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Spatio-temporal analyses of impacts of multiple climatic hazards in a savannah ecosystem of Ghana

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ABSTRACT

Ghana's savannah ecosystem has been subjected to a number of climatic hazards of varying severity. This paper presents a spatial, time-series analysis of the impacts of multiple hazards on the ecosystem and human livelihoods over the period 1983–2012, using the Upper East Region of Ghana as a case study. Our aim is to understand the nature of hazards (their frequency, magnitude and duration) and how they cumulatively affect humans. Primary data were collected using questionnaires, focus group discussions, in-depth interviews and personal observations. Secondary data were collected from documents and reports. Calculations of the standard precipitation index (SPI) and crop failure index used rainfall data from 4 weather stations (Manga, Binduri, Vea and Navrongo) and crop yield data of 5 major crops (maize, sorghum, millet, rice and groundnuts) respectively. Temperature and windstorms were analysed from the observed weather data. We found that temperatures were consistently high and increasing. From the SPI, drought frequency varied spatially from 9 at Binduri to 13 occurrences at Vea; dry spells occurred at least twice every year and floods occurred about 6 times on average, with slight spatial variations, during 1988–2012, a period with consistent data from all stations. Impacts from each hazard varied spatio-temporally. Within the study period, more 70% of years recorded severe crop losses with greater impacts when droughts and floods occur in the same year, especially in low lying areas. The effects of crop losses were higher in districts with no/little irrigation (Talensi, Nabdam, Garu-Tempane, Kassena-Nankana East). Frequency and severity of diseases and sicknesses such as cerebrospinal meningitis, heat rashes, headaches and malaria related to both dry and wet conditions have increased steadily over time. Other impacts recorded with spatio-temporal variations included destruction to housing, displacement, injury and death of people. These impacts also interacted. For example, sicknesses affected labour output; crop losses were blamed for high malnutrition; and reconstruction of properties demanded financial resources largely from sale of agricultural produce. These frequent impacts and their interactions greatly explain the persistent poverty in the area.

1. Introduction

Since 1900, global mean temperatures have risen and there is evidence that the warming rate is accelerating (IPCC, 2012). As indicated by the IPCC (2012), increases in average global temperature are very likely to alter precipitation and atmospheric moisture due to changes in atmospheric circulation and increases in evaporation and water vapour. Variability

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and/or changes in climate are most likely to bring about hazards such as high temperatures, heavy rainfall/floods, dry spells/droughts and windstorms, which will have deleterious impacts on both humans and ecosystems (Yiran, 2014). In spite of uncertainties in predicting the precise degree, nature and magnitude of changes in temperature and rainfall, and consequently, the final outcome of climate change and its impact, there is high consensus among climate scientists and global leaders on the reality of climate change (IPCC, 2014). This consensus is built upon intense research on climate variability and change (CVC) (see IPCC, 2007, 2014).

Many studies have examined the impacts of CVC and its related hazards, mostly focusing on agriculture in Africa (Challinor et al., 2007). Most of these studies have predicted the impacts of climate change on food production based on climate scenarios from global climate or general circulation models (GCMs) (Connolly-Boutin and Smit, 2015). Impacts noted in these studies vary widely but generally show negative outcomes for food crops (Challinor et al., 2007). Studies show that rainfall is expected to be more variable and less predictable with a reduced length of the growing season in West Africa (Connolly-Boutin and Smit, 2015), which could lead to a drop in crop yields by 20–50% by 2050 (Sarr, 2012). In the Upper East Region (UER) of Ghana, studies have shown severe impacts CVC on agriculture, leading to losses in crop and livestock production (e.g. Antwi-Agyei et al., 2012; Aniah et al., 2013), affecting food security (WFP, 2012; Yaro, 2013). It has also been established that climate related diseases, particularly cerebrospinal meningitis (CSM), malaria and malnutrition, are on the rise in UER (Ghana Health Service, 2012). Both ground and surface water have suffered negative consequences from CVC (UNEP-GEF, 2013), while properties and lives have been lost due to climate related events (NADMO, 2011). The impacts on these vital sectors that underpin livelihood activities (agriculture, health, water and infrastructure) combine to perpetuate poverty in UER. The impacts can be classified into direct impacts (crop and livestock losses, diseases/sicknesses, destruction of houses, displacement and injuries of people) and indirect impacts (loss of labour and incomes, cost of healthcare, and malnutrition, etc.) (IPCC, 2014).

Many existing impact studies are top-down and model-based, predicting the impacts of climatic events on yield (see Connolly-Boutin and Smit, 2015). They are also conducted at macro scales (e.g. Sarr, 2012). Other types of research examine how people have adapted to past changes and how they may adapt to future changes (e.g. Cooper et al., 2008; Jankowska et al., 2012; Sarr, 2012; Simelton et al., 2012). Yiran and Stringer (2015), for example, showed that farmers in the savannah ecosystem of Ghana are using several strategies including dry season gardening, irrigation, planting early-maturing and/or drought resistant crop varieties to adapt to poor rainfall distribution and frequent droughts. Nevertheless, most research has focused largely on impacts of single hazards on single sectors (e.g. Jones and Thornton, 2009; Antwi-Agyei et al., 2012; Grace et al., 2012). While these studies have indicated that climatic hazards affect aspects of livelihoods, what remains unclear is how the frequent and alternate occurrences of different types of hazards have cumulatively affected human livelihoods and socio-economic conditions. This is particularly important as the climate related events occur year in, year out in UER (Yiran, 2014). This study fills this knowledge gap by investigating the cumulative impacts of these hazards on different aspects of people's livelihoods over space and time, informing efforts to help the region to better bounce back from the multitude of hazards it faces.

2. Methodology

Mixed methods were used to collect data and analyse the impacts of multi-hazards over a 30-year period (1983–2012), spatially and temporally, using the UER as a case study for the savannah ecosystem. The period 1983–2012 was chosen because it is the warmest in the last 1400 years (IPCC, 2014) and data for this period are largely accessible. The UER is in north-east Ghana (Fig. 1). UER is dominated by Guinea and Sudan savannahs. It experiences all hazards that occur across the savannah systems and can act as a window to better understand the hazards across the savannah (Yiran, 2014). UER receives the lowest rainfall in the savannah zone, 1000 mm per annum on average (Logah et al., 2013) and yet, rainfed agriculture is the major economic activity. When dams in nearby Burkina Faso are spilled, water from the dams enters the UER before any other area, causing flooding. UER is also the poorest region in Ghana, with more than 89% of its inhabitants classed as poor and dependent upon their own farm produce for household food supplies (Ghana Statistical Service et al., 2009). The combination of these factors makes it a very useful area to study as it can provide wider lessons.

Primary data were collected between June and September 2013 using questionnaires, focus group discussions (FGD) and in-depth interviews (IDIs) with institutional heads or representatives as well as local people. One community was selected from each of the 13 districts in the region. The names of communities in each district were written on pieces of paper, thoroughly mixed and one community randomly selected.

In order to ensure that characteristics of urban areas were captured, the 3 largest towns were purposively selected and sampled for their respective districts. In selecting the other communities, a condition that no selected community should be within 10 km from another community was applied. This ensured good spatial distribution. This approach is similar to restricted random selection (see Stevens and Olsen, 2004). The stratification of districts into urban and rural is based on Ghana Statistical Service's (2012) classifications where districts in which rural populations are greater than urban populations are classified as rural. Urban areas were sampled in higher numbers based on the function (regional, municipal and district capital) of the town. A major reason for entering each district was because they are divided along the major ethnic groups in UER, thus stratifying the sample ethnically. A total of 210 households were then randomly sampled from the 13 selected communities in order to administer a questionnaire survey (Table 1).

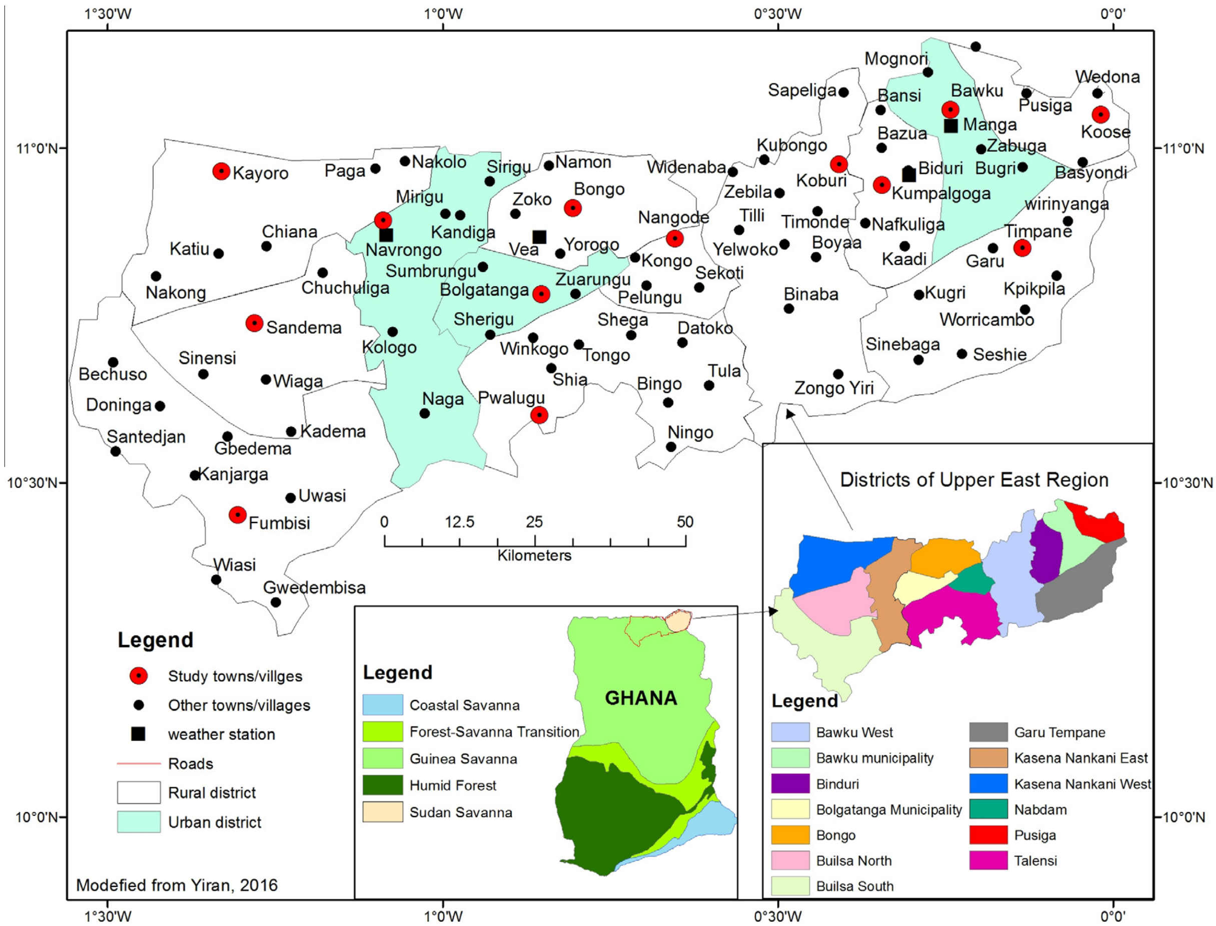

Fig. 1. Map showing the Upper East and its location in the Savannah Ecological Zone.

Table 1
Distribution of questionnaires.

District	Classification of district	Town/village selected	Number of questionnaires	No. of people in FGD
Bawku Municipal	Urban	Bawku	20	
Bawku West	Rural	Kubore	15	
Binduri	Rural	Kumpalgoga	15	10
Bolgatanga Municipal	Urban	Bolgatanga	25	
Bongo	Rural	Bongo	15	11
Builsa North	Rural	Sandema	15	
Builsa South	Rural	Fumbisi	15	
Garu-Tempane	Rural	Tempane	15	11
Kasena-Nankana East	Urban	Navrongo	15	15
Kasena-Nankana West	Rural	Kayoro	15	
Nabdam	Rural	Nagodi	15	
Pusiga	Rural	Koose	15	13
Talensi	Rural	Pwalugu	15	
Total			210	

Source: Authors.

Five FGDs were held in the communities. Although the intention was to hold a FGD in each community, discussions were halted after the fifth FGD because the data collected were similar and the discussions were considered to have reached saturation point (Rebar et al., 2011). Participants in FGDs were selected to reflect community diversity considering gender, leadership, age, education, occupation and experiences following a discussion with community leaders. To capture views from diverse people, we ensured that the composition of the groups based on the socio-demographics above varied among the villages. Proceedings were recorded manually by the researchers and results were synthesised by analysing the statements/explanations recorded by each person under key themes immediately after each FGD. IDIs were held with heads/representatives of twenty-five institutions drawn from government agencies and NGOs in the region. Six individuals in each sampled community were also purposively selected for IDIs using similar criteria to the selection of FGD participants. In order to capture responses and views from as wide a variety of people as possible, different people participated in questionnaires compared to FGD and IDI). Secondary data including crop yields, weather, disaster incidence, disaster effects and health were collected from relevant institutions and published documents.

Questionnaires were analysed using SPSS while FGDs were subjected to content analysis. Rainfall data from Ghana Meteorological Agency (GMet) were analysed using the Standard Precipitation Index (SPI). This was chosen because it is flexible, simple, suitable for shorter timescales, spatially consistent and its probabilistic nature gives it a historical context, so it is suitable for early warning as well as decision-making (World Meteorological Organisation, 2012). Criteria set by McKee et al. (1993) were used to characterise both dry (dry spells/droughts) and wet (floods/heavy rainfall) conditions, as the SPI is normally distributed (cited in World Meteorological Organisation, 2012). The SPI was calculated for 1-month, 3-month, 6-month, 9-month and 12-month timescales and analysed from 1988 to 2012 because most stations had reliable data in that period.

To determine the effects of the hazards on crops, yield data for five major crops (maize, rice, sorghum, millet and groundnuts) were detrended using auto-regression with a 3-year lag and a crop failure index was calculated in line with Simelton et al. (2009). All other datasets were analysed in Excel for trends. Results were produced as tables, charts and diagrams supported with explanations from the FGDs and in-depth interviews. Maps were produced using ArcGIS 10.2.

3. Results

The following subsections elucidate the hazards we found in UER and their resulting impacts.

3.1. Exposure to hazards

From household questionnaires, we identified that high temperatures, droughts/dry spells, floods, heavy rainfall and windstorms all occur in the UER.

3.1.1. High temperature

All respondents in the questionnaire survey indicated that temperature was very high and increasing every year. This corroborated with observed temperature data from GMet (Fig. 2).

As shown in Fig. 2, March is recording the highest maximum temperatures while the lowest occurred around August each year. The linear trends also show that increase per year is higher at Manga (in the Sudan savannah) than Navrongo (in the Guinea savannah), though both areas are almost on the same latitude. Participants in all FGDs attributed the continuous increase in temperature to vegetation degradation and a decreasing trend of rainfall in terms of both quantity and shortened duration of the rainy season. An elderly man in Koose stated that "*when I was young, there were trees around that provided shade where most households sat during the hot day but most of these trees are dead. As you can see, we now create stalls like the one I sit under and these do not blow air, so the hot air is still*". In another interview with a woman at Pwalugu, she stated that "*temperatures are so high that when you walk in the sun for long, you fall sick*". All statements regarding temperature point to increasing temperatures compared with the situation before 1992. Additionally, it was unanimously agreed in all FGDs that it is very hot when there is no rainfall or when the air is dry, particularly in the dry season or during dry spells/droughts. Participants in the FGDs explained that temperatures are very hot because the duration of the rainy season is decreasing, leading to more dry months and higher temperatures. According to them, when it rains, temperatures are lowered. They also linked declining tree cover to the rising temperatures.

3.1.2. Droughts/dry spells

Seventy-nine percent (164) of respondents in the questionnaire survey indicated that drought/dry spells occur every year (Table 2). Generally, the responses show a subtle variation in the perceived occurrences of droughts/dry spells among the communities but give an indication of spatial variation of occurrences.

However, from the responses, the return period for droughts is one or two years. This conception led to perceived differences in the duration of a dry spell or drought, with the length of dry spells or droughts varying from 2 weeks to 4 weeks (Fig. 3). The variations in duration came largely from the nature of the soil or location of farm. According to a farmer in Kubore, "*I farm close to the White Volta and I hardly experience dry spells on my farm because the soil there can retain water for a long time*". He added that the soil has a lot of organic matter that is brought in by the floods and helps to retain moisture as well as soil fertility. To him and his colleague farmers in Kubore and Kumpalgoga, the ability of the soil to keep moisture and the fertility are good reasons enough to warrant the continuous use of the area, even though sometimes flooding destroy the crops.

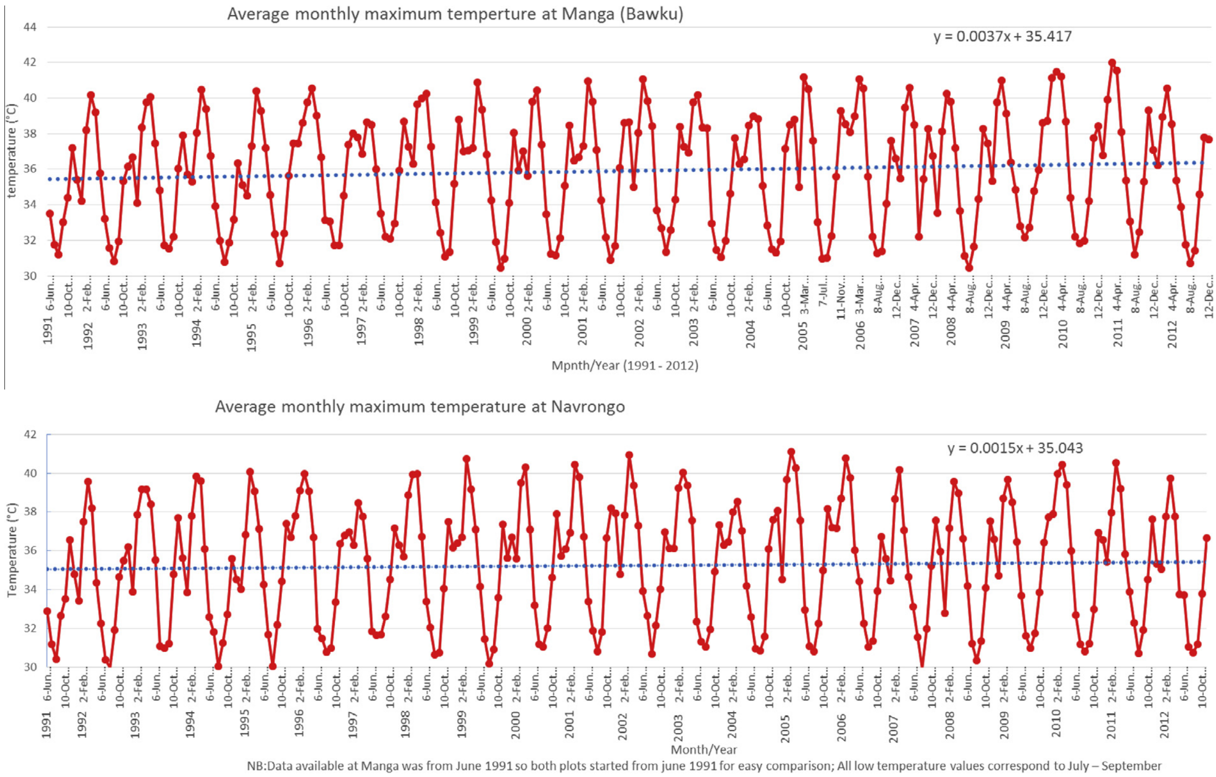

Fig. 2. Temperature trends in UER. Source: Authors.

Table 2
Frequency of droughts as perceived by respondents in UER, 1983–2013.

Communities	Percentage of respondents				Total
	Every year	Once every 2 years	Once in every 5 years	Irregular	
Bawku	88	6	6	0	100
Bolgatanga	84	16	0	0	100
Bongo	93	7	0	0	100
Fumbisi	93	7	0	0	100
Tempane	60	33	0	7	100
Koose	47	47	6	0	100
Kubore	93	7	0	0	100
Kumpalgoga	53	33	14	0	100
Nangodi	93	0	0	7	100
Navrongo	86	7	7	0	100
Pwalugu	53	0	0	47	100
Kayoro	53	0	0	20	100
Sandema	93	7	0	0	100
Total	79	13	2	6	100

Source: Authors (2013).

In the FGD at Kumpalgoga, participants who farm along the White Volta River stated that they do not have any other place to farm as they are migrant settlers. They also added that their experiences have shown that the floods come around August, so they plant early and harvest before the floods. They also now plant early maturing and short duration crops. In all the FGDs, participants noted that the occurrence of droughts/dry spells is not uniform across the region. They reported hearing of droughts in some places while they have rains, or that it is raining at other places while they have none. They also observed that drought intensity and duration varies from place to place and from year to year.

The SPIs were used to authenticate respondents' answers on the occurrences of dry spells/droughts. Results in Table 3 were constructed using the 3-month and 6-month SPIs. These two time scales were used because the study considered agricultural droughts which are of shorter time scales. From the SPI values, dry spells occurred either in one month or within every month of the rainy season in all years.

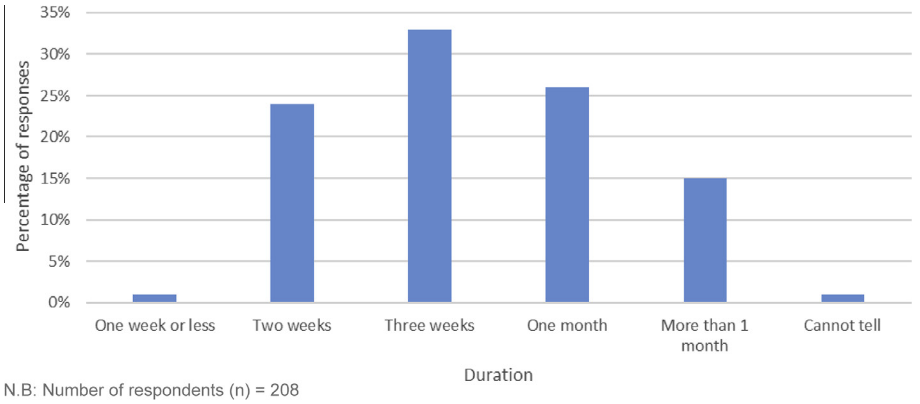

Fig. 3. Duration of droughts. *Source:* Authors (2013).

Table 3
Characteristics of droughts between 1988 and 2012 extracted from 3-month SPI.

Station	Characteristics	Year												
		1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Binduri	Duration (months)		3	8	4						4			8
	Magnitude		2.55	4.56	1.92						2.89			5.85
	Onset-End		A-J	Ma-O	Ju-O						Ju-O			Ma-O
Manga	Duration (months)	1	5	8			3	3						3
	Magnitude	1.58	4.07	5.09			1.84	2.78						2.23
	Onset-End	Au-O	A-Au	Ma-O			Au-O	J-Au						Ma-M
Navrongo	Duration (months)	4	4	2, 5			8	2	8			5		4
	Magnitude	3.64	2.96	4.97			5.65	3.08	7.93			3.84		5.02
	Onset-End	Ju-O	A-Ju	Ma-A, J-O			Ma-O	J-Ju	Ma-O			J-O		Ma-J
Vea	Duration (months)			2, 3		1	4	4	5		3			3, 2
	Magnitude			3.75		1.82	3.94	3.77	3.69		2.89			5.36
	Onset-End			Ma-A, J-Au		Ma-A	Ma-J	J-S	A-S		Au-O			Ma-M, S-O
		2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	
Binduri	Duration (months)	8	8		2				N/A					
	Magnitude	5.64	4.34		2.64									
	Onset-End	Ma-O	Ma-O		S-O									
Manga	Duration (months)	5			3				6			8		
	Magnitude	2.73			4.13				4.11			5.78		
	Onset-End	Ma-Ju			Au-O				M-O			Ma-O		
Navrongo	Duration (months)				2	8							3	
	Magnitude				1.18	6.5							2.11	
	Onset-End				S-O	Ma-O							Au-O	
Vea	Duration (months)		5	3	5	8			5			5		
	Magnitude		2.09	2.14	4.57	5.77			4.92			2.91		
	Onset-End		Ma-Ju	Ma-M	J-O	Ma-O			A-O			Ju-O		
Station		Binduri			Manga			Navrongo			Vea			
	Frequency	9			10			11			13			

Source: Authors.
N.B: Ma = March, A = April, M = May, J = June, Ju = July, Au = August, S = September, O = October.

Where dry spells were severe and prolonged, they resulted in droughts. From Table 3, the frequency of droughts varied from 9 times at Binduri to 13 at Vea in the 25 years studied. Similarly the duration varied from 1 month to 8 months – covering the entire rainy season in the latter. Most droughts, especially those lasting 4 months or more, occurred at the critical period of the rainy season when crops grow, up until harvesting. Though there were more droughts periods before the year 2000, those that occurred after 2000 generally had both longer durations and bigger magnitudes (see Table 3). The frequency of droughts was lower in the stations within the Sudan savannah (Manga and Binduri) than those in the Guinea savannah (Navrongo and Vea); this is similar to the variations in responses from questionnaire (Table 2). The Sudan savannah is a drier zone and that could account for the low frequency of droughts as most periods were considered dry spells.

3.1.3. Floods/ heavy rainfall

Unlike droughts which affected large spans of land, sometimes the entire region, responses from the questionnaire and FGDs indicate floods occurred in urban areas, water logged areas or along rivers/streams. In the urban areas, observations as well as responses from the questionnaire show that no/choked gutters and building in flood prone areas increased exposure and sensitivity to the flooding. In the rural areas, flooding occurred along river/stream valleys. Floods lasted between a few hours in a single day and a month or more, depending on the type and location. From the questionnaire survey (n = 208), the frequency of floods was also found to be varied (Fig. 4). As can be seen, more than half of respondents experience or see flooding every year.

In communities that have river/streams and/or poor drainage systems such as Bolgatanga, Navrongo, Binduri, Kubore, Sandema and Fumbisi, more than 70% of respondents indicated a yearly occurrence because they experience flash flooding or their activities are in a river valley and/or flood prone areas. In the FGD at Kumpalgoga, the participants reported increases in flood frequency and severity due to the spilling of dams in Burkina Faso. A farmer interviewed in Fumbisi stated that "*I see flooding almost every year in the last five years because when the heavy rains start, most often, it rains every day. This increases the runoff because there is no enough time for the water to percolate into the soil*".

Examination of the 12-month SPI indicated wet conditions in 1989 extending into 1990 and ending in September 1990. Another wet period occurred in 1992/1993 but this happened in Vea with the other stations remaining dry or normal. In 1995, except in Navrongo which was dry, all other stations had wet conditions. Wet conditions occurred in 1989, 1999, 2000, 2004, 2007 and 2010 in all stations. Records show that 1989, 1995, 1999, 2007 and 2010 were years of widespread flooding in the region (UNDP, 2009; The World Bank Group, 2009; NADMO, 2011). These correspond perfectly to those years with very wet conditions. The years 2000 and 2004 had very wet conditions but did not result in flooding. This is because in any year in which July, August and September are dry, flooding does not occur - this was the case for 2000 and 2004. However, communities along the White Volta reported floods to be occurring every year and attributed this to opening of dams in Burkina Faso. A NADMO official in one of the districts along the White Volta confirmed this: "*Almost every year, Burkinabes spill their dams around August and as soon as we receive information on opening of dams, we go to the communities to alert them to harvest their crops or stop going closer to the river from the date we expect the water to enter Ghana*".

3.2. Sensitivity to the hazards

It is evident from the previous section that different hazards occur with different frequencies and with spatial variations in their occurrence and duration. In this section, we examine the sensitivities of ecosystems and livelihoods to these frequent hazards.

3.2.1. Sensitivity of the ecosystem

Sensitivity was measured in terms of the adverse effects of the hazards on the ecosystem and its inhabitants. Survey responses from farmers linked the deterioration of the ecosystem largely to rainfall and temperature. Soil erosion was of particular concern to most of the farmers as the top soil is eroded. A farmer in Nangodi sated "*erosion is so severe on my land because it is sloping, so I use stone bunding to reduce the runoff*". Although responses varied among communities, more than 80% of all respondents experience erosion in the early part of the rainy season and around August. Accordingly to them, at the beginning of the season, the land is virtually bare and around August, the soil is saturated and cannot hold together. The eroded soil and other materials find their way into water bodies, silting them up. According to respondents in the Bongo FGD, some of the water bodies have disappeared while some are believed to have reduced in capacity due to siltation. Respondents also observed that watering holes dry faster when the weather is hot, leading to water scarcity for animals and domestic activities. In an in-depth interview, a woman in Pwalugu stated that "*we usually travel long distances to the river (White Volta) to dig holes in its bed and get water for domestic use because our wells, ponds and other water bodies from which we draw water get dry during the dry season and our plight worsens when there is a drought*". She added that the time spent searching for water affects time available to do other activities, especially income generating activities. This illustrates the links between weather conditions and people's abilities to improve their livelihoods.

3.2.2. Sensitivity of crops

The hazards also affected crops in varying degrees both spatially and temporally. More than 57% of respondents indicated they have shifted from planting traditional crops such as sorghum, millet, groundnuts, and local potatoes, to improved and short-duration varieties of maize because of increasing incidence of dry spells/droughts. This means land that was used to cultivate traditional crops are being used to cultivate maize, and that more land is being brought under cultivation. To confirm this, the land areas used to cultivate each of the five major crops from 1992 to 2012 was plotted (Fig. 5). Cultivated areas for traditional food crops (i.e. millet, groundnuts and sorghum) are decreasing while those for maize and rice are increasing over the period of focus.

To examine this phenomenon at the district level, two major traditional crops and maize have been mapped temporally (Fig. 6). In Fig. 6, with the exception of Talensi-Nabdam which shows a fairly stable area under cultivation for maize, all others have shown increases over the study period. In Bongo, the area used for maize is still very small showing a slow rate of adoption. The areas under cultivation for millet and sorghum are mixed but show a general decreasing trend. In the FGDs, participants could not tell whether the amount of area under cultivation for the traditional crops is being used progressively

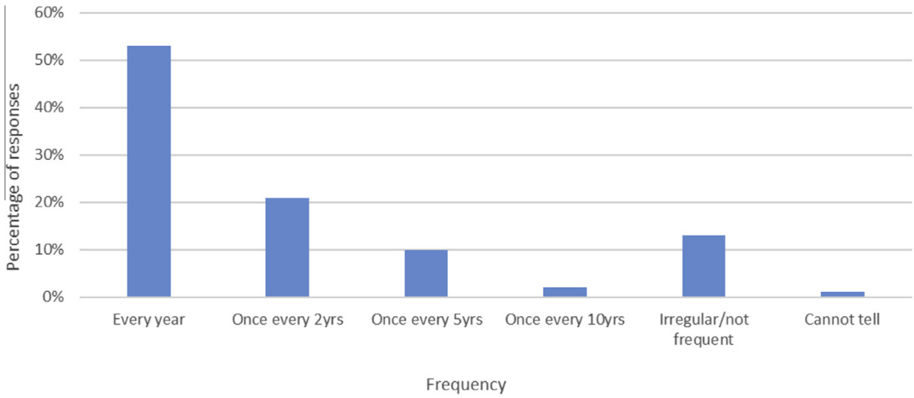

Fig. 4. Frequency of floods according to respondents. *Source:* Authors' own construct.

for maize as many of them practiced mixed cropping. They nevertheless maintained that maize cultivation is becoming prominent and is replacing the traditional crops, thus confirming the trend observed in Fig. 6. If this trend continues, the crops currently losing land area may disappear from the cropping calendar.

An interview with a crop scientist at Savannah Agricultural Research Institute (SARI) revealed that research funders are investing in maize more than traditional crops, resulting in more drought resistant maize varieties entering the market. Yield data indicated that maize and rice were the major crops produced in 2012. While crops suffered a dry spell/drought in 2013, maize survived because the people had cultivated drought resistant varieties that were able to withstand dry spells/droughts better than traditional crops. A respondent in Bongo stated that changes in rainfall (weather) had modified their food system because of frequent losses from traditional food crops. He noted: "*When I was a child over 40 years ago, if you ate food prepared with maize or rice for supper, you were considered to have slept without eating but now, maize is used to prepare different types of food for supper*".

The sensitivities (i.e. crop failures/losses) of five major staple food crops varied within and across the districts (Table 4) and in accordance with variations in SPIs calculated above. Crops are generally sensitive to climatic events but the sensitivities vary with the events, whether heavy precipitation (and subsequent flooding) or low precipitation (and subsequent droughts) or both, or even dry spells as well as their magnitudes. Crops were more sensitive to dry spells/droughts than to floods/heavy rainfall. A farmer in Pwalugu stated that "*For me, I feel dry spells are more destructive than the others because they occur anytime during the season, and affect every aspect of the crop growing stage. Sometimes, we plant three or more times before the crops survive and at maturity, a dry spell can destroy everything*". His feelings were generally expressed in many in-depth interviews and the FGDs. Years in which some of these events took place concurrently/consecutively saw very severe crops losses. As can be seen from Table 4, the crops recorded heavier losses in 2007 than in all other years, with impacts classified as high to extreme. The year 2007 experienced the combined effects of droughts in the early part of the season and heavy precipitation in the later part, which seriously affected yields. Events in 1997, 2004 and 1999 (in order of decreasing sensitivity) also affected all crops. These years had dry spells/droughts, dry spells/heavy rainfall and floods respectively. Sensitivities also vary from district to district (see Table 4) over the period (1992–2012).

Losses over the study period are greater for traditional crops than for maize and rice. Districts in the Sudan savannah (i.e. Bawku East[1] and Bawku West) experienced greater crop losses from droughts than the other districts in the Guinea savannah. Crop yield data showed that these districts adopted maize cultivation much earlier than the others.

Observations from the 2013 rainy season revealed that maize cropping was greater in the Sudan than the Guinea savannah. Farmers in all FGDs in the Bawku Districts confirmed this. In the FGD at Kumpalgoga, it was stated that they have virtually stopped cultivating groundnuts. All participants in the FGDs noted that during droughts, temperatures were also very high. This exacerbated crop losses because crops withered due to high evapotranspiration. Some respondents indicated they avoided working between 11 am and 3 pm when there is a dry spell/drought because their experiences show that weeding at that time puts hot soil around the stems of crops which burns and kills them. The questionnaire findings showed more than 60% of respondents in each surveyed community attributed agricultural losses to climatic events while the remainder attributed the losses to low soil fertility.

The frequent crop losses as indicated in Table 4 and corroborated from farmers result in food insecurity and loss of income. About 85% of respondents indicated their food supplies from local production run out completely by the end of the third month after each rainy season. But most of the smallholder farmers who depend largely on agriculture production do not have the means to buy food as they indicated their animals which they used to fall back on when they ran out food are also affected by the changes in climatic conditions. A farmer in Navrongo stated that "*I rear guinea fowls but due to the extreme heat, the eggs don't hatch well and even the keets suffer to survive, thus reducing production. The animals too grow lean*

1 Comprise Bawku Municipal, Garu-Tempane, Binduri and Pusiga.

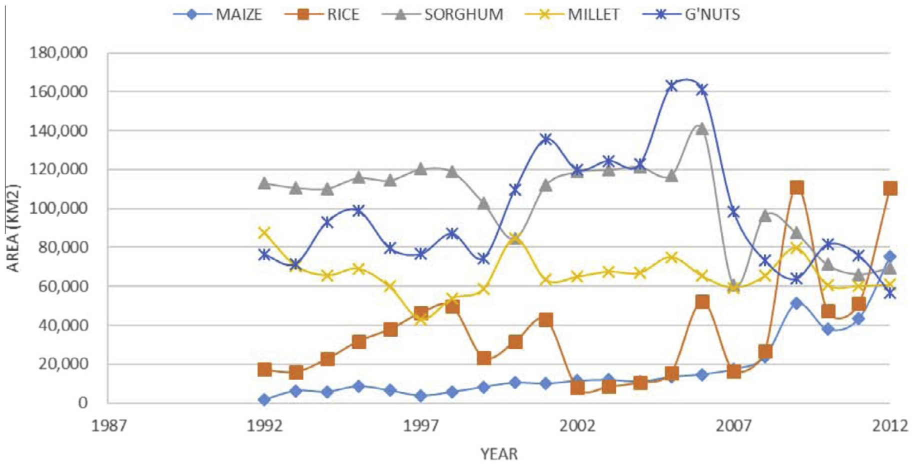

Fig. 5. Area of cultivation of major crops in hectare (1992–2012). *Source:* Created with data from Ministry of Food and Agriculture (MOFA).

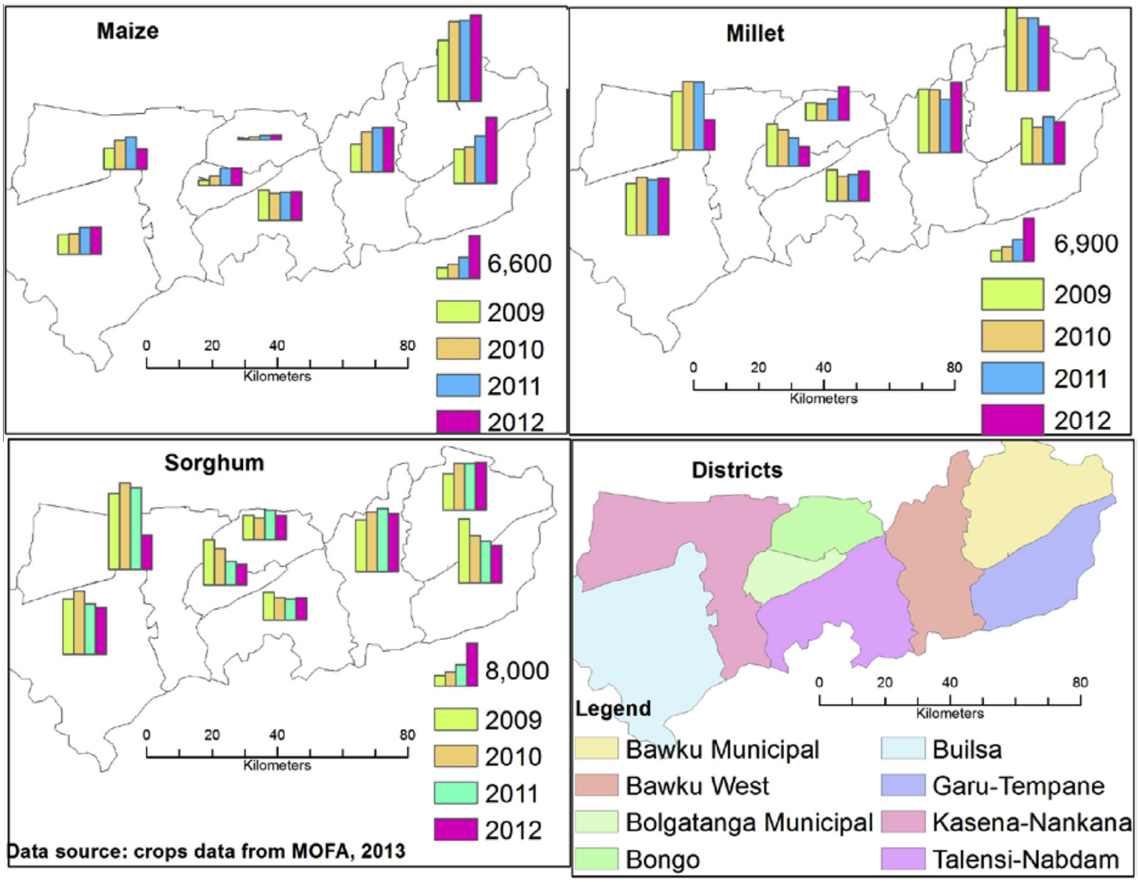

Fig. 6. Area of cultivation of three crops at district level.

and die due to lack of pasture and water in the long dry season and this is worsened by droughts". Another farmer at Kubore showed a dead keet which just died due to heat which confirmed this statement. It was an emphatic statement in all FGDs that low agricultural production has resulted in low incomes and acted as a push factor for some people to migrate. All households surveyed had at least one migrant relative who supported them with remittances.

Table 4
Sensitivity of crops to events of droughts and floods in the Upper East Region.

District	Year																	
	Crop	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Builsa	Maize			2		1			3	1		2	1	3				
	Rice	1	1	2		1	2	1						3		1	1	3
	Sorghum	1		1	2	2	1	1	1	1		1		3				1
	Millet	1		1		1			3	1	1	1	1	3				
	Groundnuts	2	1	1		1					1	1	1	1				
Kassena-Nan	Maize	1	1	3		1	2											
	Rice	1	1	2	1	1	2	2						2		1		1
	Sorghum	1	1	1		1	1	1		1				3				
	Millet			2		1	1	1	1					2				1
	Groundnuts					1	2	2			1			2				2
Bolgatanga	Maize		1	3	1	1					2	1	1	3	1			
	Rice	1	1	1	1	1			1	1	1			2		1		3
	Sorghum	1		1	1	2					2			2				1
	Millet			1	1	1	1	1			1			2			1	1
	Groundnuts	1	1	1		1	1					1		2		1	1	1
Bawku East	Maize	2	2	3	1	2				1	1		1	3	1			
	Rice		1	1							1	1	1	1				1
	Sorghum	1		1		1					3	1	1	3			1	1
	Millet		1	2		1		1			2		1	2	1		1	1
	Groundnuts		1	1		1				1	1		1	2		1	1	1
Bawku West	Maize	1		2		1	1					1		2				1
	Rice			1	1	1	1	1			2			1	1	1		1
	Sorghum			1		1	1	1			2	1	1	1		1		
	Millet			1		1	1	1			1		1	1		1		
	Groundnuts	1		1		1	1				1	1		1	1	1		
Bongo	Maize																	
	Rice	1	1	1		1	1	1			2		1	1				1
	Sorghum			1		1	1	1			1			1				1
	Millet			2		1	1	1			1		1	3			1	
	Groundnuts	1	1	1							1	1		2		1		1

Source: Authors N.B: 1 = Sensitive; 2 = highly sensitive; 3 = extremely sensitive; empty space = normal/no sensitivity.

3.2.3. Sensitivity of humans

High temperatures also affected the health of the people. Sicknesses such as CSM and headaches were reported prevalent during the hot times of the year (Fig. 7) in the questionnaire survey (n = 208). The sicknesses in Fig. 7 relate to heat and wet conditions. The sicknesses were divided into two – dry season or heat related and rainy season or/flood related. Heat related ailments (headache, CSM, body pains, high body temperature) were reported by questionnaire respondents more than wet (flood) related ailments (malaria, cholera, diarrhoea). This was attributed to the high temperatures recorded throughout the year.

Records from the Regional Health Directorate showed that the districts in the western part of UER (Builsa North and South and Kassena-Nankana East and West) had the highest cases of CSM in 2012 with Builsa having the most (179 cases). The lowest number of cases was from the east with Bawku West recording the lowest (18 cases). A trend analysis of CSM cases in UER (Fig. 8) shows an average increase of 39 cases per year since 2006.

Malaria occurrence also varied, with Bolgatanga Municipality recording the highest (7010 cases), while Bongo recoded the lowest (826 cases). Malaria occurs all year round, increasing in the rainy season because pools of water are created after heavy rains or floods which form breeding grounds for the malaria vector mosquitoes. Although reported malaria cases have been increasing since 2006, morbidity due malaria has generally declined, as is evidenced by the case fatality rates (CFR) of children aged under 5 years (Fig. 9). From Fig. 9, with the exception of Bolgatanga District, all districts met their targets of 1.2 CFR in 2012. Except in 2012, CFR for Kassena-Nanakana have been increasing while it has decreased in the other districts over the period.

IDIs with health officials attributed the downward trend of CFR to prudent policies such as the National Health Insurance Scheme (NHIS), building of Community-based Health Planning Scheme (CHPS) compounds, and provision of mosquito nets by the government and development partners. For example, a health worker in charge of one of the CHPS compounds stated that "*since I came here, I have managed minor ailments and only refer major ones to higher facilities and in some cases call the district ambulance service, thus improving the health of the people*". Treatments for malaria, CSM and the other ailments have nevertheless increased with time. An opinion leader in Kubore in the Bawku West District stated that "*I have observed that most of the people in this village are not able to work optimally during the rainy season, especially around July/August because of malaria. Each time they go to the clinic, they are given malaria treatment. In fact we spend a lot of our meagre resources battling malaria, especially for our children. During July/August too, people burn all kinds of material to dispel mosquitoes which also increase health risk related to inhalation of smoke*". Analyses of the interviews found the cost of treating all these diseases/sicknesses as a major concern. In the FGDs in most communities, participants noted that healthcare has become expensive due to the increasing cost of medicines and is consuming a greater part of their incomes.

Floods also affected human lives and other livelihood aspects. Between 65% and 80% of respondents in Kumpalgoga, Kubore, Pwalugu, Sandema and Fumbisi had their crops destroyed due to riverine flooding. Other properties destroyed included houses, but the rural communities attributed more of this to heavy and continuous rainfall. The destruction to properties in urban areas was attributed to lack enforcement of land use regulations. These communities even reported losing relatives to floods and this was confirmed by statistics from NADMO. As shown in Fig. 10, the 2007 flood had greater impacts than 2010 due to its severity. The impacts were also greater in districts such as Builsa, Kassena-Nankana, Bolgatanga, Bawku Municipal and Bawku West that had more/major streams/rivers. Windstorms generally occurred in the rainy season with minimal impacts compared to the other hazards. They also occurred less frequently. The eastern part of UER was more affected by windstorms than the rest of region due to less tree cover there. The effects were largely on roofs, and rural areas were most affected. More than 92% of survey respondents experienced their roofs being ripped off by windstorms, of which 30% reported it affecting at least one room per rainy season. The rest do not experience this problem frequently, but could not say how often. Respondents in the Sudan savannah (i.e. in Koose, Bawku, Tempane, Kumpalgoga and Kubore) indicated windstorms occurred more frequently and resulted in more severe impacts than in the Guinea savannah. We observed that many thatch roofs in these communities had logs on them to reduce wind damage.

4. Discussion

In the previous section, we examined the exposure and sensitivities of the ecosystem and people to the identified climate hazards. This section discusses the impacts and implications of the findings under broad themes of agriculture, food security and health, housing, and considering the indirect implications for poverty and the wider socio-economic context.

4.1. Agriculture

Changes in weather patterns and soil fertility were considered the major causes of losses in agricultural production but changes in weather patterns were considered most damaging. We found rising temperatures, low and uneven distribution of rainfall resulting in many and severe dry spells/droughts, floods and heavy rainfall. These have caused crop losses almost every year, as seen through our detrending analysis. They also contributed towards changing crop patterns. Dry spells in particular had greater impacts on crop production than droughts and floods. The 1997 rainy reason had only dry spells but recorded more severe crop losses (Table 4) than 1999 and 2000, when droughts/floods occurred. This finding is similar to those of Simelton et al. (2009) who noted that small droughts can have bigger impacts while bigger droughts may have small

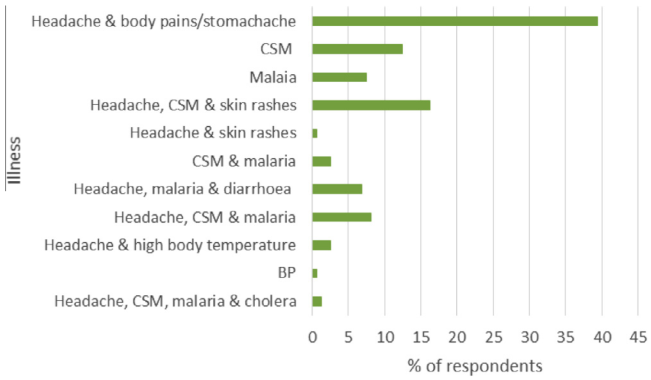

Fig. 7. Health effects of warming (high temperatures) on questionnaire respondents. *Source:* Authors (2013).

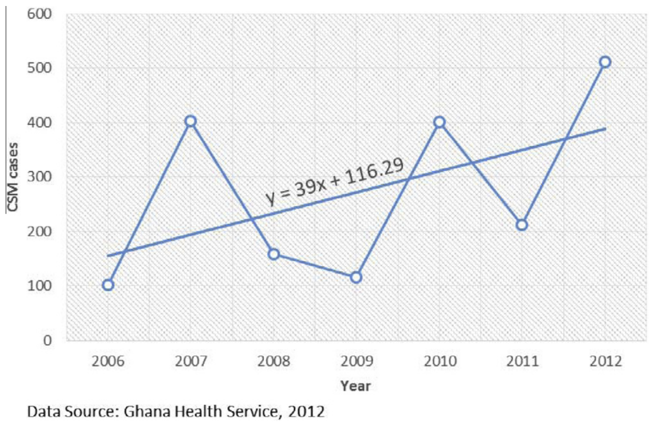

Fig. 8. Reported CSM cases in UER.

impacts. Findings show that in years with more than one hazard occurring, crop losses were most severe. For example, the concurrent occurrence of droughts and floods in the 2007 rainy season caused severe losses. Our findings are therefore consistent with those of the IPCC (2014) and many other studies that indicate climate change will have huge effects on crop production in Africa. With climate change projections indicating more severe and more frequent occurrences of dry spells, droughts and floods (IPCC, 2014), agricultural production in UER and the Ghanaian savannah and similar ecosystems is under threat if current practices continue. The climatic hazards were also found to affect livestock production as they cause diseases/sicknesses, lack of pasture and scarcity of water. This suggests that livelihood options may become further restricted.

Spatially, farms located along river valleys suffered less from the impacts of dry spells/droughts than those on uplands. Districts such as Builsa North and South, Binduri and Bawku West suffered severe crops losses whenever floods occurred. Although farms in the river valleys were subjected to riverine flooding that washed away crops and many lives and properties lost, they were able to better manage dry spells and droughts. This is because soils along river valleys were reported to retain moisture longer due to deposition of organic matter, which helped to reduce the impacts of droughts/dry spells and to maintain soil fertility. This supports findings of Govaerts et al. (2008). Planting and harvesting before floods, using early maturing crops, and practicing flood recession farming were identified as adaptation options that also contributed to continuous use of such farms. Another important socio-economic factor was the migrant status of most farmers along the White Volta. This group had few options but to use hazard prone areas. This supports findings by Adams et al. (2012) that migrants often move to cheap and vacant land in environmentally marginal areas. Besides migration, Yiran et al. (2012) found that the land tenure system where the land is divided many times among succeeding children throughout generations contributed greatly to this situation. If your portion falls in flood prone areas, you have no option but to use that piece of land.

Temperatures were found to be very high and increasing every year across UER, with severe consequences for water and soil moisture. According to Liebe et al. (undated), the high temperatures have resulted in high evapotranspiration, leading to drying of many water bodies in UER. High evapotranspiration means soils dry quickly and therefore lack moisture for plant growth, affecting crop production and pasture availability for animals. High temperatures further make grass highly combustible and easily razed by fire, especially in the dry season (Yiran et al., 2012). Thus, many animals grow lean or die as a result of lack of pasture and water (Yiran, 2014). Research has shown that increases in the frequency and prevalence of

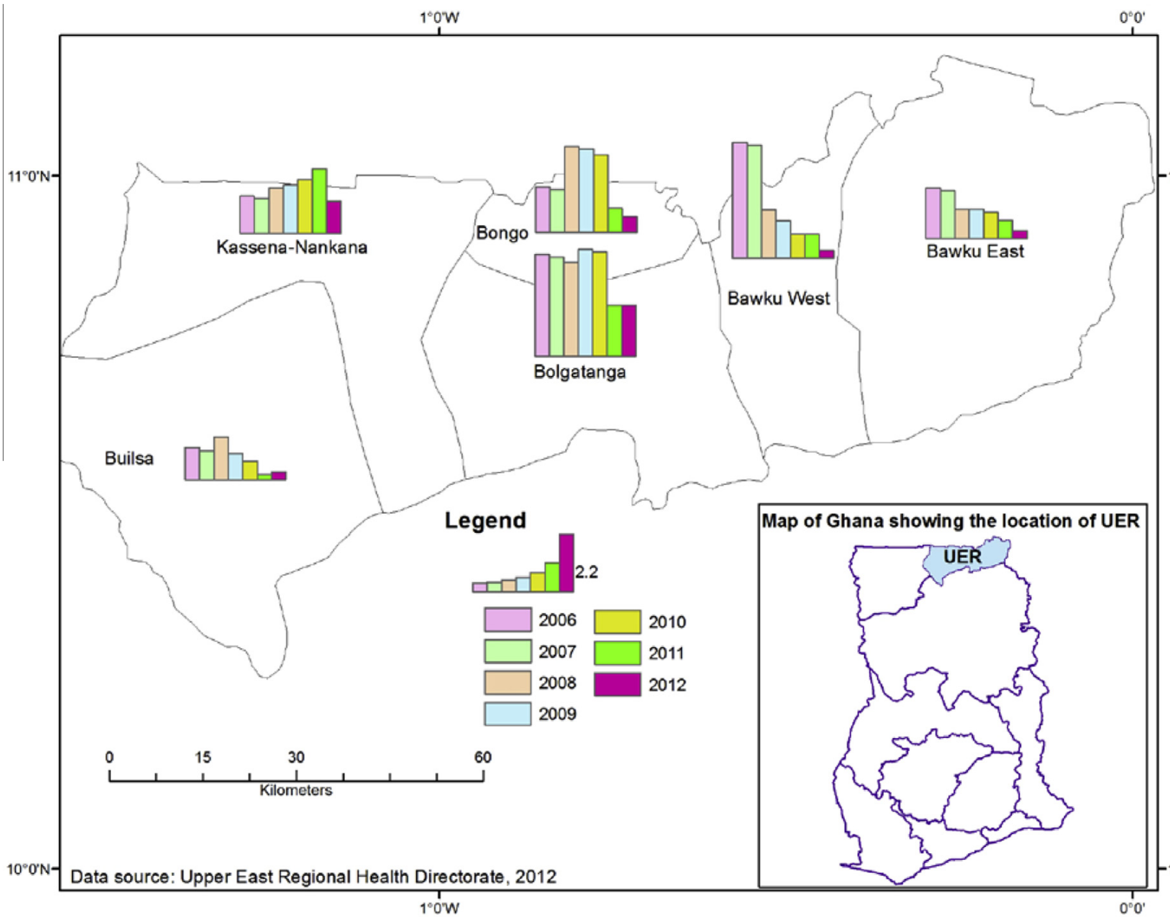

Fig. 9. Malaria case fatality rate from 2004 to 2012.

failed seasons will shift the farming system from a mixed crop-livestock towards more livestock production (Jones and Thornton, 2009; Thornton et al., 2010). But as shown above, livestock production is similarly affected by climatic hazards (see also AIACC, 2007).

4.2. Food security and health

Crop failure or low yields (see Section 3.2.2) have negative implications for food security as the majority of the people, especially in rural areas, depend largely on their own production for household food consumption. According to Yiran (2014), about 84% of a sampled population in the area relied on their own farm produce for household food supplies. Food shortages, particularly in the lean season (WFP, 2012; Yiran, 2014), have resulted food high prices (Akudugu, 2010), unaffordable by the poor. Due to this, the UER is classified as the most food insecure region in the country with variations of insecurity among the districts (WFP, 2012). Highly food insecure districts correspond to the districts with more frequent and higher agricultural losses due to hazards in UER. As a result, the region has more often relied on food aid due to the frequent losses. The highest crop losses since 1992 occurred in 2007 (Table 4) resulting in very severe food insecurity. In that year, about 50,000 people in Northern Ghana were estimated to remain highly vulnerable to food insecurity for more than a year (Armah et al., 2010). As a result, the government appealed to raise US$53 million for immediate needs, with about 45% of the aid to go to the UER and a greater percentage of the region's share also going into food supplies (IRIN, 2014).

A reduction in food quantity and the number of times food is consumed each day by many people was attributed to frequent production losses and the inability of most inhabitants to meet their food needs from alternative sources. According to Quaye (2008), reduction in food intake is prominent from the seventh month after harvest. Reduction in food intake may result in malnutrition, especially for children and pregnant women. Already the region is reported to have very high malnutrition rates (Ghana Statistical Service et al., 2009). Studies on the relationship between climate change and health show that there is a correlation between weather variables and stunting (Grace et al., 2012; Jankowska et al., 2012). A study by Boatbil and Guure (2014) showed that stunting varied among major ethnic groups of some districts in UER due to cultural practices

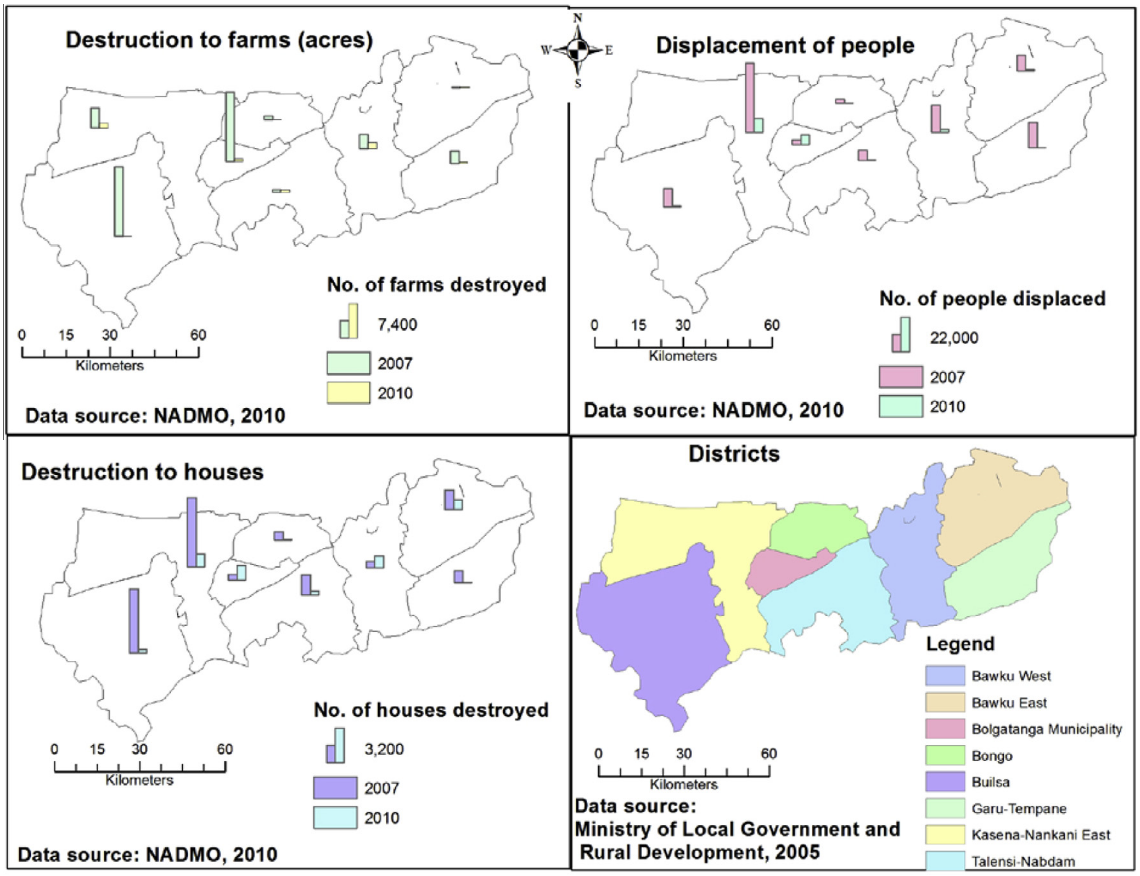

Fig. 10. Impact of floods on people and some properties.

regarding feeding. Cultural practices coupled with other food consumption practices and low productivity could worsen the level of malnutrition in highly food insecure districts and increase healthcare costs in those districts.

UER is also plagued with sicknesses and diseases related to climatic hazards, especially from heat related ailments and malaria. CSM is high in the region particularly between March and May when temperatures are very high and humidity is very low. Statistics from Ghana Health Service (2012) show that reported cases of both CSM and malaria vary among the districts. Although dams provided water for agriculture, they also provided a breeding ground for mosquitoes, contributing to the high malaria prevalence in districts with many dams. Construction of dams is also shown to increase malaria cases in Tigray, Ethiopia (McCartney et al., 2007). UER is recording high rates of deaths and injuries over space and time resulting from variations in heavy rainfall and floods (NADMO, 2011). The region has the poorest health infrastructure and personnel in the country and the situation is worst in the rural areas (Ghana Health Service, 2012). The projected increase in frequency and severity of climatic hazards (IPCC, 2014) will bear heavily on the health of the people of this and other regions in the savannah ecosystem with similar health indicators and climatic conditions. The severity of impacts suggests the area needs special consideration by policy makers in this regard.

4.3. Housing

Heavy downpours, floods and windstorms destroy buildings and essential infrastructure such as roads, schools and health facilities. Flooding in urban towns in Ghana has been blamed on heavy downpours and lack of proper drainage to channel runoff (UN-Habitat, 2011). The floods of 2007 and 2010 destroyed several homes and displaced many people (Gilgenbach et al., 2012). The displaced usually seek refuge with their neighbours or use schools as shelters until they are able to fix their homes (Yiran and Stringer, 2015). This has serious implications for children's education as they may be out of school for some time. Records at the regional NADMO office indicate that damage to buildings was higher in Binduri, Sandema, Fumbisi and Bawku West districts. These districts have major rivers that flood frequently. Public facilities such as schools and health facilities, when affected, are closed or have users crowded into the few rooms that are not destroyed. Studies in UER show several roads and bridges washed away by run-off and flooding, and schools and hospitals inundated for several days (Gyireh, 2011; Yiran, 2014).

4.4. Implications for poverty and the socio-economic context of the UER

As agriculture is the main economic activity of majority of the people (Ghana Statistical Service, 2012), agricultural production losses adversely affect the socio-economic context and make it more difficult for people to lift themselves out of poverty. Crop production losses result in inability to recover the investments made and low incomes. Livestock as an alternative route to replenishing household food (WFP, 2012) also experience high losses, especially due to droughts and high temperatures. A study by UNDP and NDPC (2012) shows that even though Ghana achieved the Millennium Development Goal of halving poverty nationally before 2015, the three northern regions still have some way to go.

People living in UER face high expenditure on health care, reconstruction of homes and high food prices resulting from the occurrence of hazards. Thus, the impacts of the hazards operate across a range of different aspects of people's lives, making it difficult for them to pursue their livelihoods and advance their overall wellbeing. IFAD (2012) found similar linkages between agriculture and other sectors of the economy influencing poverty levels. As the frequency and severity of hazards is projected to increase (IPCC, 2014), the socio-economic impacts of the hazards also look set to worsen.

5. Conclusion and recommendations

This paper has contributed to the body of knowledge on impacts of CVC on people in a savannah ecosystem by examining impacts spatio-temporally at district level. It has provided empirical evidence to deepen our understanding of the impacts of multiple, interacting climate hazards as people continue to eke a living in the region. The frequency, severity and alternate occurrence of climate hazards has been shown to have important negative impacts on the resources (food, health, housing, income) that people use in pursuing a livelihood, making it difficult for them to improve their development situation. Findings suggest that given the interaction between CVC impacts, any development agenda or adaptation policy should take a holistic view.

To address perennial flooding hazards, we suggest the construction of small dams on most of the streams that flow through UER as well as encouraging the use of other rainwater harvesting technologies in urban areas. This will reduce flow downstream thereby reducing flooding and its impacts on crops and other properties greatly. The dammed water could also be used for irrigation which will reduce dependence on rainfed agriculture and crop losses to flooding and encourage people to invest in less risky forms of agriculture. Nevertheless, this would require a health impact analysis as any augmentation in water bodies could increase malaria prevalence and other health hazards. Drought resistant crops should also be introduced to minimise the effects of droughts/dry spells.

In the health sector, we recommend investments in infrastructure, especially CHPS compounds and the use of mobile clinics to bring healthcare closer to the people. Also, increased health campaigns, use of bed nets and immunizations could help reduce the risk of CSM, malaria and other diseases that are affected by the climate. The health insurance scheme should be strengthened to reduce out of pocket spending on health care. The enforcement of land use plans and building codes is critical in infrastructural development and can prevent the siting of buildings in hazard prone areas.

We recognise that some of our recommendations require large-scale financial investments and that politics also plays an important role. Given resource constraints and competing demands on the limited resources in Ghana and many other developing countries across sub-Sahara Africa, the implementation of such recommendations will be challenging. Nonetheless, with strong political will and assistance from development partners, these recommendations can be achieved.

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