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Spatio-temporal analyses of impacts of multiple climatic hazards in the 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 over the past three decades. This paper presents a spatial, time-series analysis of the impacts of multiple hazards on the ecosystem and human livelihoods, using the Upper East Region of Ghana as a case study. Our aim is to understand the nature of hazards (e.g. their frequency, magnitude, duration etc) and how they ultimately affect humans. Primary data were collected using questionnaires, focus group discussions, in-depth interviews and personal observations. Secondary were collected from documents and reports of various institutions. Calculations of standard precipitation index and crop failure index were made using 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. Observed temperatures from the Ghana Meteorological Agency were constantly high and increasing; drought frequency varied from 9 at Binduri to 13 occurrences at Vea; dry spells occurred almost every year. Floods occurred about 6 times on average, with slight variations spatially, from 1988 to 2012, a period with consistent data from all stations. All 5 crops were highly sensitive to all climatic hazards. Destruction to housing, displacement and death of people, and malaria were attributed to floods/heavy rainfall and windstorm events. Cerebro-spinal meningitis, rashes, headaches and drying of waterbodies were attributed to high temperatures, and droughts/dry spells. All impacts varied spatio-temporally and from hazard to hazard. Perennial agricultural losses and high spending on health contribute greatly to persistent poverty. Investing in sustainable irrigation, health and diversification into other economic sectors beyond agriculture could help to tackle the impacts of the hazards whilst also reducing poverty.

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1.0 Introduction

Over the past 100 years, global mean temperatures have risen and there is evidence that the rate of warming is accelerating (IPCC, 2012). As indicated by IPCC (2012), increase in the average global temperature is very likely to lead to changes in precipitation and atmospheric moisture due to changes in atmospheric circulation and increases in evaporation and water vapour, thus changing the climate. Projections also show that the Earth's climate will continue to change at an unprecedented rate, at least until the end of the 21st century (Thornton et al, 2008). The variability and/or changes in climate are most likely to bring about hazards such as high temperatures, heavy rainfall, dry spells/droughts, floods and windstorms, which will have deleterious impact on humans and the ecosystems on the globe (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 amongst climate scientists and global leaders on the reality of climate change (IPCC, 2014). Indeed, climate variability and change has received intense research in recent times (see IPCC reports for summary of studies).

Many studies have examined the impacts of climate variability and change (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). The impacts noted in these studies vary widely but generally show negative outcomes for food crops (Challinor et al., 2007). The studies show that rainfall is expected to be more variable and less predictable with 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).

However, many of these studies are model-based, predicting the impacts of climatic events on yield, and are considered top-down approaches (see Connolly-Boutin and Smit, 2015). These studies are also conducted at macro scales (e.g. Sarr, 2012). Other types of studies 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 studies have 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). All these studies have indicated that climatic hazards affects aspects of livelihoods but what remains unclear is how the frequent and alternate occurrences of different types of hazards have cumulatively affected human livelihoods. 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.

2.0 Methodology

A mixed methods research design was used to analyse the impacts of multi-hazards over a 30-year period (1983-2012), spatially and temporally, in the savannah ecosystem using the UER as a case study. The period between 1983 and 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 (Fig. 1) is located in north-east Ghana. The UER is dominated by Guinea and Sudan savannahs, a degraded form of the Guinea savannah.

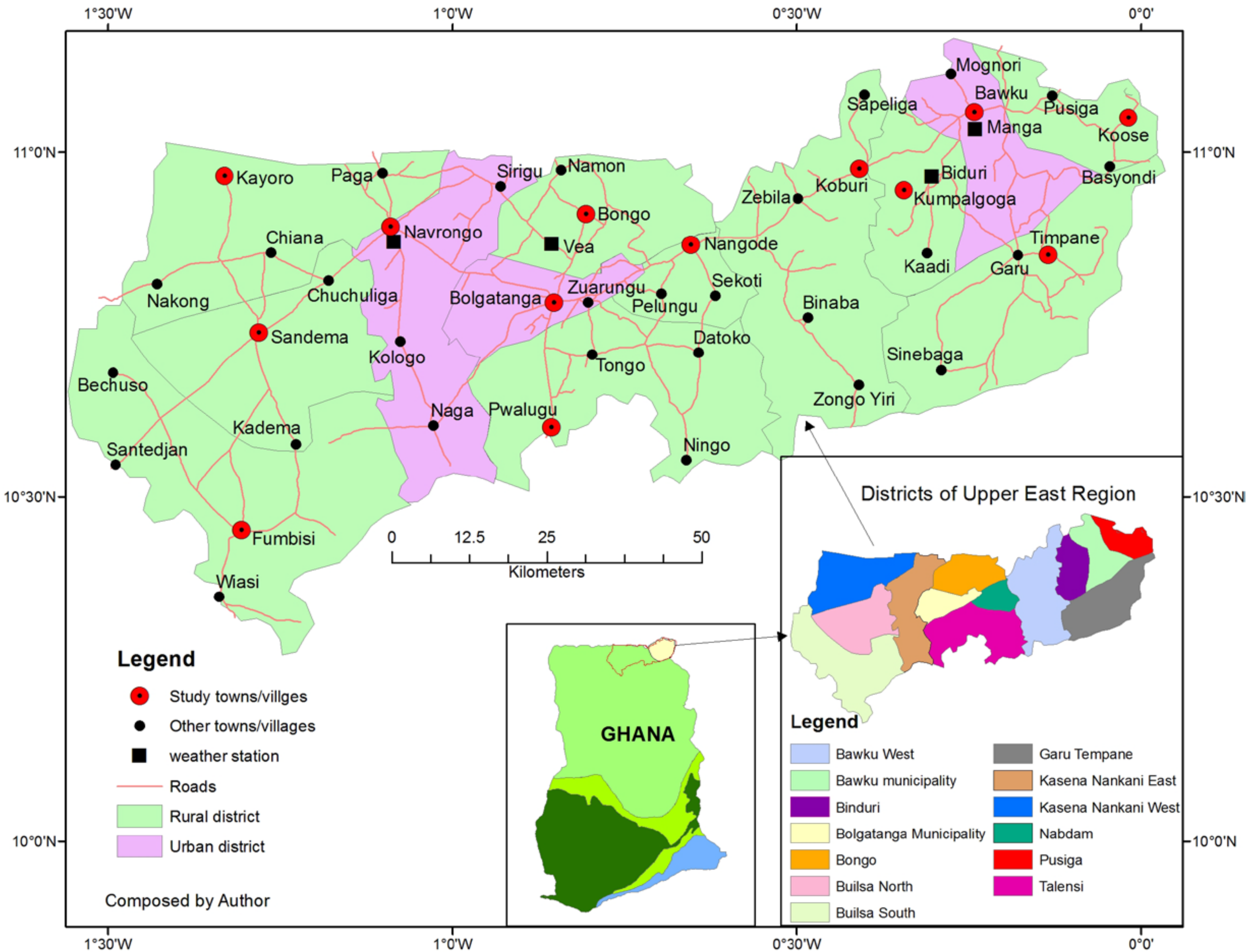

Fig. 1 Map showing the Upper East and its location in the Savannah Ecological Zone

It experiences all hazards that occur in the savannah and can act as a window to understand the hazards for the whole region (Yiran, 2014). The 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, the UER is the first to be flooded as water from the dams enter the region before any other region. The 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 using questionnaire, focus group discussions (FGD) and in-depth interviews 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 large urban towns were purposively selected and used 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. A total of 210 household heads were then randomly sampled from the 13 selected communities for a questionnaire survey (Table 1). The stratification of districts into urban and rural is based on Ghana Statistical Service (2012) classification where districts with rural population more than urban population are classified as rural. Urban areas were sampled in higher numbers based on the function (regional, municipal and district capital) of the town.

Table 1 Distribution of questionnaires

District	Classification of district	Town/village selected	Number of questionnaires	No. 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 different backgrounds and experiences following a discussion with community leaders. In order to capture views from diverse people, we ensured that the composition of the groups varied among the villages. Proceedings were recorded by the researchers and the results were synthesised by analysing the statements/explanations recorded by each person under key themes immediately after each meeting. In-depth interviews 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 the in-depth interviews using similar criteria to the selection of FGD participants. In order to capture responses and views from varied people as much as possible, we ensured that no person participated in more than one interview. Secondary data including crop yields, weather, disaster incidence and effects, soil, water 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) was analysed using the Standard Precipitation Index (SPI). This was chosen over other indices 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). The 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 (see 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 – 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. Results were produced as tables, charts and diagrams supported with explanations from the FGDs and in-depth interviews.

3.0 Results

The following subsections present the elucidation of information to identify the hazards that occur in UER and the sensitivities of the savannah ecosystem, humans and their livelihoods to the hazards.

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. Detailed analysis of the data leading to the identification of these hazard events are presented in the following subsections.

3.1.1 High temperature

All respondents in the questionnaire survey indicated that temperature was very high and seemed to be increasing every year particularly around March. This corroborated with observed weather data from GMet (Fig. 2). As shown in Fig. 2, the temperature is rising throughout the period of study, with March recording the highest temperatures. The increase in temperatures around March was exponential (Fig. 2). Participants in the 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 this 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".* In fact, all statements regarding temperature point to increasing temperatures compared with over 20 years ago. 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. The 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 hence, higher temperatures. According to them, when it rains, temperatures are lowered. They also linked less tree cover to the rising temperatures.

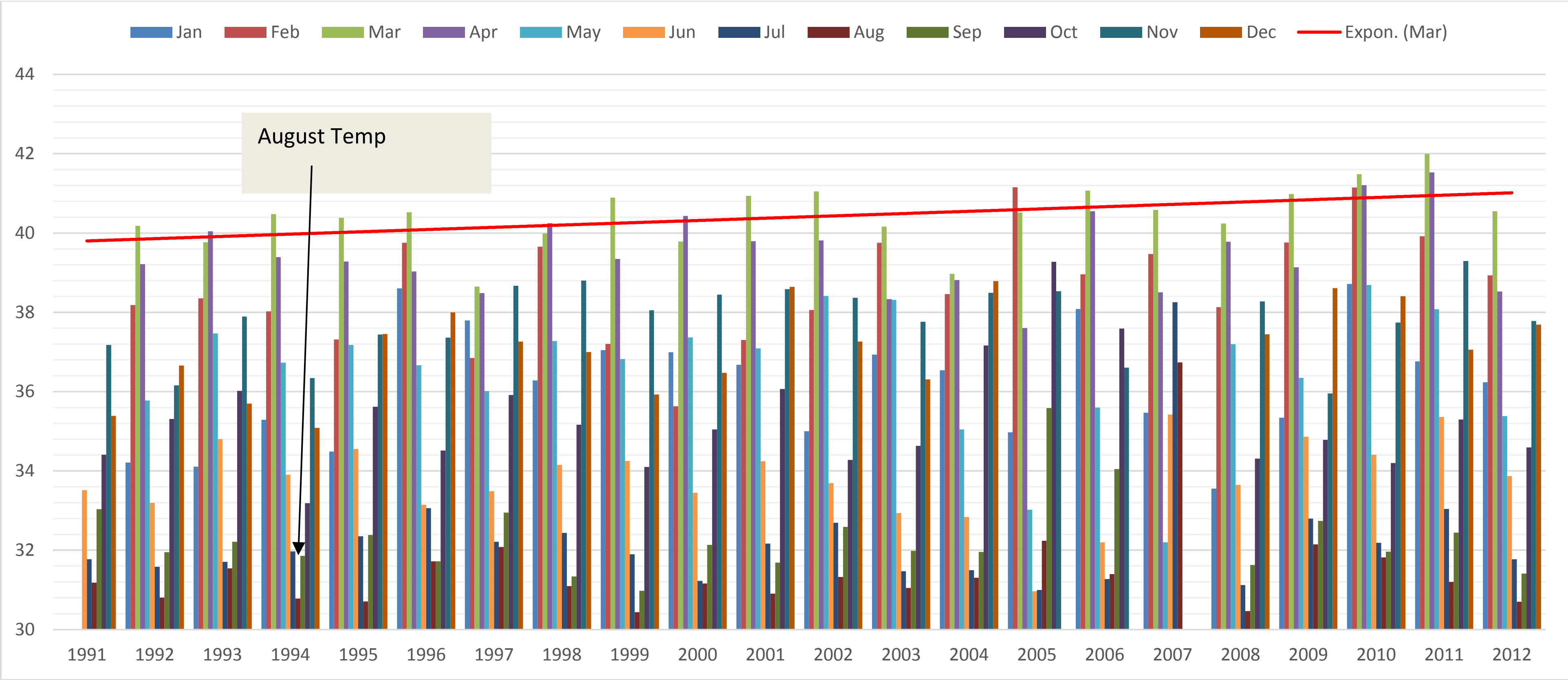

Fig. 2 Maximum average monthly temperatures (°C)[1] from 1991 to 2012

Source: Created with data from GMet

[1] All low temperature values correspond to July – September period.

3.1.2 Droughts/dry spells

79% 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.

Table 2 Frequency of droughts in UER, 1983 – 2013

	No. of respondents				
Communities	**Every year**	**Once every 2years**	**Once in every 5years**	**Irregular**	**Total**
Bawku	88%	6%	6%	0	18
Bolgatanga	84%	16%	0	0	25
Bongo	93%	7%	0	0	15
Fumbisi	93%	7%	0	0	15
Tempane	60%	33%	0	7%	15
Koose	47%	47%	6%	0	15
Kubore	93%	7%	0	0	15
Kumpalgoga	53%	33%	14%	0	15
Nangodi	93%	0	0	7%	15
Navrongo	86%	7%	7%	0	15
Pwalugu	53%	0	0	47%	15
Kayoro	53%	0	0	20%	15
Sandema	93%	7%	0	0	15
Total	79%	13%	2%	6%	208

Source: Fieldwork, 2013

This conception led to 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 there has a lot of organic matter that is brought in by the floods which helps to keep the water as well as increase the 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 though sometimes the floods destroy the crops.

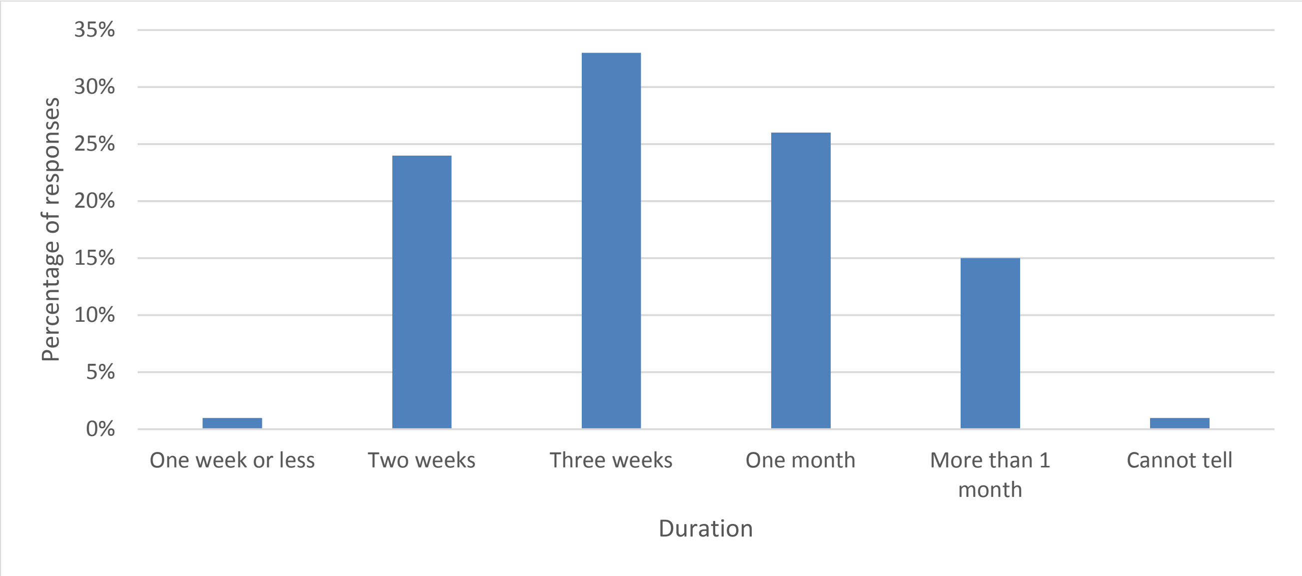

Fig 3 Duration of droughts
Source (Fieldwork, 2013)

In the FGD at Kumpalgoga, participants who farm along the White Volta 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 which mature before the floods. In all the FGDs, participants noted that the nature of 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. 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 25 years. 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). From the Table, the frequency of droughts was less 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 were accountable for 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.

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

		Year												
Station	**Characteristics**	**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' own construct. N.B: Ma=March, A=April, M=May, J=June, Ju=July, Au=August, S=September, O=October

From the questionnaire survey, the frequency of floods was also found to be varied (Fig. 4). As can be seen, more than half of the 210 household heads 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 area. 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*".

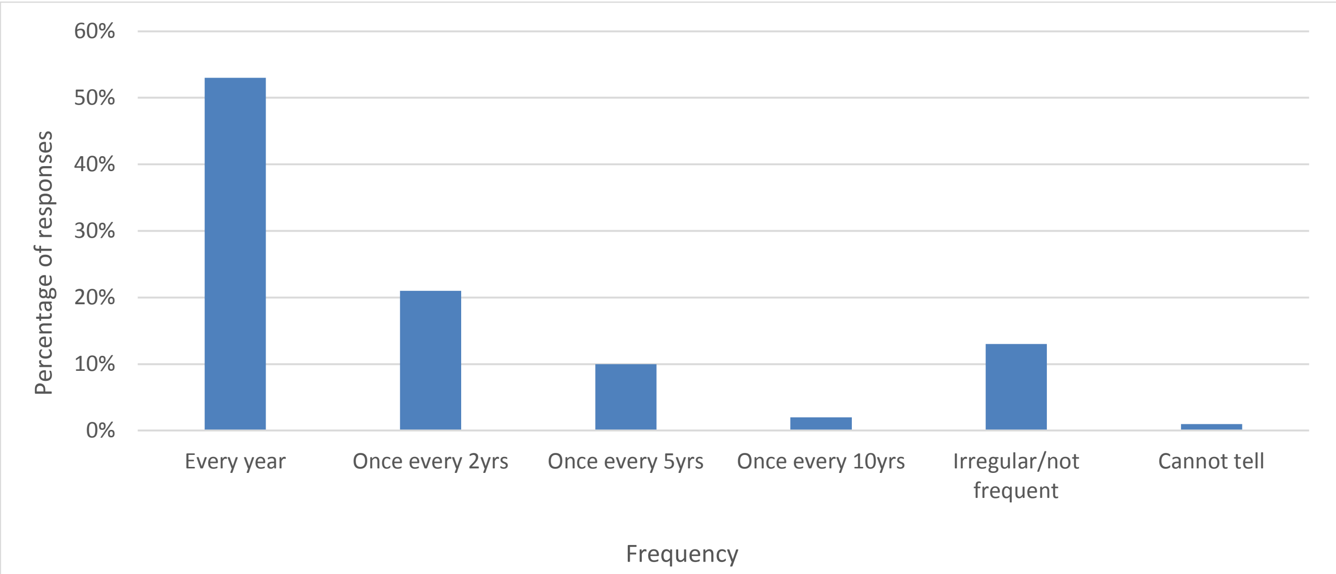

Fig 4 Frequency of floods according to respondents

Source: Authors' own construct

Examination of the 12-month SPI indicated wet conditions in 1989 extending into 1990 and ending in September 1990. Another wet condition 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 that 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 the 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 too, the soil is saturated and cannot hold together. The eroded soil and other materials find their into the water bodies silting them up. According the respondents in the Bongo FGD, some of the water bodies have disappeared while some are believed to have reduced 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*".

The severity of the various hazards on the ecosystem, as indicated by institutional representatives during interviews, is shown in Table 4.

Table 4 Sensitivity of human-ecological system to hazards

Hazard	**Severity**	**% respondents**
Floods	Very severe	56
Droughts	Very severe	80
Temperature	Severe	68
High precipitation	Very severe	44
Windstorm	Severe	56
Bushfire	Severe	60

Source: Field survey

More than 70% of respondents linked the lack of quality thatch and pasture to reduced rainfall. They noted that grass do not grow well and animals struggle to feed.

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, local potatoes, etc. to improved and short-duration varieties of maize because of increasing incidence of dry spells/droughts. To confirm this, the land areas used to cultivate each of the five major crops from 1992 to 2012 was plotted (Fig. 5).

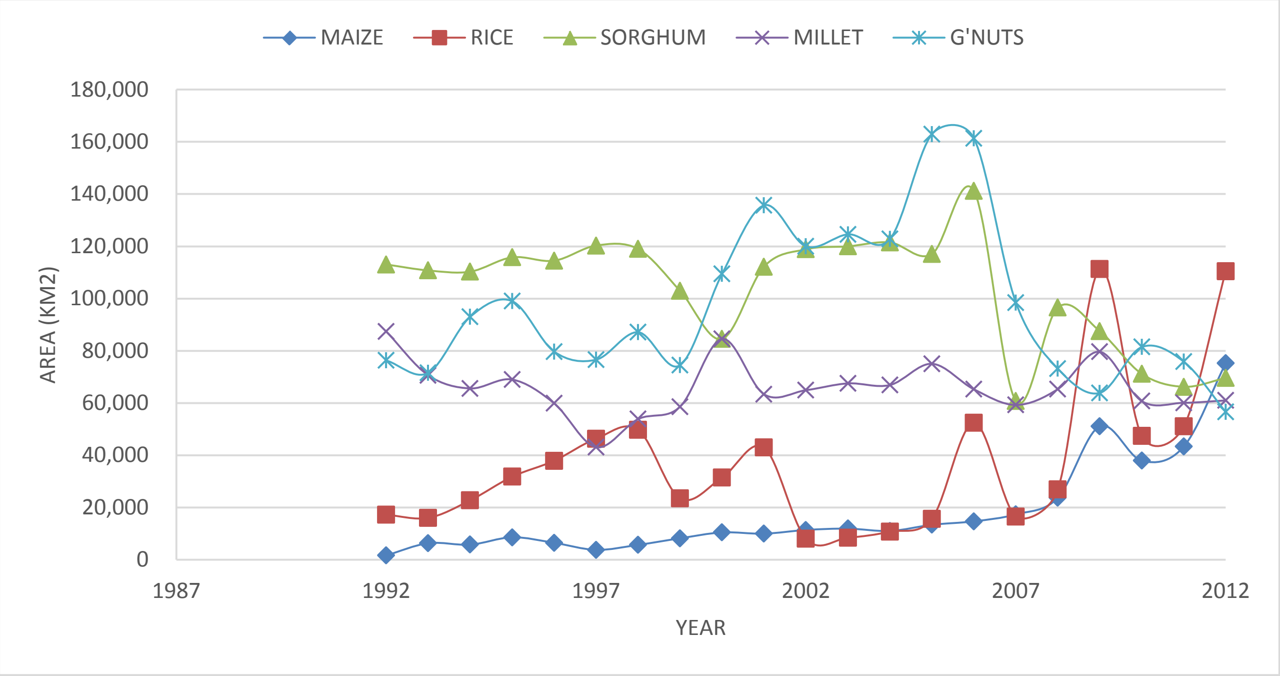

Fig. 5 Area of cultivation of major crops in hectare (1992-2012)[2]

Source: created with data from MOFA

The cultivated areas for the traditional food crops (i.e. millet, groundnuts and sorghum) are decreasing while those for maize and rice are increasing over the

[2] These are the only years with records from the SIRD of MOFA.

period of focus. Increases in rice came largely from big irrigation projects. The decrease in cultivated areas for the traditional crops supports respondents' experiences that the traditional food crops are being replaced by maize. If this trend continues, the crops losing land 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 in the market. Yield data indicated that maize and rice were the major crops produced in 2012. While maize crops suffered a dry spell/drought in 2013, they survived because the people had cultivated short duration and drought resistant varieties that are able to withstand dry spells/droughts better than traditional crops. A respondent in Bongo stated that changes in rainfall (weather) has modified their food system because of frequent losses from traditional food crops. He justified this by noting: "*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, these are used to prepare different types of food for supper*".

The sensitivities of the five major staple food crops varied within and without the districts (Table 5) and in accordance with the variations of the 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 maturing time, a dry spell can destroy everything*". His feelings were generally expressed in many in-depth interviews and the FGDs. Years that some of these events took place concurrently/consecutively, crops were highly sensitive. As can be seen from Table 5, the crops recorded heavy losses in 2007 than all other years and was classified high to extreme sensitivity.

Table 5 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

N.B: 1=Sensitive; 2= highly sensitive; 3= extremely sensitive; empty space = normal

Source (Author's own construct)

The year 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 5). Districts in the Sudan savannah (i.e. Bawku East[3] and Bawku West) experienced greater crop losses from droughts than the other districts. Crop yield data showed that these districts adopted the cultivation of maize much earlier than the others. Observations from the 2013 cropping season revealed that maize cropping was greater in the Sudan than the Guinea savannah, and farmers in all FGDs in the Bawku Districts confirmed this. In the FDG at Kumpalgoga, it was mentioned that they have virtually stopped cultivating groundnuts. In all FGDs, it was stated that during droughts, temperatures were also very high which exacerbated crop losses because crops withered due to high evapotranspiration. Some respondents indicated they avoid 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 the crops which burns and kills them. The questionnaire findings showed more than 60% in each surveyed community attributed agricultural losses to climatic events while the remainder attributed the losses to low soil fertility.

3.2.3 Sensitivity of humans

High temperatures also affected the health of the people. Sicknesses such as headache, cerebrospinal meningitis (CSM) and headaches were reported as being prevalent during the hot times of the year (Fig. 7). The sicknesses in Fig. 7 relate to heat and wet conditions. The sicknesses were divided into two – dry season or heat

[3] Divided into Bawku Municipal, Garu-Tempane, Binduri and Pusiga

related and wet season or/flood related. Heat related ailments (headache, CSM, body pains, high body temperature) were reported more than wet (flood) related ailments (malaria, cholera, diarrhoea) from the questionnaire. This was attributed to the high temperatures recorded throughout the year.

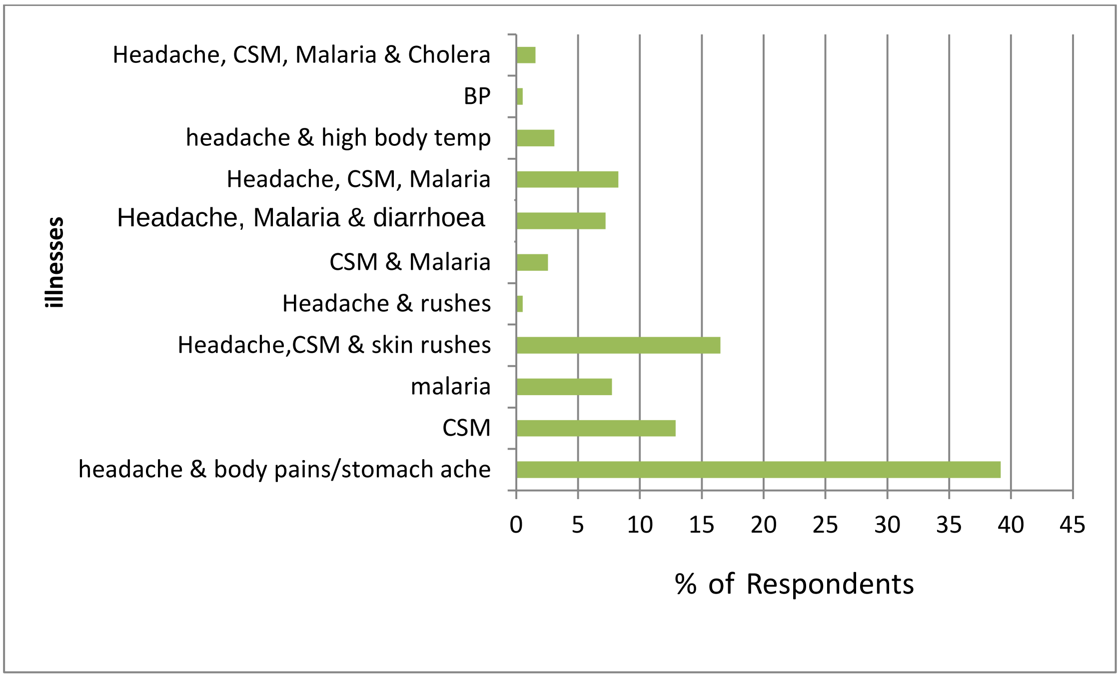

Fig. 7 Health effects of warming (high temperatures) on the inhabitants

(Source: Fieldwork, 2013)

Records from the Regional Health Directorate showed that the districts in the western part of the region (Builsa North and South and Kassena-Nankana East and West) had the highest cases of CSM in 2012 with Builsa topping with 179 cases, while the lowest were from the east with Bawku West recording the lowest with 18 cases. Malaria occurrence also varied, with Bolgatanga Municipality recording the highest of 7010, while Bongo recoded the lowest of 826 cases. Malaria cases are so high because they occur 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. These illnesses increase spending on treatment as well as affecting labour output and contributing to poverty in the area. 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 smoke*". In the FGDs in communities that had large numbers of dams or drainage problems, the people claimed malaria was high all year but other communities noted big reductions in the number of malaria cases in the dry season.

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. These communities even reported losing relatives to floods and this was confirmed by statistics from NADMO.

Windstorms generally occurred in the rainy season with minimal impacts compared to the other hazards. They also occurred less frequently. The eastern part of region was more affected by windstorms than the rest of region due to less tree cover in that part of the area. The effects were largely on roofs and rural areas were most affected. More than 92% of survey respondents have experienced the effects of windstorms in terms of their roofs being ripped off, of which 30% reported it affecting at least one room per season. The rest do not experience this problem frequently, but could not say how often. However, respondents in 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.

4.0 Discussion

In the previous section, we examined the exposure and sensitivities of the ecosystem and people to the identified hazards. This section therefore discusses the impacts and implications of the findings. Hazards have been shown to be impacting heavily on the lives of the people, as well as the ecosystem on which they depend. This section is subdivided to discuss the impacts of the hazards on climate sensitive sectors that support the livelihoods of the people.

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. This is consistent with the findings of the IPCC (2014) and many other studies that indicate climate change will have huge effects on crop production in Africa. Rainfall is low and unevenly distributed (Logah et al., 2013), resulting in many dry spells and heavy rainfall events in one or two months in a season. Thus, the frequent crop losses witnessed in the area is largely due to the dependence on rainfed crop production. Dry spells had greater impacts on crop production than droughts and floods. This similar to findings from Simelton et al. (2009) who noted that small droughts can have bigger impacts while bigger droughts have small impacts. Dry spells are erratic and can occur many times and at critical periods of the rainy season leading to bigger losses than droughts and floods. The findings show that in years with more than one hazard occurring, crop losses were more severe. For example, the concurrent occurrence of droughts and floods in the 2007 cropping season caused severe losses to crops as evidenced in the crop sensitivity index. 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.

Spatially, farms located along river valleys suffered less from the impacts of dry spells/droughts than those on uplands. 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). Although farmers in the river valleys managed dry spells and droughts better, they were subjected to riverine flooding: crops were washed away and many lives and properties were lost in these flood prone areas. Due to the migrant status of those along the White Volta, they 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 very high and increasing every year across the entire region 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. High evapotranspiration means soils dry quickly and therefore lack moisture for plant growth, affecting crop production and pasture 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 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 have negative implications for food security as majority of the people 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. Low crop production also resulted in high food prices in the market (Akudugu, 2010), unaffordable by the poor. The UER is classified as the most food insecure region in the country with variations of insecurity among the districts (WFP, 2012). The highly food insecure districts correspond to the districts with more frequent and higher agricultural losses due to hazards. The region has more often relied on food aid due to the losses. For example, droughts in early part and flooding in later part of 2007 cropping season destroyed several farms and other properties in Northern Ghana where it was estimated that about 50,000 people were remained highly vulnerable to food insecurity for more than a year (Armah et al., 2010). As a result, the government appealed to raise about 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). As found in our research, a reduction in the quantity and number of times food is consumed daily by many people is attributed to the 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 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 health cost in those districts.

The region is also plagued with sicknesses and diseases related to the 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).

The region is also recording high rates of death 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 IPCC (2014) has projected an increase in frequency and severity of droughts, floods, heat waves, heavy precipitation and windstorms among others. This will have untold effects on the health of the people of this and other regions in the savannah ecosystem with similar health indicators and climatic conditions, and 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 flooding events of 2007 and 2010 destroyed several homes and displaced many people (Gilgenbach et al., 2012). The displaced people 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 the education of children as they would 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 down 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

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

The poverty situation in the region is further exacerbated by high expenditure on health care, reconstruction of homes and high food prices resulting from the occurrence of hazards. Thus, the impacts of the hazards trigger a lot of socio-economic factors which interact variably to induce abject poverty on the people. IFAD (2010) found similar linkages between agriculture and other sectors of the economy influencing poverty. 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 the poverty situation of the region.

5.0 Conclusion and recommendations

This paper has contributed to the body of knowledge on impacts of CVC on people in the savannah ecosystem by providing empirical evidence to deepen our understanding of the impacts as they continue to eke a living. It further highlights the nexus between poverty and CVC. Persistent poverty in the area relates to the frequency, severity and alternate occurrence of climate hazards and their impacts on the livelihood activities as well as the interaction between those livelihoods. The uniqueness of our study is that it has shown that the nature of occurrence of the hazards, their impacts and the interactions of their impacts result in poor socioeconomic conditions and impinge on the broad development of the area. The findings suggest that any development agenda or adaptation policy should take a holistic view.

To address these ongoing challenges in agriculture in the face of increasing climatic hazards, we suggest that government and its development partners invest further in the agriculture sector by making available sustainable irrigation, agricultural inputs, and credit facilities. More construction of dams upstream of areas often flooded could be usefully developed to harvest runoff as well as encouraging the use of other rain water harvesting technologies but would require a health impact analysis as these could increase malaria prevalence and other health hazards. Provision of these facilities will reduce the reliance on rainfall and help people to invest in less risky forms of agriculture.

We also recommend improvements in infrastructure, especially health and education infrastructures and roads. Increased health campaigns, use of bed nets and immunizations could help reduce the risk of CSM, malaria and other diseases. The enforcement of land use plans and building codes is critical in infrastructural development. We further suggest that the economy be diversified by tapping into the other potentially viable activities that will make use of the large deposits of clay, granites, gold and other minerals captured in the various district profiles as well as providing skill training and formal education. This will help to create jobs thereby reducing dependency on agriculture, and increase incomes and reduce food insecurity in the region. Nevertheless, the success of some of these interventions, especially those on manufacturing, hinges largely on trade liberalisation policies.

We recognise that some of our recommendations require massive financial investments and that global 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 challenged. Nonetheless, with strong political will and assistance from development partners interested in poverty reduction, these recommendations can be achieved.

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