Ghana

Climate Risk Assessment for Subnational Adaptation

LoCAL
LOCAL CLIMATE ADAPTIVE LIVING FACILITY

KEI Korea Environment Institute

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Unlocking Public and Private Finance for the Poor

Ghana

Climate Risk Assessment for Subnational Adaptation

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foreword

The recent Climate Adaptation Summit 2021 strongly urged working towards climate adaptation. This collaboration involves governments, private sector organizations, indigenous peoples, youth, other civil society stakeholders and subnational actors. The design and implementation of effective adaptation activities requires an understanding of climate-related risks, so people know to what they are adapting. For a long time, climate policy has been articulated at an international or national scale which is far removed from the people affected at a local level. Local-level risk analysis and tailored adaptation actions are critical to ensure the effective management of the effects of climate change.

This climate risk assessment has been prepared as part of the Local Climate Adaptive Living Facility (LoCAL) initiative of the United Nations Capital Development Fund (UNCDF), which was launched in Ghana in 2015. LoCAL is a unique mechanism that supports local governments in tackling the adverse effects of climate change. It does so by providing financial support to local authorities in developing countries to assist their climate change adaptation activities in line with the Paris Agreement and the Sustainable Development Goals.

A major component of the LoCAL programme is analysis of climate risks at the local level. This study explores risks associated with the agriculture, water and health sectors that districts may face. Through an analysis of existing data and the modelling of climate projections, this study provides a snapshot of how future climate changes may affect the country's districts. Severity will differ, with higher maximum temperatures expected in the North and more rainfall along the coast. These insights into localized threats aim to provide a foundation for the development of tailored adaptation actions.

While this report presents an assessment of climate risk in Ghana, it is our hope that similar studies can be undertaken in other countries under the LoCAL mechanism to systematically support the implementation of climate adaptation activities. The Korea Environment Institute (KEI) and UNCDF have collaborated to this end.

Dr. Jeyong Yoon
President, Korea Environment Institute

acronyms

CVI	Climate Variability Index
GDP	gross domestic product
KEI	Korea Environment Institute
km^2	square kilometre
LoCAL	Local Climate Adaptive Living Facility
mm	millimetre
RCP	representative concentration pathway
UNCDF	United Nations Capital Development Fund

Because of climate change, Ghana is facing increased pressure on water, reduced yields leading to more poverty and food insecurity, and the loss of national revenue from cash crops such as cocoa.

– LoCAL
https://www.uncdf.org/local/ghana

1 introduction

This climate risk assessment has been prepared by the United Nations Capital Development Fund (UNCDF) and the Korea Environment Institute (KEI) as part of the Local Climate Adaptive Living Facility (LoCAL) initiative which was launched in Ghana in 2015. The study analyses the ways in which climate change is projected to affect districts in Ghana. Climate change is often characterized by warming temperatures and increases in rainfall. However, the impacts on populations can be better managed by focusing on addressing the socioeconomic systems that generate people's vulnerability to climate change (Wisner et al., 2004).

Vulnerability reflects the inability of people to access means of protection. As identified by the INFORM Risk Index, the greatest contributor to Ghana's risk ranking is its lack of coping capacity[1]. This stems from problems pertaining to governance, institutions and infrastructure.

Climate change has increased the severity and frequency of extreme weather events and temperature and rainfall variability. This in turn exacerbates many sustainable development issues related to freshwater shortages, including food insecurity, health, employment, livelihoods, gender equality, migration, poverty, and inequality, among others. This study seeks to understand exactly what risks are most likely to threaten individual districts in Ghana, and to support the future planning of climate adaptation activities that work to reduce the vulnerability of exposed populations to those risks.

In Africa, climate risks focus on the agricultural industry, which is the economic backbone of many livelihoods and is particularly sensitive to climate threats. The Sahel and West Africa have been identified as hot spots of climate impacts for future warming scenarios. Ghana has been ranked as the 70th most vulnerable country in the world, and the 74th least ready country to improve resilience to climate change and other global challenges by the Notre Dame Global Adaptation Initiative[2]. Ghana is expected to experience a rise in sea level, an increase in droughts, higher temperatures and more erratic rainfall (USAID, 2017). Northern areas are likely to experience more incidences of drought; low-lying coastal communities and ecosystems in the south will be more significantly affected by sea level rise.

To address these threats, in 2015 Ghana published its intended nationally determined contribution (INDC) under the United Nations Framework Convention on Climate Change (Republic of

[1] Source: 2020 Ghana Country Risk Profile, INFORM, Disaster Risk Management Knowledge Centre, European Commission.

[2] Source: Ghana Country Profile, ND-GAIN.

Ghana, 2015). Adaptation policy actions were presented in alignment with six priority sectors: agriculture and food security, sustainable forest resource management, resilient infrastructure in built environment, climate change and health, water resources, and gender and the vulnerable.

Although climate change threats may be similar across Ghana, their impacts will vary between regions and districts[3], affecting different sectors, stakeholders and processes in different ways. These variations justify the need to establish a coherent climate risk assessment at the district level.

Due to time constraints, this study conducts a climate risk assessment of three priority sectors – **agriculture**, **water** and **health**. Vulnerability indicators have been selected for each sector to provide an overview of the level of risk to districts from each sector due to climate change.

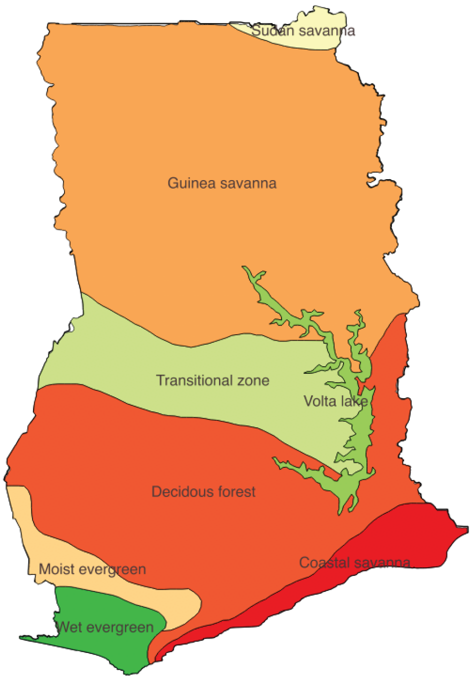
[3] Ghana is presently organized into 16 regions with 260 districts. As this division was ongoing at the time of this study, this report references the 173 districts that existed in 2010. See Ghana: Administrative Division on the City Population website.

2 context

PHYSICAL GEOGRAPHY

Ghana has a wide range of land and climate structures spread across eight ecological zones. These experience different rainfall patterns and varying lengths and severities of dry seasons (figure 2.1). In general, rainfall decreases from the South to the North, resulting in more severe dry seasons in the North. Ghana is projected to have an average temperature rise of between 1° C and 3° C by 2060, alongside a rise in sea levels and changes in seasonality (World Bank Group, 2018).

FIGURE 2.1 **Ghana's ecological zones**



SOURCE: Appiah, Osman and Boafo (2014).

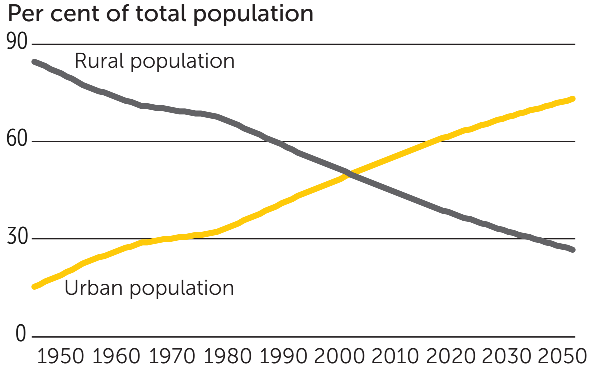
The northern regions are expected to experience accelerating desertification which may cripple the climate-sensitive agricultural industry. Ripple effects will flow through the Ghanaian economy, as agriculture is a key source of income, employment, food security and export earnings. Farmers are susceptible to shocks such as flash floods, seasonal variations in rainfall and long-term trends such as increases in average temperature. Given this, Ghana must accelerate the creation and implementation of climate adaptation and mitigation policies to protect its people by minimizing the potential harmful impacts of climate change.

POPULATION AND URBANIZATION

In the last 60 years, the population of Ghana has steadily become more urbanized. In 2021, 56 per cent of the population was urban (GSS, 2021); this is expected to rise to 73 per cent by 2050 (figure 2.2).

Almost half of the urban population increase between 2010 and 2021 (47.8 per cent) has been

FIGURE 2.2 **Shift in Ghana's rural and urban populations, 1950–2018, and projected to 2050**



SOURCE: United Nations, World Urbanization Prospects 2018.

in the Greater Accra and Ashanti regions. The urban population distribution varies by region, with the largest percentage in the Greater Accra region (91.7 per cent) and the lowest in the Upper East region (25.4 per cent) (GSS, 2021).

Urbanization has in part been driven by large-scale rural-to-urban migration. This migration stems from an array of economic, social and cultural factors, such as a desire for better employment and access to basic social amenities and services (Enu, 2014; GSS, 2014). Migration is significant to any analysis of the impacts of climate change on a population. Local changes in environmental factors – a reduction in soil fertility, food security and health security – may prompt a household to migrate (Jarawura and Smith, 2015).

The risk of climate change affecting Ghana's population stems in significant part from the vulnerability of the population. Vulnerability exists when an exposed system – people, livelihoods and assets – can be adversely affected by hazards, and is composed of sensitivity and capacity (Birkmann, 2006). The Paris Agreement acknowledges that inequities are a key driver of vulnerability. The eradication of inequities is one of the strategies that can reduce vulnerability to climate impacts, increase adaptive capacity and reduce climate risks (UN, 2015).

Many climate change studies focus predominantly on the biophysical and environmental impacts of elements such as precipitation and temperature. In contrast, **adaptation activities** focus on improving adaptive capacity and reducing vulnerability. This section explores some of the social aspects of vulnerability that may be present at the district level in Ghana, and therefore impact how localized populations are affected by and adapt to climate change.

People whose basic needs are satisfied – their human rights are protected and they enjoy provision of services including but not limited to housing, income, food security, education, water and sanitation, energy and communications – are expected to have a larger capacity to respond to shocks of any kind (economic, environmental or other) (O'Brien and Holland, 1992). The satisfaction of these basic needs can be considered a baseline from which to analyse vulnerability.

Often, poverty and lack of wealth affects the extent to which basic needs are met. Poorer people are more likely to live in hazard-prone locations and more likely to have more immediate priorities than investing in adaptation measures (Adger, 2003). Research shows a correlation between vulnerability and low literacy rates in the Sudan Savannah and Guinea Savannah ecological zones in Ghana. In 2016, 59 per cent and 55 per cent of households in Sudan Savannah and Guinea Savannah, respectively, had not obtained any formal education (Dumenu and Obeng, 2016). Illiteracy significantly limits the ability to access climate change information that would support them to act to mitigate, adapt and cope with the impacts of climate change. Illiteracy also affects people's ability to engage in livelihood activities that are not climate-dependent, and therefore stifles income-diversification options (Eriksen et al., 2007).

Alongside basic needs, vulnerability to climate is affected by connectivity, both technological and physical. Access to reliable transportation throughout the year enables rural populations to access formal markets to sell excess produce and livestock and to engage in other income-generating activities (Adger, 2003). Conversely, lack of access can isolate remote communities and increase vulnerability. Increasingly, mobile phone and internet use are creating opportunities for information systems that can keep the population informed of climate threats or impacts in a timely manner.

Other intersecting and prevalent types of vulnerability stem from dependency; gender inequalities; and discrimination on the basis of age, disability, ethnicity, religion and other factors. Female-headed households often have more difficulty recovering from the impacts of environmental hazards due to employment limitations, lower wages and family care responsibilities (Eriksen et al., 2007). In Ghana, women depend more on agricultural work and have limited access to capital and property, making it difficult for female-headed households to diversify. Through the implementation of climate change adaptation activities, local governments have the opportunity to foster a shift from the current technocratic approach to adaptation to one that places forms of social inequality at the centre of adaptation actions. A small step towards doing this is to ensure that gender-based issues are analysed in climate change vulnerability and risk assessments, and integrated in adaptation activities.

People have capacities to improve their own lives and well-being. One way these capacities can be utilized is to effectively engage with communities to ensure their knowledge is used to inform strategies, planning and adaptation processes. Meaningful dialogues should be facilitated to promote both the interlinkage between traditional forms of knowledge and scientific knowledge so policymakers are able to promote evidence-based adaptation measures.

CLIMATE-RELATED POLICIES

The government created the **Ghana Shared Growth and Development Agenda I and II (GSGDA 2010–2017)**, which outlines the framework Ghana seeks to follow to achieve its long-term social and economic goals as set out in the Ghana Vision 2020. The document demonstrates the country's resolve to increase mainstreaming of climate change into its development agenda; climate change is given due consideration in all thematic areas. The policy document acknowledges that without acting on climate change, Ghana cannot achieve its development goals.

The **Ghana National Climate Change Policy (NCCP 2013)** prioritizes five policy themes:

- Agriculture and food security
- Disaster preparedness and response
- Natural resource management
- Equitable social development
- Energy, industrial and infrastructural development

Within these, it identifies 10 strategic focus areas which map out the key challenges faced, policy objectives and policy actions to achieve the objectives. Examples of policy actions suggested are the promotion of capacity building for farmers and fishers to build awareness on climate issues, document and promote the use of indigenous knowledge, and promote agricultural diversification. The NCCP was developed from the National Climate Change Policy Framework: Ghana Goes for Green Growth (G4) discussion document.

The **National Climate Change Adaptation Strategy (NCCAS)** was released in 2012 and applies to the period from 2010 to 2020. The strategy's overarching goal is 'to increase Ghana's resilience to climate change impacts now and in the future' (CC DARE, 2012). To achieve this goal, the National Climate Change Adaptation Strategy proposes five objectives and suggests a number of interventions in eight key areas, which are all geared towards reducing vulnerability and increasing resilience to climate change impacts.

Ghana has also developed the **Climate Change Masterplan 2015–2020** to guide future development planning and bring together national adaptation priorities.

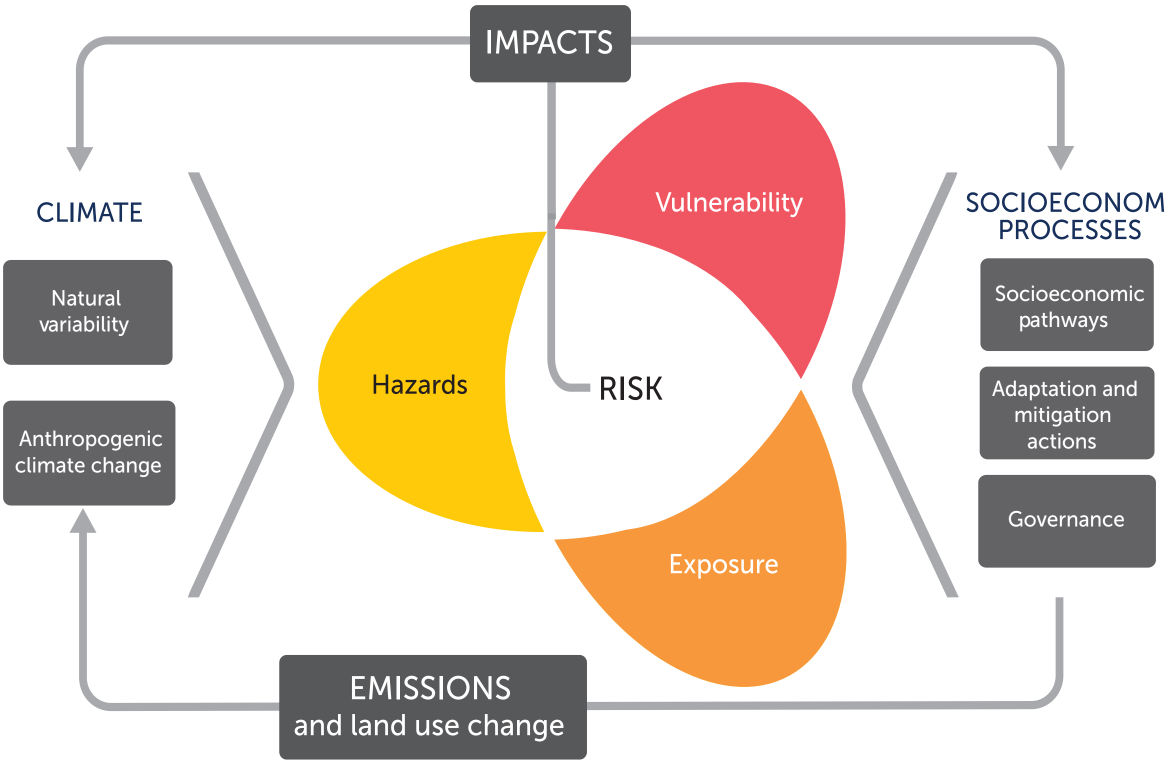
3 climate risk

Risk follows from three factors: **hazards**, **exposure** and **vulnerability**. Often, risk is represented as the probability of a hazard occurring multiplied by the impacts it will have given current or future levels of exposure and vulnerability. All three elements – hazards, exposure and vulnerability – must be present to constitute a risk to a person, livelihood or asset.

This conceptualization of risk aligns with that outlined by the Intergovernmental Panel on Climate Change (IPCC) as illustrated in figure 3.1.

In this report, hazards are defined as projected climate changes that will affect temperature, precipitation and drought. These changes are analysed in detail in the next subsection. Three

FIGURE 3.1 **Interrelations between components of climate risk**



SOURCE: IPCC (2014).

priority sectors – agriculture, water and health – have been selected for analysis. For each, an indicator of vulnerability has been selected as shown in table 3.1. Exposure is measured by population density for all sectors, districts and subsequent analysis. For more detail on the methodology for the climate risk assessment, see annex A.

HAZARDS

This subsection presents the results of analysis on how hazards are projected to affect districts. The hazards analysed are the variability of **temperature** (average, maximum and minimum temperatures) and rainfall (**precipitation**) under an RCP 6.0 scenario[1]. For precipitation, two specific indicators were analysed: (i) the total expected decrease in rainfall amounts and (ii) the percentage of rainfall reduction expected in the 2031–2040 period compared to the 2011–2020 period. Variability is an important factor, as the more variable temperature and rainfall are, the less predictable they are, and the more difficult it is to prepare for or adapt to them.

The subsection also presents findings from a **Climate Variability Index (CVI)** analysis of climate projections based on changes in climate stressors applied at the district level in order to assess which districts will be most at risk (for more on the CVI, see annex B). Based on the projections to 2031–2040 concerning temperature increases as well as rainfall reduction, the CVI has been used to identify those districts where the variability of temperature and rainfall shows greater increased or decreased values; based on this, **hot spot districts** are identified for each of the analysed variables.

[1] RCP (representative concentration pathway) 6.0 is the most widely accepted for carbon dioxide emissions scenario for projecting future risks in the global community. It correlates to a 2.2°C increase in temperature.

TEMPERATURE

Reflecting the increase in greenhouse gas concentrations, the average annual temperature in Ghana has increased by 0.88°C from 1981–2010 to 2011–2020. **Ghana is projected to encounter an average temperature rise of another 0.28°C by the decade 2031–2040 under an RCP 6.0 scenario.** The highest temperature increase is projected for the month of January, which is expected to increase by an average of 1.0°C. A rise of 1.0°C is critical and is capable of making certain crops and species infeasible. This is due not only to the rise in temperature but also because such increases bring on a faster spread of pests, drier conditions and increased pressure on water resources.

For the decade 2011–2020, figure 3.2a shows average temperatures for each month across Ghana. The data underlying this image were downscaled to obtain average temperatures for each district, which are displayed figure 3.2b.

A greater amount of change in average temperature is prevalent in the north of Ghana, as illustrated in the figure 3.3, which presents the CVI for temperature change. These maps show the expected increases in average, maximum and minimum temperatures from the period 2011–2020 to 2031–2040.

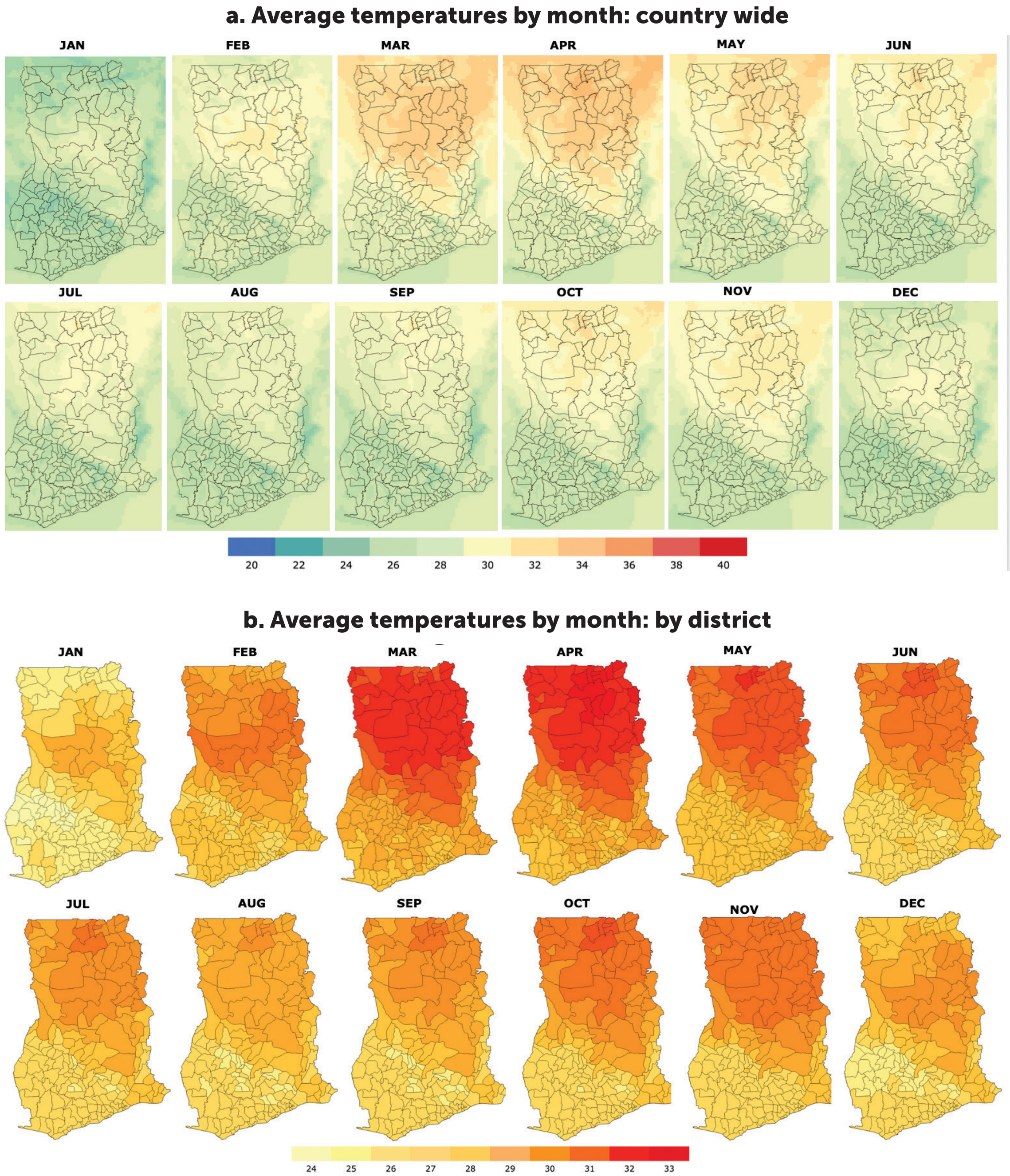
The average temperature of the Northern region is projected to rise by 2.1°C by 2031–2040 from a baseline of 1981–2010, while the Upper West and Upper East regions are projected to have average temperature rises of 2.2°C and 1.8°C, respectively. Because the Northern region displays the highest projections for maximum temperature increase and low to medium projections for minimum temperature increase, temperature variability will be significant in the Northern region. Climate change may therefore lead to erratic temperatures in the north, making it more difficult for farmers to tend their crops in typical cycles. Further, biodiversity may be affected.

TABLE 3.1 **Key sectors and associated risks analysed in this report**

Sector	Climate risk	Vulnerability indicator	Unit
Agriculture	Risk of reduction in agricultural productivity	Household agricultural dependency	% of households dependent on agriculture
Water	Risk of reduction in water availability	Access to an unim-proved source of water	% of households that can access an unimproved source of water
Health	Risk of increase in malaria incidence	Infant mortality[1]	Number of cases of infant mortality

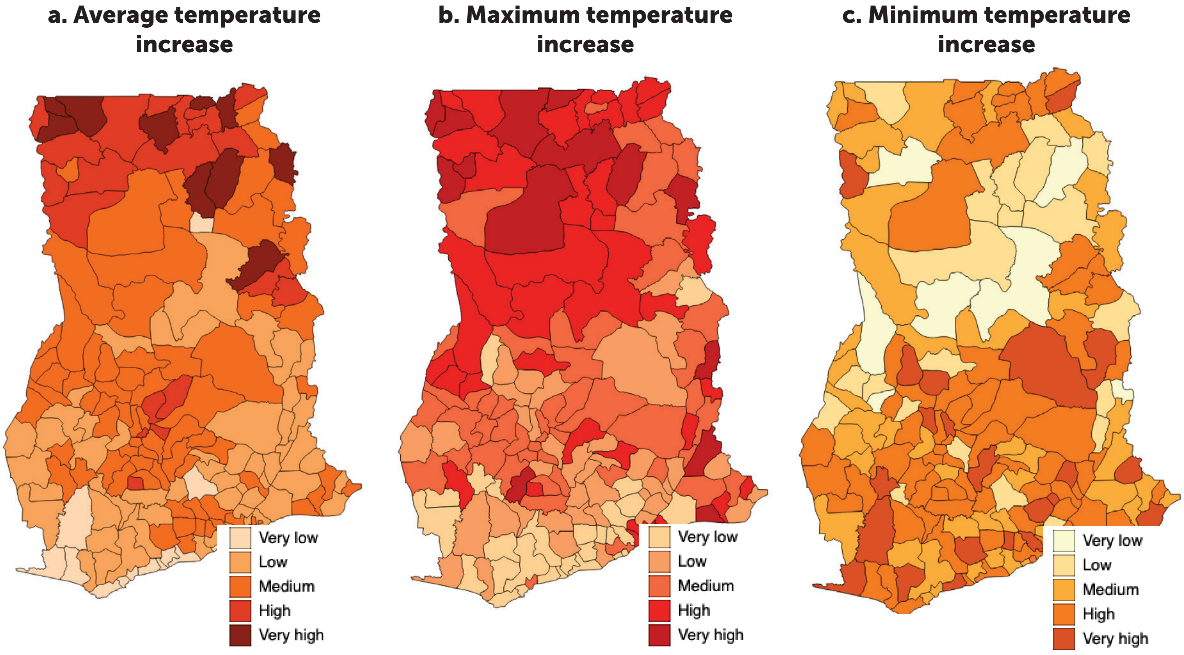
[1]An infant is defined as a child under the age of five.

FIGURE 3.2 **Projections of monthly average temperature for 2011–2020 (° C)**



SOURCE: KEI future projections (RCP 6.0).
NOTE: Data were downscaled to obtain monthly average temperature by district.

FIGURE 3.3 **Climate Variability Index by district: temperature**



PRECIPITATION

Projections of precipitation are less certain than those of temperature. The projections from this study have been irregular, showing a decrease in average rainfall for the decade 2031–2040, except for July and August, when average rainfall increases (figure 3.4).

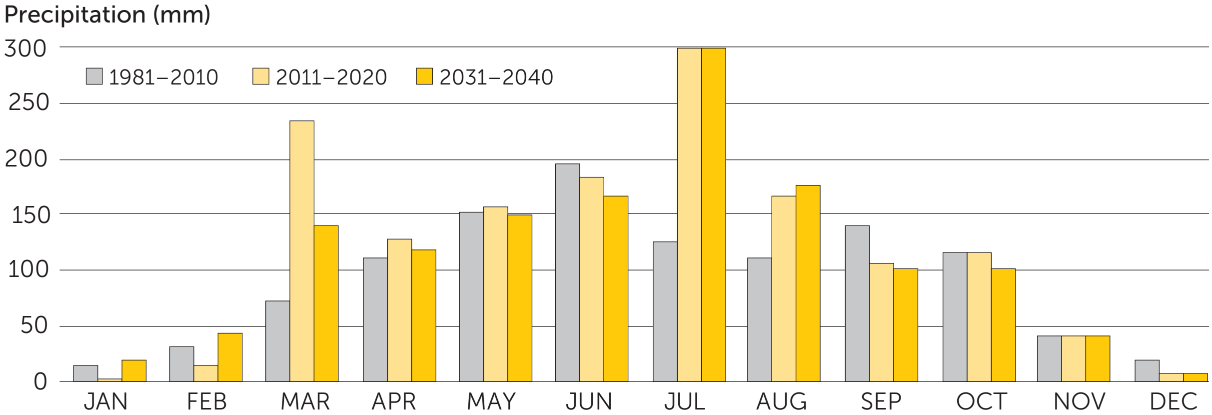
From the baseline period of 1981–2010 to 2011–2020 and to 2031–2040, the annual average precipitation decreases slightly, by 86 mm. However, regional analysis shows rainfall averages increasing in the decades 2011–2020 and 2031–2040, with only the Volta region experiencing an average rainfall decrease (figure 3.5).

Historically, Ghana has a tropical climate with a single rainy season in the north (modal), and two rainy seasons in the south (bimodal). The northern peak rainy season is usually in July and August. In the south, the first peak is in May and June, and the second in October. The projections that show rainfall increases in March, July and August suggest a shift in the bimodal rainy season, moving it earlier in the calendar year and shortening the season.

Figure 3.6 presents the CVI analysis for precipitation, showing the expected reduction in total precipitation (figure 3.6a) and the percentage of precipitation reduction (figure 3.6b) from the period 2011–2020 to 2031–2040.

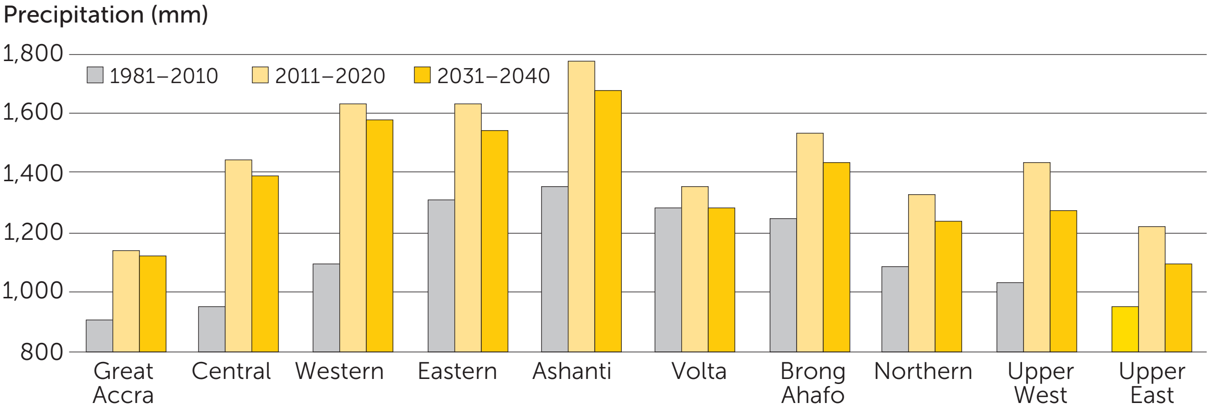
As was the case in analysing temperature change, a greater amount of precipitation reduction is expected in the north of Ghana. The southwest and central region districts (Ashanti, Western, Central Eastern and Brong Ahafo) are expected to experience higher rainfall. A handful of districts in the Upper West, Upper East and Brong Ahafo regions are expected to experience very high reductions in rainfall. Rising temperatures and declining rainfall will put the northern districts at greater risk of drought. If this pattern persists, desertification can be expected to accelerate.

FIGURE 3.4 **National average monthly precipitation**



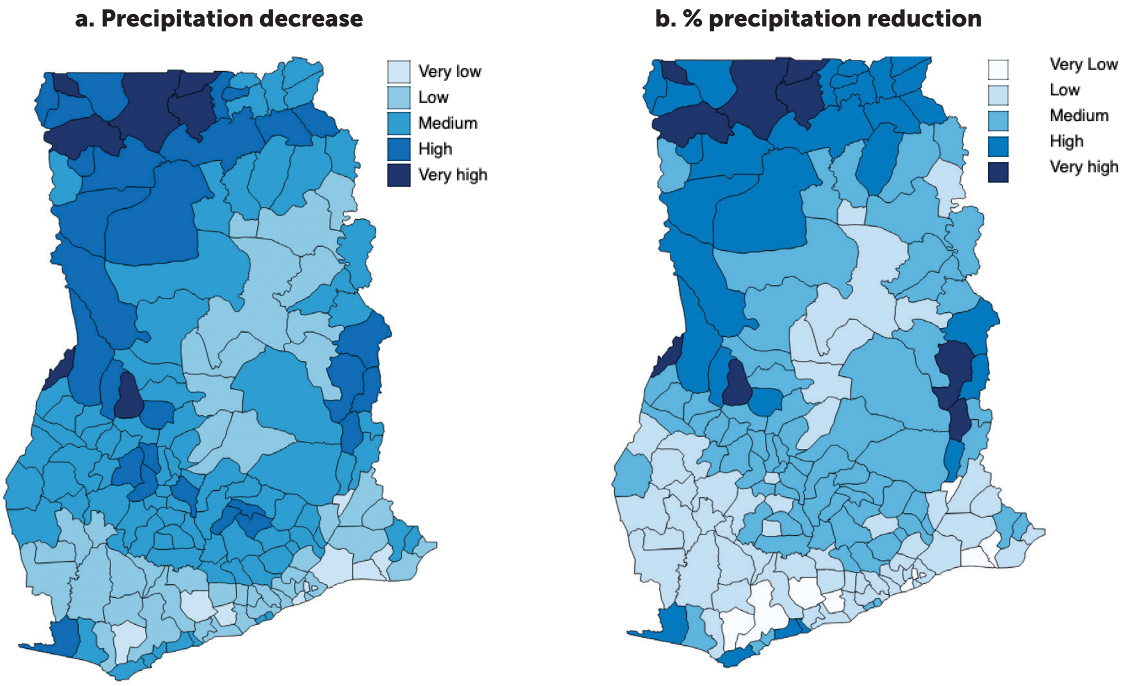
SOURCE: KEI future projections (RCP 6.0).

FIGURE 3.5 **Average precipitation by region**



SOURCE: KEI future projections (RCP 6.0).

FIGURE 3.6 **Climate Variability Index by district: precipitation**

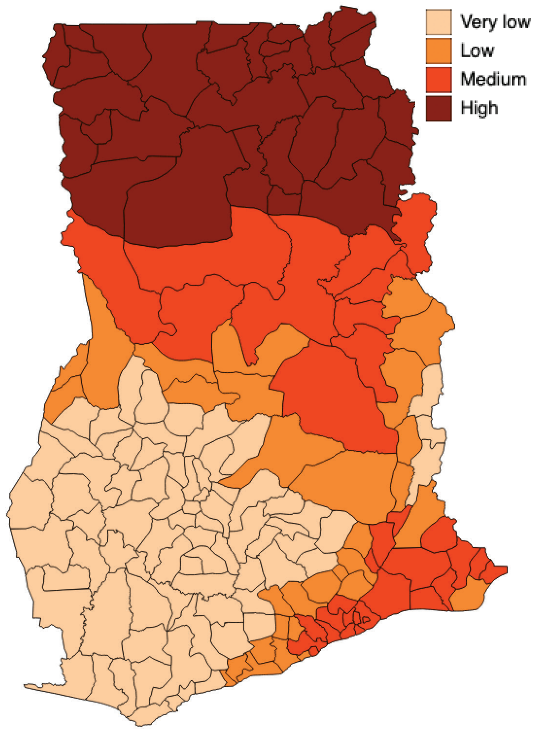


DROUGHT

Drought is a secondary climate stressor that is driven by both climate conditions and social and economic stressors. Through its impact on precipitation and temperature, climate change is predicted to increase the severity and length of future droughts in Ghana. Many climatic models predict regional drying by 2100. When rain falls less frequently, less water is retained within the watershed and more is lost to storm water runoff. As such, annual rainfall quantity and distribution affect aridity and drought. Similarly, higher temperatures increase soil evaporation and transpiration (also known as evapotranspiration), which leads to drier soils and vegetation.

In Ghana, national and local drought and flood risk assessments were performed in 2014 under the Community Resilience through Early Warning (CREW) programme supported by the United Nations Development Programme. The drought risk assessment identified drought risk levels by district for the year 2010. This report has used this drought risk assessment to define a Drought Hazard Index, which highlights the districts with the greatest threat of drought in 2010 (figure 3.7).

FIGURE 3.7 **Drought Hazard Index by district**



EXPOSURE AND VULNERABILITY SECTOR ANALYSIS

AGRICULTURE

Ghana has a rich agricultural resource base characterized by abundant land and diverse agro-ecological conditions. Agriculture is one of the key sectors within the Ghanaian economy; it utilizes 57 per cent of the country's land, and accounts for 18.3 per cent of gross domestic product (GDP) and 44.7 per cent of the labour force (CIA, 2021). While the sector's contribution to Ghana's GDP has declined since 1983 as a result of growing extractive industries, it still remains the primary source of livelihood for about 75 per cent of the rural population.

Agriculture is highly significant for the regions of Ghana, in particular the Northern and Brong Ahafo regions. Country wide, 48 per cent of Ghana's agricultural land is used for bush fallow and other uses; 28.8 per cent for unimproved pasture; 13.6 per cent for tree crops; and 9.6 per cent for annual crops (MOFA, 2017).

As climate change poses a significant threat to the agriculture sector in Ghana, many national economic growth and poverty reduction efforts have focused on improving the sector's resilience (Antwi-Agyei et al., 2018). Increased temperatures and rainfall variability are projected not only to reduce yields of cocoa, as discussed in box 3.1, but also cassava, maize and cereal crops, among others. Erratic precipitation patterns are projected to cause complete crop failures once every five years in most northern areas (Frenken, 2005). This will make it increasingly difficult for farmers to plan their growing seasons with accuracy. This, in turn, will affect food security – indirectly through effects on subsistence crops and directly through effects on cash crops. Approximately 18 per cent of Ghanaians who fall below the extreme poverty line are chronically subject to food insecurity and have agriculture-dependent livelihoods (GSS, MOFA, WFP and FAO, 2020). Table 3.2 summarizes the anticipated direct impacts of climate change on the agriculture sector and its indirect impacts on people, livelihoods and economy.

This report has illustrated how agricultural productivity will likely be reduced by climate change. To analyse the risk, agricultural dependency was chosen as an indicator for vulnerability. Figure 3.8 shows the agricultural dependency of households by district, highlighting that this is generally greater in the north of the country than in the south. The figure also provides a list of the districts with very high agricultural dependency.

Exposure, vulnerability and hazard factors can be combined into an index that identifies the districts most at risk of a reduction in their agricultural productivity. Figure 3.9 presents a map showing the geographic locations of the districts at the greatest risk of reduced agricultural productivity.

BOX 3.1 **Case study: cocoa**

Cocoa is one of Ghana's major export crops and accounts for 74 per cent of agricultural GDP and 20–25 per cent of total foreign exchange earnings (World Bank Group, 2018). The cocoa supply chain in Ghana employs 3.2 million people and over 800,000 smallholder families depend on farming cocoa for their livelihoods (Masters, Baker and Flood, 2010). Therefore, it is essential to protect cocoa crops from the impacts of climate change.

Cocoa is highly sensitive to rising temperatures and dry seasons. The trees need even temperatures between 18° and 32°C, with a constant rainfall of between 1,000 and 2,500 mm per annum to achieve optimum yield (Anim-Kwapong and Frimponge, n.d.). Climate change will lead to an increase in temperatures and rainfall variability, which will adversely affect cocoa productivity and reduce suitable cultivation areas. Just four months of dry weather can lead to seedling mortality, reduced bean size and an increase in pest attacks (Choudhary and D'Alessandro, 2015).

A 2013 study found that most areas then suitable for cocoa production will decrease in suitability by 2050. While most areas showed a slight decrease in suitability, some, such as the Western and Brong Ahafo regions, showed larger decreases (Läderach et al., 2013).

TABLE 3.2 **Impacts of climate change on agriculture**

Issue	Hazard	Direct impact	Indirect impact
Increased intensity and variability of rainfall	• Drought • Flooding	• Loss of arable land • Increased likelihood of short-run crop failure • Decreased long-run production	• Production risks • Loss of income and livelihoods • Decline in national economic output • Poverty and food insecurity • Losses in foreign export earnings • High food price volatility
Increased intensity and variability of temperatures	• Heat waves • Sea level rise • Flooding and saline intrusion into freshwater aquifers	• Crop loss/failure, reduced yields of major staple crops: cassava, yams, plantains, maize, rice • Cacao seedling mortality • Accelerated prevalence of pests and crop diseases • Destruction of coconut plantations • Scarcity of freshwater	

SOURCES: Calzadilla et al. (2013); Cline (2007); and Mahato (2014).

WATER

Water and climate change are inextricably linked. Climate change is realized not only through droughts, floods and storms, but also through reductions in access to potable water and increases in contaminated water sources. Safe drinking water is necessary to ensure hygiene, good human health and productivity. However, access to safe drinking water fluctuates throughout the year and is unevenly distributed among regions, with the south-west having more reliable water sources than the coastal and northern regions (Yeleliere, Cobbina and Duwiejuah, 2018). Figure 3.10 shows that in 2017 only 36.4 per cent of the population of Ghana had access to safely managed drinking water services;

FIGURE 3.9 **Risk of agricultural productivity reduction**

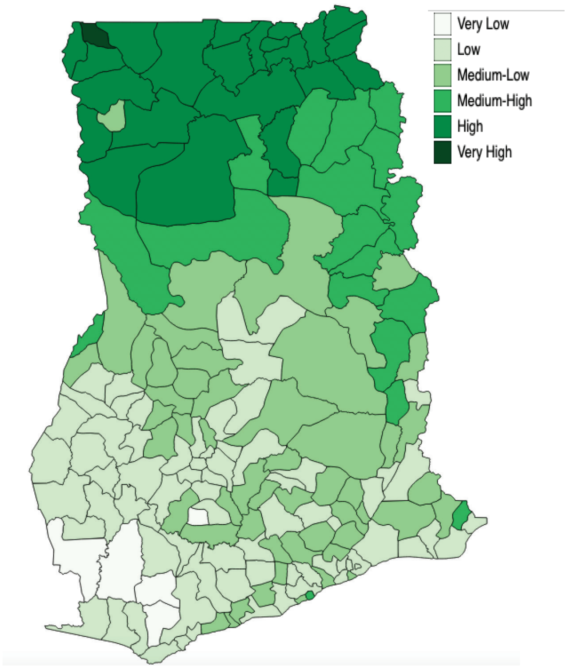
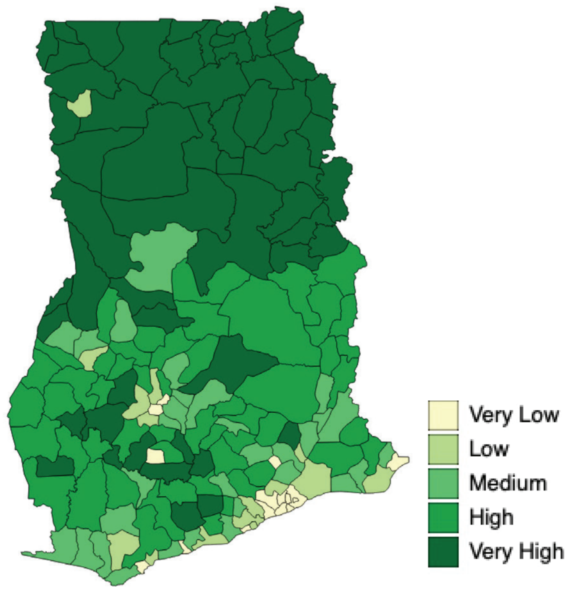


FIGURE 3.8 **Household agricultural dependency hot spots and most vulnerable districts**



Rate	ID	District	Region
1	803	Savelugu Nanton	Northern
2	826	Tolon Kumbungu	Northern
3	814	Chereponi	Northern
4	812	Karaga	Northern
5	810	Gushiegu	Northern
6	808	Sawla Tuna Kalba	Northern
7	811	Bole	Northern
8	802	Yendi	Northern
9	804	Bunkpurugu Yunyoo	Northern
10	818	Mamprusi West	Northern
11	801	Tamale	Northern
12	815	Saboba	Northern
13	825	Gonja West	Northern
14	807	Nanumba South	Northern
15	806	Nanumba North	Northern

SOURCE: Ghana Statistical Service, 2010 Population and Housing Census.

of this, 11.5 per cent were rural population and 56.5 per cent were urban population[2].

Lack of access to potable domestic water increases the risk of such diseases as diarrhoea. In Ghana, children are especially at risk of such diseases; diarrhoea causes 9 per cent of the deaths of children under the age of five (UNICEF, 2012). Even without the added pressures of climate change, the trend towards urbanization and economic growth will continue to put pressure on Ghana's water supply. In 2017, only 40 per cent of urban residents had access to piped water, compared with 80 per cent in 2000[3].

Climate impacts will affect Ghana's hydrology, and in particular, the agricultural sector. Rain-fed agriculture and livestock production depend on rainwater, which is expected to increase in variability, thereby impeding the sustainability of livelihoods, food security and nutrition. In Ghana, agriculture is also dependent on freshwater from the Volta, South-Western and Coastal river systems. Climate models project water flows in the Volta Basin to decrease by 24 per cent by 2050 and 45 per cent by 2100 (USAID, 2017). This corresponds to projections showing the annual average precipitation in the Volta region is expected to decrease by 2031–2040. Decreased river flows in the Volta Basin expose Ghana to the risk of water insecurity. Additionally, climate issues may exacerbate existing political tensions between Ghana and Burkina Faso, as Burkina Faso's withdrawal from the Volta Basin reduces the water available for hydropower in Ghana (USAID, 2017).

This section has illustrated the complexity and interlinked nature of climate impacts on water, summarized in table 3.3. Changes in water availability not only directly affect agriculture and access to potable water, but can significantly affect health and political instability, and trigger refugee flows. Further, extreme weather events such as flooding can lead to saltwater intrusion, damage to infrastructure and damage to sanitation services.

To analyse the risk of climate change diminishing water availability, a vulnerability indicator was chosen, it being the households that use an unimproved source of water. Through the data analysis conducted, Figure 3.11 shows that the use of unimproved sources of water is most prevalent in the Northern, Ashanti, Western and Volta regions. The figure includes a list of those districts that have very high usage of unimproved sources of water.

Combining the exposure, vulnerability and hazard factors for the water sector, figure 3.12 presents a map showing the geographic locations of the districts at the greatest risk of reduced water availability.

HEALTH

Adequate water, hygiene and sanitation are essential components of providing basic health services and preventing the spread of disease. Though significant evidence shows handwashing to be the most cost-effective way of preventing diarrhoeal diseases, in 2017 data showed that 17 per cent of Ghanaians had no handwashing facilities, and 42 per cent had limited facilities[4]. Figure 3.13 shows that all regions of Ghana had less than 65 per cent coverage of basic handwashing service facilities with soap and water in 2017.

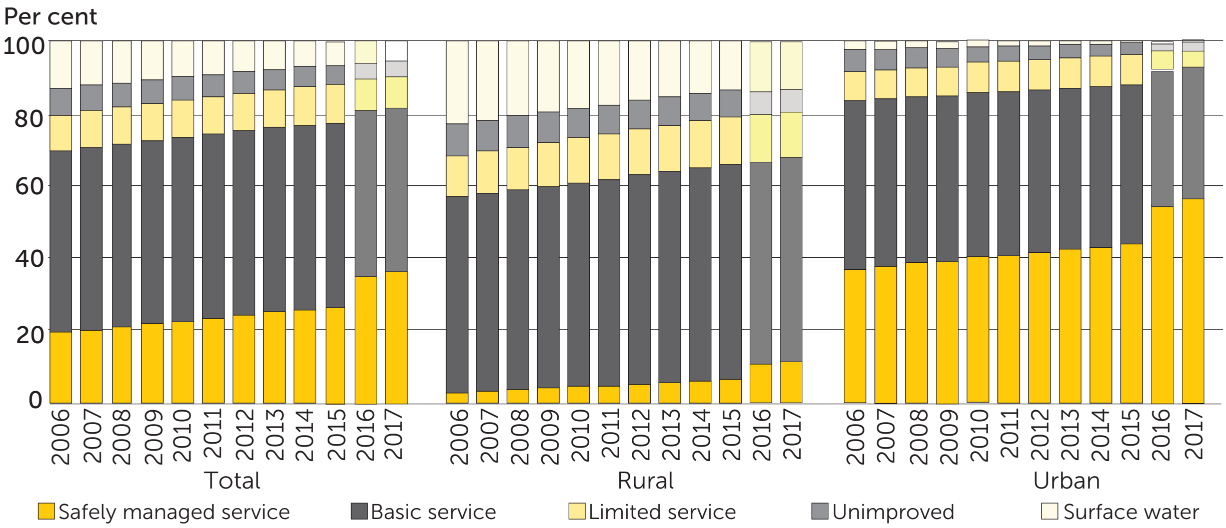
In 2015, less than 15 per cent of households in Ghana had access to basic sanitation services.

[2] Source: WHO/UNICEF Joint Monitoring Programme for Water Supply, Sanitation and Hygiene, People using safely managed drinking water services (% of population) – Ghana, 2017.

[3] Source: WHO/UNICEF Joint Monitoring Programme for Water Supply, Sanitation and Hygiene, https://washdata.org/.

[4] Source: WHO/UNICEF Joint Monitoring Programme for Water Supply, Sanitation and Hygiene, https://washdata.org/data/household#!/gha.

FIGURE 3.10 **Household drinking water service levels, 2006–2017**



SOURCE: WHO/UNICEF Joint Monitoring Programme for Water Supply, Sanitation and Hygiene, People using safely managed drinking water services (% of population) – Ghana, 2017.

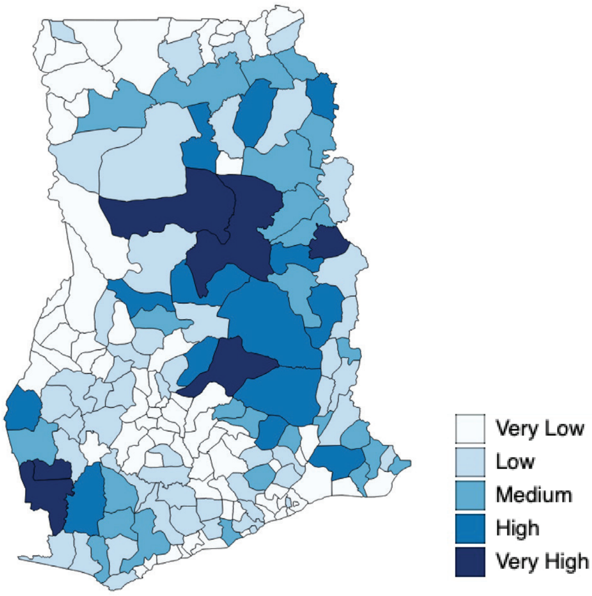
NOTE: *Safely managed:* drinking water from an improved water sources which is located on premises, available as needed and free from faecal and priority contamination; *basic:* drinking water from an improved source provided collection time is not more than 30 minutes for a roundtrip including queuing; *limited:* drinking water from an improved source where collection time exceeds 30 minutes for a roundtrip, including queuing; *unimproved:* drinking water from an unprotected dug well or unprotected spring; *surface water:* drinking water directly from a river, dam, lake, pond, stream, canal or irrigation channel.

TABLE 3.3 **Impacts of climate change on water**

Issue	Hazard	Direct impact	Indirect impact
Increased intensity and variability of rainfall	• Drought • Flooding	• Reduced river flows, particularly in Volta Basin • Reduced availability of surface and ground resources • Decrease in water quality • Contaminated water resources due to salinization	• Damage to infrastructure from flooding • Political instability • Reduced water reliability • Negative impacts on a range of sectors (food security, agriculture, industry, energy, health) • Reduced generation capacity of hydroelectric dams
Increased intensity and variability of temperatures	• Heat waves • Sea level rise • Flooding and saline intrusion into freshwater aquifers		

SOURCES: Gersonius et al. (2013); Khan et al. (2011); and USAID (2017).

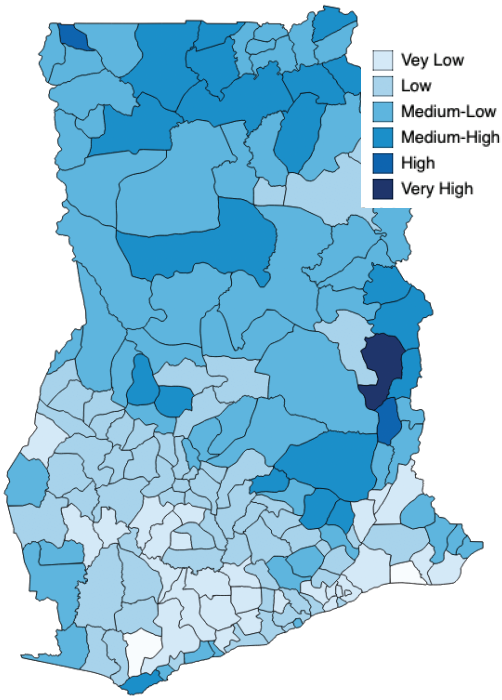
FIGURE 3.11 **Use of unimproved sources of water and district hot spots**



Rate	ID	District	Region
1	805	Gonja Central	Northern
2	610	Nkwanta North	Volta
3	311	Sefwi Akontombra	Western
4	529	Sekyere Afram Plains South	Ashanti
5	816	Gonja East	Northern
6	318	Aowin Suaman	Western
7	608	Krachi East	Volta
8	423	Kwahu North	Eastern
9	826	Tolon Kumbungu	Northern
10	813	Kpandai	Northern
11	716	Kintampo South	B. Ahafo
12	812	Karaga	Northern
13	519	Sekyere Central	Ashanti
14	714	Pru	B. Ahafo
15	411	Fanteakwa	Eastern

SOURCE: Ghana Statistical Service, 2010 Population and Housing Census.

FIGURE 3.12 **Risk of water availability reduction**

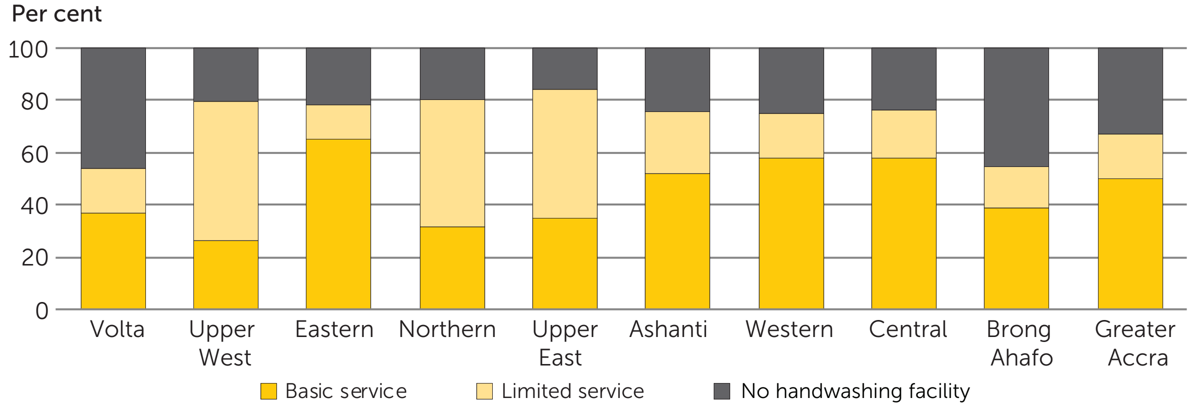


This makes Ghana one of the countries in which the lowest percentage of the population has decent toilets (Appiah-Effah et al., 2019). In 2017, 18.1 per cent of households in Ghana practiced open defecation, and this percentage rose to 50 per cent among the poorest households. This reflects the financial disparity between those who do and do not have access to sanitation services[5].

Climate change will exacerbate existing stressors on human health (table 3.4). As outlined in the previous section, water availability is expected to become increasingly less predictable, and flooding threatens to destroy water points and sanitation facilities and to contaminate water sources. Without clean water, the population is at increased risk of contracting disease. As is often the case, those expected to feel the greatest impacts on their health are those who are already vulnerable and currently live with inadequate levels of sanitation and hygiene or suffer from poor health.

[5] Source: WHO/UNICEF Joint Monitoring Programme for Water Supply, Sanitation and Hygiene, https://washdata.org/.

FIGURE 3.13 **Hygiene coverage by region, 2017/2018**



SOURCE: GSS (2018).

NOTE: *Basic service:* handwashing facility with soap and water in the household; *limited service:* handwashing facility without soap or water.

One significant health effect of climate change will be increased incidences of vector-borne diseases – in particular, malaria. In Ghana, malaria is one of the most significant public health problems and is among the leading causes of morbidity. In 2012, malaria accounted for 38 per cent of all outpatient illness, 35 per cent of all admissions and 34 per cent of all deaths of children under age five (Ghana Health Service, 2012). Approximately 3.3 million cases of clinical malaria are reported in public health facilities across Ghana each year. Over a quarter of these cases are among children under age five (USAID, 2012). The transmission of vector-borne diseases such as malaria and dengue fever depends on the presence of specific temperature and precipitation conditions that enable the development of both the parasite and the vector – the mosquito. Increased temperature of the environment in which mosquitoes breed boosts their rates of reproduction, increases the number of meals they take and prolongs their breeding season. Specific temperature ranges are also important for the development of the parasite in the mosquito. It

TABLE 3.4. **Impacts of climate change on health**

Issue	Hazard	Direct impact	Indirect impact
Increased intensity and variability of rainfall	• Drought • Flooding	• Increase in incidence of meningitis • Increased risk of guinea worm infestation • Flooding of latrines • Destroyed sanitation services • Reduction in availability of drinking water • Reduction in quality of drinking water • Increase in cases of water • Deaths and injuries	• Lower productivity • Loss of income and livelihoods • Increase in poverty • Changes in the transmission zones of mosquito-borne diseases and the people affected • Malnutrition and hunger • Altered rates of heat- and cold-related illness, especially cardiovascular and respiratory diseases
Increased temperatures and temperature variability	• Heat wave • Sea level rise • Flooding and saline intrusion	• Increase in cases of measles • Increase in incidences of malaria • Increased risk of guinea worm infestation • Increase in pathogens in water leading to increased risk of disease • Pollution and/or inundation of wells	

SOURCES: UNEP (2015); and USAID (2012).

has been shown that at a temperature of 20°C, the parasite requires 30 days to develop, but at a temperature of 25°C, only 12 days are required (Shapiro, 2017). Therefore, increased temperatures create optimal conditions for a parasite to undergo development and render a mosquito infectious.

The frequency and amount of precipitation is an indicator commonly used to approximate the formation of temporary bodies of water that may be important breeding sites. More erratic rainfall, and an increase in variability of precipitation, will make it more difficult to predict which temporary bodies of water may be breeding sites for mosquitoes.

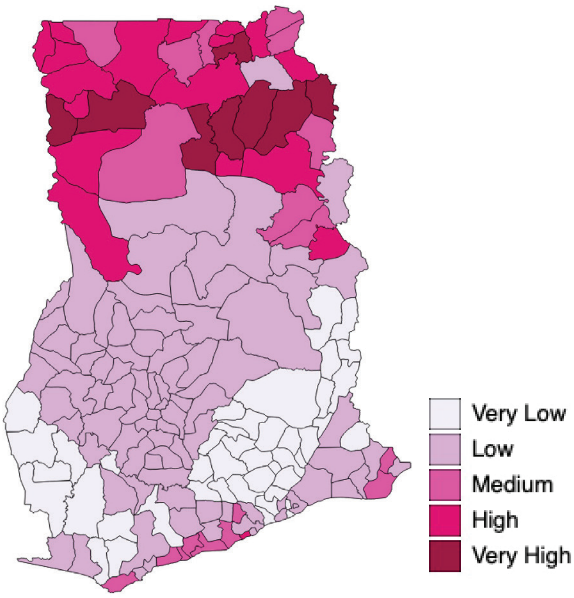
The most suitable indicator for identifying the risk of malaria is infant mortality from that disease. Because data on infant mortality from malaria were not available at the district level, overall infant mortality has been selected as a proxy. Figure 3.14 shows that higher rates of infant mortality occur in the Northern, Upper East and Upper West regions. A list of the districts that have very high and high infant mortality is also provided in the figure.

The risk index for increases in malaria was created by combining the incidences of exposure, vulnerability and hazard factors. This index highlights the districts most at risk of an increase in malaria incidences as a result of climate impacts. Figure 3.15 presents a map showing the geographic locations of the districts at the greatest risk of increased malaria incidences.

CLIMATE RISK BY DISTRICT

Many of the districts in the Northern, Upper West and Upper East regions are at very high risk of being significantly affected by climate change. Conversely, some districts in the Western region have been projected to be at very low risk of impacts from climate change. These results are consistent with projections that the north of Ghana is expected to experience large increases in temperature and major reductions in rainfall. This may lead to drought and desertification, which would severely affect the agricultural industry and food security.

FIGURE 3.14 **Infant mortality and district hot spots**



Rate	ID	District	Region
1	803	Savelugu Nanton Municipal	Northern
2	826	Tolon Kumbungu	Northern
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4	1009	Talensi Nadbdam	Upper East
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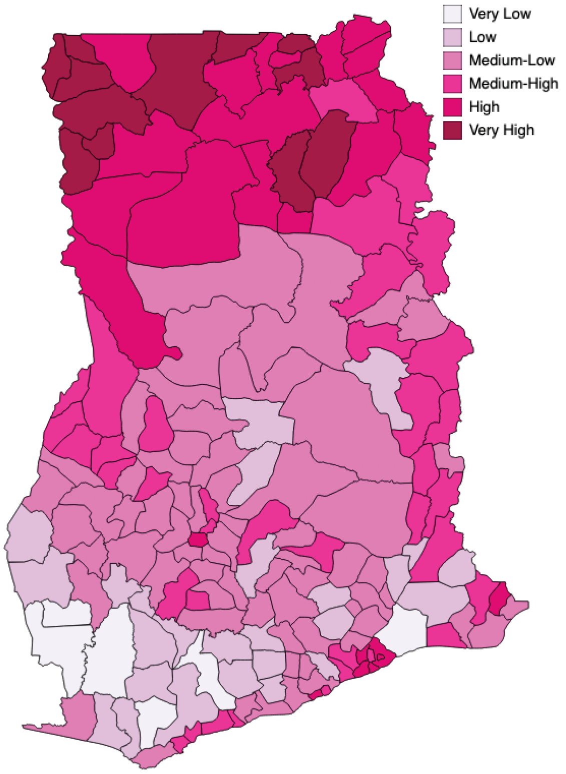
6	810	Gushiegu	Northern
7	902	Wa East	Upper West
8	903	Wa West	Upper West
9	1005	Bongo	Upper East
10	808	Sawla Tuna Kalba	Northern
11	901	Wa	Upper West
12	909	Nadowli	Upper West
13	911	Lawra Nandom	Upper West
14	204	Efutu Municipal	Central
15	811	Bole	Northern
16	802	Yendi	Northern

SOURCE: Ghana Statistical Service, 2010 Population and Housing Census.

FIGURE 3.15 **Risk of increase of malaria impacts and district hot spots**



Case studies reported below illustrate how districts may use the climate risk assessment for their adaptation planning. In particular, districts may use the district-level risk scores for each sector to support the identification of suitable adaptation activities.

In **Ahanta West District**, the most at-risk sector is water, based on a vulnerability indicator of access to potable water. The district is located in the wettest region of Ghana, and the abundant rainfall it experiences currently supports agrarian activities. However, the high level of rainfall severely affects most of the roads in the district and causes flooding which contaminates clean water sources. During heavy rains, two issues collide: roads become undriveable and accessibility to parts of the district becomes problematic. Also, access to potable water decreases, which may have significant health implications and is worsened by lack of road usability. One recommended adaptation would be to reduce the impact of heavy rains and flooding by improving drainage systems so water points do not get contaminated; tarring main and feeder roads to improve vehicle accessibility during heavy rains; and/or providing more access points to potable water.

The greatest sector threat to **Adansi South District** stems from the agriculture sector, due to a risk of reduction in agricultural productivity. The district has experienced a highly variable and unpredictable climate over the last five years; floods and drought can occur in the same location within months. This has presented a threat to food productivity and security, particularly as production is predominantly rain-fed. The uncertainty of weather patterns means a likely decrease in yield from loss of land, uncertainty of what and when to plant, and a fall in revenue from crops. Adaptation actions in this district should focus on reducing agricultural and crop dependency. This could be achieved through such activities as crop rotation and diversification, training farmers on resilient seeds and introducing methods of irrigation.

Fanteakwa District is located in the Eastern region of Ghana. The climate risk assessment shows the water sector is the most at risk, as the district has a high prevalence of use of unimproved sources of water. Like Ahanta West, Fanteakwa's greatest challenge is the flooding that occurs from the Birim, Boso, Afram and Akrum Rivers, which destroys infrastructure and contaminates clean water sources. The communities most affected are those near rivers. Any increase in precipitation will exacerbate existing impacts. Communities in the district could be protected by rainwater harvesting. Rainwater harvesting is an effective alternative water supply solution and simultaneously can act to reduce the risk of flooding as it reduces the volume of storm water.

annexes

ANNEX A: DETAILED STUDY APPROACH AND METHODOLOGY

Study approach

Data and methods

- Hazards
- Exposure
- Vulnerability
- Risk
- Agriculture
- Water
- Health

ANNEX B: ADDITIONAL INDEXES

Normalized values of temperature and rainfall variability and drought hazard level

Climate Variability Index

Non-climatic Vulnerability Index

ANNEX A: DETAILED STUDY APPROACH AND METHODOLOGY

This annex supplements the assessment prepared by UNCDF and KEI through LoCAL. It presents the key methodological steps of the climate risk assessment.

STUDY APPROACH

The assessment models the impact of a changing climate on temperature, precipitation and drought, and analyses how these changes will affect the agriculture, water and health sectors by selecting a vulnerability indicator for each sector. The climate projections are downscaled from a country-wide lens to a district level, to provide an indication of the local effects of climate change. The vulnerability indicators are also analysed at a district level so districts can see their risks from climate change in each sector.

Ghana is organized into 16 regions with 260 districts. As this division was ongoing at the time of this study, the report and this annex reference the 173 districts that existed in 2010. While it is a limitation of the methodology that the analysis was conducted at the time of the division, we feel that the results are still significant for adaptation planning. Newer districts may find it useful to look at the districts they would have been part of in 2010 to identify their climate risks from this report.

It is acknowledged that a limitation of this study is the uncertainty attached to the climate projections, and the limited number of sectors analysed.

DATA AND METHODS

This subsection presents an overview of the methods and data used for each step of the analysis that makes up the climate risk assessment. Risk can be understood as a function of three factors – hazards, exposure and vulnerability – all of which must be present in order to pose a risk to a person, livelihood or asset.

Hazards

Climate is a complex system in which a multitude of interrelated components and variables intervene. To assess how future changes in climate would affect Ghana, a process of climate downscaling was used. This involved taking information known at the country scale to make predictions at a local scale. The key steps undertaken for climate downscaling were as follows:

- Selecting key climate variables
- Selecting future scenarios and time horizons
- Obtaining climate projection data
- Making projections and analysing trends

Selecting key climate variables. The primary climate variables used in this report are **precipitation**, or rainfall (P); and **temperature** (T), for which three data points are used: average temperature (Tavg), minimum temperature (Tmin) and maximum temperature (Tmax). **Drought** is analysed as a secondary climate variable to contribute to the analysis of climate risks to agriculture. These climate variables constitute the hazards component of the risk assessment.

Hazards are typically defined as a combination of slow onset trends and extreme events. They are external climate signals, as they do not depend on exposure or vulnerability, and they cannot be influenced by adaptation or other measures which seek to manage climate-related loss and change. In this study, the slow onset changes in temperature and precipitation form the hazard component of the risk calculations. It is acknowledged that a limitation of this study, due to time and resource constraints, is that sudden extreme events such as flash floods have not been taken into consideration.

Selecting future scenarios and time horizons. The climate data used in this report were obtained from the 22 synoptic stations of the Ghana Meteorological Agency. The analysis conducted was performed using a baseline time frame of 1981–2010, and projection data for the decades 2011–2020 and 2031–2040. In the study, a carbon dioxide–emissions scenario was used as the input scenario for projecting future climatic changes; this scenario was RCP 6.0, which correlates to a 2.2°C increase in temperature.

Obtaining climate projection data. The projections were conducted by obtaining data points at a global scale using the Community Earth System Model, followed by dynamic downscaling of the material using the Weather Research and Forecast Model (box A.1).

A list of derivatives was considered in the process of dynamic downscaling when obtaining the detailed climate projection maps. The factors included latitude, longitude, humidity and surface pressure among others. Table A.1 shows the full list of variables.

Projections and trends analysis. For the decade periods, values of P, Tmax, Tmin and Tavg for each of the 12 months were calculated by taking an average of that month's values over the decade. For example, the precipitation for May was averaged across all years from 2011 to 2020 to obtain the average May precipitation for the decade. For the individual years 2031 and 2041, monthly P, Tmax, Tmin and Tavg values were obtained directly.

The analysis of average temperatures and precipitation was defined using data from 1981 to 2010 as a baseline period. The analysis by district was conducted using data from the nearest Ghana Meteorological Agency weather station to each district. The analysis of maximum and minimum temperatures was defined using data from 2011 to 2020 as a baseline period, as Tmax and Tmin data were not available for the 1981–2010 period.

BOX A.1 **Climate regional projection process for Ghana**

Global-scale climate projections. The Community Earth System Model is a global climate model that provides state-of-the-art computer simulations of the Earth's past, present and future climate states. Based on current economic growth and mitigation initiatives, the RCP 6.0 scenario was applied in the global-scale climate projections. RCP 6.0 is the most widely accepted scenario for projecting future risks in the global community. Only one scenario was applied in the Ghana climate risk assessment study due to time limitations. It was processed at a six-hour interval, regarding the boundary conditions. CESM v.10.2 was applied for the years 2010–2030.

Dynamic downscaling. Developed in the late 1990s, the Weather Research and Forecast Model is a downscaled meteorological model that can generate atmospheric simulations using real data or idealized conditions. It is used for various meteorological applications across scales from metres to thousands of kilometres. While the basic scale is 250 km by 190 km, the climate projections applied in this report were refined to 7 km by 7 km. It took three to four months to downscale the Ghana projections to 7 km by 7 km.

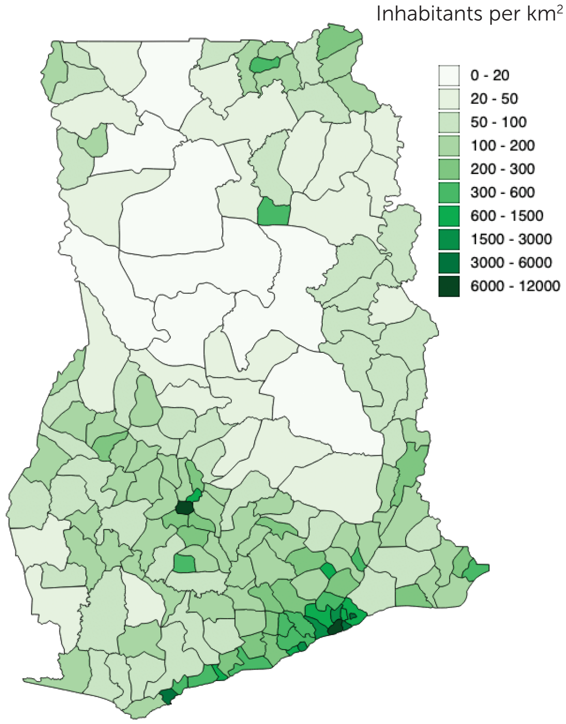
Exposure

The term 'exposure' refers to people, livelihoods or assets that are geographically located in the proximity of potential hazard events (GIZ and Eurac Research, 2017; UNISDR, 2009). Exposure is a necessary but not sufficient determinant of risk. Indicators for exposure are often numbers, densities or proportions such as population exposed, value of economic services exposed or proportion of livelihoods dependent on natural resources exposed.

TABLE A.1 **Variables considered**

Type	Variable
3D	Latitude
	Longitude
	Hybrid level at midpoints
	Time
	Number of longitudes
	Number of latitudes
	Temperature
	Relative humidity
	Zonal wind
	Meridional wind
	Geopotential heigh
2D	Surface pressure
	Sea level pressure
	Fraction of area covered by land
	Surface temperature
	Reference height temperature
Pressure	Reference pressure
	Hybrid A coefficient at layer midpoints
	Hybrid B coefficient at layer midpoints
Soil temperature and moisture	Volumetric soil water
	Soil temperature

FIGURE A.1 **Ghana's population density, 2010**



SOURCE: Ghana Statistical Service, 2010 Population and Housing Census.

NOTE: The 2010 survey was used as it was the source of the most recent data available for all districts at the time of the assessment.

This report uses **population density** in the districts as the measure of exposure to climate change impacts in the agriculture, water and health sectors. The population of Ghana was estimated to be 30,417,856 in 2019, of which 50.7 per cent were male and 49.3 per cent were female[1]. The majority of Ghana's population reside in the principal cities of Ashanti (20 per cent) and the Greater Accra Region (17 per cent) and are concentrated along the coast (figure A.1).

Vulnerability

Vulnerability is comprised of **sensitivity and capacity**; within that, capacity is comprised of adaptive capacity and coping capacity. Key definitions of these terms follow.

- **Sensitivity:** the degree to which a system is affected by its exposure to climate impacts. Examples of sensitivity indicators are population of dependent demographic groups, or livelihood dependence of affected sectors.
- **Adaptive capacity:** the ability of systems to take advantage of opportunities and adjust in order to mitigate potential damages.
- **Coping capacity:** the ability to manage and overcome adverse conditions in the short to medium term.

Ideally, in order to assess the vulnerability of a system, indicators would be chosen for each of the three components. The higher a sensitivity indicator, the higher the vulnerability; and the higher a capacity indicator, the lower the vulnerability. Due to time constraints, this study selected only sensitivity indicators for use in

[1] Source: World Bank Data – Ghana (2020).

the vulnerability component of the climate risk assessment. Note, however, that when looking at climate adaptation strategies to reduce risk, activities can be undertaken to **reduce vulnerability either by reducing sensitivity or by increasing adaptive or coping capacities**.

Table A.2 presents the sensitivity indicators selected for each of the three sectors and the units of measurement. For the agricultural sector, household dependency on agriculture was chosen as a sensitivity indicator rather than agricultural employment, because the latter is likely to underestimate the extent to which a particular district is dependent on agriculture. Household agricultural dependency encompasses the extent to which households may be dependent on agriculture not just through income and employment but also food security and export earnings.

Data availability at the district level was an inhibiting factor in the selection of sensitivity indicators for the water and health sectors. Accordingly, the most relevant available indicator or proxy indicator was selected. The literature suggests that the vulnerability of the health sector is best measured through life expectancy; however, such data were not available at the district level.

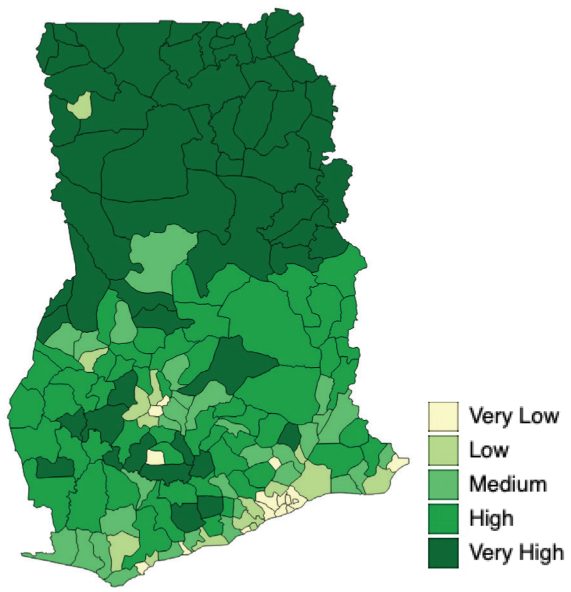
Figures A.2, A.3 and A.4 show those districts that are most vulnerable for each sector using the sensitivity indicator analysis and data from Ghana's 2010 Population and Housing Census.

TABLE A.2 **Sensitivity indicators**

Sector	Climate risk	Vulnerability indicator	Unit
Agriculture	Risk of reduction in agricultural productivity	Household agricultural dependency	% of households dependent on agriculture
Water	Risk of reduction in water availability	Access to an unimproved source of water	% of households that can access an unimproved source of water
Health	Risk of increase in malaria incidence	Infant mortality[1]	Number of cases of infant mortality

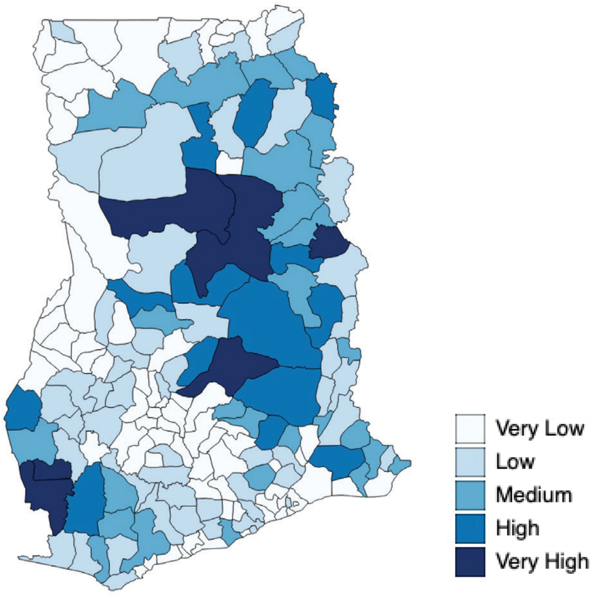
[1]An infant is defined as a child under the age of five.

FIGURE A.2 **Household agricultural dependency hot spots and most vulnerable districts**



Rate	ID	District	Region
1	803	Savelugu Nanton	Northern
2	826	Tolon Kumbungu	Northern
3	814	Chereponi	Northern
4	812	Karaga	Northern
5	810	Gushiegu	Northern
6	808	Sawla Tuna Kalba	Northern
7	811	Bole	Northern
8	802	Yendi	Northern
9	804	Bunkpurugu Yunyoo	Northern
10	818	Mamprusi West	Northern
11	801	Tamale	Northern
12	815	Saboba	Northern
13	825	Gonja West	Northern
14	807	Nanumba South	Northern
15	806	Nanumba North	Northern

FIGURE A.3 **Use of unimproved sources of water hot spots and most vulnerable districts**



Rate	ID	District	Region
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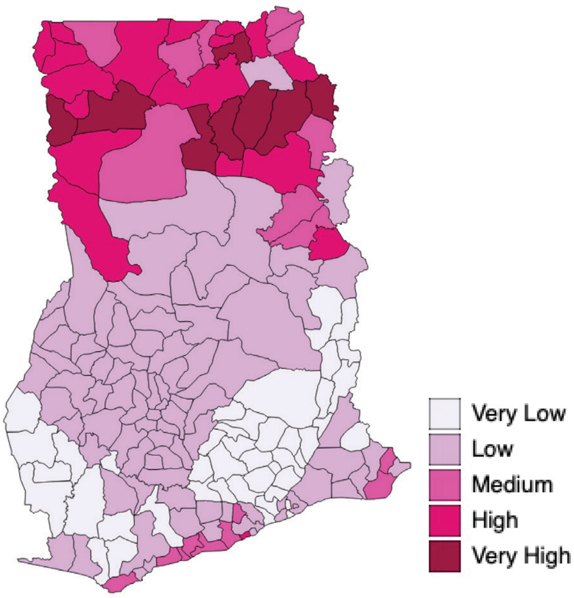
6	318	Aowin Suaman	Western
7	608	Krachi East	Volta
8	423	Kwahu North	Eastern
9	826	Tolon Kumbungu	Northern
10	813	Kpandai	Northern
11	716	Kintampo South	B. Ahafo
12	812	Karaga	Northern
13	519	Sekyere Central	Ashanti
14	714	Pru	B. Ahafo
15	411	Fanteakwa	Eastern

FIGURE A.4 **Infant mortality hot spots and most vulnerable districts**



Rate	ID	District	Region
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9	1005	Bongo	Upper East
10	808	Sawla Tuna Kalba	Northern
11	901	Wa	Upper West
12	909	Nadowli	Upper West
13	911	Lawra Nandom	Upper West
14	204	Efutu Municipal	Central
15	811	Bole	Northern
16	802	Yendi	Northern

Risk

This subsection explains how the three components of risk discussed above – hazards, exposure and vulnerability – were combined to create a climate risk assessment for each of the sectors.

Indicators for calculations. Table A.3 shows the indicators and their weightings that contributed to the risk indices for each of the sectors (agriculture, water and health).

Normalization. All the data for the indicators listed in table A.3 were normalized so that all the

TABLE A.3 **Indicators and weightings for the calculation of a district-level risk index for agriculture, water and health**

Risk factor	Indicator	Range		Classification	Calculation weightings		
		From	To		Agriculture	Water	Health
Hazards	Average temperature variability (VTavg) (°C)	< 0.1		Very low	0.2		
		0.1	0.19	Low			
		0.2	0.29	Medium			
		0.3	0.39	High			
		> 0.4		Very high			
	Maximum temperature variability (Vtmax) in (°C)	< 0.1		Very low			0.25
		0.1	0.19	Low			
		0.2	0.29	Medium			
		0.3	0.39	High			
		0.4	0.5	Very high			
	Rainfall reduction percentage (% P)	< 0.5		Very low	0.2	0.5	0.25
		0.6	2	Low			
		2.1	2.9	Medium			
		3	3.9	High			
		> 4		Very high			
	Drought hazard index (0–1)	0	0.19	Very low	0.2		
		0.2	0.39	Low			
		0.4	0.59	Medium			
		0.6	0.79	High			
		0.8	1	Very high			
Exposure	Population density (people/km²)	0	50	Very low	0.2	0.2	0.25
		51	200	Low			
		201	600	Medium			
		601	3,000	High			
		> 3,000		Very high			
Vulnerability	Agricultural dependency (% households dependent on agriculture)	0	15	Very low	0.2		
		16	30	Low			
		31	50	Medium			
		51	75	High			
		76	100	Very high			
	Household access to an unimproved source of water (%)	0	12	Very low		0.3	
		13	26	Low			
		27	40	Medium			
		41	52	High			
		53	66	Very high			
	Infant mortality * 1,000 (< 5 years)	0	17	Very low			0.25
		18	34	Low			
		35	52	Medium			
		53	70	High			
		71	87	Very high			

data points lay between a minimum of 0 and a maximum of 1. Normalization is also known as 'min-max normalization', the formula for which follows:

$$x_n = \frac{x_i - x_{min}}{x_{max} - x_{min}}$$

- x_i represents the individual data point to be transformed
- x_{min} the lowest value for this indicator
- x_{max} the highest value for this indicator
- x_n is the new value you wish to calculate

Once all the data were normalized, the hazard, exposure and vulnerability composite values were weighted for each sector. Then, each normalized indicator was multiplied by its weighting, and those were summed for each sector to create a composite risk index for each sector in each district. Six levels of risk are defined within the risk index: very high, high, medium high, medium low, low and very low.

Following are the risk maps and indices for the three sectors analysed.

- Figure A.5 and table A.4 show the risk of a reduction in agricultural productivity by district
- Figure A.6 and table A.5 show the risk of a reduction in water availability by district.
- Figure A.7 and table A.6 show the risk of an increase in the impacts of malaria by district.

FIGURE A.5 **Risk of agricultural productivity reduction hot spots**

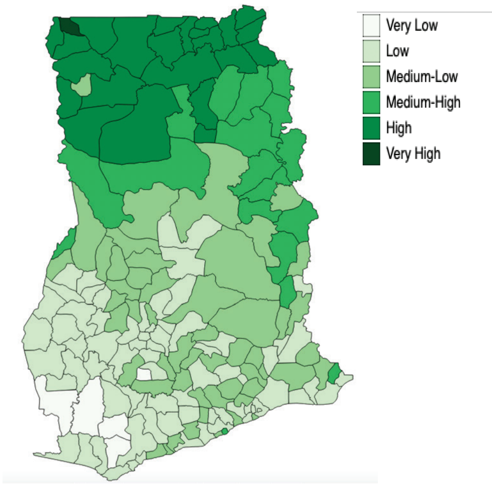

FIGURE A.6 **Risk of water availability reduction hot spots**

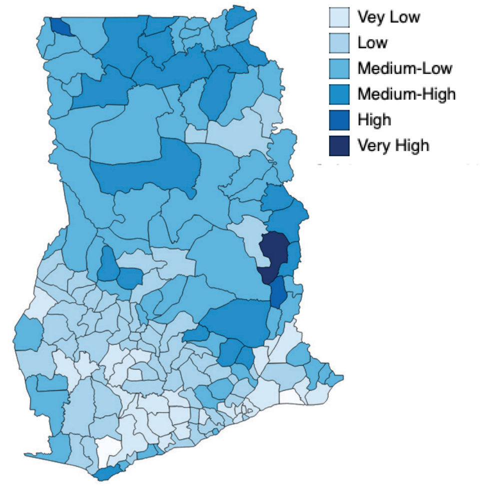

FIGURE A.7 **Risk of increase of malaria impacts hot spots**

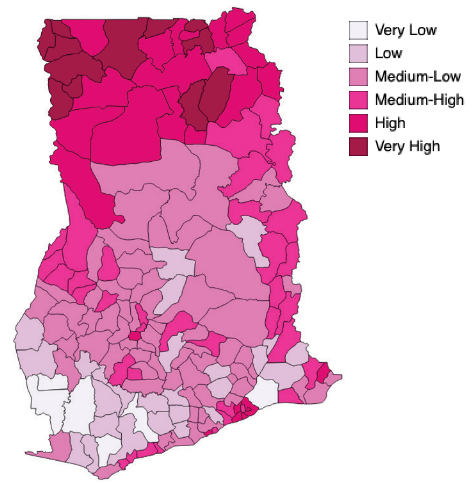

TABLE A.4 **Districts most at risk of agricultural productivity reduction**

Rate	District	Region	Rate	District	Region
1	Lambussie	U. West	54	Cape Coast	Central
2	Bawku	U. East	55	Agona East	Central
3	Mamprusi East	Northern	56	Birim Central	Eastern
4	Bolgatanga	U. East	57	Lower Manya Krobo	Eastern
5	Kasena Nankani West	U. East	58	Afigya Sekyere	Ashanti
6	Bunkpurugu Yunyoo	Northern	59	Dayi North	Volta
7	Sissala East	U. West	60	Sene	B. Ahafo
8	Tamale	Northern	61	Suhum Kraboa Coaltar	Eastern
9	Jirapa	U. West	62	Akyemansa	Eastern
10	Lawra Nandom	U. West	63	Krachi West	Volta
11	Savelugu Nanton	Northern	64	Nkoranza North	B. Ahafo
12	Builsa	U. East	65	Komenda Edina Eguafo	Central
13	Sawla Tuna Kalba	Northern	66	Abura Asebu Kwaman	Central
14	Mamprusi West	Northern	67	Tongu North	Volta
15	Nadowli	U. West	68	Kintampo North	B. Ahafo
16	Kasena Nankani East	U. East	69	Wenchi	B. Ahafo
17	Bongo	U. East	70	Techiman	B. Ahafo
18	Wa East	U. West	71	Kintampo South	B. Ahafo
19	Wa West	U. West	72	Ledzokuku Krowor	G. Accra
20	Bawku West	U. East	73	Ajumako Enyan Esiam	Central
21	Garu Tempane	U. East	74	Yilo Krobo	Eastern
22	Talensi Nabdam	U. East	75	Kwahu East	Eastern
23	Gonja West	Northern	76	Akwapim South	Eastern
24	Sissala West	U. West	77	Ahafo Ano South	Ashanti
25	Karaga	Northern	78	Adansi South	Ashanti
26	Zabzugu Tatale	Northern	79	Offinso North	Ashanti
27	Gushegu	Northern	80	Hohoe	Volta
28	Chereponi	Northern	81	Tano South	B. Ahafo
29	Bole	Northern	82	Ga South	G. Accra
30	Tolon Kumbungu	Northern	83	Efutu	Central
31	Biakoye	Volta	84	Akwapim North	Eastern
32	Jaman North	B. Ahafo	85	Fanteakwa	Eastern
33	Nanumba North	Northern	86	Atiwa	Eastern
34	Nanumba South	Northern	87	Birim North	Eastern
35	Yendi	Northern	88	Kwahu North	Eastern
36	Kpandai	Northern	89	Offinso	Ashanti
37	Saboba	Northern	90	Ejura Sekyedumase	Ashanti
38	Krachi East	Volta	91	Asante Akim South	Ashanti
39	Ketu North	Volta	92	Amansie Central	Ashanti
40	Nkwanta South	Volta	93	Bosome Freho	Ashanti
41	Gonja Central	Northern	94	Sekyere Afram Plains	Ashanti
42	Awutu Senya 2	Central	95	Upper Denkyira West	Central
43	Wa	U. West	96	Gomoa East	Central
44	Upper Manya Krobo	Eastern	97	Gomoa West	Central
45	Akatsi	Volta	98	STMA	Western
46	Jaman South	B. Ahafo	99	Bia	Western
47	Tain	B. Ahafo	100	New Juaben	Eastern
48	Gonja East	Northern	101	Kwahu South	Eastern
49	Adaklu Anyigbe	Volta	102	Bekwai	Ashanti
50	Nkoranza South	B. Ahafo	103	Atwima Mponua	Ashanti
51	Kadjebi	Volta	104	Jasikan	Volta
52	Akim West	Eastern	105	Tano North	B. Ahafo
53	Nkwanta North	Volta	106	Asunafo South	B. Ahafo

TABLE A.5 **Districts most at risk of water availability reduction**

Rate	District	Region	Rate	District	Region
1	Krachi East	Volta	54	Offinso North	Ashanti
2	Lambussie	U. West	55	Sekyere Central	Ashanti
3	Biakoye	Volta	56	Gonja West	Northern
4	Mamprusi East	Northern	57	Nanumba South	Northern
5	Nkwanta North	Volta	58	Akatsi	Volta
6	Gonja Central	Northern	59	Adaklu Anyigbe	Volta
7	Bunkpurugu Yunyoo	Northern	60	Akim West	Eastern
8	Builsa	U. East	61	Afigya Sekyere	Ashanti
9	Mamprusi West	Northern	62	STMA	Western
10	Karaga	Northern	63	Mampong	Ashanti
11	Kasena Nankani West	U. East	64	Ketu South	Volta
12	Nkoranza South	B. Ahafo	65	Kasena Nankani East	U. East
13	Sissala East	U. West	66	Bongo	U. East
14	Nkwanta South	Volta	67	Bawku West	U. East
15	Upper Manya Krobo	Eastern	68	Gushegu	Northern
16	Wa East	U. West	69	Bole	Northern
17	Kwahu East	Eastern	70	Nanumba North	Northern
18	Kwahu North	Eastern	71	Ketu North	Volta
19	Bawku	U. East	72	Wa	U. West
20	Kadjebi	Volta	73	Kintampo North	B. Ahafo
21	Techiman	B. Ahafo	74	Pru	B. Ahafo
22	Fanteakwa	Eastern	75	Wa West	U. West
23	Ahanta West	Western	76	Tain	B. Ahafo
24	Nadowli	U. West	77	Komenda Edina Eguafo	Central
25	Chereponi	Northern	78	Aowin Suaman	Western
26	Cape Coast	Central	79	Krachi West	Volta
27	Sekyere Afram Plains	Ashanti	80	Nkoranza North	B. Ahafo
28	Tolon Kumbungu	Northern	81	Ahafo Ano South	Ashanti
29	Jirapa	U. West	82	Efutu	Central
30	Sawla Tuna Kalba	Northern	83	Offinso	Ashanti
31	Jaman North	B. Ahafo	84	Juabeso	Western
32	Awutu Senya 2	Central	85	Ellembelle	Western
33	Gonja East	Northern	86	Saboba	Northern
34	Bia	Western	87	Adansi South	Ashanti
35	Kwahu South	Eastern	88	Tano South	B. Ahafo
36	Jomoro	Western	89	Ejura Sekyedumase	Ashanti
37	Wenchi	B. Ahafo	90	Tongu North	Volta
38	Kintampo South	B. Ahafo	91	Akwapim North	Eastern
39	Savelugu Nanton	Northern	92	Gomoa West	Central
40	Garu Tempane	U. East	93	Asunafo South	B. Ahafo
41	Kpandai	Northern	94	Ahafo Ano North	Ashanti
42	Sene	B. Ahafo	95	Nzema East	Western
43	Sefwi Akontombra	Western	96	Yendi	Northern
44	Bolgatanga	U. East	97	Lower Manya Krobo	Eastern
45	Lawra Nandom	U. West	98	Akim East	Eastern
46	Talensi Nabdam	U. East	99	Kwahu West	Eastern
47	Dayi North	Volta	100	Shama	Western
48	Hohoe	Volta	101	Wassa Amenfi East	Western
49	Jasikan	Volta	102	Ledzokuku Krowor	G. Accra
50	Sissala West	U. West	103	Ga South	G. Accra
51	Zabzugu Tatale	Northern	104	Atiwa	Eastern
52	Suhum Kraboa Coaltar	Eastern	105	New Juaben	Eastern
53	Yilo Krobo	Eastern	106	Mfantsiman	Central

TABLE A.6 **Districts most at risk of malaria impacts**

Rate	District	Region	Rate	District	Region
1	Kasena Nankani West	U. East	54	Berekum	B. Ahafo
2	Lambussie	U. West	55	Ga West	G. Accra
3	Lawra Nandom	U. West	56	Kpandai	Northern
4	Wa	U. West	57	Dayi North	Volta
5	Talensi Nabdam	U. East	58	Shama	Western
6	Karaga	Northern	59	Jaman South	B. Ahafo
7	Sissala East	U. West	60	Kwabre East	Ashanti
8	Jirapa	U. West	61	Amansie Central	Ashanti
9	Bongo	U. East	62	Obuasi	Ashanti
10	Wa West	U. West	63	Adentan	G. Accra
11	Savelugu Nanton	Northern	64	Afigya Sekyere	Ashanti
12	Nadowli	U. West	65	Nanumba North	Northern
13	Wa East	U. West	66	Tain	B. Ahafo
14	Bawku West	U. East	67	Sunyani West	B. Ahafo
15	Bolgatanga	U. East	68	Awutu Senya 2	Central
16	Builsa	U. East	69	Kwahu South	Eastern
17	Mamprusi West	Northern	70	Tano South	B. Ahafo
18	Bawku	U. East	71	Hohoe	Volta
19	Garu Tempane	U. East	72	Akatsi	Volta
20	Kasena Nankani East	U. East	73	Asante Akim North	Ashanti
21	Bole	Northern	74	Dangme East	G. Accra
22	Ashaiman	G. Accra	75	Ahanta West	Western
23	Sawla Tuna Kalba	Northern	76	Jasikan	Volta
24	Tamale	Northern	77	Ketu South	Volta
25	Bunkpurugu Yunyoo	Northern	78	Kintampo North	B. Ahafo
26	Sissala West	U. West	79	Sekyere East	Ashanti
27	Ketu North	Volta	80	Atwima Kwamwoma	Ashanti
28	Ledzokuku Krowor	G. Accra	81	Nkoranza South	B. Ahafo
29	Tolon Kumbungu	Northern	82	Bosomtwe	Ashanti
30	Efutu	Central	83	Gomoa East	Central
31	Ga East	G. Accra	84	Dormaa East	B. Ahafo
32	AMA	G. Accra	85	Atwima Nwabiagye	Ashanti
33	Chereponi	Northern	86	Gonja Central	Northern
34	Gonja West	Northern	87	Jomoro	Western
35	Kumasi	Ashanti	88	Nanumba South	Northern
36	Tema	G. Accra	89	Mampong	Ashanti
37	Gushegu	Northern	90	Nkoranza North	B. Ahafo
38	Cape Coast	Central	91	Asunafo South	B. Ahafo
39	Ga South	G. Accra	92	Lower Manya Krobo	Eastern
40	Mamprusi East	Northern	93	Adansi North	Ashanti
41	Zabzugu Tatale	Northern	94	Gonja East	Northern
42	STMA	Western	95	Offinso	Ashanti
43	Kadjebi	Volta	96	Berekum	B. Ahafo
44	Komenda Edina Eguafo	Central	97	Ga West	G. Accra
45	Krachi East	Volta	98	Kpandai	Northern
46	Ho	Volta	99	Dayi North	Volta
47	Nkwanta South	Volta	100	Shama	Western
48	Jaman North	B. Ahafo	101	Jaman South	B. Ahafo
49	Biakoye	Volta	102	Kwabre East	Ashanti
50	Techiman	B. Ahafo	103	Amansie Central	Ashanti
51	Saboba	Northern	104	Obuasi	Ashanti
52	Yendi	Northern	105	Adentan	G. Accra
53	Sunyani	B. Ahafo	106	Afigya Sekyere	Ashanti

ANNEX B: ADDITIONAL INDICES

TABLE B.1: **Normalized values of temperature and rainfall variability and drought hazard level, by region and district**

Region	ID	District	Temperature			Rainfall		Drought hazard
			V Tavg	V Tmax	V Tmin	VP	%VP	
Greater Accra	101	Tema	0.25	0.80	0.72	0.76	0.74	Medium
	102	Accra Metro Area	0.21	0.80	0.54	0.86	0.86	Medium
	103	Ga West	0.42	0.70	0.54	0.69	0.70	Medium
	104	Ga East	0.29	0.92	0.62	0.80	0.79	Medium
	105	Ledzokuku Krowor	0.12	0.80	0.62	0.75	0.72	Medium
	106	Adentan	0.47	0.83	0.60	0.88	0.89	Medium
	107	Ashaiman	0.49	0.90	0.80	0.86	0.86	Medium
	110	Ga South	0.34	0.74	0.66	0.67	0.63	Medium
	112	Dangme East	0.42	0.91	0.69	0.97	1.00	Medium
	116	Dangme West	0.34	0.09	0.66	0.80	0.79	Medium
Central	201	Cape Coast	0.02	0.05	0.65	0.43	0.27	Low
	202	Komenda Edina Eguafo	0.19	0.19	0.83	0.43	0.34	Very low
	203	Assin North	0.34	0.24	0.43	0.63	0.67	Very low
	204	Efutu	0.08	0.13	0.58	0.58	0.45	Low
	205	Upper Denkyira East	0.23	0.24	0.64	0.70	0.74	Very low
	206	Agona West	0.53	0.19	0.73	0.70	0.71	Low
	207	Awutu Senya	0.48	0.05	0.85	0.72	0.71	Medium
	208	Mfantsiman	0.14	0.00	0.79	0.69	0.60	Low
	209	Asikuma Odoben Brakwa	0.44	0.11	0.68	0.69	0.72	Very low
	210	Abura Asebu Kwaman	0.00	0.18	0.42	0.70	0.67	Low
	211	Ajumako Enyan Esiam	0.49	0.01	0.58	0.87	0.87	Low
	212	Assin South	0.55	0.36	0.86	0.81	0.82	Very low
	213	Upper Denkyira West	0.35	0.12	0.37	0.54	0.61	Very low
	214	Gomoa East	0.29	0.45	0.72	0.72	0.70	Medium
	215	Gomoa West	0.38	0.21	0.58	0.72	0.70	Low
	216	Agona East	0.40	0.13	0.89	0.65	0.68	Low
	217	Lower Denkyira	0.32	0.12	0.70	0.71	0.75	Very low
	299	Awutu Senya 2	0.07	0.08	0.73	0.54	0.46	Medium
Western	301	STMA	0.07	0.14	0.50	0.51	0.45	Very low
	302	Tarkwa Nsuaem	0.27	0.05	0.91	1.00	0.98	Very low
	303	Nzema East	0.24	0.25	0.62	0.68	0.67	Very low
	304	Sefwi Wiawso	0.44	0.69	0.61	0.65	0.70	Very low
	305	Bibiani Anhwiaso	0.42	0.14	0.84	0.65	0.69	Very low
	306	Jomoro	0.13	0.23	0.94	0.36	0.32	Very low
	307	Ahanta West	0.17	0.16	0.79	0.40	0.27	Very low
	308	Wassa Amenfi East	0.25	0.34	0.75	0.69	0.74	Very low
	309	Prestea Huni	0.21	0.16	0.57	0.75	0.78	Very low
	310	Shama	0.15	0.41	0.43	0.52	0.53	Very low
	311	Sefwi Akontombra	0.32	0.17	0.65	0.73	0.75	Very low
	312	Ellembelle	0.17	0.05	0.68	0.56	0.53	Very low
	314	Wassa Amenfi West	0.20	0.26	0.86	0.77	0.79	Very low
	315	Bia	0.33	0.37	0.74	0.49	0.56	Very low
	318	Aowin Suaman	0.23	0.04	0.51	0.74	0.76	Very low
	319	Mpohor Wassa East	0.29	0.03	0.43	0.80	0.81	Very low
	321	Juabeso	0.37	0.41	0.78	0.55	0.61	Very low

Region	ID	District	Temperature			Rainfall		Drought hazard
			V Tavg	V Tmax	V Tmin	VP	%VP	
Eastern	401	New Juaben	0.34	0.21	1.00	0.44	0.57	Low
	402	Birim Central	0.51	0.37	0.51	0.50	0.55	Low
	403	Kwahu West	0.37	0.34	0.67	0.38	0.54	Very low
	404	Akim East	0.30	0.07	0.61	0.53	0.63	Very low
	405	Akwapim North	0.38	0.30	0.78	0.61	0.61	Low
	406	Lower Manya Krobo	0.21	0.35	0.64	0.50	0.49	Medium
	408	Suhum Kraboa Coaltar	0.39	0.18	0.88	0.43	0.53	Low
	409	Akim West	0.45	0.16	0.77	0.47	0.58	Low
	410	Yilo Krobo	0.42	0.40	0.74	0.46	0.49	Low
	411	Fanteakwa	0.22	0.32	0.72	0.54	0.51	Very low
	412	Asuogyaman	0.31	0.39	0.76	0.76	0.75	Medium
	413	Kwahu South	0.48	0.64	0.45	0.46	0.43	Very low
	414	Atiwa	0.39	0.42	0.47	0.40	0.53	Very low
	415	Kwahu East	0.53	0.21	0.54	0.47	0.42	Very low
	416	Upper Manya Krobo	0.23	0.43	0.92	0.47	0.45	Low
	417	Birim South	0.55	0.37	0.60	0.59	0.63	Very low
	418	Akyemansa	0.31	0.30	0.64	0.43	0.49	Very low
	419	Birim North	0.40	0.30	0.66	0.38	0.51	Very low
	420	Akwapim South	0.31	0.39	0.38	0.67	0.66	Medium
	422	Kwaebibirem	0.19	0.32	0.40	0.43	0.50	Very low
	423	Kwahu North	0.35	0.54	0.61	0.60	0.50	Low
Ashanti	501	Kumasi	0.45	0.58	0.62	0.48	0.62	Very low
	502	Obuasi	0.64	0.68	0.75	0.50	0.62	Very low
	503	Ejisu Juaben	0.52	0.28	0.36	0.34	0.47	Very low
	504	Bekwai	0.44	0.27	0.56	0.57	0.62	Very low
	505	Mampong	0.63	0.48	0.75	0.45	0.46	Very low
	506	Offinso	0.53	0.37	0.99	0.37	0.41	Very low
	509	Ejura Sekyedumase	0.57	0.27	0.79	0.46	0.45	Very low
	510	Ahafo Ano South	0.55	0.46	0.74	0.39	0.51	Very low
	511	Ahafo Ano North	0.38	0.54	0.57	0.50	0.57	Very low
	512	Amansie West	0.41	0.57	0.68	0.53	0.61	Very low
	513	Asante Akim South	0.56	0.25	0.89	0.46	0.55	Very low
	514	Atwima Nwabiagye	0.35	0.53	0.55	0.36	0.48	Very low
	515	Adansi South	0.34	0.53	0.74	0.41	0.54	Very low
	516	Adansi North	0.40	0.60	0.77	0.46	0.57	Very low
	517	Amansie Central	0.42	0.85	0.79	0.49	0.59	Very low
	518	Atwima Mponua	0.39	0.55	0.67	0.57	0.65	Very low
	519	Sekyere Central	0.60	0.43	0.63	0.61	0.61	Very low
	520	Bosome Freho	0.45	0.45	0.73	0.50	0.57	Very low
	521	Atwima Kwamwoma	0.49	0.45	0.69	0.44	0.55	Very low
	522	Offinso North	0.43	0.36	0.73	0.47	0.49	Very low
	523	Afigya Sekyere	0.59	0.49	0.82	0.41	0.46	Very low
	524	Kwabre East	0.78	0.42	0.74	0.49	0.58	Very low
	525	Afigya Kwabre	0.48	0.37	0.77	0.42	0.47	Very low
	526	Sekyere East	0.67	0.55	0.77	0.41	0.47	Very low
	527	Bosomtwe	0.40	0.41	0.70	0.49	0.56	Very low
	528	Asante Akim North	0.51	0.61	0.68	0.47	0.49	Very low
	529	Sekyere Afram Plains	0.46	0.51	0.68	0.61	0.59	Low

Region	ID	District	Temperature			Rainfall		Drought hazard
			V Tavg	V Tmax	V Tmin	VP	%VP	
Volta	601	Keta	0.36	0.37	0.94	0.72	0.69	Low
	602	Hohoe	0.39	0.52	0.45	0.44	0.53	Very low
	603	Dayi North	0.21	0.69	0.38	0.47	0.37	Low
	604	Ho	0.38	0.96	0.58	0.63	0.68	Low
	605	Kadjebi	0.37	0.80	0.79	0.23	0.32	Very low
	606	Tongu South	0.40	0.67	0.44	0.89	0.90	Medium
Volta	607	Dayi South	0.37	0.48	0.79	0.85	0.85	Medium
	608	Krachi East	0.36	0.57	0.88	0.27	0.18	Low
	609	Ketu North	0.35	0.73	0.76	0.55	0.50	Medium
	610	Nkwanta North	0.60	0.10	0.77	0.50	0.41	Low
	611	Biakoye	0.21	0.48	0.31	0.27	0.10	Low
	612	Nkwanta South	0.51	0.42	0.36	0.30	0.26	Low
	613	Ketu South	0.44	0.38	0.46	0.67	0.65	Medium
	614	Jasikan	0.40	0.64	0.17	0.40	0.51	Very low
	617	Krachi West	0.30	0.25	0.68	0.63	0.57	Medium
	620	Tongu North	0.38	0.48	0.48	0.80	0.79	Medium
	621	Akatsi	0.46	0.51	0.42	0.59	0.55	Medium
	624	Adaklu Anyigbe	0.25	0.26	0.96	0.63	0.63	Medium
Brong Ahafo	701	Kintampo North	0.45	0.65	0.14	0.49	0.45	Medium
	702	Asunafo North	0.36	0.32	0.46	0.59	0.64	Very low
	703	Berekum	0.43	0.73	0.28	0.45	0.50	Very low
	704	Wenchi	0.47	0.05	0.79	0.32	0.33	Very low
	705	Sunyani	0.36	0.55	0.20	0.52	0.55	Very low
	706	Dormaa	0.45	0.48	0.38	0.56	0.63	Very low
	707	Nkoranza South	0.45	0.21	0.96	0.23	0.22	Very low
	708	Techiman	0.43	0.39	0.85	0.15	0.17	Very low
	709	Tano North	0.40	0.45	0.74	0.54	0.57	Very low
	710	Tano South	0.54	0.57	0.32	0.47	0.49	Very low
	711	Atebubu	0.43	0.40	0.61	0.65	0.63	Low
	712	Asunafo South	0.52	0.57	0.44	0.56	0.63	Very low
	713	Jaman South	0.40	0.63	0.50	0.41	0.47	Low
	714	Pru	0.35	0.51	0.54	0.66	0.64	Low
	715	Jaman North	0.56	0.43	0.44	0.14	0.16	Low
	716	Kintampo South	0.37	0.60	0.45	0.55	0.55	Low
	717	Nkoranza North	0.57	0.63	0.22	0.49	0.51	Low
	718	Dormaa East	0.52	0.53	0.55	0.54	0.58	Very low
	719	Sunyani West	0.52	0.65	0.38	0.48	0.51	Very low
	720	Asutifi	0.25	0.48	0.45	0.60	0.65	Very low
	721	Sene	0.40	0.40	0.86	0.59	0.54	Medium
	722	Tain	0.44	0.61	0.00	0.26	0.30	Low

Region	ID	District	Temperature			Rainfall		Drought hazard
			V Tavg	V Tmax	V Tmin	VP	%VP	
Northern	801	Tamale	0.06	0.70	0.35	0.61	0.62	High
	802	Yendi	0.58	0.57	0.23	0.62	0.59	High
	803	Savelugu Nanton	0.87	0.65	0.35	0.48	0.45	High
	804	Bunkpurugu Yunyoo	0.60	0.55	0.57	0.37	0.33	High
	805	Gonja Central	0.43	0.62	0.22	0.53	0.52	Medium
	806	Nanumba North	0.80	0.56	0.72	0.61	0.57	Medium
	807	Nanumba South	0.75	0.34	0.74	0.60	0.57	Medium
	808	Sawla Tuna Kalba	0.66	0.58	0.52	0.26	0.29	High
	809	Mamprusi East	0.70	0.53	0.29	0.31	0.29	High
	810	Gushegu	0.57	0.58	0.15	0.50	0.46	High
	811	Bole	0.50	0.75	0.52	0.32	0.33	Medium
	812	Karaga	0.84	1.00	0.30	0.43	0.39	High
	813	Kpandai	0.42	0.71	0.58	0.68	0.64	Medium
	814	Chereponi	0.72	0.54	0.30	0.52	0.45	High
	815	Saboba	0.55	0.82	0.54	0.69	0.66	High
	816	Gonja East	0.39	0.69	0.12	0.65	0.63	Medium
	817	Zabzugu Tatale	0.48	0.69	0.59	0.48	0.42	Medium
	818	Mamprusi West	0.78	0.80	0.66	0.30	0.28	High
	825	Gonja West	0.57	0.84	0.75	0.35	0.37	High
	826	Tolon Kumbungu	0.59	0.66	0.22	0.55	0.52	High
Upper West	901	Wa	0.40	0.89	0.59	0.31	0.29	High
	902	Wa East	0.61	0.76	0.04	0.26	0.27	High
	903	Wa West	0.64	0.81	0.88	0.40	0.42	High
	904	Sissala East	0.79	0.83	0.58	0.00	0.00	High
	905	Sissala West	0.87	0.74	0.24	0.27	0.26	High
	906	Lambussie	1.00	0.74	0.51	0.03	0.01	High
	907	Jirapa	0.86	0.86	0.69	0.23	0.23	High
	909	Nadowli	0.65	0.68	0.56	0.10	0.12	High
	911	Lawra Nandom	0.63	0.87	0.59	0.24	0.25	High
Upper East	1001	Bolgatanga	0.78	0.49	0.66	0.38	0.30	High
	1002	Bawku	0.71	0.62	0.64	0.46	0.28	High
	1003	Kasena Nankani East	0.66	0.73	0.58	0.36	0.32	High
	1004	Bawku West	0.86	0.74	0.61	0.45	0.34	High
	1005	Bongo	0.87	0.78	0.68	0.41	0.32	High
	1006	Garu Tempane	0.53	0.72	0.81	0.47	0.35	High
	1007	Kasena Nankani West	0.75	0.87	0.61	0.10	0.09	High
	1008	Builsa	0.83	0.72	0.72	0.11	0.08	High
	1009	Talensi Nabdam	0.73	0.78	0.70	0.44	0.35	High

SOURCE: KEI future projections (RCP 6.0).

CLIMATE VARIABILITY INDEX

The variables analysed (Tavg, Tmin, Tmax, P) were merged to form the CVI. The CVI enables the identification of districts where the variability of temperature (average, maximum and minimum) and rainfall (precipitation) is the greatest. The index is based on projections of changes in temperature and rainfall in the period 2031–2040 and is calculated by taking the difference of each variable value between the periods 2011–2020 and 2031–2040. These values were then normalized to be expressed in a range of values from 0 to 1, and districts were placed on a five-point variability scale (very low, low, medium, high, very high).

TABLE B.2 **Climate (temperature and rainfall) Variability Indexes and Drought Hazard Index, by region and district**

Region	ID	District	Temperature			Rainfall		Drought hazard
			V Tavg	V Tmax	V Tmin	VP	% VP	
Greater Accra	101	Tema	Low	High	High	Low	Low	Medium
	102	Accra Metro Area	Low	High	Medium	Very low	Very low	Medium
	103	Ga West	Medium	High	Medium	Low	Low	Medium
	104	Ga East	Low	Very high	High	Low	Low	Medium
	105	Ledzokuku Krowor	Very low	High	High	Low	Low	Medium
	106	Adentan	Medium	Very high	Medium	Very low	Very low	Medium
	107	Ashaiman	Medium	Very high	Very high	Very low	Very low	Medium
	110	Ga South	Low	High	High	Low	Low	Medium
	112	Dangme East	Medium	Very high	High	Very low	Very low	Medium
	116	Dangme West	Low	Very low	High	Very low	Low	Medium
Central	201	Cape Coast	Very low	Very low	High	Medium	High	Low
	202	Komenda Edina Eguafo	Very low	Very low	Very high	Medium	High	Very low
	203	Assin North	Low	Low	Medium	Low	Low	Very low
	204	Efutu	Very low	Very low	Medium	Medium	Medium	Low
	205	Upper Denkyira East	Low	Low	High	Low	Low	Very low
	206	Agona West	Medium	Very low	High	Low	Low	Low
	207	Awutu Senya	Medium	Very low	Very high	Low	Low	Medium
	208	Mfantsiman	Very low	Very low	High	Low	Low	Low
	209	Asikuma Odoben Brakwa	Medium	Very low	High	Low	Low	Very low
	210	Abura Asebu Kwaman	Very low	Very low	Medium	Low	Low	Low
	211	Ajumako Enyan Esiam	Medium	Very low	Medium	Very low	Very low	Low
	212	Assin South	Medium	Low	Very high	Very low	Very low	Very low
	213	Upper Denkyira West	Low	Very low	Low	Medium	Low	Very low
	214	Gomoa East	Low	Medium	High	Low	Low	Medium
	215	Gomoa West	Low	Low	Medium	Low	Low	Low
	216	Agona East	Medium	Very low	Very high	Low	Low	Low
	217	Lower Denkyira	Low	Very low	High	Low	Low	Very low
	299	Awutu Senya 2	Very low	Very low	High	Medium	Medium	Medium
Western	301	STMA	Very low	Very low	Medium	Medium	Medium	Very low
	302	Tarkwa Nsuaem	Low	Very low	Very high	Very low	Very low	Very low
	303	Nzema East	Low	Low	High	Low	Low	Very low
	304	Sefwi Wiawso	Medium	High	High	Low	Low	Very low
	305	Bibiani Anhwiaso	Medium	Very low	Very high	Low	Low	Very low
	306	Jomoro	Very low	Low	Very high	High	High	Very low
	307	Ahanta West	Very low	Very low	High	Medium	High	Very low
	308	Wassa Amenfi East	Low	Low	High	Low	Low	Very low
	309	Prestea Huni	Low	Very low	Medium	Low	Low	Very low
	310	Shama	Very low	Medium	Medium	Medium	Medium	Very low

Region	ID	District	Temperature			Rainfall		Drought hazard
			V Tavg	V Tmax	V Tmin	VP	% VP	
Western	311	Sefwi Akontombra	Low	Very low	High	Low	Low	Very low
	312	Ellembelle	Very low	Very low	High	Medium	Medium	Very low
	314	Wassa Amenfi West	Very low	Low	Very high	Low	Low	Very low
	315	Bia	Low	Low	High	Medium	Medium	Very low
	318	Aowin Suaman	Low	Very low	Medium	Low	Low	Very low
	319	Mpohor Wassa East	Low	Very low	Medium	Low	Very low	Very low
	321	Juabeso	Low	Medium	High	Medium	Low	Very low
Eastern	401	New Juaben	Low	Low	Very high	Medium	Medium	Low
	402	Birim Central	Medium	Low	Medium	Medium	Medium	Low
	403	Kwahu West	Low	Low	High	High	Medium	Very low
	404	Akim East	Low	Very low	High	Medium	Low	Very low
	405	Akwapim North	Low	Low	High	Low	Low	Low
	406	Lower Manya Krobo	Low	Low	High	Medium	Medium	Medium
	408	Suhum Kraboa Coaltar	Low	Very low	Very high	Medium	Medium	Low
	409	Akim West	Medium	Very low	High	Medium	Medium	Low
	410	Yilo Krobo	Medium	Low	High	Medium	Medium	Low
	411	Fanteakwa	Low	Low	High	Medium	Medium	Very low
	412	Asuogyaman	Low	Low	High	Low	Low	Medium
	413	Kwahu South	Medium	High	Medium	Medium	Medium	Very low
	414	Atiwa	Low	Medium	Medium	High	Medium	Very low
	415	Kwahu East	Medium	Low	Medium	Medium	Medium	Very low
	416	Upper Manya Krobo	Low	Medium	Very high	Medium	Medium	Low
	417	Birim South	Medium	Low	Medium	Medium	Medium	Very low
	418	Akyemansa	Low	Low	High	Medium	Medium	Very low
	419	Birim North	Medium	Low	High	High	Medium	Very low
	420	Akwapim South	Low	Low	Low	Low	Low	Medium
	422	Kwaebibirem	Very low	Low	Low	Medium	Medium	Very low
	423	Kwahu North	Low	Medium	High	Medium	Medium	Low
Ashanti	501	Kumasi	Medium	Medium	High	Medium	Low	Very low
	502	Obuasi	High	High	High	Medium	Low	Very low
	503	Ejisu Juaben	Medium	Low	Low	High	Medium	Very low
	504	Bekwai	Medium	Low	Medium	Medium	Low	Very low
	505	Mampong	High	Medium	High	Medium	Medium	Very low
	506	Offinso	Medium	Low	Very high	High	Medium	Very low
	509	Ejura Sekyedumase	Medium	Low	High	Medium	Medium	Very low
	510	Ahafo Ano South	Medium	Medium	High	High	Medium	Very low
	511	Ahafo Ano North	Low	Medium	Medium	Medium	Medium	Very low
	512	Amansie West	Medium	Medium	High	Medium	Low	Very low
	513	Asante Akim South	Medium	Low	Very high	Medium	Medium	Very low
	514	Atwima Nwabiagye	Low	Low	Medium	High	Medium	Very low
	515	Adansi South	Low	Medium	High	Medium	Medium	Very low
	516	Adansi North	Medium	Medium	High	Medium	Medium	Very low
	517	Amansie Central	Medium	Very high	High	Medium	Medium	Very low
	518	Atwima Mponua	Low	Medium	High	Medium	Low	Very low
	519	Sekyere Central	High	Medium	High	Low	Low	Very low
	520	Bosome Freho	Medium	Medium	High	Medium	Medium	Very low
	521	Atwima Kwamwoma	Medium	Medium	High	Medium	Medium	Very low
	522	Offinso North	Medium	Low	High	Medium	Medium	Very low
	523	Afigya Sekyere	Medium	Medium	Very high	Medium	Medium	Very low
	524	Kwabre East	High	Medium	High	Medium	Medium	Very low
	525	Afigya Kwabre	Medium	Low	High	Medium	Medium	Very low
	526	Sekyere East	High	Medium	High	Medium	Medium	Very low

Region	ID	District	Temperature			Rainfall		Drought hazard
			V Tavg	V Tmax	V Tmin	VP	% VP	
Ashanti	527	Bosomtwe	Medium	Medium	High	Medium	Medium	Very low
	528	Asante Akim North	Medium	High	High	Medium	Medium	Very low
	529	Sekyere Afram Plains	Medium	Medium	High	Low	Medium	Low
Volta	601	Keta	Low	Low	Very high	Low	Low	Low
	602	Hohoe	Low	Medium	Medium	Medium	Medium	Very low
	603	Dayi North	Low	High	Low	Medium	High	Low
	604	Ho	Low	Very high	Medium	Low	Low	Low
	605	Kadjebi	Low	Very high	High	High	High	Very low
	606	Tongu South	Medium	High	Medium	Very low	Very low	Medium
	607	Dayi South	Low	Medium	High	Very low	Very low	Medium
	608	Krachi East	Low	Medium	Very high	High	Very high	Low
	609	Ketu North	Low	High	High	Medium	Medium	Medium
	610	Nkwanta North	High	Very low	High	Medium	Medium	Low
	611	Biakoye	Low	Medium	Low	High	Very high	Low
	612	Nkwanta South	Medium	Medium	Low	High	High	Low
	613	Ketu South	Medium	Low	Medium	Low	Low	Medium
	614	Jasikan	Medium	High	Very low	Medium	Medium	Very low
	617	Krachi West	Low	Low	High	Low	Medium	Medium
	620	Tongu North	Low	Medium	Medium	Low	Low	Medium
	621	Akatsi	Medium	Medium	Medium	Medium	Medium	Medium
	624	Adaklu Anyigbe	Low	Low	Very high	Low	Low	Medium
Brong Ahafo	701	Kintampo North	Medium	High	Very low	Medium	Medium	Medium
	702	Asunafo North	Low	Low	Medium	Medium	Low	Very low
	703	Berekum	Medium	High	Low	Medium	Medium	Very low
	704	Wenchi	Medium	Very low	High	High	High	Very low
	705	Sunyani	Low	Medium	Very low	Medium	Medium	Very low
	706	Dormaa	Medium	Medium	Low	Medium	Low	Very low
	707	Nkoranza South	Medium	Low	Very high	High	High	Very low
	708	Techiman	Medium	Low	Very high	Very high	Very high	Very low
	709	Tano North	Medium	Medium	High	Medium	Medium	Very low
	710	Tano South	Medium	Medium	Low	Medium	Medium	Very low
	711	Atebubu	Medium	Medium	High	Low	Low	Low
	712	Asunafo South	Medium	Medium	Medium	Medium	Low	Very low
	713	Jaman South	Medium	High	Medium	Medium	Medium	Low
	714	Pru	Low	Medium	Medium	Low	Low	Low
	715	Jaman North	Medium	Medium	Medium	Very high	Very high	Low
	716	Kintampo South	Low	Medium	Medium	Medium	Medium	Low
	717	Nkoranza North	Medium	High	Low	Medium	Medium	Low
	718	Dormaa East	Medium	Medium	Medium	Medium	Medium	Very low
	719	Sunyani West	Medium	High	Low	Medium	Medium	Very low
	720	Asutifi	Low	Medium	Medium	Medium	Low	Very low
	721	Sene	Medium	Low	Very high	Medium	Medium	Medium
	722	Tain	Medium	High	Very low	High	High	Low

Region	ID	District	Temperature			Rainfall		Drought hazard
			V Tavg	V Tmax	V Tmin	VP	% VP	
Northern	801	Tamale	Very low	High	Low	Low	Low	High
	802	Yendi	Medium	Medium	Low	Low	Medium	High
	803	Savelugu Nanton	Very high	High	Low	Medium	Medium	High
	804	Bunkpurugu Yunyoo	Medium	Medium	Medium	High	High	High
	805	Gonja Central	Medium	High	Low	Medium	Medium	Medium
	806	Nanumba North	Very high	Medium	High	Low	Medium	Medium
	807	Nanumba South	High	Low	High	Medium	Medium	Medium
	808	Sawla Tuna Kalba	High	Medium	Medium	High	High	High
	809	Mamprusi East	High	Medium	Low	High	High	High
	810	Gushegu	Medium	Medium	Very low	Medium	Medium	High
	811	Bole	Medium	High	Medium	High	High	Medium
	812	Karaga	Very high	Very high	Low	Medium	High	High
	813	Kpandai	Medium	High	Medium	Low	Low	Medium
Northern	814	Chereponi	Very high	Medium	Low	Medium	Medium	High
	815	Saboba	Medium	Very high	Medium	Low	Low	High
	816	Gonja East	Low	High	Very low	Low	Low	Medium
	817	Zabzugu Tatale	Medium	High	Medium	Medium	Medium	Medium
	818	Mamprusi West	High	Very high	High	High	High	High
	825	Gonja West	Medium	Very high	High	High	High	High
	826	Tolon Kumbungu	Medium	High	Low	Medium	Medium	High
Upper West	901	Wa	Medium	Very high	Medium	High	High	High
	902	Wa East	High	High	Very low	High	High	High
	903	Wa West	High	Very high	Very high	Medium	Medium	High
	904	Sissala East	High	Very high	Medium	Very high	Very high	High
	905	Sissala West	Very high	High	Low	High	High	High
	906	Lambussie	Very high	High	Medium	Very high	Very high	High
	907	Jirapa	Very high	Very high	High	High	High	High
	909	Nadowli	High	High	Medium	Very high	Very high	High
	911	Lawra Nandom	High	Very high	Medium	High	High	High
Upper East	1001	Bolgatanga	High	Medium	High	High	High	High
	1002	Bawku	High	High	High	Medium	High	High
	1003	Kasena Nankani East	High	High	Medium	High	High	High
	1004	Bawku West	Very high	High	High	Medium	High	High
	1005	Bongo	Very high	High	High	Medium	High	High
	1006	Garu Tempane	Medium	High	Very high	Medium	High	High
	1007	Kasena Nankani West	High	Very high	High	Very high	Very high	High
	1008	Builsa	Very high	High	High	Very high	Very high	High
	1009	Talensi Nabdam	High	High	High	Medium	High	High

SOURCES: KEI future projections (RCP 6.0) and Community Resilience through Early Warning (CREW) programme drought hazard mapping.

NON-CLIMATIC VULNERABILITY INDEX

To assess non-climatic vulnerability (also known as structural or social vulnerability), a vulnerability index was developed based on socioeconomic variables identified through a thorough literature review. Six key components were assessed: human security, agricultural dependency, connectivity, inclusion, inequality and gender equity. For each variable, indicators were chosen for which district-level data could be obtained.

The data for each indicator were normalized and then ranked by vulnerability on a scale from 1 to 5 (1 being the lowest level of vulnerability and 5 the highest). Then, the indicator scores were summed with an equal weighting for each district to combine the components to create the Non-climatic Vulnerability Index. Indicators were equally weighted because there is no evidence in the literature to suggest that any one indicator is more or less significant than another in influencing vulnerability to climate change.

Finally, the index values were mapped, using GIS open source software (Q-GIS), into six vulnerability categories (very low, low, medium low, medium high, high, very high) based on their total scores. Table B.3 outlines the six components of the non-climatic vulnerability index, and the corresponding indicators used.

Figure B.1 displays a map of the non-climatic vulnerability index; table B.4 ranks the districts most at risk.

FIGURE B.1 **Non-climatic vulnerability at the district level and most vulnerable districts**

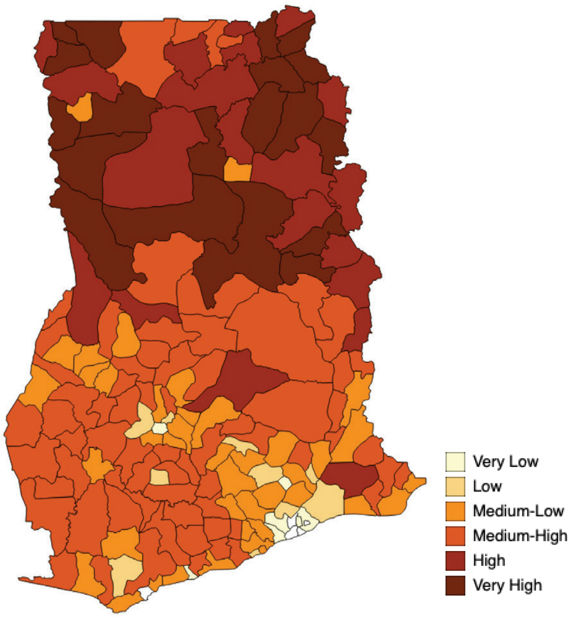

TABLE B.3 **Non-climatic vulnerability components, indicators and sources**

Component	Suggested indicator	Proxy indicator (available at district level)	Source of information
Human security	Housing quality	Housing quality index (based on outer walls, floor and roof main materials quality)	GSS PHC 2010
	Food security	% of food-insecure households; or chronic malnutrition among children < 5 years	WFP, MOFA and GSS (2012); Ghana DHS 2014 (regional level)
	Access to improved sources of water	% of households accessing an improved water source	GSS PHC 2010
	Access to improved sources of sanitation	% of households accessing improved sanitation facilities	GSS PHC 2010
	Access to education	Illiterate population; or population that never went to school	GSS PHC 2010
	Access to health services	Infant mortality	GSS PHC 2010
	Access to energy	% of households accessing electricity % of households using wood and charcoal as cooking energy	GSS PHC 2010
Connectivity	Access to communications: roads, media, phones and internet	Population with mobile phones (12 years or older) Population using Internet (12 years or older)	GSS PHC 2010
Sustainable and resilient livelihoods	Dependence on agriculture (crop farming, tree growing, livestock and fisheries)	Households dependent on agriculture	GSS PHC 2010
Inclusion of the most vulnerable and excluded	People in a more vulnerable condition	Population below poverty line	GSS (2015)
		Women-headed households	GSS PHC 2010
		Population dependency rate (<15 + >65 years)	
Inequality reduction	Wealth distribution	Gini coefficient of welfare distribution	GSS (2015)
Gender equity	Equitable access to education, health, employment opportunities and leisure time, etc.	Difference between % of illiterate men and women	GSS PHC 2010

NOTE: DHS = Demographic and Health Survey; GSS PHC = Ghana Statistical Service Population and Housing Census.

TABLE B.4 **Social vulnerability district hot spots**

Rate	ID	District	Region	Rate	ID	District	Region
1	811	Bole	Northern	54	704	Wenchi Municipal	B. Ahafo
2	903	Wa West	Upper West	55	515	Adansi South	Ashanti
3	906	Lambussie	Upper West	56	609	Ketu North	Volta
4	807	Nanumba South	Northern	57	1003	Kassena Nankani East	Upper East
5	804	Bunkpurugu Yunyoo	Northern	58	713	Jaman South	B. Ahafo
6	808	Sawla Tuna Kalba	Northern	59	311	Sefwi Akontombra	Western
7	1004	Bawku West	Upper East	60	614	Jasikan	Volta
8	902	Wa East	Upper West	61	611	Biakoye	Volta
9	816	Gonja East	Northern	62	522	Offinso North	Ashanti
10	813	Kpandai	Northern	63	209	Asikuma Odoben Brakwa	Central
11	1006	Garu Tempane	Upper East	64	718	Dormaa East	B. Ahafo
12	907	Jirapa	Upper West	65	511	Ahafo Ano North	Ashanti
13	905	Sissala West	Upper West	66	1007	Kassena Nankani West	Upper East
14	810	Gushiegu	Northern	67	509	Ejura Sekyeredumase Mun.	Ashanti
15	809	East Mamprusi	Northern	68	519	Sekyere Central	Ashanti
16	812	Karaga	Northern	69	212	Assin South	Central
17	815	Saboba	Northern	70	701	Kintampo North Municipal	B. Ahafo
18	805	Gonja Central	Northern	71	513	Asante Akim South	Ashanti
19	826	Tolon Kumbungu	Northern	72	215	Gomoa West	Central
20	825	Gonja West	Northern	73	518	Atwima Mponua	Ashanti
21	814	Chereponi	Northern	74	211	Ajumako-Enyan-Essiam	Central
22	817	Zabzugu Tatale	Northern	75	418	Akyemansa	Eastern
23	1005	Bongo	Upper East	76	510	Ahafo Ano South	Ashanti
24	818	Mamprusi West	Northern	77	516	Adansi North	Ashanti
25	802	Yendi	Northern	78	319	Mpohor Wassa East	Western
26	911	Lawra Nandom	Upper West	79	710	Tano South	B. Ahafo
27	806	Nanumba North	Northern	80	303	Nzema East Municipal	Western
28	803	Savelugu Nanton Mun.	Northern	81	203	Assin North Municipal	Central
29	610	Nkwanta North	Volta	82	415	Kwahu East	Eastern
30	1009	Talensi Nadbdam	Upper East	83	315	Bia	Western
31	529	Sekyere Afram Plains S.	Ashanti	84	318	Aowin Suaman	Western
32	1008	Builsa	Upper East	85	504	Bekwai Municipal	Ashanti
33	612	Nkwanta South	Volta	86	216	Agona East	Central
34	620	Tongu North	Volta	87	607	Dayi South	Volta
35	716	Kintampo South	B. Ahafo	88	416	Upper Manya Krobo	Eastern
36	1002	Bawku	Upper East	89	321	Juabeso Bia	Western
37	605	Kadjebi	Volta	90	308	Wassa Amenfi	Western
38	715	Jaman North	B. Ahafo	91	512	Amansie West	Ashanti
39	714	Pru	B. Ahafo	92	413	Kwahu South	Eastern
40	711	Atebubu-Amantin	B. Ahafo	93	217	Lower Denkyira	Central
41	210	Abura Asebu Kwamankesse	Central	94	506	Offinso Municipal	Ashanti
42	617	Krachi West	Volta	95	707	Nkoranza South Municipal	B. Ahafo
43	608	Krachi East	Volta	96	523	Sekyere South	Ashanti
44	904	Sissala East	Upper West	97	1001	Bolgatanga Municipal	Upper East
45	721	Sene	B. Ahafo	98	205	Upper Denkyira East Mun.	Central
46	712	Asunafo South	B. Ahafo	99	603	Dayi North	Volta
47	520	Bosome Freho	Ashanti	100	417	Birim South	Eastern
48	624	Adaklu Anyigbe	Volta	101	306	Jomoro	Western
49	517	Amansie Central	Ashanti	102	213	Upper Denkyira West	Central
50	606	Tongu South	Volta	103	702	Asunafo North Municipal	B. Ahafo
51	621	Akatsi	Volta	104	720	Asutifi	B. Ahafo
52	423	Kwahu North	Eastern	105	314	Wassa West	Western
53	717	Nkoranza North	B. Ahafo	106	304	Sefwi Wiawso Municipal	Western

DROUGHT RISK INDEX

A Drought Hazard Index was defined to identify districts likely to experience drought. Under the Community Resilience through Early Warning (CREW) programme, national and local-level drought and flood risk assessments were performed for Ghana with the support of the United Nations Development Programme in 2014. The drought risk assessment identified drought risk levels by district for the year 2010. The data from the drought risk assessment were normalized and used to create a Drought Hazard Index for this study, which feeds into the calculation of risk in reduction of agricultural productivity as per table A.3.

The Drought Hazard Index is also a component of the drought risk index which is comprised in equal weightings of the normalised values of the following indicators:

- Average temperature variability (VTavg)
- Percentage reduction in rainfall (%VP)
- Drought hazard index
- Population density
- Non-climatic vulnerability index

Figure B.2 displays a map of the Drought Risk Index; table B.4 ranks districts by drought risk.

FIGURE B.2 **Drought Risk Index and most vulnerable districts**

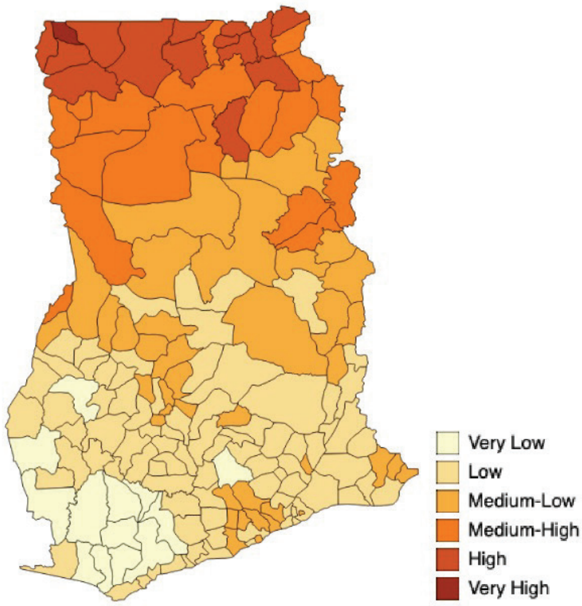

TABLE B.5 **Districts most at risk of drought**

Rate	ID	District	Region	Rate	ID	District	Region
1	906	Lambussie	U. West	54	701	Kintampo North	B. Ahafo
2	907	Jirapa	U. West	55	707	Nkoranza South	B. Ahafo
3	1005	Bongo	U. East	56	409	Akim West	Eastern
4	1004	Bawku West	U. East	57	501	Kumasi	Ashanti
5	1002	Bawku	U. East	58	708	Techiman	B. Ahafo
6	1007	Kasena Nankani West	U. East	59	103	Ga West	G. Accra
7	904	Sissala East	U. West	60	713	Jaman South	B. Ahafo
8	1001	Bolgatanga	U. East	61	816	Gonja East	Northern
9	1008	Builsa	U. East	62	704	Wenchi	B. Ahafo
10	803	Savelugu Nanton	Northern	63	509	Ejura Sekyedumase	Ashanti
11	905	Sissala West	U. West	64	605	Kadjebi	Volta
12	809	Mamprusi East	Northern	65	526	Sekyere East	Ashanti
13	911	Lawra Nandom	U. West	66	505	Mampong	Ashanti
14	1009	Talensi Nabdam	U. East	67	717	Nkoranza North	B. Ahafo
15	909	Nadowli	U. West	68	406	Lower Manya Krobo	Eastern
16	903	Wa West	U. West	69	506	Offinso	Ashanti
17	818	Mamprusi West	Northern	70	215	Gomoa West	Central
18	804	Bunkpurugu Yunyoo	Northern	71	206	Agona West	Central
19	812	Karaga	Northern	72	415	Kwahu East	Eastern
20	1006	Garu Tempane	U. East	73	721	Sene	B. Ahafo
21	1003	Kasena Nankani East	U. East	74	216	Agona East	Central
22	808	Sawla Tuna Kalba	Northern	75	105	Ledzokuku Krowor	G. Accra
23	902	Wa East	U. West	76	201	Cape Coast	Central
24	814	Chereponi	Northern	77	106	Adentan	G. Accra
25	825	Gonja West	Northern	78	413	Kwahu South	Eastern
26	806	Nanumba North	Northern	79	710	Tano South	B. Ahafo
27	807	Nanumba South	Northern	80	214	Gomoa East	Central
28	901	Wa	U. West	81	401	New Juaben	Eastern
29	810	Gushegu	Northern	82	510	Ahafo Ano South	Ashanti
30	715	Jaman North	B. Ahafo	83	405	Akwapim North	Eastern
31	811	Bole	Northern	84	420	Akwapim South	Eastern
32	826	Tolon Kumbungu	Northern	85	620	Tongu North	Volta
33	817	Zabzugu Tatale	Northern	86	624	Adaklu Anyigbe	Volta
34	612	Nkwanta South	Volta	87	204	Efutu	Central
35	802	Yendi	Northern	88	102	AMA	G. Accra
36	609	Ketu North	Volta	89	603	Dayi North	Volta
37	815	Saboba	Northern	90	502	Obuasi	Ashanti
38	608	Krachi East	Volta	91	602	Hohoe	Volta
39	524	Kwabre East	Ashanti	92	521	Atwima Kwamwoma	Ashanti
40	611	Biakoye	Volta	93	410	Yilo Krobo	Eastern
41	813	Kpandai	Northern	94	504	Bekwai	Ashanti
42	621	Akatsi	Volta	95	529	Sekyere Afram Plains	Ashanti
43	523	Afigya Sekyere	Ashanti	96	513	Asante Akim South	Ashanti
44	613	Ketu South	Volta	97	211	Ajumako Enyan Esiam	Central
45	610	Nkwanta North	Volta	98	104	Ga East	G. Accra
46	107	Ashaiman	G. Accra	99	101	Tema	G. Accra
47	299	Awutu Senya 2	Central	100	202	Komenda Edina Eguafo	Central
48	805	Gonja Central	Northern	101	528	Asante Akim North	Ashanti
49	402	Birim Central	Eastern	102	527	Bosomtwe	Ashanti
50	207	Awutu Senya	Central	103	718	Dormaa East	B. Ahafo
51	801	Tamale	Northern	104	712	Asunafo South	B. Ahafo
52	110	Ga South	G. Accra	105	416	Upper Manya Krobo	Eastern
53	722	Tain	B. Ahafo	106	522	Offinso North	Ashanti

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