Journal of the British Academy, **7(s2)**, 183–214. DOI https://doi.org/10.5871/jba/007s2.183
Posted 7 August 2019.

Rapid urbanisation and implications for indigenous knowledge in early warning on flood risk in African cities

RAYMOND ABUDU KASEI,
MIRIAM DALITSO KALANDA-JOSHUA
and DANIEL TUTU BENEFOR

Abstract: By 2050, 3.2 million people in urban areas could be at risk from pluvial flooding, an increase of 1.2 million from 2015. It is, thus, imperative to understand existing coping strategies because such strategies play critical roles in developing adaptation strategies to climate change. Current studies demonstrate the role of indigenous knowledge (IK)—gathered through observations of plant indicators, animal behaviour and astronomy—in the management of climate risks. However, the use of IK in weather predictions in urban areas, specifically in Africa, is under-studied. This article assesses the role of IK in early warning of flood risks in informal urban settlements vis-à-vis urbanisation in Africa. The results reveal that people in Ghana depend on local indicators for predicting climate hazards (floods and droughts) because they provide a timely and spatial fit compared with conventional forecasts. Hence, there is a need to consider the validation and integration of relevant indigenous knowledge into early warning scientific systems for effective early warnings and adaptation strategies.

Keywords: Cities, urban, climate change, floods, indigenous/traditional knowledge, early warning.

INTRODUCTION

Recently, there has been growing awareness that scientific knowledge alone is inadequate to address climate crises, whilst the role of local or indigenous knowledge (IK) in generating climate knowledge and adaptation strategies is increasingly being acknowledged (Finucane 2009, Joshua *et al.* 2017, Mafongoya & Ajayi, 2017a, 2017b). There is no standard definition of IK. This paper adopts the Berkes (2012) definition, which states that IK is

> a cumulative body of knowledge, practice, and belief, evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment.

Many studies have reported how local people for many decades have relied on IK for informed decisions in managing climate risks based on their long-term observations of plant indicators, animal behaviour and astronomy (Kalanda-Joshua *et al.* 2011, Kangalawe *et al.* 2011, Kijazi *et al.* 2013, Nkomwa *et al.* 2013, Nyong *et al.* 2007, Roncoli *et al.* 2009). For example, in Swaziland, in addition to observing wind direction and the shape of a crescent moon, local people observe 'nest heights of emahloko birds (*Ploceus* spp.) in trees to predict floods' (Mafongoya & Ajayi 2017b: 40). When nests are high, floods are likely to occur. Similarly in Mpasu, rural Malawi, a dark cloud in the west is indicative of imminent floods; hence people have to move to higher ground (Kalinga-Chirwa *et al.* 2011, Nkomwa *et al.* 2013). Additionally, other indicators of heavy rains (for example, winds blowing in all directions) are indicative of floods in the rainy season, whereas a high occurrence of the stalk-boring moth—*mbozi*—is indicative of drought in Mpasu and Mphampha, rural Malawi (Joshua *et al.* 2017). In this regard, IK has been found useful in predicting imminent weather conditions. Although parameters used in observations differ, there is increasing evidence in the literature that shows convergence between IK and conventional science: for example, convergence of IK system forecasts with scientific forecasts, climate change and seasonal predictions (Joshua *et al.* 2017, Kalanda-Joshua *et al.* 2011, Mafongoya *et al.* 2017). Hence, there is evidence of the integration of scientific climate and weather forecasts or policy-related adaptation. However, though considerable attention has been paid to the use of IK in climate or weather predictions in rural areas, and specifically in Africa (Chanza & Mafongoya 2017, Joshua *et al.* 2017, Mafongoya *et al.* 2017, Mubaya *et al.* 2017), urban space is under-studied. In addition, studies have shown that some IK indicators, such as those based on flora, are losing their value in the face of climate change, but this is context specific (Joshua *et al.* 2017). Hence, localised studies on IK for decision making in urban space deserve special attention. This paper focusses on assessing the role of indigenous knowledge in the early warning of flood risks in informal urban settlements.

It is widely reported that the world is rapidly urbanising (Punjabi & Johnson 2018, UNDESA 2019), and many cities and their peri-urban areas, particularly in developing countries experiencing rapid urbanisation, are struggling to manage the combined effects of a growing population and climate risks, especially among the poor, who are faced with multiple stresses and low adaptive capacity (Johannessen *et al.* 2014). While increasing attention has been paid to the social, political and environmental effects of urbanisation (Johannessen *et al.* 2014, Punjabi & Johnson 2018), the impacts of climate risks and coping strategies in urban informal settlements are poorly understood.

Several studies have found that flood vulnerability in urban areas has become an increasingly severe and more frequent problem in most African cities, with adverse consequences for the urban poor who cannot afford the highly bureaucratic processes and high costs of formal landownership and are hence attracted to unplanned informal settlements/areas/slums, mostly overcrowded and found in marginal land (ActionAid, 2006, Douglas *et al.* 2008, Joshua *et al.* 2017, Rice & Steinkopf Rice 2012, Satterthwaite 2008, Satterthwaite *et al.* 2007). Douglas *et al.* (2008) have uncovered a wide range of adverse impacts of urban flooding on poor urban dwellers, including: loss of basic livelihoods, spread of waterborne diseases, restricted movement, homelessness and, in extreme cases, loss of life. Rapid and uncontrolled urbanisation, densification of informal settlements, marginalisation and urban poverty increase the vulnerability to flood hazards in these low-income communities in developing countries (Zoleta-Nantes 2000). This makes the link between informal urbanisation and human vulnerability to flood hazards in African cities apparent and worthy of scrutiny. This includes understanding how the local communities in informal settlements perceive climate risks: in particular, flooding experiences, preparation and coping. A comparative study with a rural community provides important insights for informed policy and interventions.

As stated above, for many decades, traditional communities in Africa have continued to rely heavily on their own indigenous knowledge systems (IKS) in systematic observations of their environment and dealing with natural hazards. These communities, particularly those in hazard-prone areas, have collectively generated a vast body of knowledge on disaster prevention and mitigation, early warning preparedness and responsiveness. This knowledge, also known as traditional or local knowledge, is obtained through observation and study and is often based on cumulative experience handed down from generation to generation (Berkes 2012, Kalanda-Joshua *et al.* 2011, Pareek & Trivedi, 2011). The indigenous observations and interpretations are considered social capita for the poor and an invaluable resource for scientific studies. As put by Mafongoya and Ajayi (2017a: 19)

> this knowledge contributes to climate science by offering observations and interpretation at a much smaller spatial scale with considerable temporal depth, and by highlighting aspects that may not be considered by climate scientists.

Conventional weather and climate forecasting is ‘often criticised for not delivering concise information on local climatic variation and for its poor communication, i.e. messages are too scientific and technical’ for local people with a low level of education (Joshua *et al*. 2017). Additionally, increased rainfall variability in many parts of Africa has increased uncertainty in seasonal rainfall prediction, hence ‘posing a greater challenge to scientists in their efforts to improve forecast accuracy and reliability’ (Joshua *et al.* 2017). In this context, studies now widely agree that conventional science alone cannot adequately address climate challenges (Finucane, 2009, Joshua *et al.* 2017). Over the past decade reports from the International Panel on Climate Change (IPCC) have repeatedly highlighted the value of IK in informing climate adaptation strategies that are affordable, participatory and sustainable (InterAcademy Council 2010, IPCC 2007a, 2007b). IK is viewed as a collaborative concept that, combined with scientific approaches, can be applied to produce better knowledge systems and informed policies that are context specific (Joshua *et al.* 2017, Whyte 2013). Indigenous/traditional peoples who are vital and active parts of many ecosystems may therefore help to enhance the resilience of these ecosystems. The livelihoods of most indigenous rural communities turned urban still depend on natural resources that are directly affected by climate change and variability and human interference, and they often inhabit economically and politically marginal areas in diverse, but fragile, ecosystems. Despite its usefulness, IK is under-documented in urban studies. IK and its relevance are often site specific (Kalanda-Joshua 2011, Nkomwa *et al.* 2014). Hence, there is a need for contextualised studies. This study assessed the relevance of IK in weather and climate forecasting for adaptation to climate variability in the agricultural sector. IK indicators commonly used for weather and climate forecasting in the villages were established through focus group discussions (FGDs) and key informant and household interviews. Subsequently, people's perceptions of climate change and variability were compared with scientific hydro-meteorological data, which allowed for applicability analyses of identified IK in agricultural adaptation. The results revealed the various forms of traditional indicators. This paper seeks to assess the effect of indigenous flood early warning systems in preparing communities to better manage imminent floods in the informal settlements of Accra and Tamale.

The cases of Tamale (in the savannah) and Accra (Ghana's capital and situated along the coast) reflect the situation in many cities in sub-Saharan Africa, where rapid informal urbanisation is engendering various forms of vulnerability to ecosystem hazards, which local authorities are struggling to come to terms with, and to some extent international disaster agencies are still to direct their spotlights on them. One of the major vulnerabilities to rapid urbanisation has been flooding, which is largely caused by residents who have defied planning regulations and built substandard houses in flood-prone zones, creating informal settlements which are usually outside formal planning controls.

The majority of the flood-prone communities of Accra and Tamale consist of informal settlements, according to the National Disaster Management Organization (NADMO 2009). Residents of these informal settlements live in very poor and deplorable conditions and in vulnerable physical and socio-economic circumstances. These settlements are found along intermittently used banks of rivers and lagoons in the city, the fringes of solid waste disposal sites, railway lines, the fringes of unused industrial sites, and other unused public spaces, and undeveloped peripheries of the city, mostly low-lying lands, among other places. Since these locations are seen as illegal, they have very little or no access to basic household and community critical amenities such as infrastructure, including water, sanitation, waste disposal, drainage networks and access roads. Similar to other African urban slums, these areas are prone to flooding events and disasters.

Between 1955 and 2015, property worth over US$130 million was destroyed, over 300 lives were lost and 50,000 people were rendered homeless either directly or indirectly as a result of frequent flood events, according to several accounts and media reports (Adinku 1994, EM-DAT 2016, Gyau-Boakye 1997). While these estimates may not capture the uninsured assets of poor households in low-income communities, due to the lack of accurate data on slum communities, it is difficult to estimate the actual damage costs of flood hazards in informal settlements in Ghana (Okyere *et al.* 2013: 63). Official estimates of flood costs in Accra totally neglect the real impacts of flood hazards on residents in informal settlements and their capacities to respond. Thus, while the losses of high-income areas in the city are more tangible and easily measurable in economic terms because they are usually insured (Karley 2009: 37, Okyere *et al.* 2013: 62–3), the impact and loss within low-income and informal communities are less tangible, because they are usually not insured and hence the losses are immeasurable by formal institutions. Furthermore, the agency of individual households and community groups in dealing with or recovering from these losses is also ignored in planning for post-hazard resettlement and rehabilitation by city authorities. Such flood management interventions by the metropolitan assemblies are hardly ever participatory, since city officials perceive these slum dwellers and their informal settlements as the main causes of the problem (Amoako 2015). Yet, these are locations where the majority of the urban poor population and those most vulnerable to climate risks and flooding live.

Climate change, according to experts and their projections, will exacerbate flood events by increasing their frequency, intensity and extent, as the IPCC warns that global warming related climate change is likely to lead to, among other things, more floods and increased threats to human health in the absence of formal urban structures (SEDAC 2017). This, plus continued urbanisation, imply increased exposure to flooding events in informal settlements. Adaptation is therefore essential. Two pathways are early warning preparedness and response. In the absence of formal structures, it is therefore important to understand how people in these settlements prepare for and respond to flooding events. Such information can help to build resilience into these ecosystems and residents' livelihoods which are often believed to be traditional.

MATERIALS AND METHODS

This paper is partly made up of some syntheses of materials and a survey of selected institutions operating within the flood management spaces of Accra and Tamale. Accra is the capital city of Ghana in West Africa. Tamale is the capital city of Northern Ghana, and is largely peri-urban including several rural communities surrounding it, offering a rural perspective on the questions. Similar surveys were conducted in selected communities of the remaining eight regions of Ghana (Table 1) to validate the urban and rural dynamics of the country. Mini-workshops and interviews were carried out with flood victims from the selected communities. Nine institutions enmeshed in flood management in the cities and communities were preselected for the field study.

Both unstructured questionnaires and in-depth interviews were used. A key manifestation of how prepared the officers were was the number of relevant government policy documents organised beforehand and given to the researchers during the

Table 1. Study communities, corresponding districts and regions.

Community	District	Region
Galaka Kobori	Bawku West	Upper East
Binde Najong No 1&2	Bunkpurugu-Yunyoo	Northern
Dikpe Bagri Zongo	Lawra	Upper West
New Onyinase Ahenbronose Twimia Nkwanta	Techiman	Brong Ahafo
amakom Anwomeso	Kumasi	Ashanti
Krobo Anlo Beach	Shama	Western
Kwaproh	Cape Coast	Central
Avenor Alogboshie Odawna	Accra	Greater Accra
Begoso Bososo	Fanteakwa	Eastern
Torve Wute	Akatsi-North	Volta

interviews. We also scheduled informal interviews with some retired public officials believed to have worked on and gained extensive knowledge of urban and rural flooding in Ghana. Government policy documents were also reviewed to validate views sampled during the institutional surveys.

Local /indigenous/traditional knowledge to flood hazard

The methodology for categorisation, analysis and documentation of the function and use of IK and its further influence on adaptation to climate change in all the study areas was conducted by adopting a similar approach to that of Kihupi *et al*. (2002).

Figure 1. Overview of the location of the eleven selected districts.

Where conditions did not favour this approach, necessary modifications were made. Key informant interviews and FGDs were used in data collection. Twenty-five questionnaires were administered to different groups of community residents who were 35 years or older, and had lived in the community for twenty years or more, while FGDs were organised in each of the selected communities with a flexible representation of age classes. This was to ensure that the views and knowledge base of all the residents of the community were captured, irrespective of their age. A total of one thousand and fifty questionnaires were administered in twenty-one communities for the study (Figure 1). Additional information was obtained from personal observations and key informant interviews with both sexes of farmers, NADMO officials and staff of district agricultural directorates. Various community-based techniques used in weather forecasting were explored. Areas of discussion included trends in temperature and rainfall observed in the communities; the impacts of the observed changes, which were validated with statistical data on the communities; and the indigenous approaches passed on from generation to generation and how these communities in their quest to manage the observed changes in climate use them. Access to and use of conventional weather forecasts in decision making were interrogated.

FGDs were important in weighing and balancing the information collected through interviews and one-on-one discussions, with a view to producing generalisations that represent the traditional knowledge existing in the community and the pattern of climatic variables over various climate windows. These trends then created an adequate background to how the communities whose populations ranging from about 43,000 to 1 million (Table 2) are responding or used to respond to these impacts on adaptation strategies.

Table 2. Population of the selected districts.

	District	Total	Males	Females
1.	Shama	81,966	38,704	43,262
2.	Cape Coast Metropolis	169,894	82,810	87,084
3.	Accra Metropolis	1,848,614	887,673	960,941
4.	Akatsi (Akatsi South)	128,461	59,165	69,296
5.	Fanteakwa	108,614	54,010	54,604
6.	Kumasi Metropolis	2,035,064	972,258	1,062,806
7.	Techiman Municipal	206,856	100,498	106,358
8.	Bunkpurugu Yunyoo	122,591	60,240	62,351
9.	Bawku West	94,034	45,114	48,920
10.	Lawra	100,929	48,641	52,288
11.	Tamale Municipal	233,252	115,926	117,326

Flood categorisation and trends

McKee defines the SPI as the number of standard deviations by which the cumulative precipitation at a given time scale (usually 1, 3 or 6 months and 1 or 2 years) deviates from the long-term mean. In order to determine the SPI of any catchment and period, 1, 3, 12 and 24 months of precipitation data are accumulated and fitted to a gamma distribution, which is a necessary condition for the SPI calculation to avoid bias (McKee *et al.* 1993, Ntale & Gan 2003). The SPI is the value of z from the standard normal distribution calculated on the basis of the same cumulative probability as the gamma distribution. Therefore, the SPI values are the standardisation of total gamma-transformed accumulated precipitation values.

A positive value of SPI indicates that precipitation is above average and a negative value indicates it is below average. Accordingly, values of SPI ranging from −1 to +1 express a normal precipitation regime and values out of this range represent relevant deviations from the normal amount of rainfall. Values of SPI ranging from +1 to +1.5 and +1.5 to +2.0 are associated with moderately wet and very wet periods, respectively, and SPI values exceeding +2.0 are representative of extremely wet periods. Moderately dry, very dry and extremely dry spells are characterised by the same SPI ranges with a negative sign (McKee *et al.* 1993).

The IPCC predicts that 'heavy precipitation events, which are very likely to increase in frequency, will augment flood risk' (IPCC 2007a, see also Nicholls *et al.* 2007). These floods will affect life and livelihoods in human settlements in all areas: for example, coastal zones, river deltas and mountains. Flooding is also increasing in urban areas, causing severe problems for poor people (Bates *et al.* 2008, InterAcademy Council 2010, IPCC 2014, WMO 2003).

Ghana's national communication to the United Nations Climate Change Conventions (UNFCCC) states that there is clear evidence that the potential negative impacts of climate change are immense, and Ghana is particularly vulnerable due to its lack of capacity to undertake adaptive measures to address environmental problems and the socio-economic costs of climate change. These include climate change associated health problems, climate-induced disruption of agricultural systems, flooding of coastal areas, which are already undergoing erosion, among a host of other problems; hence the importance of this study.

PERCEIVED RAINFALL TRENDS AND OCCURRENCE OF FLOODS FROM THE PERSPECTIVES OF LOCAL PEOPLE

The different survey participants felt that the rainfall pattern was changing, with notable effects on the occurrence of flooding in their locations. They mainly mentioned changes in precipitation, specifically in relation to onset, cessation, quantity, intensity and distribution. First, we describe rainfall trends and associated indicators in the rural community of Tamale. Then we report trends in Accra from the perspectives of local people.

Trends in precipitation and flooding from the perspective of local people in the rural community of Tamale

Quantity of rainfall

Communities surveyed in the rural districts were unanimous that rainfall has been increasing over the past thirty years. In all the FGDs, the communities were unanimous that the quantity of rainfall has seen gradual increases over the last thirty years and even beyond, for as long as they could remember. Also, 87.5 per cent of respondents to the questionnaires indicated that rainfall has increased in the district. In the last five years, the communities have observed a marked increase in the quantity of rainfall. About 9 per cent of respondents were, however, of the opinion that rainfall has decreased and 3.4 per cent think that there has been no change in the quantity of rainfall.

Invariably, this observed increase in the quantity of rainfall was based on noticeable manifestations of changes in rainfall-dependent and related landmarks in the communities as well as livelihood-based activities. The indicators below were used as evidence to buttress the observed increases in the quantity of rainfall:

i *Increased flooding (frequency and intensity)*: There is increased flooding. Flooding has become frequent in the community now compared to previous years. For the past ten years, the place has recorded flooding every year, but since 2007, the flood situation has been intense and in a single year, at least three flood occurrences could be recorded. From January to July 2011, three major floods were recorded. The floods are pronounced because of increased rainfall, which never used to be the case for the previous forty years. For example, in the Enchi market, where flooding has been a regular feature, the market women have observed a worsening situation since 2007 when flooding became an annual occurrence, with sometimes as many as three heavy floods in a year.

ii *Occurrence of pools of water*: In recent times, pools of water have been gathering on footpaths leading to farms due to the increased rainfall. This has resulted in accessibility difficulties which never used to be the case.
iii *Destruction of physical infrastructure by flood waters*: Buildings and other structures are frequently destroyed by flood waters.
iv *Increase in space covered by flood waters*: In the past, the community did not experience total flooding even during heavy rains that resulted in flooding. But now a whole community gets flooded, leaving just a small segment of the community to undertake evacuation and temporary resettlement.

Intensity of rainfall

According to the observations of the communities in the district, there has been increased intensity in rainfall since the late 1960s. This observation was supported by 93.2 per cent of the respondents in individual interviews. The communities' observation of increased intensity of rainfall was based on the following observations:

i Previously, flooding in the community occurred every ten years but now flooding occurs every year because the rains come very strongly. Previous flood years were 1968, 1978, 1987, and 2007.
ii There have been landslides on some hills, which have destroyed farmlands in recent years due to very strong rainfall.
iii Rainfall currently comes with strong winds, which usually rip off the roofs of buildings and destroy homes and property. This did not happen previously.

Number of rainy days

From the FGDs and questionnaires administered, the study established that the number of rainy days per week in a typical rainy season has increased over the past thirty years. There is a change from an average of three to five rainy days per week.

Seasonal variation

The rainfall pattern has completely changed. The focus-group participants reported that the rain no longer comes as and when it used to in previous years. There was general consensus on the change in the rainfall pattern, with 92 per cent of surveyed people confirming that the rainfall pattern has changed. The communities based their observations of the seasonal variation in the onset and distribution of rainfall on their understanding of rainfall patterns, which have characterised their locality and have also been the basis on which farming operated.

Precipitation and flooding trends from the perspective of local people in the urban communities of Accra

Similar factors were highlighted in the urban community of Accra, but indicating a contrasting rainfall pattern and occurrence of floods. In the following, we describe the trend in precipitation and occurrences of flooding, as presented by urban communities of Accra.

Quantity of rainfall

The quantity of rainfall is decreasing in the Accra Metropolitan area. According to the surveyed communities, the amount of rainfall that has been experienced in recent times has declined drastically, and they based their assertion on the following observations:

i *Low water levels in lagoons*: The water level in the lagoons in the community has decreased significantly in recent years. Since the damming of the Volta River, the major source of water inflow into the lagoon has been rainfall; hence the reduction in water level in the lagoon is proof that rainfall quantity has decreased.

ii *Reduced flow of the Volta River*. In the 1970s and 1980s, when rainfall was high, the Volta River used to overflow its banks and passed through the community during the peak of the rainy season, but now that hardly occurs. The rainy season then was continuous and had lots of rain.

iii *Disappearance of pools of rain water in the community*: There used to be pockets of water and lakes around the community, but they are no more.

iv *Declining trends in flooding*: Flooding is not occurring now as it used to in previous years when rainfall was always followed by flooding of the community. Now flooding is a rare occurrence. Floods in the communities in the past were mostly associated with rainfall, which caused the lagoons and lakes to overflow into the communities, so the reduction in these occurrences is an indication that rainfall has decreased over the years.

v *Reduced attention to storm channels*: Previously, channels/drains were regularly constructed in the communities during the rainy season to take flood waters away from the community into the sea, but this is no longer done because the rains are not what they used to be, and no longer pose threats of flooding to the community.

Intensity of rainfall

Rainfall has reduced in intensity. This was based on the following manifestations:

i Previously, heavy rainfall was very strong and one could not walk through it, but now such rains are very rare. Rainfall mostly comes as light showers. The heavy rains that were witnessed in the 1980s are no longer seen in the 2000s.
ii Houses are not being destroyed during rains as they used to be in the 1970s and 1980s when very strong rains would always destroy houses.
iii Rains used to come with a lot of thunder and lightning, but all that has ceased in recent years.
iv Previously the thumping of rain drops could be felt heavily on the aluminium roofing sheets, but that scenario is no longer felt. *Kpekuitsi*, an intense rain which means that people could not look straight ahead but had to look down when walking in the rain, does not happen anymore. Nowadays, one can just walk through the rain with ease and only worry about being wet.
v The community used to flood after 2 hours of rainfall, but now flooding will occur only after about 6 hours of rainfall.
vi Formerly, it would rain after very thick dark clouds had formed and the rains came heavily, but now the clouds can be white and it will rain and such rains are not strong.
vii In recent years, intense rainfall may come for about 30 minutes to about an hour and then stop. Previously heavy rains could be continuous for a longer time.

Number of rainy days

The number of rainy days per week in a typical rainy season has decreased in the urban Accra area. The people had observed that:

i In current years, especially in the 2000s, the average number of rainy days in a week during the peak rainy season is about two compared with the same periods in the early 1980s when it could rain almost every day of the week, or at least four to five days out of the seven days in a week would record rainfall.
ii In the past, there used to be times when families would stay indoors and food would be prepared for three days because the rains did not stop, but now this does not happen.

Seasonal variation

The major and minor rainy seasons have not changed, but whereas the major rainy season continues to record rainfall, the minor season is becoming extinct. The community responses were, however, divided about the onset of the rainy season: some believed that the onset of the rainy season had not changed, while others believed that the onset of rainy season had not necessarily changed but was no longer predictable. Reported observed evidence of variations in rainfall:

i About thirty years ago (1980s), the rainy season would start in January and end in July, with a drop in rainfall in April. But now there are no rains from January to March; rains start in May and end in July.
ii Rains still come in the major season but in the minor season rain is becoming extinct.
iii The rainy season does not record consistent rainfall. The rains start and there are intermittent periods of no rain.
iv The onset of the rainy season has also slightly changed and become less predictable. There are years when the rains do not come at the expected time.

Despite these contrasting rainfall trends, both spatial systems experience floods. Flooding in the informal settlement of Accra is related to the Odaw drain, the main river flowing through the city into the ocean. The problem observed and reported by the respondents is compounded by the following factors:

i urbanisation of the catchment causing very fast runoff;
ii urbanisation of the old riverbed and low-lying flood plain areas, reducing the area available for river flow and storage;
iii limited discharge capacity of the Odaw drain and its tributaries;
iv backwater effects from solid waste and structures, like bridges and the Korle Lagoon interceptor weir;
v possible interaction between high tide at sea and the downstream parts of the river.

The above-mentioned problems cause, amongst other things, the hotspots of *Alogboshi*, *Avenor* and *Odawna* to be flooded within hours of a heavy rainfall event. The flood comes very fast and is especially dangerous when it occurs at night.

Comparison with empirical evidence using rainfall data and the occurrence of extreme weather events showed some similarities with the perceptions of the respondents. The respondents' recollections and descriptions of the various events matched the statistical records. (See Figures 2 and 3.) This suggests the reliability of local people's knowledge of the climate.

The situation in these two different spatial systems reflects what is happening at national level. See Figure 4 and Table 3. Figure 4 shows extreme climate events relative to mean annual rainfall and mean annual temperature in Ghana from 1950 to 2012. Figure 4 shows the country's experience of inter-annual rainfall variability. It further shows years when the country experienced droughts and floods. Ghana has been adversely affected by numerous climate hazards—defined as natural phenomena that may cause loss of life, injury or other health impacts, property damage, social and economic disruption, or environmental degradation (UNISDR 2009)—over the past

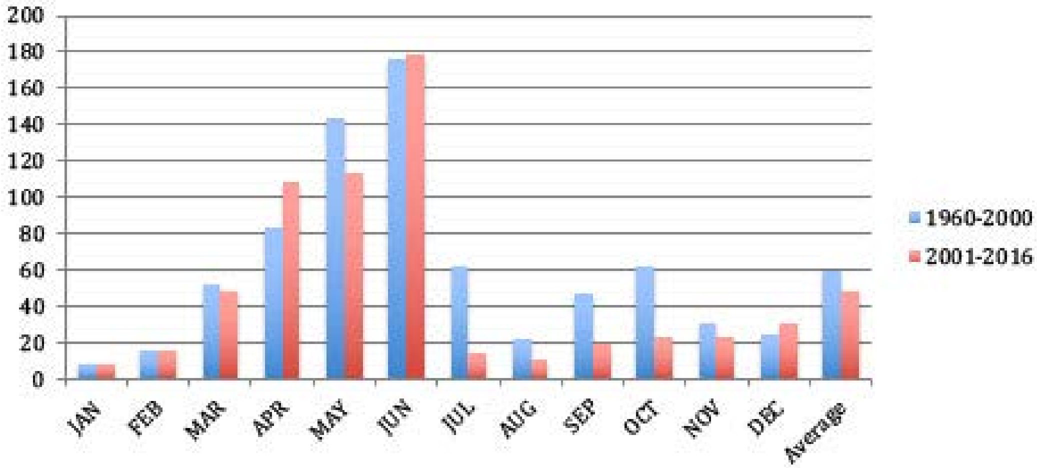

Figure 2. Monthly average from 1960 to 2000 compared with 2001–2016 monthly averages for Accra.

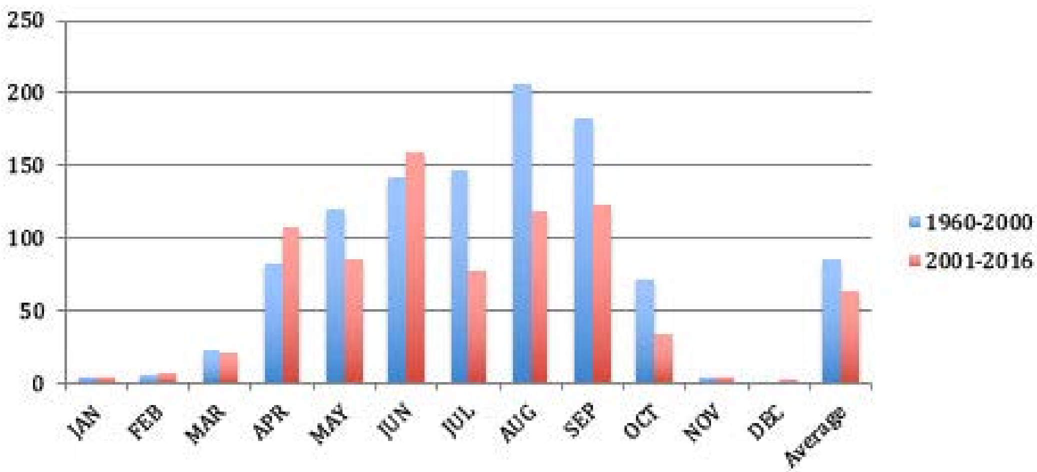

Figure 3. Monthly average from 1960 to 2000 compared with 2001–2016 monthly averages for Tamale.

five decades (Figure 4). These include at least three droughts and nineteen floods, which have cumulatively affected over sixteen million people and resulted in at least 444 deaths—excluding the undocumented numbers of deaths resulting from droughts. The occurrence of climate-related disasters in Ghana has had a major negative impact on the standard of living of people in the country (Okyere *et al.* 2012).

Similarly, Table 3 shows the occurrence of climate hazards in Ghana from 1968 to 2017. The table further shows the impacts of these climate hazards. Overall, floods are the commonest disaster in recent times. Given Ghana's reliance on rain-fed agriculture, these hazards pose the greatest threats to the agricultural sector in the country,

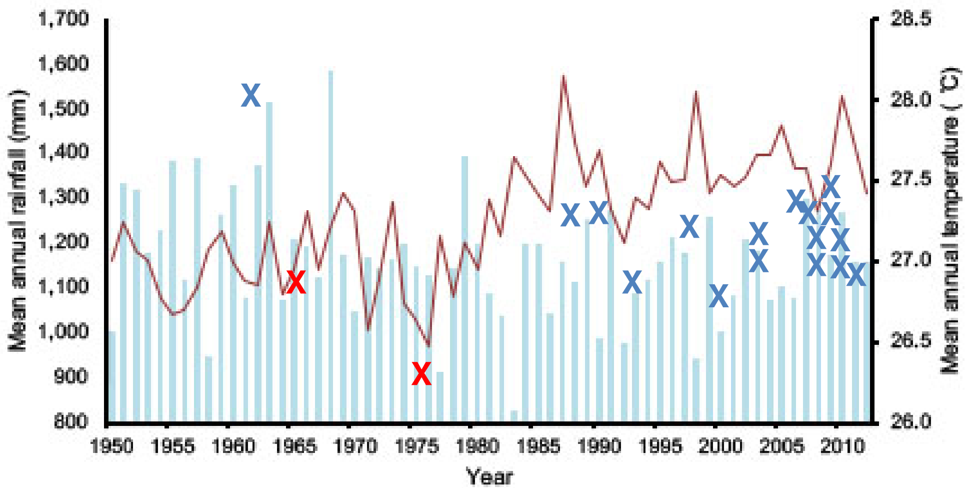

Figure 4. Extreme climate events (droughts and floods) relative to mean annual rainfall (left-hand *y*-axis; bars) and mean annual temperature (right-hand *y*-axis; line) in Ghana from 1950 to 2012.

Table 3. List of climate hazards and their impacts in Ghana between 1968 and 2017 (EM-DAT 2016).

Year	Disaster description	Region/s affected	Total deaths	Total people affected	Total damage (US$)
1968	Flood	Central	–	25,000	74,700,000
1971	Drought	Countrywide	–	12,000	100,000
1977	Drought	Northern, Upper East, Upper West	–	–	–
1983	Drought	Countrywide	–	12,500,000	–
1989	Flood	Northern	7	2,800	–
1991	Flood	Greater Accra	5	2,000,000	–
1995	Flood	Greater Accra	145	700,000	12,500,000
1999	Flood	Northern, Upper East, Upper West	52	324,602	21,000,000
2001	Flood	Greater Accra	12	144,025	–
2002	Flood	Greater Accra	–	200	–
2002	Flood	Greater Accra	4	2,000	–
2007	Flood	Northern, Upper East, Upper West	56	332,600	–
2008	Flood	Northern	–	58,000	–
2009	Flood	Greater Accra, Ashanti, Volta, Western, Central, Eastern	16	19,755	–
2009	Flood	Northern	24	139,790	–
2010	Flood	Greater Accra, Central, Volta	45	7,500	–
2010	Flood	Brong Ahafo, Eastern, Western, Upper East, Upper West, Northern	18	9,674	–
2011	Flood	Eastern	6	12,571	–
2011	Flood	Greater Accra, Eastern, Volta	14	81,473	–
2013	Flood	Northern, Volta	5	25,000	–
2015	Flood	Greater Accra	25	5,000	12,000,000
2016	Flood	Greater Accra	10	–	–

with the most immediate consequence being a decrease in crop production—especially sorghum, millet, maize and groundnuts. These losses negatively impact the livelihoods of smallholder farmers, particularly in the northern savanna zones (Choudhary *et al.* 2016). When crops fail, farmers often resort to selling livestock to supplement their income. As the food deficit increases, farmers are forced to sell more valuable livestock, including draft and transport animals, such as oxen and donkeys (Toulin 1986), reducing the productive capacity of farms in the long term. Similarly, floods have devastating effects both in urban and in rural settings, often leading to humanitarian crises. Factors include the effects of climate change on the hydrology of the country; extreme weather events, such as continuous and intense rainfall, rivers breaking their banks, increased return flow of rivers and more artificiality through poor land-use practice and associated planning; and the destruction of the environment by human activities, resulting in land-cover change. These may include farming, deforestation, sand winning, and the destruction of natural storm breakers such as wetlands, building in waterways, poor siting of transport, and industrial, waste management and settlement infrastructure.

Given these trends and the impact on people's livelihoods and the national economy, well-informed interventions are necessary to reduce national vulnerability. Likewise, there is a need for an adequate understanding and crafting of future climate projections and management of extreme weather events. This is the focus of the next section.

CLIMATE CHANGE AND FLOOD MANAGEMENT IN ACCRA AND TAMALE

The projections for the future climate of Ghana—particularly with respect to rainfall and temperature—are consistent with the projections for other regions. It is projected that the wet seasons will get wetter while the dry season will get drier. In line with the projections for other regions (caused primarily by the intensification of the hydrological cycle), it is expected that the proportion of total annual rainfall that falls in heavy events will increase. On the other hand, there is a projected trend towards a decrease in dry season rainfall (January–June). If risk-mitigation measures are not put in place, these trends suggest that there will be an increase in drought and flooding risks in Ghana. The emerging trends from climate change modelling projections are an increase in intensity or frequency or both. The projection reveals that the exposure of the cities in the north and coastal areas would prevail and may worsen (Figures 5 and 6). Figure 5 shows the annual deviation from the normal distribution of rainfall in the area. The analysis highlights an increase in occurrence of very wet years with

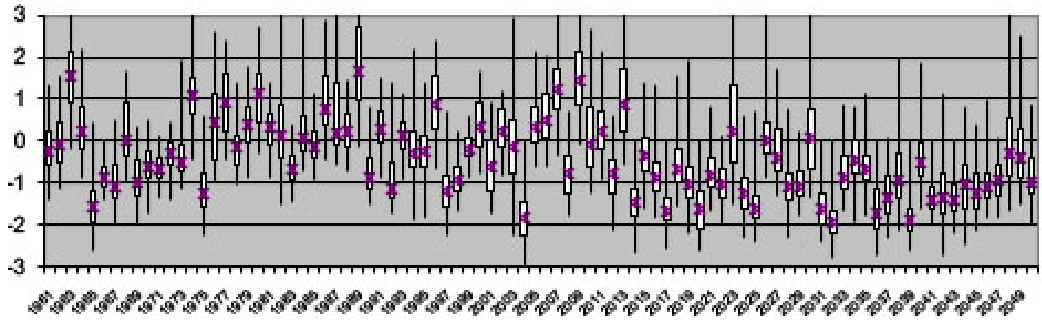

Figure 5. SPI values with confidence intervals against various years from 1961 to 2050 graphs for the northern part of Ghana.

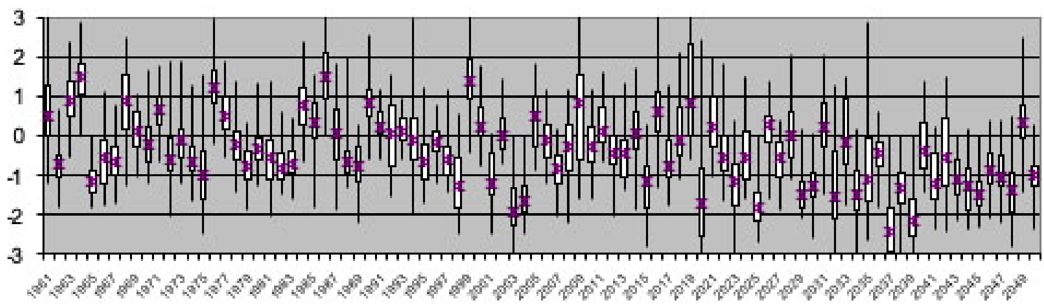

Figure 6. SPI values with confidence intervals against various years from 1961 to 2050 graphs for the southern part of Ghana.

the possibility of flood events of higher intensities. Figure 6, on the other hand, shows similar characteristics to the northern part with the potential for increased flooding from the already frequent occurrence of flooding in the coastal zone.

Additional SPI analyses were conducted on projected precipitation based on IPCC's A1B scenarios against the base period of 1961–2000 (Figures 5 and 6). Although no coherent trends are found in the areas around the basin (Kasei 2009, Paeth *et al.* 2005), inter-annual rainfall variability is more pronounced in the northern part of Ghana (Figures 5 and 6). The northern part of the basin is most vulnerable to these variations because it has a mono-modal rainfall pattern compared to the south, which has relatively higher rainfall amounts due to its bi-modal rainfall pattern.

Model projections give a blend of moderate and extremely dry and wet years in the future (Table 4) raising the alarm about extreme climate hazards. The SPI also indicates an increase in the frequency of moderate to severe droughts and floods in the future.

Figures 5, 6 and Table 4 show scenario projections with unchanged frequency of flooding for the future compared to the base period but assigning more severe events to the future. The southern parts of Ghana will, however, experience an increase in

Table 4. Comparison of climate occurrences of past (1961–2005 estimated) with future (2006–2050 A1B-simulated) for the Volta Basin.

SPI value	Classification	Past (observed) 1961–2005 No. of occurrences	Future (simulated) 2006–2050 No. of occurrences
+2	Severely wet	5	5
+1	Moderate wet	5	5
0	Normal year	16	10
−1	Moderate dry	11	6
−2	Severely dry	7	22

flood events in the future compared to the north, threatening the very dense and ever-increasing population of Accra.

In the event of extreme climate disasters, such as the 2007 floods in northern Ghana and central and western regions, the impacts are usually overwhelmingly high, as relevant agencies are least prepared or have put hardly any structures in place to absorb the shocks. Such impacts could, however, be minimised through proper planning and integration of climate change (CC) and disaster risk reduction (DRR) measures into all facets of national development planning, particularly at the district level and across sectors.

The main sources of vulnerability include poverty and development pressures (including low economic growth, rising population pressures and unplanned urbanisation (Gencer 2013)). Other sources include: fragile and degraded environments. It is in the light of this that NADMO, which has a mandate to coordinate all disasters and emergencies in the country, set up the Climate Change and Disaster Risk Department in 2009, charged with the responsibility of addressing climate change issues with a disaster focus within the organisation sourced from key informants.

The activities of NADMO in relation to climate change are geared towards attaining the targets of the National Climate Change policy which seeks to address DRR. In this regard, NADMO has undertaken a number of activities that seek to address climate change in DRR. The organisation, with support from the Norwegian government, has undertaken the Community Resilience through Early Warning (CREW) project. The project was piloted in ten districts, one from each region. The project installed early warning gadgets in the pilot districts. NADMO with assistance from GIZ undertook a climate change awareness creation workshop for some basic schoolteachers in the Northern and Greater Accra Regions. Within the organisation some district NADMO offices have been given a basic understanding of climate change. The organisation is in the process of setting up climate change desks in all its regional and district offices.

Moving forward, NADMO has identified sovereign risk transfer as a way of adapting to the effects of climate change, especially in the area of agriculture. This is in line with the Sendai framework for Disaster Risk Reduction priority 3 according to a key informant interview. NADMO in collaboration with GIZ is piloting the Integrated Climate Risk Management (ICRM) project in some selected districts in the Northern and Volta Regions. The country has also signed a Memorandum of Understanding (MoU) with the African Risk Capacity (ARC) for possible accession to the ARC. The policy will cover flood and drought.

Despite these efforts NADMO is making in advancing climate change issues in its activities, the organisation is still facing some challenges. The organisation has yet to fully incorporate climate change activities into the structure of the organisation by setting up climate change desks in all the regional and district offices as well as building the capacity of the staff in these offices. The climate change department is yet to have a technical committee to support and guide the department in its activities. Notwithstanding these challenges, the organisation realises that climate change is and will be a central theme in managing disasters in the country.

Flood warning for communities

With increasing flood risk in a warming world, investment in developing a credible early warning system, embedded within a flood risk reduction system from national to local levels and coupled with systematic vulnerability reduction efforts, is critical for saving lives and protecting livelihood assets.

Rainfall-related hazards could be predicted at least three to five days in advance. With the aid of monitoring systems, skill in estimating the intensity of rainfall can also be improved to provide reasonably accurate rainfall forecasts to issue early warnings. Institutions like NADMO and the Accra and Tamale metropolitan assemblies need warning information about abnormally high or untimely rainfall to enable them to mobilise in advance. If communicated and understood properly, an early warning system could help make contingency planning and evacuation more precise and, therefore, put people and potentially economic/livelihood assets out of harm's way. This has eluded the assemblies so far and has rendered them incapable of dealing with the frequent dangers and relegated to mere distribution of relief items to surviving victims after disasters.

NADMO, located in the Ministry of the Interior, and the Ghana Meteorological Agency (GMet), are the key actors in early warning in Ghana. NADMO is mandated (i) to manage disasters by coordinating the resources of government institutions and non-governmental agencies, and (ii) to develop the capacity of communities to respond effectively to disasters and improve their livelihoods through social mobilisation, employment generation and poverty reduction projects. GMet, on the other hand, is responsible for monitoring hydrometeorological and climate events and for issuing forecasts. The two agencies are linked through GMet's membership of NADMO's technical committee on hydrometeorology.

Warning of an extreme weather event with a lead-time of five days or more would be beneficial for preserving assets and livelihoods. The current equipment and technical capacity limitations of GMet do not allow it to issue information with significant lead-time. In addition, even considering that GMet would be able to provide this information, it does not necessarily mean that at-risk communities would be forewarned of impending hazards. To be useful, technical early warning information from GMet needs to be translated into potential impacts and advisories at the local level by warning dissemination agencies, such as NADMO, and the sectoral agencies Ministry of Food and Agriculture, Department of Community Water and Sanitation. For example, if NADMO forecasts that there will be intense rainfall over northern regions in a given time period, decision makers need to know what the impacts would be on people living in different areas (for example, downstream versus upstream) or on different livelihood groups (for example, pastoralists, farmers, miners). Currently, translation of technical warning information into potential impacts at the local level is also a major constraint for NADMO and other relevant agencies that deal with weather and climate-sensitive sectors. This agrees with earlier studies that formal institutions or conventional science alone cannot adequately address climate challenges (Finucane 2009, Joshua *et al.* 2017).

This study revealed that all respondents said they were aware of the forecasts of GMet. More than half of the respondents (56.8 per cent) said they were aware of both the seasonal and daily forecasts of GMet; 6 per cent were aware only of the daily forecasts and 36.4 per cent were aware only of the seasonal forecasts. Of these respondents, 61 per cent said they received the GMet forecasts regularly and the remaining 38 per cent said they did not receive regular weather information. The major source of information for weather forecasts was the radio; 67 per cent said they got their information solely from listening to the radio and a further 24 per cent got their information from both radio and television.

The respondents underscored that access to the information is not necessarily reflected in usage of the information. Despite the majority, over 60 per cent, of the respondents admitting to receiving GMet forecasts regularly, only 26.4 per cent of the respondents said they planned their livelihood activities based on the weather forecasts that they receive. About 31 per cent said they sometimes planned their activities based on the weather forecasts, whilst 43 per cent emphatically said they do not plan their activities based on the weather information for several reasons.

i Most believed more in local knowledge and experience of the weather upon which they made their decisions. See Box 1 for some of the IK systems that local communities in rural Tamale have used to predict weather or climate to make informed decisions. In this regard, most of the respondents who are crop farmers prefer to stick with their traditional planting seasons and would not make any effort to change their planting season based on any GMet information.

ii Not finding time or making any effort to listen and really pay attention to any weather information

iii Sometimes the GMet predictions do not come true and have caused disappointments and losses. They were of the opinion that the weather forecasts are not reliable and fail most of the time.

At the back of all these challenges, there is no well-established channel for communicating early warning information to communities. Hence, even assuming that there is perfect early warning information for impending hazards, there could still be a significant lag between the issuance of information and information reaching the communities, and the actual response. This justifies the need to consider integration of relevant local or indigenous knowledge into early warning systems.

Box 1. Traditional knowledge indicators for weather and climate forecasting or early warning of climate risks in Tamale.

These are based on local observations of insects and other animals' behaviour, plant phenology, atmospheric and other indicators

- *Ambient temperature*: When ambient temperatures get very warm in the early part of the year, from January to April, it signifies good rainy season. The intensity of heat is an indication of how intense the rainy season will be.
- *A bird (locally called Akpo):* These birds are usually sighted as male and female, around January to March. The appearance of the bird, usually in early January indicates that rains will be good for the impending rainy season. When the bird appears, it is heard throughout the community because it makes a lot of noise.
- *A worm:* Yellowish in colour with some fluffy furs on the body. They live in the soil like crabs. The worm lives in the soil and when it comes out of the soil before the rainy season, it is an indication of a good rainy season.
- *Ants:* Brownish with pincers which they use to bite. When during farming a farmer mistakenly hits the mud of these ants, they are agitated and bite the farmer. Wherever they are, the python cannot be found there because the ants can kill it. The *likei* are not poisonous. Whenever the ants leave the

highland to the lowland near the streams or rivers, it is an indication of little rain and no floods. But when they move from the stream area to the upland, it means there will be heavy rains, which can cause flooding. So the ants are an indicator of both higher rainfall and no rainfall.

- *Bird (locally called Avakpo)*: A small to medium-sized bird. The upper parts are blackish and its under- parts are white heavily streaked with black. The under-wing flight feathers are white with a black trailing edge. The under-wing coverts are mostly black with white spots. The appearance of the hawk signifies the end of the rainy season. In the community, the farming season starts at the end of the rainy season and that is the time the hawk comes home to catch chicken whiles farmers are away. So the appearance of the hawk signifies both the end of rainy season and also the beginning of the farming season.
- *Frog:* Long-legged frog with brownish camouflage skin. The frog is found around the lagoons and ponds. The croaking of the frog is an indicator of imminent rains. When the frog starts croaking in the afternoon, it means there is going to be rains in the evening. The croaking of the frog is not an indication of the intensity of rainfall but that it will rain.
- *Ant:* They are smaller than the black ones found in homes; does not bite. It is black; its egg is white and bigger than the ant. The ants live on the ground and if it's about raining, they are seen them in great numbers and in rows, carrying their eggs. Sometimes when this scenario of the ants moving with their eggs is seen, it rains on that particular day. Other times, it may rain in a few days.
- *Hot weather*: The temperature is so uncomfortable, and hot beyond the normal temperature felt during the day. There will be rainfall by evening or during the night
- *Ants:* They are black. They live around houses, sometimes under pots of water. When it's about to rain the ants carry their eggs to a safe place, they will later bring the eggs back. Anytime the ant is seen carrying its eggs, it means it's getting nearer to the rainy season; sometimes in one week or four days, the rains will come.
- *Flowering of baobab tree*: The moment it flowers the rain will start before the flowers turn into fruit. When the flowers are first seen, then in three or four days, it will rain. If the rains are not good, it does not flower well.
- *Worm:* It lives on the ground and is long, about the length from the finger to the wrist. It is pale blue in colour. It has no legs just like a snake. It has no tongue and a small head. It is as big as the second finger. The worm comes out when it is about to rain, so their appearance signifies imminent rainfall.

- *Caterpillars:* It is black in color with some white rings all over the body. When it appears, it chews all the vegetation. When these caterpillars are seen in their numbers in March/April before the rainy season, it is a sign of no or little rainfall in the year. When the caterpillars do not appear, it is a sign of good rains. The people alleged that in some communities in the Northern Region, these caterpillars are eaten as food.
- *Grasshoppers:* It is either green or brown in colour. When grasshoppers appear in their numbers in the month of April, it is an indication that it may not rain. When they appear in their numbers in March/April, it means the rains will not be good for the season.

Source: Focus group participants

As stated earlier, traditional and local communities have unrelentingly to rely greatly on their own trusted indigenous knowledge systems in observing the atmospheric systems and dealing with accompanying hazards. These communities, particularly those in flood-prone areas, have collectively generated a vast body of knowledge on disaster prevention and mitigation, early warning preparedness and response from cumulative experience handed down from generation to generation (Pareek & Trivedi 2011). Indigenous or local people who have stayed in an area for many decades are vital and active parts of the ecosystems they belong to and would be critical in helping to enhance the resilience of these ecosystems. As emphasised above, the livelihoods of most indigenous rural communities depend greatly on natural resources that are directly affected by climate change and variability, and they often inhabit economically and politically marginal areas in diverse, but fragile, ecosystems. According to some experts, traditional communities interpret and react to climate change impacts in creative ways, sometimes drawing on traditional knowledge as well as on new technologies to find solutions, which may help society at large to cope with the impending changes (Jan & Anja 2007). Doss and Morris (2001) underscored that the perspectives of the indigenous people, and considering the way they think and behave in relation to climate change and variability, would always have a significant role to play in addressing and managing climate change and its impacts.

In Ghana, the majority of the population within the rural areas is still dependent on traditional approaches to sustenance to develop and improve their livelihoods. The same cannot be said about the urbanised areas whose ecosystems are largely compromised. Despite the fact that efforts have been made towards fighting climate change from scientific viewpoints, there is a great need for research and policies directed towards indigenous knowledge and perception, in order to reduce the vulnerability of these rural dwellers and enhance their cultural resilience and adaptive capacity. It is, therefore, important to understand indigenous perceptions of climate change and their preferred strategies towards adaptation.

CONTINGENCY PLANNING IN GHANA

As presented earlier, floods are a common feature in Ghana, but currently the existing documentation on Ghana's preparedness for floods is scanty and often scattered among the NGO communities and implemented in isolation. Whilst there is a national generic disaster preparedness document that ought to be updated every six months, scenarios hardly reflect the true state of affairs in Ghana. Although it is laudable to make such a national effort, the emphasis of the document had been on post-disaster phases, fashioned in the context of search and rescue missions. However, with the expected effects of climate change and hence increased flooding, it is becoming clear that society will have to learn to live with floods and make pre-flood disaster preparedness (missing locally) an important phase of contingency planning in Ghana.

In many African countries, Ghana included, city authorities have approached urban flood vulnerability among residents of informal settlements in two main ways: firstly, blaming residents who have defied planning regulations and built substandard houses in flood-prone zones; and, secondly, labelling residents as passive victims of flood hazards due to their disadvantaged locations in the city; both tackling the problem and flying in the face of contingency planning.

POLICY IMPLICATION AND RECOMMENDATION

The successes of risk reduction efforts depend to a large extent on a good understanding of the evolving nature of the spatial/geographical range and incidence of disaster risk. NADMO, planning agencies, and district assemblies should have a good knowledge of the nature of a hazard, the geographical range and incidence of a hazard, the changes that are expected to occur relative to physical (for example, climate change) and social changes, and the population who will be most affected by the hazard.

While there is an understanding of the physical exposure of different parts of Ghana to hazards (for example, rainy season flooding in Accra, erosion and sea-level rise in coastal zones, floods and droughts in the northern regions), the level of understanding of the nexus between the physical and social factors is still sketchy and incomplete.

Experiences in other countries reveal that social status, gender and race affect the way people experience or do not experience disasters. However, the social and economic characteristics of the population at risk at a disaggregated level are poorly understood in Ghana. This impedes the development of disaster risk management strategies that are targetted to the needs of a certain group of the population. While hazard maps are already available for selected districts in the country, the fast-changing nature of population dynamics, coupled with the changes in the manifestation of climatic and hydro-meteorological hazards due to climate change, have not yet been fully captured in these maps. In addition, there is no system for continuous hazard risk monitoring. Available maps are static and there is no strategy for updating them on a regular basis (for example, every five years or so depending on the hazard).

It has emerged from the analyses of the inputs into contingency planning that real-time monitoring of weather events, especially rainfall-related factors, will be critical and GMet needs to prepare a seasonal weather forecast, which will serve as a guide for preparedness activities. Such data would require regular updates that will provide useful information regarding the characteristics of the rains during the rainy season.

During the rainy season, information from GMet stations and meteorological satellites are required to create 24-hour and many-day forecasts to provide early warning information on areas prone to daily heavy rains. Existing tools and communication avenues need to be strengthened whilst appropriate modalities are established, so that the information received is timely and action taken appropriately by several other stakeholder institutions, as outlined earlier. Where discharges and spillage of water from reservoirs are involved, conscious relationships and hence linkages between such areas, especially those upstream and downstream, would help minimise the risk of flooding and the potential impacts.

A number of communities within the three northern regions have recently been experiencing frequent incidences of floods due to heavy storms extending both to Burkina Faso and into the northern regions. There is an urgent need to initiate action to mitigate or reduce the effects of the floods. This can be achieved through a series of educational and structured programmes in the area. In the educational arena, awareness creation is the key item to consider. Early warning systems need to be put in place, taking advantage of the culture and communication tools of the communities in the area.

A high-priority step in the strategy for flood disaster risk reduction is an early warning system, which will be instrumental in enhancing coping capacity in the short term. Not all flood events can be forecast by an early warning system. Many flood events happen as a result of sudden high-intensity rainfall, silting and blockage of drainage canals, or collapse of dikes and bunds, and do not happen as a predictable gradual build-up of flood levels. However, on the main streams that flow within the communities, the time elapsed from change in hydro-meteorological parameters upstream to floods downstream is large enough to warrant an early warning system.

The extent of the vulnerability of a population to hazards has spatial, economic, and social dimensions. Similar to any disaster management system that is predominantly driven by emergency response, Ghana has not yet carried out a national exercise of identifying the vulnerability of different population groups and their livelihoods and identifying ways to systematically address them. Ideally, this exercise should provide input into the country's development plan and into district development plans to make sure that the effort to develop reduces—rather than exacerbates—exposure to hazards.

In Ghana, there is a wealth of indigenous knowledge related to anticipating the onset of disasters. They have been mapped (under the Africa Adaptation Programme) and the challenge now is to how to incorporate indigenous knowledge into an early warning system that is predominantly technical and scientific in nature.

Despite this, indigenous and other traditional people are only rarely considered in academic, policy and public discourses on climate change, despite the fact that they are greatly impacted by impending changes in climate (Berkes & Jolly 2001). Although the importance of indigenous knowledge has been realised in the design and implementation of sustainable development projects, little has been done to incorporate this into formal climate change adaptation strategies. This has basically been due to the over-concentration of efforts on scientific and conventional approaches.

Acknowledgements

This work was supported by the SNV Netherlands Development Organization in partnership with HKV of the Netherlands. Immersive support was received from the Community Resilience through Early Warning (CREW) team of the National Disaster Management Organization of Ghana (NADMO) and the Water Resources Commission of Ghana. Special thanks are due to the Ministry of Environment, Science, Technology and Innovation of Ghana, The Environmental Protection Agency and the University for Development Studies. The views expressed in this document cannot be taken to reflect the official opinions of these organisations.

REFERENCES

ActionAid (2006), 'Unjust Waters. Climate Change, Urban Flooding and the Rights of the Urban Poor in Africa, Key Findings from Six African Cities', ActionAid International Secretariat, Johannesburg. https://www.actionaid.org.uk/sites/default/files/doc_lib/unjust_waters.pdf

Adinku, S. A. (1994), 'Disaster Preparedness: A Sociological Study of the Flood Problem in the Odaw Catchment in Accra', Department of Sociology, University of Ghana.

Amoako, C., (2015), *Flood Vulnerability and Responses in Urban Informal Communities in Accra, Ghana*, PhD thesis (Clayton, Monash University Press). https://monash.figshare.com/articles/Flood_vulnerability_and_responses_in_urban_informal_communities_in_Accra_Ghana/4711564

Bates, B. C., Kundzewicz, Z. W., Wu, S. & Palutikof, J. P. (eds) (2008), 'Climate Change and Water', Technical Paper of the Intergovernmental Panel on Climate Change, IPCC Secretariat, Geneva.

Berkes, F. (2012), *Sacred Ecology*, 3rd edn, (New York, Routledge). https://doi.org/10.4324/9780203123843

Berkes, F. & Jolly, D. (2001), 'Adapting to Climate Change: Socio-ecological Resilience in a Canadian Western Arctic Community', *Conservation Ecology*, 5(2): 18. https://doi.org/10.5751/ES-00342-050218

Chanza, N. & Mafongoya, P. L. (2017), 'Indigenous-based Climate Science from the Zimbabwean Experience: From Impact Identification, Mitigation and Adaptation', in P. L. Mafongoya & O. C. Ajayi (eds), *Indigenous Knowledge Systems and Climate Change Management in Africa* (Wageningen, CTA), Chapter 4, 67–94.

Choudhary, V., Christienson, G., D'Alessandro, S. P. & Josserand, H. P. (2016), 'Ghana: Agricultural Sector Risk Assessment', Agriculture Global Practice Note, World Bank, Washington, DC. http://documents.worldbank.org/curated/en/412431468198000868/Ghana-agricultural-sector-risk-assessment

Dodman, D., Dalal-Clayton, B. & McGranahan, G. (2013), 'Integrating the Environment in Urban Planning and Management Key Principles and Approaches for Cities in the 21st Century', United Nations Environment Programme, Geneva. file:///C:/Users/Jan/Downloads/-Integrating%20the%20environment%20in%20urban%20planning%20and%20management_%20key%20principles%20and%20approaches%20for%20cities%20in%20the%2021st%20century%20-20132014%20Urban%20Planning%20Report_LR.pdf

Doss, C. & Morris, M. (2001), 'How Does Gender Affect the Adoption of Agricultural Innovations? The Case of Improved Maize Technology in Ghana', *Agricultural Economics*, 25: 27–39. https://doi.org/10.1016/S0169-5150(00)00096-7

Douglas, I., Alam, K., Maghenda, M., Mcdonnell, Y., Mclean, L. & Campbell, J. (2008), 'Unjust Waters: Climate Change, Flooding and the Urban Poor in Africa', *Environment and Urbanization*, 20: 187–205. https://doi.org/10.1177/0956247808089156

EM-DAT (2016), 'Disaster List for Ghana'. http://emdat.be/disaster_list/index.html

Finucane, M. (2009), 'Why Science Alone Won't Solve the Climate Crisis: Managing the Climate Risks in the Pacific', *Asia Pacific Issues*, 89: 1–8.

Gencer, E. A. (2013), *The Interplay Between Urban Development, Vulnerability, and Risk Management* (New York, Springer). https://doi.org/10.1007/978-3-642-29470-9

Gyau-Boakye, P. (1997), 'Flood Control Measures: Hazard Mapping', Water Research Institute of Centre for Scientific and Industrial Research (CSIR), Accra.

InterAcademy Council (2010), 'Review of the IPCC Processes and procedures', report by the Inter Academy Council Amsterdam. http://reviewipcc.interacademycouncil.net/

IPCC (2007a), *Climate Change 2007: Impacts, Adaptation and Vulnerability*, Intergovernmental Panel on Climate Change (Cambridge, Cambridge University Press). https://www.ipcc.ch/site/assets/uploads/2018/03/ar4_wg2_full_report.pdf

IPCC (2007b), 'Summary for Policymakers, Fourth Assessment Report (AR4)', Intergovernmental Panel on Climate Change, New York. https://www.ipcc.ch/site/assets/uploads/2018/02/ar4-wg1-spm-1.pdf

IPCC (2014), *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* R. K. Pachauri & L. A. Meyer (eds). International Panel on Climate Change, Geneva. https://www.ipcc.ch/site/assets/uploads/2018/05/SYR_AR5_FINAL_full_wcover.pdf

Jan, S. & Byg, A.. (2007), ‘Indigenous Peoples and Climate Change’, University of Oxford and Missouri Botanical Garden. https://archive.org/stream/fs_cc_Indigenous_Peoples_and_Climate_Change/Indigenous_Peoples_and_Climate_Change_djvu.txt

Johannessen, A., Rosemarin, A., Thomalla, F., Swartling, G., Stenström, T. A. & Vulturius, G. (2014), ‘Strategies for Building Resilience to Hazards in Water, Sanitation and Hygiene (WASH) Systems: The Role of Public Private Partnerships’, *International Journal of Disaster Risk Reduction*, 10: 102–15. https://doi.org/10.1016/j.ijdrr.2014.07.002

Joshua, M., Ngongondo, C., Monjerezi, M., Chipungu, F. & Malidadi, C. (2017), ‘Relevance of Indigenous Knowledge in Weather and Climate Forecasts for Agricultural Adaptation to Climate Variability and Change in Malawi’, in P. L. Mafongoya & O. C. Ajayi (eds), *Indigenous Knowledge Systems and Climate Change Management in Africa* (Wageningen, CTA), Chapter 9, 185–218.

Kalanda-Joshua, M., Ngongondo, C., Chipeta, L. & Mpembeka, F. (2011), ‘Integrating Indigenous Knowledge with Conventional Science: Enhancing Localised Climate and Weather Forecasts in Nessa, Mulanje , Malawi’, *Journal of Physics and Chemistry of the Earth*, 36(14–15): 996–1003. https://doi.org/10.1016/j.pce.2011.08.001

Kalinga-Chirwa, R., Ngongondo, C., Kalanda-Joshua, M., Kazembe, L., Pemba, D. & Kululanga, E. (2011), ‘Linking Rainfall and Irrigation to Clinically Reported Malaria Cases in Some Villages in Chikhwawa District, Malawi’, *Journal of Physics and Chemistry of the Earth*, 36(14): 887–94. https://doi.org/10.1016/j.pce.2011.07.053

Kangalawe, R., Mwakalila, S. & Masolwa, P. (2011), ‘Climate Change Impacts, Local Knowledge and Coping Strategies in the Great Ruaha River Catchment Area, Tanzania’, *Natural Resources*, 2: 2012–223. https://doi.org/10.4236/nr.2011.24027

Karley, N. K. (2009), ‘Flooding and Physical Planning in Urban Areas in West Africa: Situational Analysis of Accra, Ghana’, *Theoretical and Empirical Researches in Urban Management*, 13: 25–41.

Kasei, R. (2009), *Modelling Impact of Climate on Water Resources in the Volta Basin, West Africa*, Series No. 69 (Göttingen, Cuvillier Verlag).

Kihupi, N. I., Kingamkono, R., Rwamugira, W., Kingamkono, M., Mhita, M. & Brien, K. O. (2002), ‘Promotion and Integration of Indigenous Knowledge in Seasonal Climate Forecasts’, consultancy report submitted to Drought Monitoring Center (Harare, Zimbabwe), The Pilot Project Research Team, Sokoine University of Agriculture, Tanzania.

Kijazi, A. L., Chang’a, L. B., Liwenga., E. T., Kanemba, A. & Nindi, S. J. (2013), ‘The Use of Indigenous Knowledge in Weather and Climate Prediction in Mahenge and Ismani Wards, Tanzania’, *Journal of Geography and Regional Planning*, 6(7): 274–80. https://doi.org/10.5897/JGRP2013.0386

Mafongoya, P. L. & Ajayi, O. C. (2017a), ‘Indigenous Knowledge and Climate Change: Overview and Basic Propositions’, in P. L. Mafongoya & O. C. Ajayi (eds), *Indigenous Knowledge Systems and Climate Change Management in Africa* (Wageningen, CTA), Chapter 1, 17–28.

Mafongoya, P. L. & Ajayi, O. C. (2017b), ‘Indigenous Knowledge Systems: Their History, Development Over Time and Role in Sustainable Development and Climate Change Management’, in P. L. Mafongoya & O. C. Ajayi (eds), *Indigenous Knowledge Systems and Climate Change Management in Africa* (Wageningen, CTA), Chapter 2, 29–42.

Mafongoya, P. L., Jiri, O. Mubaya, C. P. & Mafongoya, O. (2017), ‘Using Indigenous Knowledge for Seasonal Quality Prediction in Managing Climate Risk in Sub-Saharan Africa’, in P. L. Mafongoya & O. C. Ajayi (eds), *Indigenous Knowledge Systems and Climate Change Management in Africa* (Wageningen, CTA), Chapter 3, 43–66.

McKee, T. B., Doesken, N. J. & e Klei, J. (1993), ‘The Relationship of Drought Frequency and Duration to Time Scales’, in *Eighth Conference on Applied Climatology*, 17–22 January, Anaheim, CA.

Mubaya, C. P, Mafongoya, P. L., Jiri, O., Mafongoya, O. & Gwenzi, J. (2017), 'Seasonal Climate Prediction in Zimbabwe Using Indigenous Knowledge Systems', in P. L. Mafongoya & O. C. Ajayi (eds), *Indigenous Knowledge Systems and Climate Change Management in Africa* (Wageningen, CTA), Chapter 5, 95–114.

NADMO (2009), 'Summary of Disaster Events in Ghana', webpage, National Disaster Management Organization, available from: http://www.nadmo.gov.gh

Nicholls, R. J., Wong, P. P., Burkett, V. R., Codignotto, J. O., Hay, J. E., McLean, R. F. & Ragoonaden Sand Woodroffe, C. D. (2007), 'Coastal Systems and Low-lying Areas', in M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. van der Linden & C. E. Hanson (eds), *Climate Change 2007: Impacts, Adaptation and Vulnerability*', Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (Cambridge, Cambridge University Press), 315–56. https://www.ipcc.ch/site/assets/uploads/2018/03/ar4_wg2_full_report.pdf

Nkomwa, E. C., Kalanda Joshua, M., Ngongondo, C., Monjerezi, M. & Chipungu, F. (2013), 'Assessing Indigenous Knowledge Systems and Climate Change Adaptation Strategies in Agriculture: A Case Study of Changaka Village, Chikhwawa, Southern Malawi', *Journal of Physics and Chemistry of the Earth*, 67: 164–72. https://doi.org/10.1016/j.pce.2013.10.002

Ntale, H. K. & e Gan, T. Y. (2003), 'Drought Indices and their Application to East Africa', *International Journal of Climatology*, 23: 1335–57. https://doi.org/10.1002/joc.931

Nyong, A., Adesina, F. & Osman-Elasha, B. (2007), 'The Value of Indigenous Knowledge in Climate Change Mitigation and Adaptation Strategies in the African Sahel', *Mitigation and Adaptation Strategies for Global Change*, 12(5): 787–97. https://doi.org/10.1007/s11027-007-9099-0

Okyere, C. Y, Yacouba, Y. & Gilgenbach, D. (2012), 'The Problem of Annual Occurrences of Floods in Accra: An Integration of Hydrological, Economic and Political Perspectives', Interdisciplinary Term Paper, Universitat Bonn.

Okyere, C. Y., Yacouba, Y. & Gilgenbach, D. (2013), 'The Problem of Annual Occurrences of Floods in Accra: An Integration of Hydrological, Economic and Political Perspectives', *Theoretical and Empirical Researches in Urban Management*, 8: 45–79.

Paeth, H., Born, K., Podzun, R. & Jacob, D. (2005), 'Regional Dynamic Downscaling Over West Africa: Model Evaluation and Comparison of Wet and Dry Years', *Meteorologische Zeitschrift*, 14: 349–67. https://doi.org/10.1127/0941-2948/2005/0038

Pareek, A. & Trivedi, P. C. (2011), 'Cultural Values and Indigenous Knowledge of Climate Change and Disaster Prediction in Rajasthan, India', *Indian Journal of Traditional Knowledge*, 10(1): 183–9.

Punjabi, Bharat, Johnson, Craig A. (2018), 'The Politics of Rural–Urban Water Conflict in India: Untapping the Power of Institutional Reform', *World Development*, in press. https://doi.org/10.1016/j.worlddev.2018.03.021

Rice, James & Steinkopf Rice, Julie (2012), 'Debt and the Built Urban Environment: Examining the Growth of Urban Slums in the Less Developed Countries, 1990–2010', *Sociological Spectrum: Mid-South Sociological Association*, 32(2): 114–37. https://doi.org/10.1080/02732173.2012.646154

Roncoli, C., Jost, C., Kirshen, P., Sanon, M., Ingram, K. T.,Woodin, M., Somé, L., Ouattara, F., Sanfo, B. J., Sia, C., Yaka, P. & Hoogenboom, G. (2009), 'From Accessing to Assessing Forecasts: An End-to-end Study of Participatory Climate Forecast Dissemination in Burkina Faso (West Africa)', *Climatic Change*, 92: 433–60. https://doi.org/10.1007/s10584-008-9445-6

Satterthwaite, D. (2008), 'Climate Change and Urbanisation: Effects and Implications for Urban Governance', United Nations Secretariat, New York.

Satterthwaite, D., Huq, S., Reid, H., Pelling, M. & Romero Lankao, P. (2007), 'Adapting to Climate Change in Urban Areas: the Possibilities and Constraints in Low- and Middle-income Nations', Human Settlements Discussion Paper, International Institute for Environment and Development, London. https://pubs.iied.org/10549IIED/

SEDAC (2017), 'IPCC Fifth Assessment Report (AR5) Observed Climate Change Impacts Database, Version 2.01', NASA Socioeconomic Data and Applications Center, Palisades, NY. https://sedac.ciesin.columbia.edu/data/set/ipcc-ar5-observed-climate-impacts-v2-01

Toulin, C. (1986), 'Drought and the Farming Sector: Loss of Farm Animals and Post-drought Rehabilitation', Alphan—African Livestock Analysis Network 10. https://core.ac.uk/download/pdf/132634764.pdf

UNDESA (2019), *World Economic Situation and Prospects 2019*, United Nations Department of Economic and Social Affairs (New York, United Nations). https://www.un.org/development/desa/dpad/wp-content/uploads/sites/45/WESP2019_BOOK-web.pdf

UNISDR (2009), 'Terminology on Disaster Risk Management', available at https://www.unisdr.org/we/inform/terminology

Whyte, K. P. (2013), 'On the Role of Traditional Ecological Knowledge as a Collaborative Concept: A Philosophical Study', *Ecological Processes*, 2: 2–7. https://doi.org/10.1186/2192-1709-2-7

Yankson, P. W. K., & Bertrand, M. (2012), 'Challenges of Urbanization in Ghana', in E. Ardayfio-Schandorf, P. W. K. Yankson & M. Bertrand (eds), *The Mobile City of Accra: Urban Families, Housing and Residential Practices* (Dakar, Council on the Development of Social Science Research in Africa).

Zoleta-Nantes, D. (2000), 'Flood Hazard Vulnerabilities and Coping Strategies of Residents of Urban Poor in Metro Manila, The Philippines', in D. J. Parker (ed.), *Floods Volume I* (Abingdon, Routledge).

Notes on the authors:

Raymond Kasei is Head of the Climate Change and Food Security Department of the University for Development Studies, Tamale, Ghana. He is a modeller and climatologist with wide experience as an environmental and social scientist who combines subject matter expertise in hydrology, climate and social change, gender and modelling for research, teaching and development.
rakasei@gmail.com

Recent publications:

Kasei, R. A., Daniel, T. B., Benjamin, D. D. & Kaba, N. C, (2019), 'Impact of Climate Change and Farmers' Perspectives to Food Security and Policy Implications for Adaptation in Ghana' in *Sustainable Development in Africa: Case Studies* (Denver, CO, Spears Media Press), Chapter 4, 65–92.

Dovie B. K. D & Kasei, R. A., (2018), 'Hydro-climatic Stress, Shallow Groundwater Wells and Coping in Ghana's White Volta Basin', *Science of the Total Environment*, 636: 1268–78. https://doi.org/10.1016/j.scitotenv.2018.04.416

Miriam Kalanda-Joshua is a Senior Lecturer in Geography, University of Malawi, Chancellor College, Geography and Earth Sciences Department. Her research interests and experiences are in environmental studies, agricultural geography, food security, water resources management, climate change adaptation, indigenous knowledge systems, rural development and policy analysis.

Recent publications:

Andersson Djurfeldt, A., Djurfeldt, G., Hillbom, E., Isinika, A. C., Kalanda-Joshua, M. D., Chilwizhi Kaleng'a, W., Kalindi, A., Msuya, E., Mulwafu, W. & Wamulume, M. (2019), 'Is There Such a Thing as Sustainable Agricultural Intensification in Smallholder-based Farming in Sub-Saharan Africa? Understanding Yield Differences in Relation to Gender in Malawi, Tanzania and Zambia, *Development Studies Research*, 6(1): 62–75, https://doi.org/10.1080/21665095.2019.1593048

Joshua, M., Ngongondo, C., Monjerezi, M., Chipungu, F. & Malidadi, C. (2017), 'Relevance of Indigenous Knowledge in Weather and Climate Forecasts for Agricultural Adaptation to Climate Variability and Change in Malawi', in P. L. Mafongoya & O. C. Ajayi (eds), *Indigenous Knowledge Systems and Climate Change Management in Africa* (Wageningen, CTA), Chapter 9, 185–218.

Daniel Tutu Benefor is a Principal Programme Officer at the Environmental Protection Agency (EPA) of Ghana. His research includes: Tools for Climate Change Impact, Vulnerability and Adaptation Assessment, Carbon Financing and CDM Project Development, Geo-information for Sustainable Forest Management, Research and Project Proposal Writing Skill, Tools for Greenhouse Gas Mitigation Assessment and GIS and Remote Sensing for Environmental Modelling.

Recent publications:

HEI Household Air Pollution–Ghana Working Group (2019), 'Contribution of Household Air Pollution to Ambient Air Pollution in Ghana', Communication 19, Health Effects Institute, Boston, MA.

Fourth National Greenhouse Gas Inventory Report (2018), Environmental Protection Agency, Ghana.

Tutu Benefoh, T., Villamor, G.B., van Noordwijk, M., Borgemeister, C., Asante, A. W. & Asubonteng, K. O., 'Spatial Patterns of Soil Nitrogen, Phosphorous and Organic Carbon in Cocoa-forest Landscape of Ghana' (in press).

To cite the article: Raymond Abudu Kasei, Miriam Dalitso Kalanda-Joshua and Daniel Tutu Benefor (2019), 'Rapid urbanisation and implications for indigenous knowledge in early warning on flood risk in African cities', *Journal of the British Academy*, 7(s2): 183–214.
DOI https://doi.org/10.5871/jba/007s2.183

Journal of the British Academy (ISSN 2052–7217) is published by

The British Academy

10–11 Carlton House Terrace, London, SW1Y 5AH
www.thebritishacademy.ac.uk