of crops are established, the second round (rice and groundnut) are planted, usually with about a one month interval, provided the rains are available.

Early millet should be ready for harvest around July, which is the month that coincides with hunger periods (lean season), and it is expected to sustain the household until the time that other crops, such as guinea corn, late millet, and groundnut, will be ready for harvest. However, delay in rainfall has shifted the cultivation periods of most

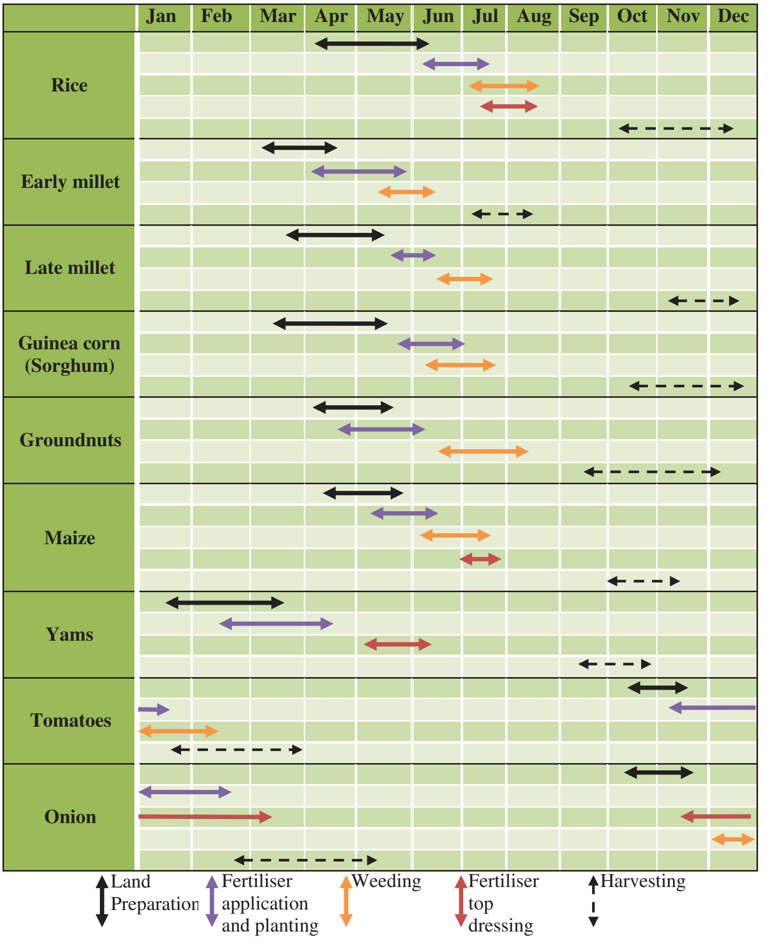

Figure 4. *Cropping calendar of food crops in Upper East Region, Ghana.*
Source: Gyasi *et al*., 2006.

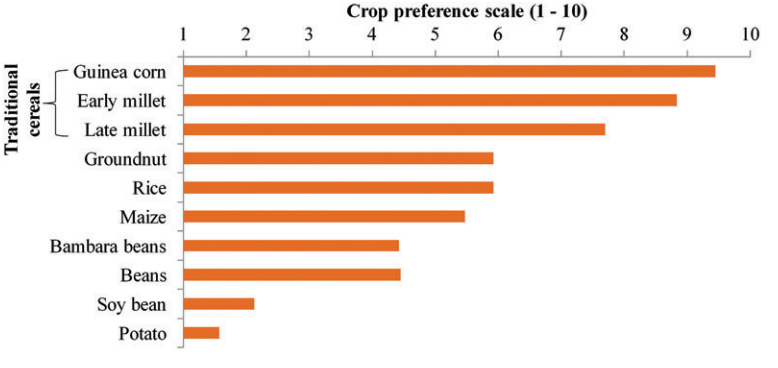

Figure 5. *Crop preference ranking of farmers in the study area (1 = lowest, 10 = highest).*

Table 2. Plots and land area cultivated by the sampled households in the rainy season.

Crop	Number of plots cultivated	Area of land cultivated (ha)
Traditional cereals	366	136
Groundnut	200	63
Rice	135	27
Maize	37	11

crops. A shift in planting date may have an impact on early millet production because the pollen may then be formed during the periods of heaviest rainfall which can easily wash away pollen, resulting in low yield or crop failure. As a delay in rainfall also poses risks to farming activities, as does fluctuating rainfall and an early end to the rainy season. Fluctuation of rainfall, in the form of drought between rains, poses delays to the second round of cultivation. When cultivation of the second round of crops is delayed, their growing period is extended which may lead to crop failure if the rainy season finishes early. Delay in the second round of cultivation also has implications; when the land is prepared but rain does not come in the amount required for cultivation, weeds may take over the land. Crops with longer maturity duration suffer from the impact of an early finish to rainfall as it disrupts their growth cycle. Also, ground-bearing fruits, such as groundnut, suffer from an early end to rainfall, because when rain stops the soil becomes hard and uprooting may become difficult, thus leading to crop loss. Some farmers applied water to their groundnut crop areas during the harvesting period to make uprooting easier and the avoid loss of fruits, while others hit the soil before uprooting.

Non-climatic factors that affect agricultural land-use dynamics

Early millet is a very important crop for the farmers because its maturity period coincides with the period of hunger. Surprisingly, some farmers claimed to have reduced the cultivation because it is attacked by birds. A question was raised regarding whether the impact from birds has worsened over time, with the response, 'In the olden days, children always scared the birds, however, children go to school now, and there is nobody to scare them'. Despite the claims of bird infestations in early millet, there are very few millet plots where scarecrows were used. Bird attacks on early millet usually occur during the period when early millet is ready for harvest. To prevent bird infestations, early millet may be harvested earlier, prior to maturity.

Farming households usually have a preference for some crops more than others, for example, millet is said to be more palatable than guinea corn, and the children always prefer it to guinea corn. However, guinea corn has better yields than millet (Figure 6), and farmers claimed they get satisfied quicker when they consume guinea corn as compared to millet. Similarly, it was observed that 60 per cent of surveyed households claimed that the land area they cultivate for guinea corn has increased in the past five years. This finding is in accordance with Ministry of Food and Agriculture (2012) report (Figure 7), and with Dalton and Zereyesus's (2013) studies on the economic impact assessment of guinea corn, millet and other grains which showed that, in Ghana, the area harvested for guinea corn in the past two decades is increasing, while that of millet is decreasing.

Older farmers claimed to have reduced the area cultivated for groundnut due to the longer distance of large plots from their house. Thus, they only cultivate a relatively small area around their house, which they can easily manage without having to work long distance. Decrease in area of land cultivated for groundnut was also associated with the increase in the cost of seed during the cultivation period.

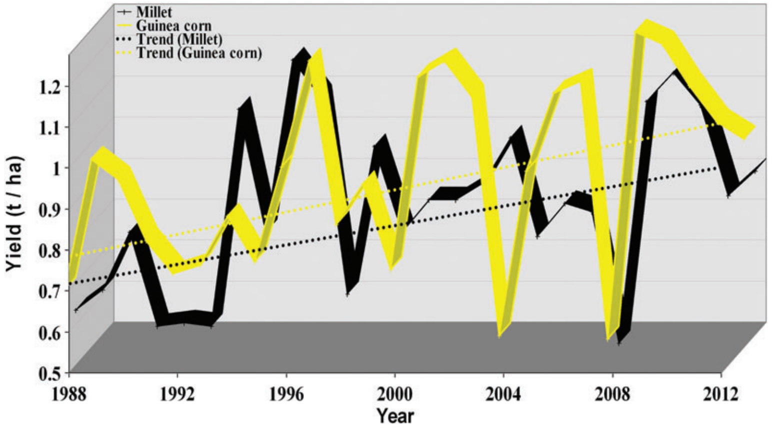

Figure 6. *Trend in yield of millet and guinea corn in the Upper East Region, Ghana between 1987-2011. Source*: **MoFA, 2012.**

The role of fertilizer in improving crop growth and yield cannot be overemphasized, and this has been reported in several studies. Laboratory analysis of soil samples collected from the study area showed that levels of organic matter in the soil ranged between 0.53 and 2.02 per cent, with an average of 1.19 per cent. Similarly, Veihe (2002) observed that the organic matter content level of the soil was low, mostly less than 2 per cent. Adequate fertilizer application is very important for maize and rice production. For example, Badmos *et al.* (2014) reported that some farmers in the study were willing to increase the area cultivated for maize if they had adequate access to fertilizer.

Rice cultivation is carried out both in the rainy and dry season. Rain-fed rice cultivation is done on the lowland valleys, and on soils that can hold water very well. An irrigation dam was built at Vea in 1980, with the aim of promoting irrigation farming during the dry season to guarantee food security, lessen poverty and provide potable water (Adongo *et al.*, 2014). However, there has not been major maintenance (Adongo *et al.*,

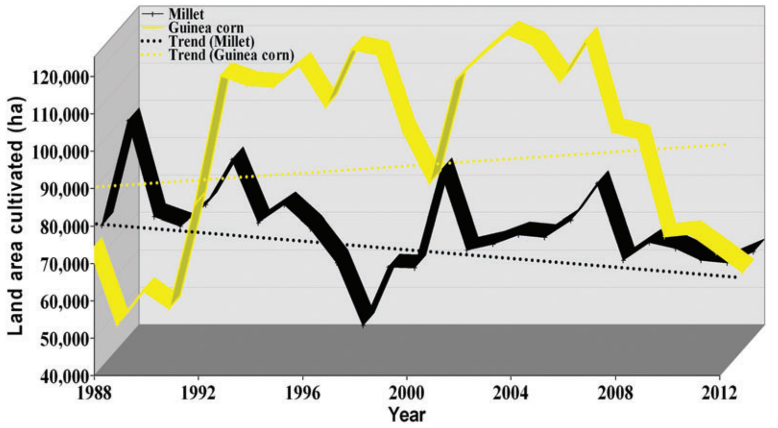

Figure 7. *Trend in area cultivated for millet, guinea corn in the Upper East Region, Ghana between 1987-2011. Source*: **MoFA, 2012.**

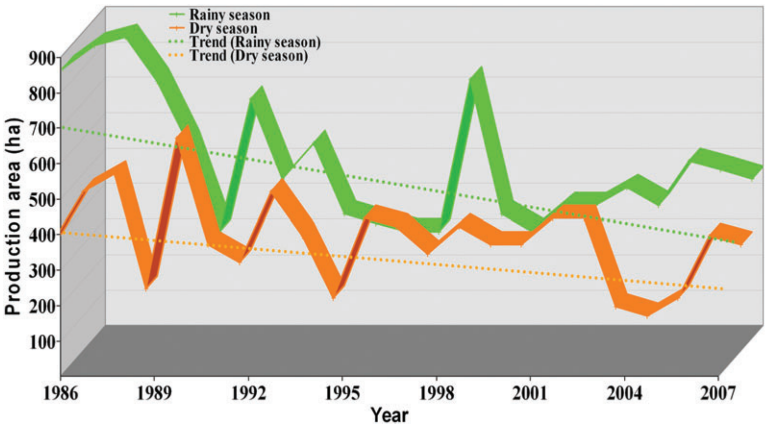

Figure 8. *Trend in cultivated areas of Vea irrigation scheme, 1986-2007.*
Source: Ofosu, 2011.

2014; Schulz, 2017). Cultivated areas in the Vea irrigation scheme have shown a decline both in rainy and dry season (Figure 8). Poor condition of irrigation laterals and canals has reduced the total area of land supplied with water, thus reducing the size of land cultivable. Ofosu (2011) reported that the Vea and Tono irrigation projects are underperforming (50 per cent performance) due to farmer's unwillingness to pay the water levies, the bad state of the canals which prevented large portions of the developed area from being irrigated, a lack of financial assistance for farmers to secure fertilizer for dry season farming activities, and an increased production of tomatoes from White Volta sub-basin increasing market competition for the market and a resulting loss for some tomato farmers.

Conclusion and recommendations

Climate change/variability has come to stay for a long time. Farmers are aware of the changing climate, and they are experiencing the impacts. Erratic rain has affected and disrupted various farming activities. Agriculture is climate dependent, and a high percentage of Africans derive their livelihood from rain-fed agricultural activities, thus, any extreme alteration in the climate system will have negative impact on people's livelihood. Poverty levels in this part of the world are high, land degradation is prominent and access to factors of production is lacking. Addressing the challenges posed by environmental change on agriculture requires all encompassing strategies. Conclusively, climate change has been interacting with socio-economic factors; in fact, it may aggravate the poverty level. A holistic approach would best address local or regional change. A collaborative effort from stakeholders is needed to be able to come up with appropriate measures that can be used to manage the impacts of the changing environment. Research is very necessary to the development of any nation. Hence, intensification of research within the study region and nearby regions would improve preparedness for future local/regional change.

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