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March 2011

Centre for Climate Change Economics and Policy

Working Paper No. 55

Sustainability Research Institute

Paper No. 25

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Mapping the Vulnerability of Crop Production to Drought in Ghana Using Rainfall, Yield and Socioeconomic Data

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Abstract

This study evaluates new multi-scale, multi-indicator methods for assessing the vulnerability of crop production to drought at a national and regional scale by identifying differences across and within ten regions of Ghana, a country that faces many climate and crop production challenges typical of sub-Saharan Africa. We highlight key methodological steps required to improve drought sensitivity and vulnerability assessments for dynamic dryland farming systems typified by multiple drivers of change and thresholds of risk that are dynamic in space and time. We outline how a quantitative national and regional study is a critical first step in assessing differences in the drought sensitivity of food production systems. We show how this enables the formulation of more targeted district and community level research that can explore the drivers of vulnerability and change on a local-scale. The results of national and regional scale analyses show that vulnerability to drought has both discernible geographical patterns and socioeconomic associations, with the Northern, Upper West and Upper East regions being most vulnerable. These regions also have the lowest adaptive capacity due to low socioeconomic development and have economies based largely on rain-fed agriculture. Within regions we find considerable differences between districts that can be explained only partly by socioeconomic variables with further community and household-scale research required to explain the causes of differences in vulnerability status. Our results highlight that national and regional scale multi-indicator vulnerability assessments are a vital (and often ignored) first step in assessing vulnerability across a large area. These inputs can guide both local-level research and also demonstrate the need for region-specific policies to reduce vulnerability and to enhance drought preparedness within dryland farming communities.

Keywords: vulnerability, crop production, farming systems, drought sensitivity, Ghana, adaptive capacity, socioeconomic.

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1 Introduction

Research and policy debates on the world's drylands are increasingly focused on the challenges of undertaking coupled human-environmental assessments in systems typified by multiple drivers of change and dynamic thresholds that lead to high levels of variability in both space and time (Reynolds et al., 2007). This leads to significant applied geographical research challenges for developing and applying suitable frameworks for assessing climate change vulnerability (e.g. Turner et al., 2003; Adger, 2006; Fraser, 2007) and for providing cross-sectoral and multi-scale policy advice in relation to climate change and land degradation (e.g. Reed et al., 2011).

The purpose of this paper is to show how these challenges may be addressed by conducting a multi-sectoral and multi scalar climate vulnerability analysis for Ghana as a case study. This is important because the IPCC's regional assessments of climate change impacts for Africa imply declining grain yields are likely and predict that agricultural production and food security in sub-Saharan Africa will be negatively affected particularly relating to increased drought intensity and frequency linked to greater inter-annual rainfall variability (Boko et al., 2007). Further, recent climate-crop modelling studies suggest that agriculture will be disproportionately affected in West Africa (e.g. Lobell et al., 2008), but the impacts will vary spatially and this requires further investigation through more detailed assessments of key regions such as that provided in this paper. This paper also builds from analyses undertaken in other parts of the globe where data are more widely available and variability is not as marked (e.g. Simelton et al., 2009, 2010).

To assess the integrated nature of rural agricultural development challenges, the concept of vulnerability emerged within development debates in the 1990s (Chambers, 1994) and has been widely applied to a range of climate-related issues. In the IPCC Third Assessment Report, McCarthy et al. (2001, p. 6) define vulnerability as "the degree to which an environmental or social system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes". Assessing vulnerability, therefore, requires an integrated assessment across a range of disciplinary spheres and scales requiring new geographical assessment tools and frameworks. Furthermore, the vulnerability of a system to climate change may be characterised as a function of the exposure, sensitivity and adaptive capacity of the system (McCarthy et al., 2001). To operationalize this, we adopt the following definitions to guide an assessment of Ghana's vulnerability to climate change:

- Exposure has been defined by O'Brien et al. (2004, p. 305) as the "degree of climate stress upon a particular unit of analysis; it may be represented as either long-term changes in climate conditions, or by changes in climate variability, including the magnitude and frequency of extreme events". Our study builds on these discussions by defining exposure as the degree to which a particular system is exposed to meteorological drought (Tilahun, 2006; Fraser, 2007) given that this is the major threat to African farming systems (UNDP, 2007). Therefore, this paper uses meteorological data as a way

of creating an exposure index that reflects the degree to which different farming regions were exposed to drought.

- Sensitivity reflects the responsiveness of a given system to climatic stimuli, either positively or negatively, and may be influenced by the socioeconomic and ecological conditions of the system (IPCC, 2001). In this paper, sensitivity is inferred through the harvest losses associated with different droughts and is determined through the development of a crop yield sensitivity index.
- Adaptive capacity in the context of climate change has been defined by the IPCC (2007) as the capacity of a system to adjust to the changing climate in order to reduce potential damages and take advantage of associated opportunities. Adaptive capacity is thought to be closely linked to livelihood asset ownership (Moser, 1998). This means that people who have more assets (financial, human, natural, physical and social) can in general be considered to have a higher adaptive capacity and therefore be less vulnerable (Moser, 1998). In this paper, adaptive capacity is defined as the ability of a region to cope with the impacts of climate change (particularly drought) and it is estimated by a set of proxy socioeconomic indicators.

Several scholars have attempted to holistically assess the vulnerability of communities or farming systems to climate change using a variety of different approaches (e.g. Luers et al., 2003; Turner et al., 2003; Fraser, 2007; Simelton et al., 2009). Some have applied quantitative crop modelling to identify where harvests may decline or increase due to climate change (e.g. Lobell et al., 2008; Challinor et al., 2009; Challinor et al., 2010). For example, Challinor et al. (2010) use a crop model that simulates biophysical adaptive capacity, and add a socioeconomic vulnerability index to highlight socioeconomic adaptive capacity. These quantitative models offer useful communication and visual tools to policy makers by making complex scientific data more comprehensible (Fraser, 2006). However, crop models as vulnerability assessment tools are subject to various limitations. For instance, the adaptations included in most crop models are hypothetical and often assumes either “no adaptation” or “optimal adaptation” by farmers.

Another typical approach to quantifying vulnerability is to define a set of proxy indicators (Luers et al., 2003) and assess vulnerability by estimating indices or averages for those selected indicators (Gbetibouo et al., 2010). Indicators are useful for monitoring and studying trends and exploring conceptual frameworks and are also applicable across different scales including the household, district, region and nation (Gbetibouo et al., 2010). However, indicators are limited by a lack of information on the choice of appropriate variables and the relative weightings required to establish a vulnerability index in a particular region (Luers et al., 2003). These limitations led Simelton et al. (2009) to correlate crop drought vulnerability with socioeconomic indicators to identify what makes regions resilient or vulnerable to drought in China. This approach is useful in that it uses rainfall and harvest data to establish the characteristics of vulnerable and resilient cases. The limitation, however,

is that this approach considers only two components of vulnerability (exposure and sensitivity) without fully capturing adaptive capacity.

The aim of this paper is to develop and apply a multi-scale quantitative approach to vulnerability assessment within Ghana to identify which of the country's regions and districts are most vulnerable to drought. To achieve this aim, the study objectives are:

1. to develop a methodological approach that combines aspects of crop-drought vulnerability with socioeconomic indicators;
2. to use existing rainfall and yield data as well as proxy indicators of adaptive capacity to evaluate vulnerability for Ghana's ten regions and the districts within the most vulnerable regions;
3. to reflect on the utility of using this sort of quantitative approach as a tool for use in other countries.

By meeting these objectives, this paper contributes to geographical and scientific debates on the development of integrated vulnerability assessments that can be applied in geographical areas for which more detailed data may be lacking. This paper also contributes to these debates in that we highlight the value of initial broad-scale quantitative analyses as the starting point for more detailed, multi-method analyses of climate change vulnerability. This sort of methodological innovation is widely called for across the climate and development literature (Keskitalo, 2008; Yin et al., 2002) and our study should, therefore, be seen as an attempt to develop geographical analysis tools that offer important new methodological opportunities.

2 Study Area and Methods

2.1 Study Area

Ghana covers a range of agro-ecological zones typical of West Africa and located between latitudes 4.5°N and 11.5°N and longitudes 3.5°W and 1.3°E. Administratively, Ghana is divided into 10 regions, which are further sub-divided into 170 districts within six agro-ecological zones (Fig. 1). Average annual rainfall ranges between 800 and 2400 mm, along a rainfall gradient that sees increased aridity from north to south (Ghana Government, 2008). Generally, most parts of Ghana have annual temperatures above 24°C (Ghana Environmental Protection Agency (GEPA), 2001).

Ghana's population is around 18.9 million (Ghana Statistical Service, 2000). The country's economy depends on rain-fed agriculture. Agriculture provides employment to about 57% of Ghana's labour force and contributes to about 44% of its Gross Domestic Product (Ministry of Food and Agriculture, Ghana (MoFA), 2007). The amount and pattern of rainfall plays a key role in determining agricultural productivity (Seini et al., 2004) with Ghana's agricultural production highly

climate-sensitive especially in relation to drought events. In recent years, climate related problems such as drought and floods have resulted in severely reduced food production (MoFA, 2007).

In terms of future predictions, annual mean temperature in Ghana has been projected to increase by 0.6°C, 2.0°C and 3.9°C by the years 2020, 2050 and 2080 respectively, whilst rainfall has been projected to decrease by 2.8%, 10.9% and 18.6% for the same periods (GEPA, 2007). These future predictions of warming and drying, together with greater variability will lead to increased intensity and frequency of extreme events of droughts and floods as witnessed across dynamic dryland environments globally (Reynolds et al., 2007). The increased temperature and reduced rainfall will also mean increased evaporation and further reduction of runoff and available water. This shortens the length of the growing season in Ghana, as in many sub-Saharan African countries (Lobell et al., 2011), and this will have substantial implications for crop yields and food security.

2.2 Research Design and Methods

This research forms the basis of an integrated and multi-scale approach to explore the drivers of farming system vulnerability to drought at the national, regional, district and community levels. This paper presents the first stages of this integrated research programme in which we develop and apply a crop drought vulnerability index and socioeconomic indicator approach to map vulnerability at regional and district scales. Work presented in this paper took three stages.

The first stage involved the determination of sensitivity of crop harvest to drought by creating a crop yield sensitivity index that made use of historic yield data at both regional and district scales. The second stage involved using existing rainfall data to estimate drought exposure at the same spatial scales by calculating regional and district level drought indices. The third stage involved the determination of an adaptive capacity index by using proxy socioeconomic data available from Ghana census data.

The concept of vulnerability is operationalized mathematically as:

$$V = f(E + S - AC) \tag{1}$$

In this equation, V is vulnerability of regions to drought, E is exposure to drought (reflected in the size of drought), S is the sensitivity of crop harvest to rainfall perturbations, and AC is adaptive capacity of regions to cope with drought (determined using socioeconomic proxy indicators).

2.2.1 Determining ‘sensitivity’ of crop harvest to rainfall perturbations

To determine the sensitivity of crop harvest to rainfall perturbations, a crop yield sensitivity index was calculated using methods adapted from Simelton et al. (2009). Yield data for maize for all 10

regions of Ghana were obtained from the national Ministry of Food and Agriculture, for the period 1992-2007. Maize was selected as the test crop because it is the main crop grown, being consumed as a staple across the country (Kasei & Afuakwa, 1991), and is of importance to the country's socioeconomic development. The period of 1992-2007 was selected due to the availability of yield data.

Yields were detrended to reduce the influence of increased agricultural technology in order to highlight inter-annual yield variation as a result of rainfall (Easterling et al., 1996). To determine the crop yield sensitivity index, we calculated the linear trend for each yield for each region between 1992 and 2007. The equation for this trend line was used to calculate the expected yield in each year as a linear model of the time series of the actual (detrended) yield. The expected yield was then divided by the actual yield for each year to generate a crop yield sensitivity index (equation 2).

$$\text{Crop yield sensitivity index} = \frac{\text{Expected yield}}{\text{Actual yield}}$$

(2)

2.2.2 Determining 'exposure' to drought

The estimation of exposure to drought also followed the procedures developed by Simelton et al. (2009) for the calculation of the exposure index. Monthly rainfall data were obtained from the Ghana Meteorological Agency for 1971-2007. A standard 30-year climatological period, in this case from 1971-2000, was used to eliminate year-to-year variations and is considered adequate for agrometeorological planning (Todorov, 1985). The maize growing period in Ghana is 126-200 days between April and August and this period coincides with the moisture requirements during flowering (Kasei & Afuakwa, 1991). To develop the exposure index, the average of the 30-year rainfall period for the 5-month period (April-August) from 1971-2000 was divided by each year's average rainfall for this period (April-August) which represents the growing season for maize as shown in equation (3).

$$\text{Exposure index} = \frac{\text{mean long - term growing season rainfall for 1971 - 2000}}{\text{mean growing season rainfall for each year 1992 - 2007}}$$

(3)

This study considered only rainfall because it is the most critical hydrological variable for agricultural productivity (Tilahun, 2006). Sivakumar et al. (2005) have reported that significant reductions in crop yield have always been attributed to abnormally low precipitation-induced drought rather than warming-induced increases in evapotranspiration rates.

2.2.3 Determining ‘adaptive capacity’ to cope with drought

The adaptive capacity required to cope with drought is thought to depend on five livelihoods assets: financial, human, natural, physical and social capital assets (e.g. Gbetibouo et al., 2010). Two proxy indicators of adaptive capacity were considered for this study: human capital (represented by literacy rates (%)) and financial capital (represented by poverty rates (%)). These proxy socioeconomic indicators were obtained from the census data by the Ghana Statistical Service (2000). Although this is a simplifying assumption, these two proxy indicators (see equation 4) were selected because they were the only indicators where data were available for all ten regions. In this study, natural capital is included in the sensitivity component of vulnerability and it is assumed that the greater the natural capital the less the sensitivity of that region to the impacts of drought. Lack of data prevented the inclusion of social and physical capital assets in the national and regional-levels data analyses and these two capital assets will be explored in subsequent phases of this multi-scale research using household and village level livelihood studies in regions identified by this study as being notably vulnerable to drought.

$$\text{Adaptive Capacity} = (\text{Literacy Rate}/100) + ((100-\text{Poverty Rate})/100) \quad (4)$$

Hence, the overall mean vulnerability of a particular region was estimated from the following:

$$\text{Vulnerability} = [(\text{crop yield sensitivity index} + \text{exposure index}) - \text{adaptive capacity}] \quad (5)$$

2.3 Mapping crop drought vulnerability at the district scale

The methods described above were used to map vulnerability at the regional scale where proxy socioeconomic data were available. Having identified the most vulnerable regions, we then mapped food systems vulnerability at the district scale within the most vulnerable regions in order to identify the most vulnerable districts within these regions. Due to the lack of proxy socioeconomic data at the district levels, a crop drought vulnerability analysis following the procedures adapted by Simelton et al. (2009) was used to achieve this (equation 6).

$$\text{Crop drought vulnerability index} = \frac{\text{crop yield sensitivity index}}{\text{exposure index}} \quad (6)$$

It was hypothesised that in situations where major droughts resulted in insignificant loss of crop harvest in a particular district then there may be underlying high levels of adaptive capacity, reflecting the socioeconomic conditions of the district. Such a district is considered ‘resilient’. In contrast, in situations where there were large losses in crop harvest following minor rainfall perturbations then

there may have been underlying low levels of adaptive capacity that made such an area ‘vulnerable’. In this study, we use the crop drought vulnerability analysis to estimate vulnerability indices for only vulnerable districts within the most vulnerable regions. Despite its limitations, the crop drought vulnerability index approach is useful as it uses rainfall and regional crop harvest data to identify vulnerable cases in geographical regions where there is limited proxy socioeconomic indicators to estimate adaptive capacity.

In the district level analysis, we focused on foods more associated with these poor regions, namely sorghum and millet for the construction of the crop yield sensitivity index. Whilst regional geographical boundaries in Ghana have remained constant, district boundaries have changed over the study period and this makes it difficult to have reliable data for this finer level analysis. We overcame this challenge by not considering districts that have recently had their borders changed.

2.4 Data analysis

Once overall mean vulnerability was calculated, a *k*-means cluster analysis using the STATISTICA software package was undertaken to group the regions according to vulnerability. *k*-means clustering is a statistical approach that can group cases into distinct clusters by seeking groups that minimise variability within clusters and maximise variability between clusters (Levia & Page, 2000). *k*-means cluster analysis has been applied to several geographical problems (e.g Ahern et al., 2006; Kennedy & Naaman, 2008; Levia & Page, 2000) and we assess its value to spatial vulnerability assessments in dynamic systems here.

3 Results

The overall crop yield sensitivity of the various regions in Ghana to drought is presented in Fig. 2. The analysis indicates that the Upper East and Upper West regions are the most sensitive in terms of exposure to drought. Farmers in these two regions mostly practice subsistence farming and are heavily dependent on rain-fed agriculture. Again, because of the inherent low soil fertility in these regions (see Quansah, 2004), only certain types of crops (mainly cereals such as maize, sorghum and millet) can thrive and these crops require appreciable amount of water during growth.

Fig. 3 shows that the majority of regions in Ghana experienced medium levels of drought with the four regions of the south experiencing high levels of drought and the most northwest region a low level.

The overall adaptive capacity for the various regions is shown in Fig. 4. The Northern, Upper East and Upper West regions show the lowest adaptive capacity of all the regions in Ghana suggesting that these regions have the lowest capacity to cope with drought. The Greater Accra and the Ashanti Regions show the highest adaptive capacity (Fig. 4).

Fig. 5 shows the results of the k-means cluster analysis and demonstrates that there are three different clusters according to their vulnerability: half of the regions in Ghana are moderately vulnerable to drought, whilst a third is highly vulnerable and only two regions have low vulnerability. Fig. 6 presents this analysis spatially, showing that the Northern, Upper East and Upper West regions are the most vulnerable to drought while the lowest vulnerability regions are the most urbanized and developed regions: Ashanti and Greater Accra.

Figures 7, 8 and 9 provide a district level breakdown for the three most vulnerable regions (Northern, Upper West and Upper East regions). In general, millet recorded high vulnerability indices in all the districts within the three most vulnerable regions compared with sorghum and maize except in the Bawku East district in the Upper East (Fig. 7), Wa district in the Upper West (Fig. 8) and Saboba and Zabzugu districts in the Northern region (Fig. 9). The districts within the Northern regions recorded the lowest vulnerability indices for all crops during the study period. For instance, Gambaga and Damongo in the Northern regions recorded the lowest vulnerability indices for both millet and maize (Fig. 9).

While the standard errors within the data are high, the general trend is that the districts in the Upper East region recorded higher mean vulnerability indices for both sorghum and millet compared with those in the Northern and Upper West regions. Within the Upper East region, the Bongo district recorded the highest mean vulnerability index for the investigated period (Fig. 7) and, therefore, has become the focus of an ongoing research programme at the village and household level. Key informant and expert interviews with extension officers, agricultural staff and meteorological experts were conducted to select specific vulnerable farming communities within the Bongo district for the village level research.

4 Discussion

The results show that there are strong spatial and socioeconomic patterns in terms of vulnerability to drought in Ghana. In particular, results suggest that the vulnerability of the regions is highest in the Northern, Upper West and Upper East Regions (Fig. 6) that are characterised by low levels of social, economic and physical assets, e.g. low literacy rates, high poverty rates, low infrastructural development and high population densities (Ghana Statistical Service, 2000). Even within these vulnerable regions, there was different vulnerability among the various districts. The Bongo district (Upper East region) recorded the highest mean vulnerability index due to the high poverty level and low literacy rates in the region in general and the Bongo district in particular. In addition, high poverty levels in the Upper East region make it difficult for farmers to afford fertilizers to improve the fertility of the soils.

Poverty can lead to marginalisation and limit the amount of capital assets that may be needed to reduce the impacts of drought on livelihoods of farming communities (Adger & Kelly, 1999) such as those in the Northern, Upper West and Upper East regions. For example, an estimated 90%, 80% and

70% of people in the Upper East, the Upper West and the Northern regions respectively are considered to be poor (Ghana Statistical Service, 2000). Though poverty may not be directly equated with vulnerability, it constrains the capability of communities to cope with the impacts of drought (Sen, 1999). This is because the poor are confronted with other non-environmental shocks and stresses that place additional constraints on their limited assets to cope with the impacts of drought (Stringer et al., 2009). Moreover, poverty may compel people to live in environmentally fragile areas which could worsen their vulnerability to climate and other environmental changes. High poverty levels in these vulnerable regions will further inhibit the potential for sub-Saharan Africa's poor farmers to manage the impacts of climate change (Morton, 2007).

Soils in the Bongo district are also characterised by stoniness and gravel and these, together with iron-pan in the soils, make them highly unproductive (Quansah, 2004). Continuous cropping of farmland in the Upper East region without the addition of appropriate soil amendments has left the soil with low fertility and in a highly unproductive state. In addition, low socioeconomic development and erratic rainfall patterns (in terms of both onset and duration) make farmers in the Upper East region in general, and the Bongo district in particular, extremely vulnerable. This vulnerability has serious ramifications for farming communities in these regions because rain-fed agriculture is the predominant occupation.

The results from this study further reveal that the Guinea Savannah and Sudan Savannah agro-ecological zones are the most vulnerable to increasing drought events. These agro-ecological zones experience a uni-modal rainfall pattern and are predominantly characterised by drier conditions and fragile agro-ecosystems. As a result, these types of regions are also likely to be vulnerable to climate change. Soils within the Guinea and Sudan Savannah agro-ecological zones have poor fertility that, together with desertification, exacerbates food insecurity in these regions.

Our results support the findings of Gbetibouo et al. (2010) for South Africa, which indicate that vulnerability of a farming region to drought is linked to the socioeconomic development characteristics of that particular region. Indeed, vulnerability is greatly influenced by the degree of development and socioeconomic status of a particular group or community (Ribot et al., 1996). The ability of a community or region to cope with the impacts of climate change is reflected in the assets and entitlements that a community or region can assemble to reduce vulnerability (Moser, 1998). It is well documented that the entitlements of individuals to capital assets including, financial, human, natural, physical, and social capitals could affect their ability to cope with the impacts of climate change (Sen, 1981).

Many writers have highlighted the role of social capital in coping with the impacts associated with environmental (climate) change in communities (see e.g. Adger, 2003, Pretty, 2003; Fraser, 2006). Pretty (2003) argues that households which are socially well connected are better placed to cope with the impacts of an environmental (climate) change. For instance, people can rely on their social networks including friends and family for food and shelter during drought or flood induced

famine. In addition, financial capital assets such as savings, remittances and pensions offer an individual other livelihood options and thereby reduce their vulnerability to environmental change. Natural capital assets including natural flow stocks and other environmental resources (Scoones, 1998) may provide useful economic opportunities to communities and individuals. For instance, during dry spells, farming communities within the catchments areas of an irrigation dam can go into irrigation farming. Members of a community may also pick wild fruits during famine to reduce their vulnerability to drought induced famine.

Physical assets are also crucial in reducing the impacts of environmental change. Access to markets and good road networks can ensure that farm produce are transported to the market in good time and sold in order to obtain financial resources. Human capital assets such as education may also affect the vulnerability of a particular community to environmental change. For instance, good education may increase the income earning opportunities of rural households whose livelihoods depend on agriculture (see Paavola, 2008). This is because the poorly educated may be excluded from well paid wages jobs due to their lack of skills for such jobs (Rakodi, 1999). This is particularly important in rain-fed agriculture dependent countries like Ghana where most of the workers in non-farm jobs are educated. In addition, education can greatly enhance a person's capacity to access information which may include the use of new technology (Weir, 1999).

Adaptive capacity is also dependent on the availability of appropriate government and non-governmental institutions and policies as well as structures in mediating access to the livelihood assets and entitlements. However, these factors have not been considered in this analysis due to a lack of available data and will be considered further in the next phases of an integrated multi-scale analysis.

The next phase of this research is to explore the drivers of vulnerability and identify the adaptation pathways of individual farmers to climate variability and change at a local-scale. In this regard, the quantitative and large scale analysis presented here enabled us to identify case study districts within these regions, from which study villages were chosen using expert interviews and village level census data (where this exists). The findings, however, go beyond simply setting up the next phase of more in-depth research. This study also enables policy and development project advice and extension activity to be focused on areas of the greatest need in terms of vulnerability to climate change and future drought events.

5 Conclusions

This study has developed and applied a quantitative, multi-scale and multi-indicator analysis that has identified the relative vulnerabilities of the various regions in Ghana, as well as the relative vulnerabilities of different districts within the most vulnerable regions. The proposed spatially-explicit methodology is integrative in that it shows both the biophysical conditions of these farming regions by way of an exposure index and a crop yield sensitivity index whilst considering the socioeconomic conditions of the regions. Vulnerability has been expressed as a function of exposure, sensitivity and

adaptive capacity (McCarthy et al., 2001). Exposure was determined by developing an exposure index, whilst sensitivity was estimated through construction of a crop yield sensitivity index. Proxy indicators including poverty levels and literacy levels were used to estimate the adaptive capacity of the various regions in Ghana, thus extending the methodology employed by Simelton et al. (2009).

The analysis shows that vulnerability to drought in Ghana is linked to the level of socioeconomic development and is spatially differentiated. This suggests the need for region- and district-specific policies, as different regions and districts within them display different levels of vulnerability. The farming communities in the most vulnerable regions (Northern, Upper East and Upper West) largely depend on rain-fed agriculture, which is very sensitive to climate change, as a key livelihood strategy. Thus, livelihood diversification strategies including non-farm income sources should be vigorously pursued by policy makers in these regions. The implication of the results presented in this study is that policy makers need to formulate more specific and targeted climate adaptation policies to reduce the vulnerabilities of farmers whose livelihoods depend largely on rain-fed agriculture. The approach outlined in the present study is particularly useful in evaluating the vulnerability of a particular region, community or system to drought in developing countries where data for proxy socioeconomic indicators of exposure, sensitivity and adaptive capacity may be less readily available.

Acknowledgements

This research was funded by the Commonwealth Scholarships, UK and the International Foundation for Science with input from Evan Fraser supported by an ESRC Inter-disciplinary Research Fellowship. The support of the Economic and Social Research Council is gratefully acknowledged for Elisabeth Simelton.

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Figures

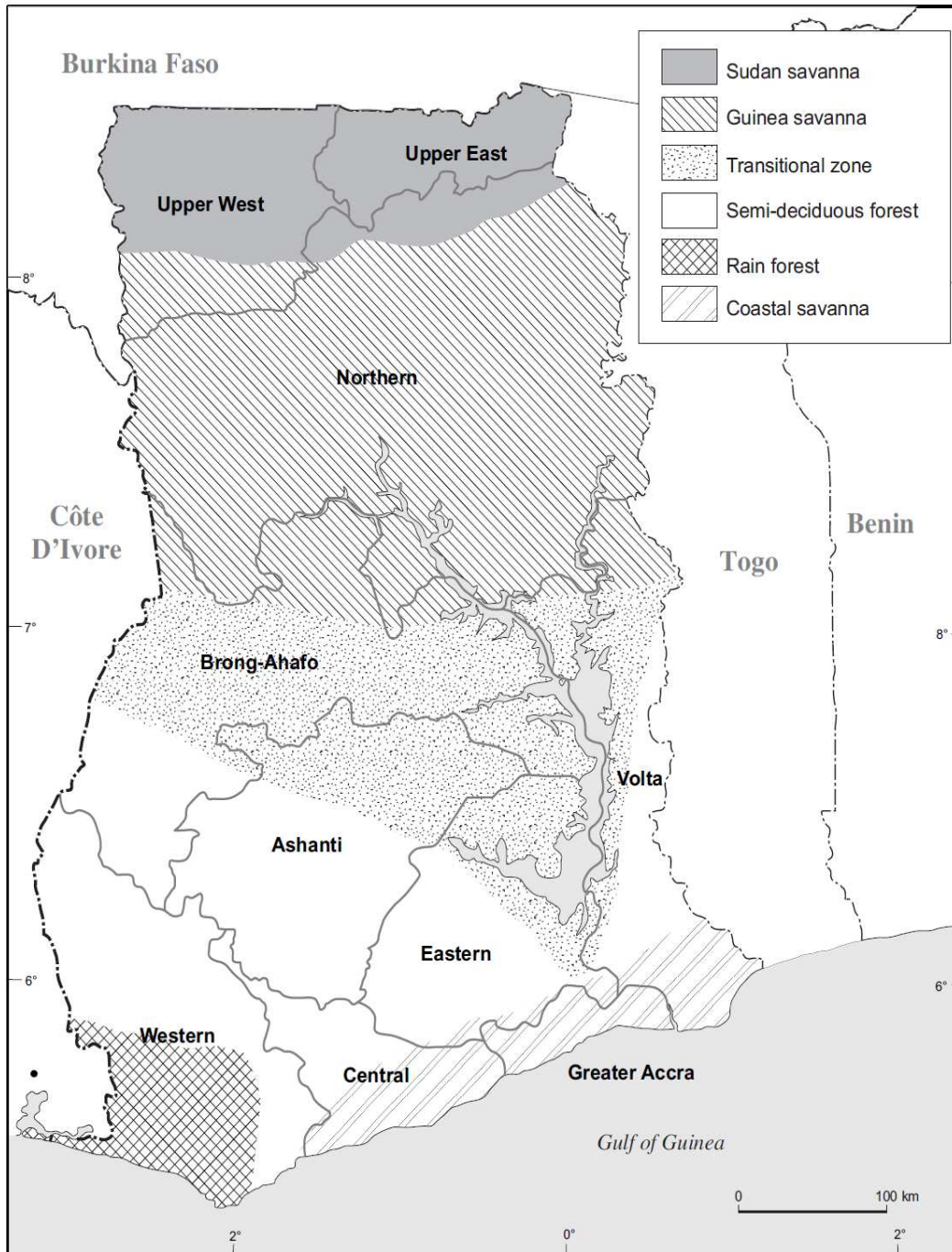


Fig. 1. Ghana showing the administrative regions and agro-ecological zones.

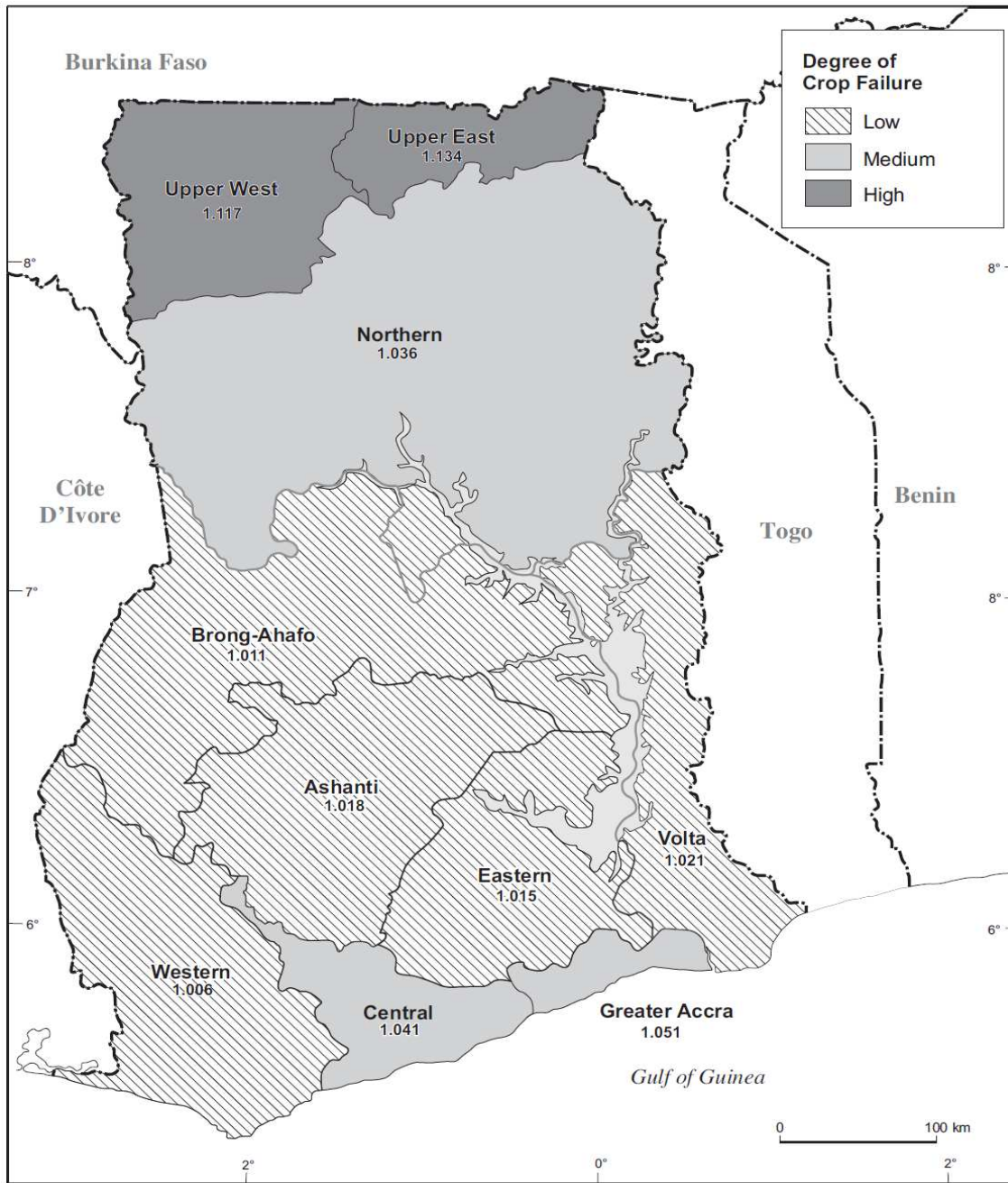


Fig. 2. Crop yield sensitivity indices of the various regions in Ghana.

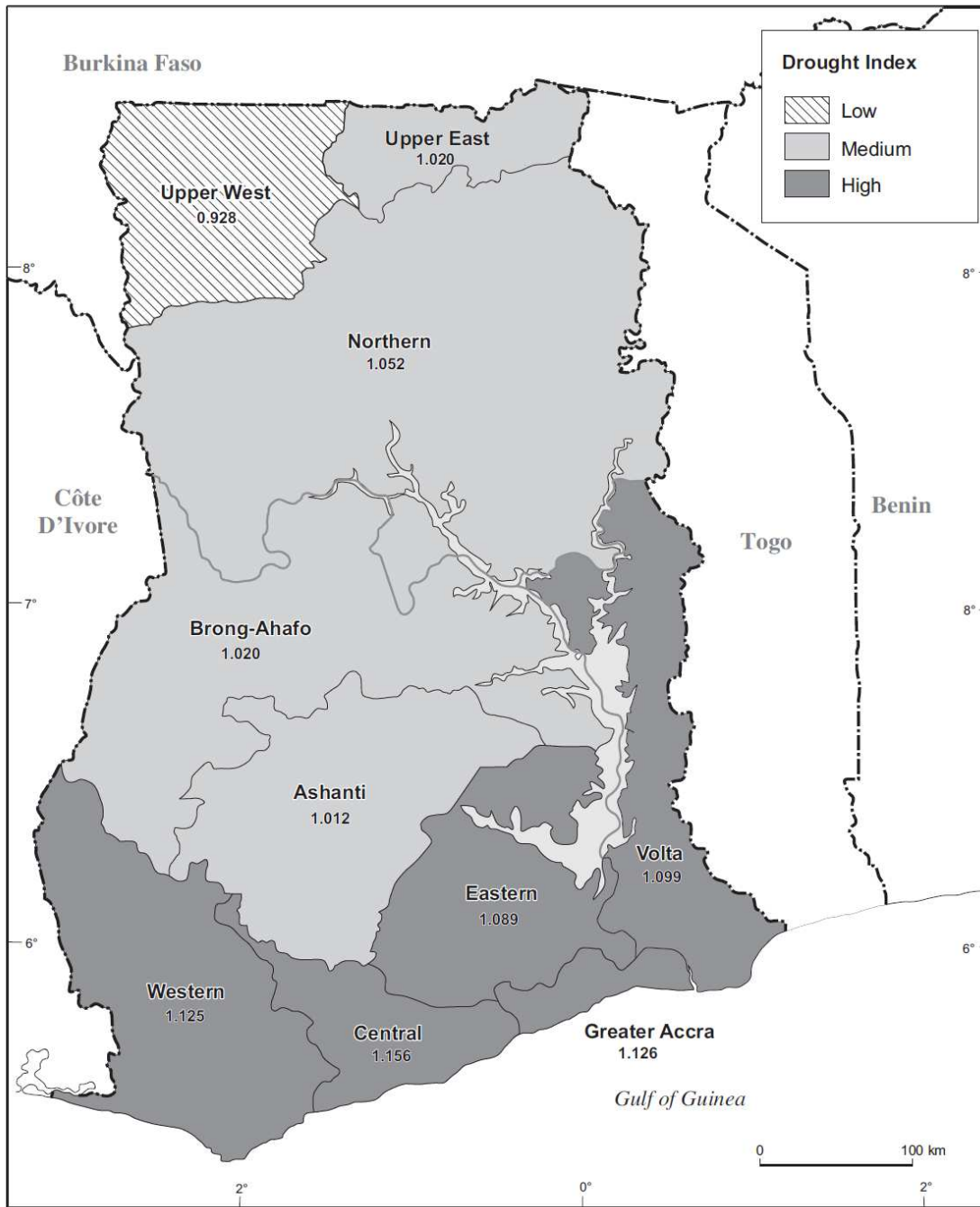


Fig. 3. Exposure indices of the various regions in Ghana.

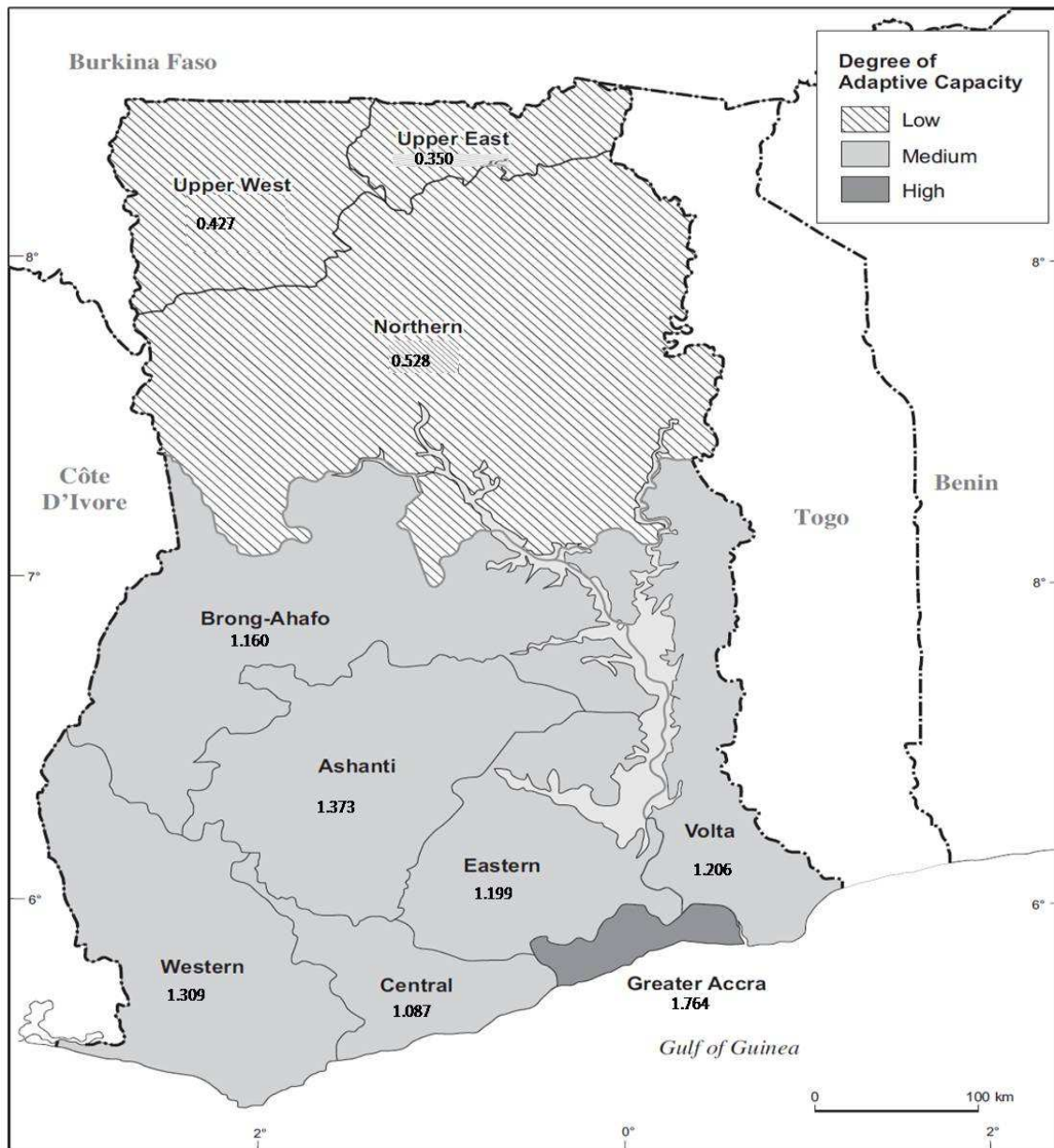


Fig. 4. Adaptive capacity indices of the various regions in Ghana.

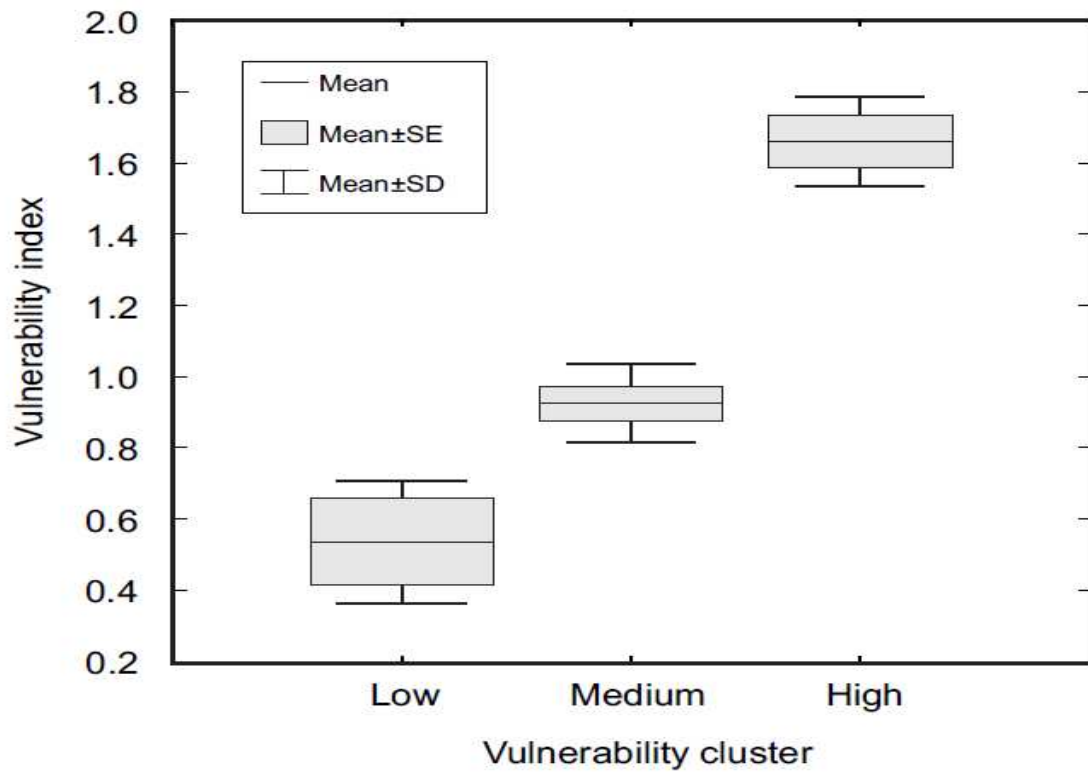


Fig. 5. Box whiskers plot of vulnerability indices clusters derived by k-means cluster analysis.

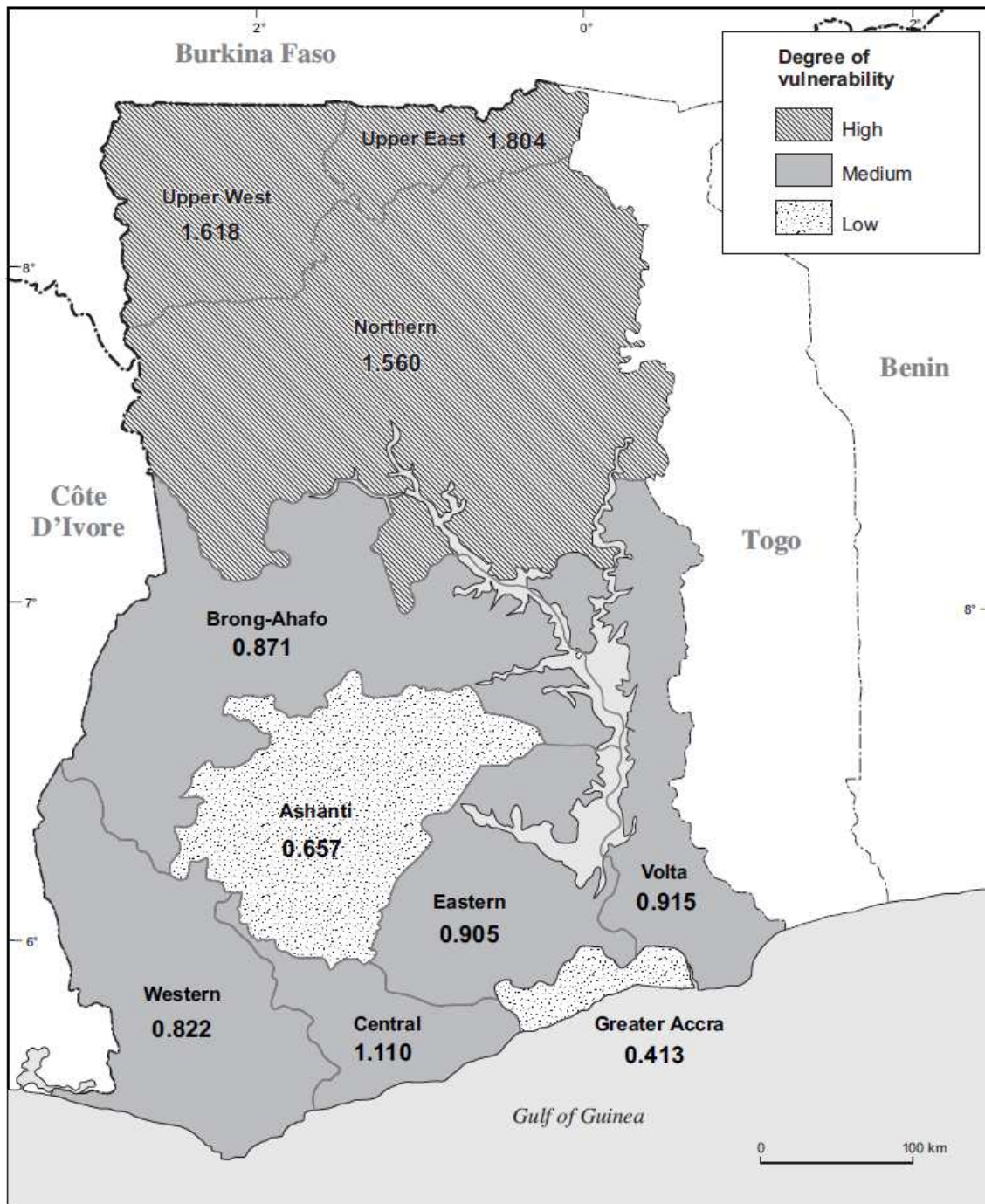


Fig. 6. Vulnerability indices of the various regions in Ghana.

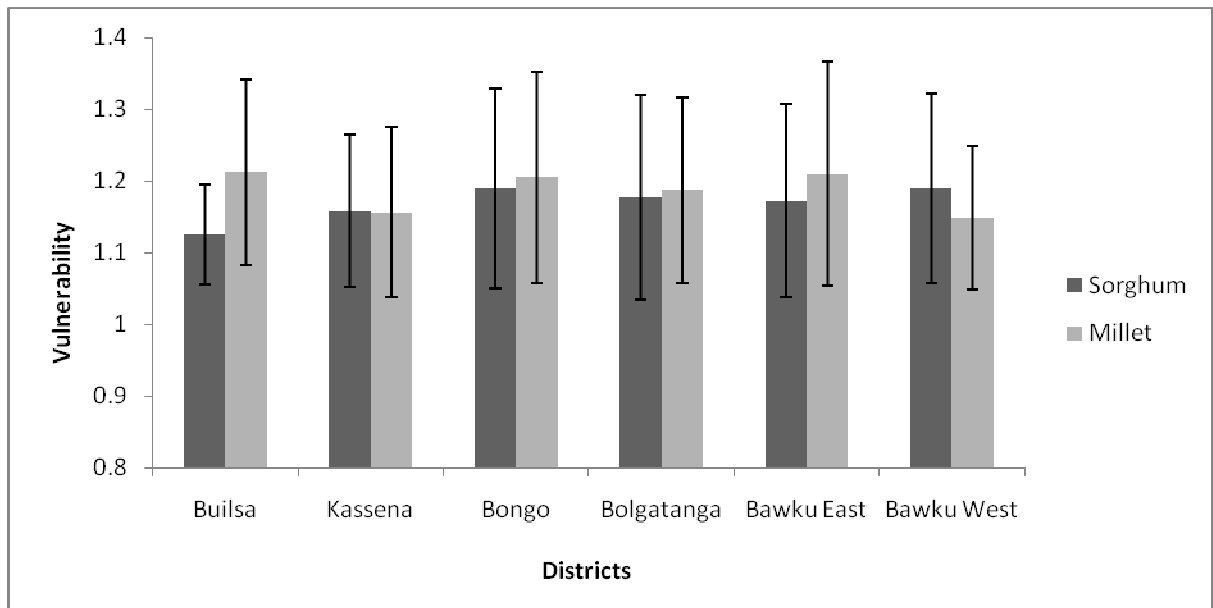


Fig. 7. Mean vulnerability indices of districts in the Upper East region, Ghana

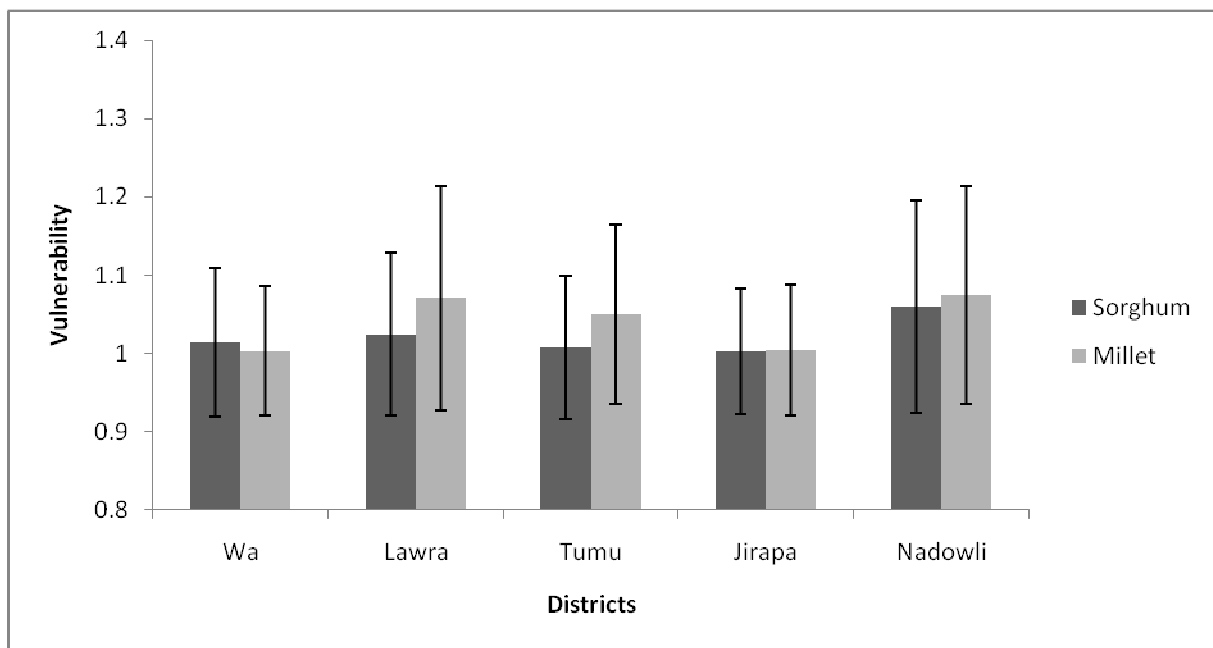


Fig. 8. Mean vulnerability indices of districts in the Upper West region, Ghana.

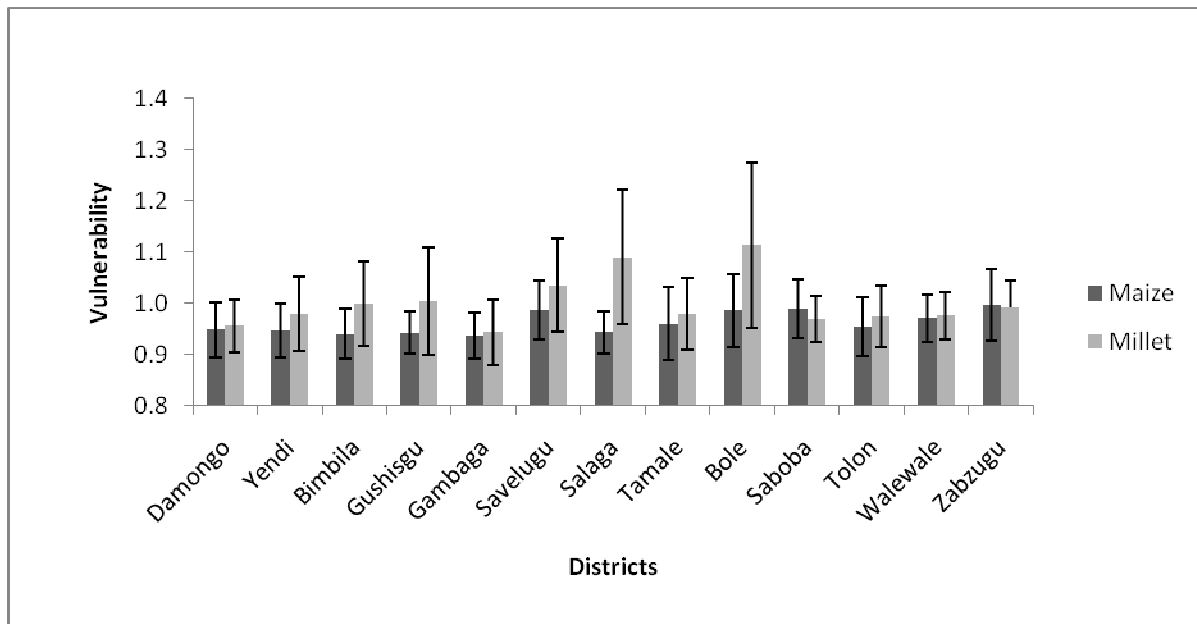


Fig. 9. Mean vulnerability indices of districts in the Northern region, Ghana.