Volta Flood and Drought Management

ADAPTATION FUND

Project "Integrating Flood and Drought Management and Early Warning for Climate Change Adaptation in the Volta Basin"

National Consultation Report for Ghana

Project Partners:

WORLD METEOROLOGICAL ORGANIZATION

AUTORITE DU BASSIN DE LA VOLTA – VBA – VOLTA BASIN AUTHORITY

Global Water Partnership West Africa

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Abbreviations/Acronyms

ACP	African, Caribbean and Pacific States
ARC	African Risk Capacity
ASPIRE	Adaptive Social Protection - Information for Enhanced Resilience
CECAR-Africa	Enhancing Resilience to Climate and Ecosystem Changes in Semi-Arid Africa
CERSGIS	Centre for Remote Sensing and Geographic Information Services
CFS	Climate Forecast System
CIMA	International Centre for Environmental Monitoring
CREW	Community Resilience through Early Warning
CSIR	Council for Scientific and Industrial Research
CSSTE	Centre for Space Science and Technology Education
CTCN	Climate Technology Centre and Network
Delft-FEWS	Deltares Flood Forecasting and Early Warning System
DRM	Disaster Risk Management
DTM	Digital Terrain Model
ECMWF	European Centre for Medium-Range Weather Forecasts
ECOWAS	Economic Community of West African States
EoC	National Emergency Operation Centre
EPA	Environmental Protection Agency
EU	European Union
EWS	Early Warning System
FANFAR	Reinforced cooperation to provide operational flood forecasting and alerts in West Africa
FAO	Food and Agriculture Organization of the United Nations
FDMT	Flood and Drought Management Tool
FEWS NET	Famine Early Warning Systems Network
GARID	Greater Accra Resilient and Integrated Development
GDP	Gross Domestic Product
GFDRR	Global Facility for Disaster Reduction and Recovery
GHA	Ghana Highway Authority
GIDA	Ghana Irrigation Development Authority
GIS	Geographic Information System
GMES	Global Environmental Monitoring Service
GMet	Ghana Meteorological Agency
GPM	Global Precipitation Meaasurement
GPRS	General Packet Radio Service

GSM	Global System for Mobile communications
HEC-RAS	Hydrologic Engineering Center's River Analysis System
HSD	Hydrological Services Department of Ghana
HKV	Consultancy Company from the Netherlands
IFM	Integrated Flood Management
IFRC	International Federation of Red Cross
ILGS-FES	Institute of Local Government Studies / Friedrich Ebert Foundation
IT	Information Technology
IWRM	Integrated Water Resources Management
LC/LU	Land Cover / Land Use
LUPSA	Land Use and Spatial Planning Authority
MDA	Municipal and District Assemblies
MMDAs	Metropolitan, Municipal and District Assemblies
MOFA	Ministry of Food and Agriculture
MWH	Ministry of Works and Housing
NADMO	National Disaster Management Organizations
NCP	National Contingency Plan
NDMP	National Disaster Management Plan
NGOs	Non-Governmental Organizations
NOAA	National Oceanic and Atmospheric Administration
NSOP	National Standard Operational Plan
PARADeS	Participatory assessment of flood related disaster prevention and development of an adapted coping system in Ghana
RCCs	Regional Coordinating Councils
REWARD	Reversing Ecosystem and Water Degradation in the Volta River Basin
SERVIR	Connecting Space to Village in West Africa
SRTM	Shuttle Radar Topography Mission
SWAT	Soil and Water Assessment Tool
SWIFT	Science for Weather Information and Forecasting Techniques
TCPD	Town and Country Planning Department
THAMO	Trans African Hydro Meteorological Observatory
TRMM	Tropical Rainfall Measuring Mission
TUD	Technical University of Delft
UK MET	United Kingdom's national weather service
UNCCD	United Nations Convention to Combat Desertification
UNEP	United Nations Environment Programme
UNDP	United Nations Development Programme

UNDRR	United Nations Office for Disaster Risk Reduction
UNISDR	UN International Strategy for Disaster Reduction
UNW-AIS	UN-Water Activity Information System
USGS	United States Geological Survey
VFDM	Volta Flood and Drought Management project
VRA	Volta River Authority
WADI	WAscal Data Infrastructure
WASCAL	West African Science Service Centre on Climate Change and Adapted Land Use
WEAP	Water Evaluation And Planning
WISD	
WMI	Water Management International
WMO	World Meteorological Organization
WRC	Water Resource Commission
WRF	Weather Research and Forecasting
WRI	Water Research Institute

About this report

The document aims to assess the national capabilities and needs for developing forecasting and early warning system for flood and drought events, as part of the activity under the framework of the VFDM project "Integrating Flood and Drought Management and Early Warning for Climate Change Adaptation in the Volta Basin", funded by the Adaptation Fund.

A national consultation meeting on understanding current *National Capabilities and needs for Flood and Drought Forecasting and Early Warning Systems* in Ghana was carried out with a mission to Accra from the 3rd to the 5th of December 2019. The terms of reference are presented in the Annex 6. During the mission, the consultation team attended several meetings with various national agencies involved in floods and drought management in Ghana. Annex 7 presents the list of agencies and the respective focal points that have been consulted. The findings of the meetings, integrated with a desk study conducted in December 2019 and January 2020 from open source information, are reported in this document.

The draft report was shared with the National Agencies for their review on the 15th of April 2020 and feedbacks and further information provided from national agencies till September 2020 were also integrated in the current version. In January 2021, a National workshop (originally foreseen in October 2020 and postponed due to Covid pandemic) was organized to present the report findings, the analysis carried out and have a joint discussion with the participants to finalize the general recommendations and develop an action plan. The final report of the National workshop, including the results of interactive sessions on EWS assessment, recommendations and the list of participants, is presented in the Annex 8. After the workshop, this national consultation report was finalized.

The report is structured as follows, firstly a general introduction on the country is presented, followed by a desk review of the areas mainly affected by floods and drought, with a focus relating to the part of the Volta basin that crosses the country. Subsequently, an overview of the institutional framework related to EWS for floods and drought was performed as well as an analysis on the national hydro-meteorological capabilities. This information supported and complemented the *End-to-End EWS for Flood Forecasting and Drought Prediction Analysis* that was presented by first introducing the methodology and then the preliminary results. Finally, past and ongoing projects are described and general recommendations, as well as the project action plan for the future, are presented.

The timeline of the exchanges that took place with the stakeholders is shown in Figure 1.

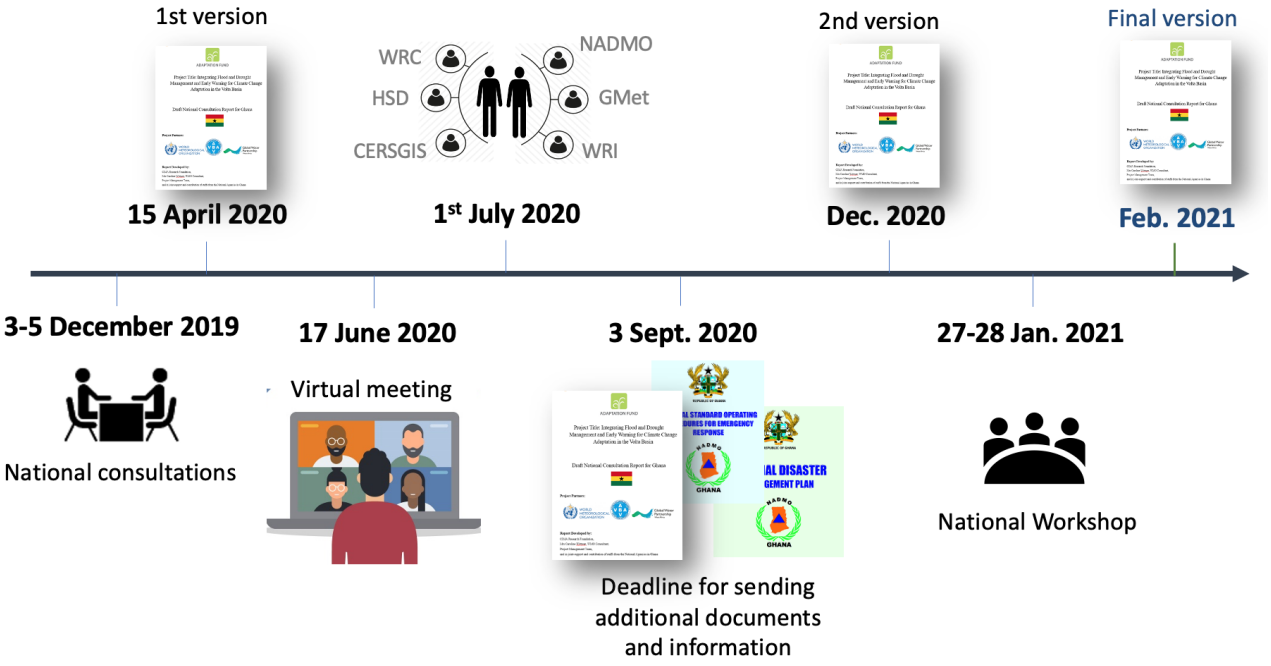

Figure 1: Timeline of the steps leading to the report finalization.

1. Country Profile

Ghana is located on the Atlantic Coast and shares its three borders with Togo, Cote d'Ivoire and Burkina Faso. To date, the country has a population of around 31 million people distributed within an area of 238 535 km^2 (WorldPopulationReview, 2020). The area stretches over four main vegetation zones: Coastal Savannah in the southeast, Tropical Rain Forest (evergreen) in the southwest, Tropical Deciduous Forest in the centre-south and Savannah in the central and northern areas (Figure 2) (Abbam, et al., 2018).

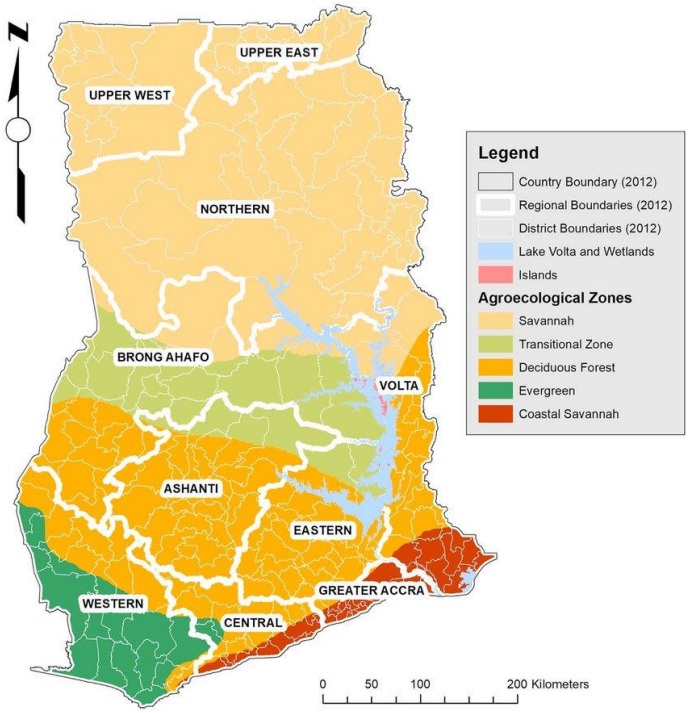

Figure 2. Vegetation zones in Ghana

Both the Savannah zone in the eastern coast and the Tropical Rain Forest zone in the western coast experience two rainy seasons, one from March to July and a shorter one from September to November. Along the western coast the rains are far more abundant than along the eastern coast, reaching 2000 mm/year compared to around 800 - 900 mm/year on the later (Figure 3) (Logah, et al., 2013). In the Tropical Deciduous Forest, the rainfall reaches 1300-1400 mm/year, with a rainy season that starts in the mid-June and ends in mid-September. Finally, the Ghanaian Savannah zone has a total annual rainfall of about 1000-1300 mm/year, with a rainfall period from July to September (Siaw, 2001).

Ghana's climate is tropical with mean annual temperature variations ranging between 26°C on the southwest coast and 27-30°C in the northeast areas. From February to April, temperatures can exceed 40°C in the northern regions (UNDP, 2008) (Siaw, 2001).

The rainy period is usually characterised by torrential rain, where intensity often exceeds the absorption capacity of the soil, creating high amounts of runoff and consequent erosion. About 70 % of the country is subject from moderate to severe sheet and gully erosion, despite a topography characterised by gentle slopes, with a series of hills only along the eastern border (FAO, 2005).

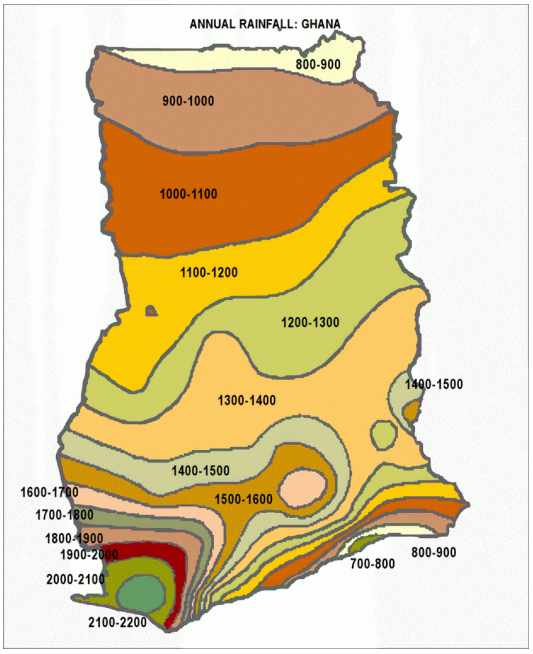

Figure 3. Spatial distribution of average annual total rainfall

From the north to the south, Ghana has a rich river geomorphology. It is drained by the Volta, south-western and coastal rivers systems, covering respectively the 70%, 22% and 8% of the country (Ghana Maritime Authority, 2001). Although the Volta Basin's area is significant in the country, its most populated areas are located outside the basin. The majority of the population lives in urban areas located in the regions of Ashanti, Central and Greater Accra. The highest concentration of people is in the urban areas of Accra, Kumasi and Tamale (FAO, 2005).

About 47.5% of the labour force is engaged in services, 33.5% in agriculture and 19% in industry. Services make up 43% of Ghana's GDP, while industry 32% (mainly manufacturing, telecommunications and energy), and agriculture 25% (Figure 4), resulting in a very diverse economy compared to neighbouring West African countries (Statista, 2020). The country has one of the fastest-growing economies in the world. Currently, Ghana is the Africa's second biggest gold producer and second-largest cocoa producer. The country has eleven main languages, but English is the national official language.

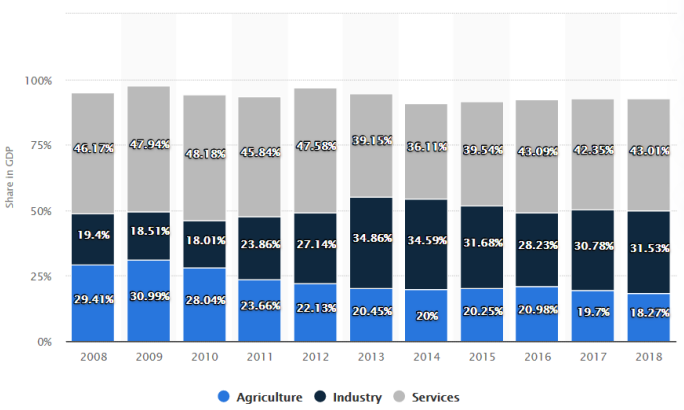

Figure 4. Source in GDP between 2008 and 2018 (Statista, 2020)

2. Main Flood and Drought risk areas

Over the past 100 years, hydro-meteorological hazards have been the most common causes of disasters and emergencies in Ghana (Ansah, et al., 2020). The country is particularly affected by flash floods, which occur in urban areas or in informal settlements where anthropogenic factors worsen the impact.

Floods have become an annual phenomenon, affecting many parts of the country during the major rainy season. Northern Ghana is the main region affected, due to its topological features. Its flat surface promotes water stagnation, and the loamy clay soil does not favour water retention. Additionally, the region experiences long periods of dry spells that lead to the formation of barren soil and a consequently high runoff coefficient.

Table 1. Main flood events and affected areas from 2003 to 2019

Date	Event	Impact	Location	Sources
6 – 12 October 2019	Torrential rains combined with water releases from the Bagre dam in Burkina Faso	19 people died 26000 people affected 2000 houses destroyed 3000 buildings were severely damaged Damage to farmlands	Upper East Region. Main impacted districts: Bongo district and Navrongo town	https://reliefweb.int/sites/reliefweb.int/files/resources/MDRGH016do.pdf
August 2018	Heavy and continuous seasonal rainfall exacerbated by the annual opening of the Bagre dam (in Burkina Faso). The spilled water found its way in the Black and White Volta rivers which overflowed	15 people died 12000 hectares of farmland had been affected by the flooding 1500 households affected 31000 people affected 196 km^2 of farmland destroyed	Upper east region and Northern Region: Bakwu west district and Talensi districts	https://reliefweb.int/report/ghana/ghana-emergency-plan-action-operation-update-dam-spillage-upper-east-region-dref
June 2018	Heavy rainfall during the major rainy season	14 deaths 34076 people displaced economic loss estimated at $168,289	Accra and Kumasi	https://www.hindawi.com/journals/amete/2020/4230627/
10th July 2017	Flood emergency	1000 people displaced 26 houses collapsed Several hectares of farmlands destroyed	Greater Accra, Eastern, Western and Central Regions	https://reliefweb.int/sites/reliefweb.int/files/resources/MDRGH014dfr.pdf

June 2015	Heavy thunderstorm and cascade disaster of floods and fire, driven by both natural and human factors.	25 deaths related to the flooding 200 deaths related to the explosion	Southern Ghana with major impact in Accra	http://floodlist.com/africa/ghana-floods-june-2015
March/April 2013	Severe storms	5 deaths 25,000 people affected	Northern Ghana: Thamale Metropolitan, Gushegu, Savelugu/Nanton, Tatale/Sanguili, Yendi, Saboba, Tolon	https://reliefweb.int/disaster/fl-2013-000041-gha
November 2010	Floods	700,000 people displaced 3000 building collapsed 23000 acres of farmlands destroyed	55 communities affected in the Gonja district located in the Savannah region	https://www.graphic.com.gh/news/general-news/flood-disaster-profile-of-ghana.html
June/July 2009	Heavy rain and the release of excess water from dams in Burkina Faso	23 deaths 51,000 people affected Property damage	Southern Ghana, Accra Central and Volta regions	https://reliefweb.int/report/benin/west-africa-region-responds-flood-damage http://www.nadmo.gov.gh/images/NADMO_documents/2015_documents/NCP-NADMO_FINAL_OF_FINALS.pdf
August/November 2007	Flooding Heavy rainfall + spillage from the Bagre and Kompienga Dams in Burkina Faso	61 deaths 300,000 people affected Destruction of homes, disruption to water supply systems, loss of livelihoods through damage to cropped farms and livestock, damage to infrastructure including the collapse of nine Bridges, damage to road networks and schools.	Upper east region, upper west region, northern region and western region	https://reliefweb.int/report/ghana/ghana-situation-report-floods-nov-2007 http://www.nadmo.gov.gh/images/NADMO_documents/2015_documents/NCP-NADMO_FINAL_OF_FINALS.pdf

According to a study carried out by HKV in 2016 within CREW project, flood prone areas are mainly located in the Northeast, Savannah, Northern, and Volta regions (Figure 5a) (CREW project, 2015). The analysis is consistent with the geographical distribution of floods identified by NADMO, according to historical data (NADMO, 2010). According to historical information, the areas most affected by floods are the Ashanti, Brong Ahafo, Central, Eastern, Greater Accra, Upper East and Volta Regions, especially during the period between May-July and September-November. The areas most frequently affected by the floods are quite unchanged even under climate change projections (Figure 5b) (CREW project, 2015) (UNDRR, 2019).

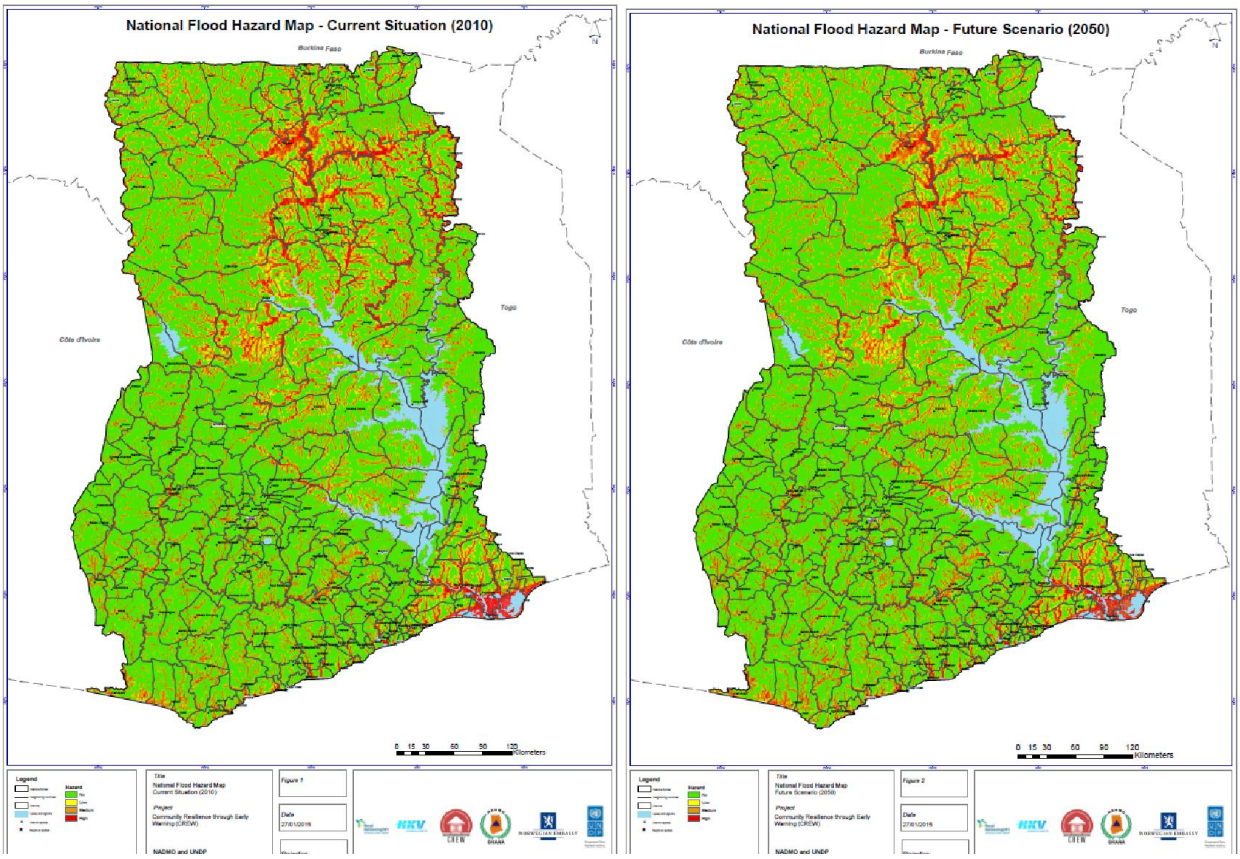

Figure 5. National Flood Hazard Map for the current situation (a) and for a future scenario 2050 (b) (CREW project, 2015).

Besides intense precipitation, several other factors contribute to flood disasters in urban areas: improper land use (e.g. building construction in wetlands and waterways), poor waste management, increases in impervious surface, and inadequate drainage systems (e.g. siltation problems, wrong sizing) (Kusimi, 2018) (Madu & Kuei, 2017) (Almoradie, et al., 2020). This occurs especially in Accra, Kumasi, Tema, Cape Coast and Sekondi Takorad (Kusimi, 2018).

Flood events are not only caused by heavy rain. Ghana also experiences man-made floods mainly caused by dam spillages. During the peak of the rainy season, Burkina Faso's authorities release flows from two large dams (Bagre and Kompienga dams) into the major river channels of the Oti and White Volta. The operations cause the flooding of the plains around these two river channels, affecting the Upper East, North East and Northern Regions.

Given the high concentration of people on the coastal areas as well as the high presence of services and productive assets, the Ashanti, Greater Accra, Western, Easter and Central regions have the highest vulnerability to riverine floods (Figure 6 and Figure 7). According to an assessment carried out by UNDRR with CIMA Research Foundation (UNDRR, 2019), the Ashanti and Western regions have the highest risk of flooding given both the high vulnerability and the high flood hazard.

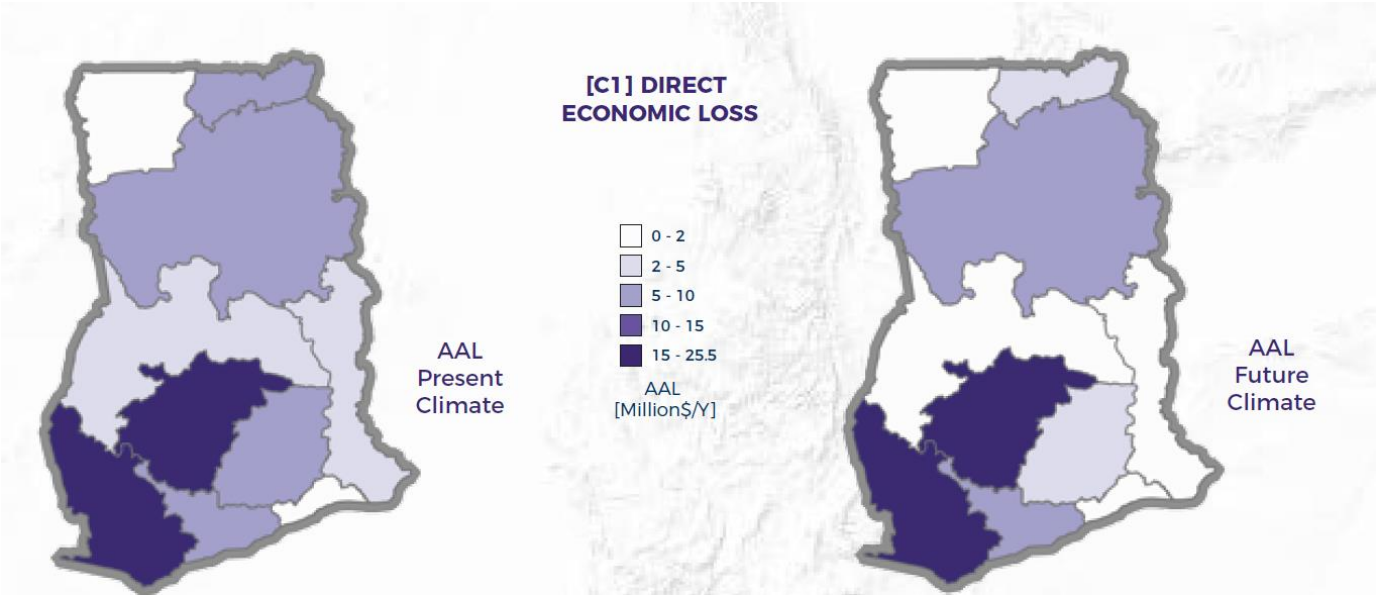

Figure 6. Direct Economic Loss in Ghana for the present and future climate (UNDRR, 2019)[1]

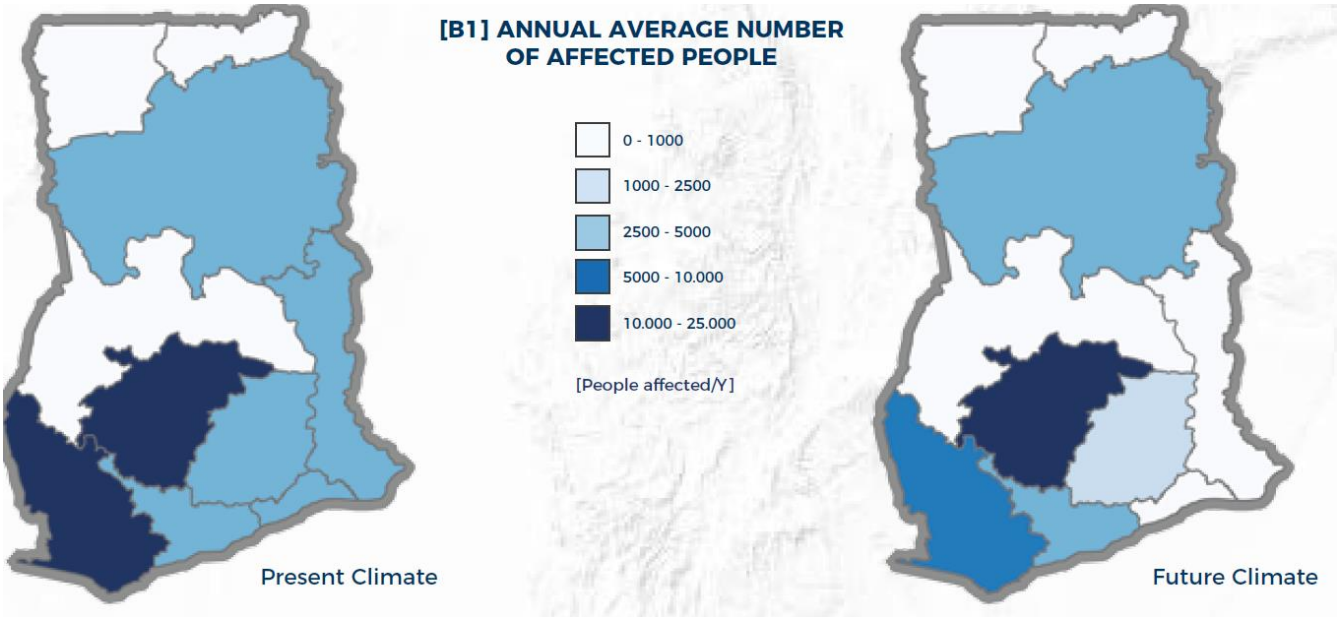

Figure 7. Annual average number of affected people in the present and future climate (UNDRR, 2019).

Drought is not perceived from the population and the authorities to be as dangerous as floods, although Ghana's economy relies heavily on climate-sensitive sectors such as agriculture, forestry and hydro-energy (GFDRR,

[1] Present climate: 1951-2000, future climate: 2050-2100

2011). More than 25% of its GDP is dependent on agricultural production, which is predominantly rain-fed. Changes in rainfall patterns can have, therefore, a serious impact on the country's economy. Major droughts in 1982, 1990-1992 and 2004/2005 brought the topic to public attention, promoting the initialization of an institutional framework, policies and the adoption of drought impact reduction measures. Currently, some farmers apply the practice of planting their crops over a period of three to four weeks to reduce the risk of losing all of their crops in case that a serious drought event would occur during the critical early growth phase (CTCN, 2016).

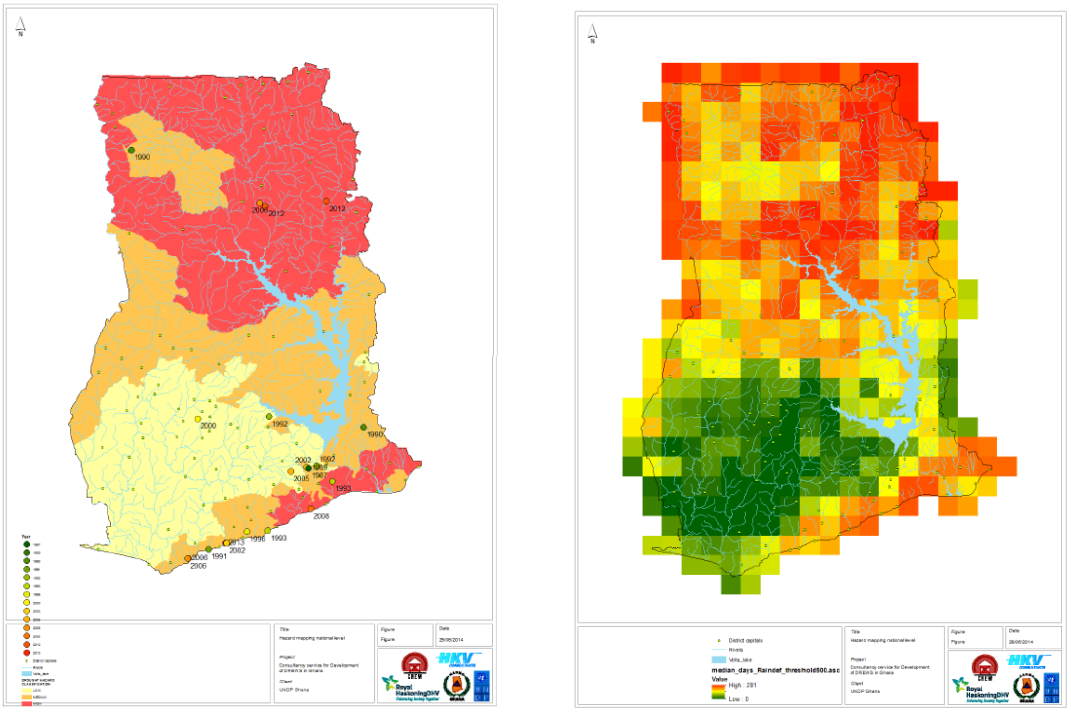

Figure 8. Location of Drought Hazard from the historical disaster database(a). Spatial distribution of number of days that the rainfall deficit is above 500 mm based on a database from 1998 to 2011(b) (CREW project, 2015).

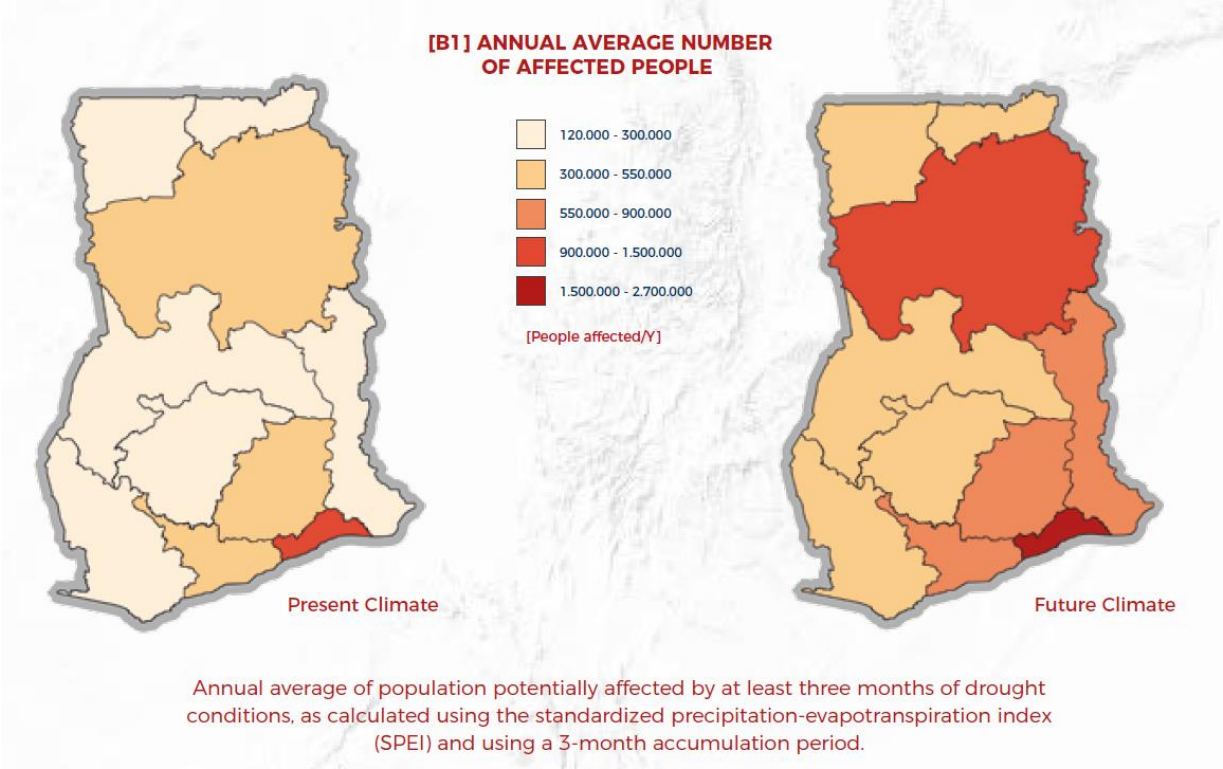

Figure 9. Drought risk maps considering potential affected population(UNDRR, 2019).

Droughts are especially recurrent in the Northern and Savannah regions, where agricultural practices dominate the local economy (UNDRR, 2019) and in the Greater Accra, where population density is the highest (Figure 9). According to the National Disaster Management Plan (NADMO, 2010) (Table 2) and the historical disaster database (Figure 8a), the Upper East, Upper West and Volta regions are also affected by drought, mainly in the month of April.

The National Development Planning Commission (2015) noticed that drought severity and frequency have increased across the country in the last 50 years. Droughts in Ghana occur either due to a reduction in precipitation amounts and frequency (meteorological drought) and/or a decrease in the stream flow (hydrological drought). Meteorological drought usually occurred when precipitation fell below 900 mm/year, as Ghana experienced in 1983, 1993 and 2001. Hydrological droughts, however, mostly affected the Volta River System in Ghana because its flow is highly dependent on the influx of rivers from neighbouring countries (Burkina Faso, Cote d'Ivoire, Benin, Togo and Mali). In 2001, 2007 and 2013-2014, this inflow had been significantly reduced, leading to a decrease in the water level in the Akosombo and Kpong reservoirs, and the Bui dam. This resulted in a reduction in power generation from hydro-electric sites in the areas, affecting negatively the industry, health and tourism sectors (UNW-AIS, 2015).

Table 2. Geographical distribution of hydro-meteorological hazards (NDMP –NADMO 2010)

Disaster Type	*Areas of Occurrence*	*Period of Occurrence*
Floods Rainfall – runoff floods	Ashanti, Brong Ahafo, Central, Eastern, Greater Accra, Northern & Volta Regions Upper East & Upper West Regions	May – July & September – November
Man-made floods (Dam-burst spillage)	Greater Accra, Northern, Upper East, Upper West & Volta Regions	January - December
Tidal waves	Central, Greater Accra, Volta & Western Regions.	August - October
Rain/wind storm	Central, Eastern, Northern, Upper East, Upper West, Mid/Northern Volta & Western Regions	March – May June - August
Drought	Greater Accra, Northern, Upper East, Upper West & Volta Regions	November – April & May – October (when the rains fail)

The regions most affected by droughts and floods (Northern, Upper West and Upper East regions) are also the most vulnerable, with the lowest adaptive capacity due to low socio-economic development (UNCCD, 2016). The current dynamic and demographic changes are increasing the impact of hydro-meteorological extremes, especially in urban areas where the growth of informal urban settlements and poor urban governance are worsening the effect of these events (GFDRR, 2011). Weather hazards also significantly affect communities located in the Ghana's Savannah area due to the high prevalence of poverty and the deepening vulnerability (Aboagye, et al., 2013).

According to a study on impacts of multiple climatic hazards in a savannah ecosystem of Ghana (Yiran & Stringer, 2016), communities located in the Upper East Region experience drought/dry spells every year, leading to losses in crop and livestock production. However, the frequent alternate occurrence of floods and dry spells shows that the water scarcity experienced is not only due to drought, but also poor water management.

3. The Volta Basin in Ghana: the Black and White Volta river, the Oti river and the Lower Volta

The Volta River, with a catchment area extending nearly 70% of the country, is by far the largest river, draining the entire north, centre and east of Ghana (Figure 10) (WRC, 2020). Notwithstanding its large coverage, only 36% of the country's population lives in the basin (IWMI, 2005). High population concentrations do exist in Tamale and Bolgatanga.

The basin is divided into 3 main climatic zones: the wetlands in the south, a tropical transition zone just north of it, and the tropical north, which covers most of the Volta Basin. The major sub-basins of the Volta are the

Black Volta (with Mali, Burkina Faso and Cote d'Ivoire upstream), the Red and White Volta (with Burkina Faso upstream), the Oti (with Burkina Faso, Togo and Benin upstream) and the Lower Volta, which includes Lake Volta. Lake Volta is the largest man-made lake in the world, created by the construction of the Akosombo dam. The dam generates 80% of the power produced in the country.

The Ghanaian Volta Basin faces a high risk of weather-related hazards, including landslides, coastal erosion, urban floods, farmland flooding and dry spells. Flood and drought events occur especially in the northern part of the country, with a major risk present in the North-eastern, Northern and Savannah regions because of extensive rain-fed agriculture. In the Upper East regions, the floods in the White and Black Volta river basins are mainly caused by the spill from the Bagre dam in Burkina Faso which is often cause of impacts given the high social vulnerability and low adaptive capacity of the affected areas (Almoradie, et al., 2020). Drought events are also a risk to the basin as they can reduce the production of hydroelectric energy in the Akosombo dam, the main source of electricity on which Ghana relies, with terrible consequences for the country's economy (Bond, et al., 2018).

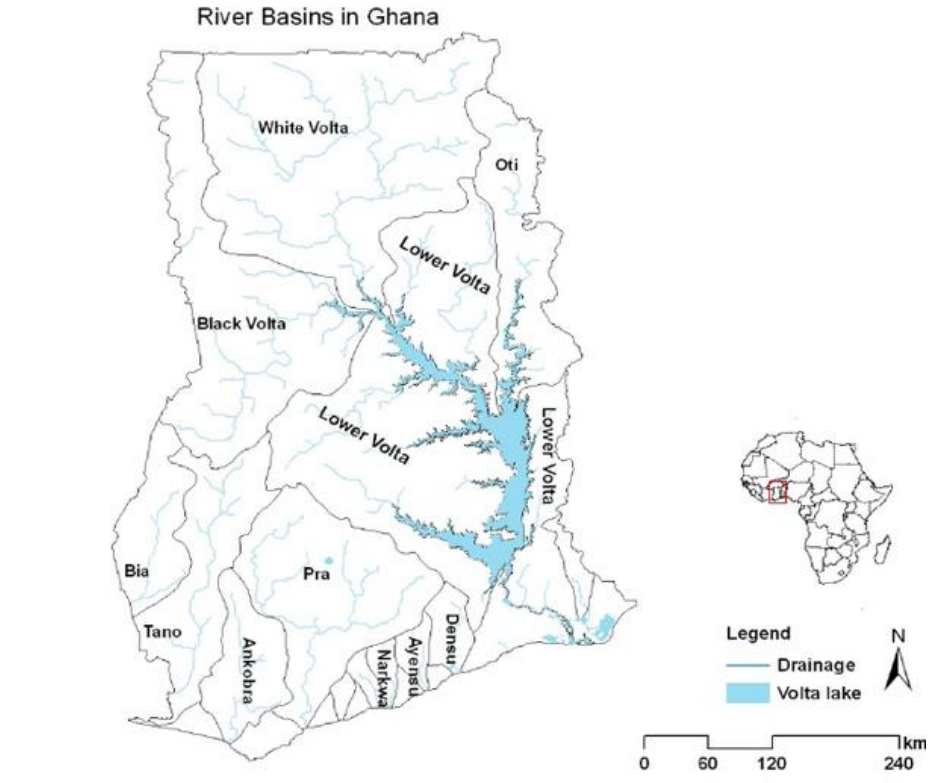

Figure 10. River basins in Ghana

4. Overview of the legal and institutional framework

4.1 State system

Ghana is a unitary constitutional republic with a parliamentary multi-party system. The head of the state and of the government is the executive president, who is elected for a maximum of two four-year terms by universal suffrage. The Parliament has legislative power, while the Cabinet holds the executive power. Ghana has a judiciary power held by the Courts of Justice.

4.2 Administrative organization

Ghana is divided into sixteen administrative regions, which are further sub-divided into 230 districts (Figure 11). For each administrative region, the head of the state appoints regional ministers who are responsible for public health, environmental protection, sanitation and the provision of basic education according to national directives. Under the districts, there are other sub-structures: sub-metropolitan, urban, town, zonal, area councils and finally, unit committees. The local government system is shown in Figure 12.

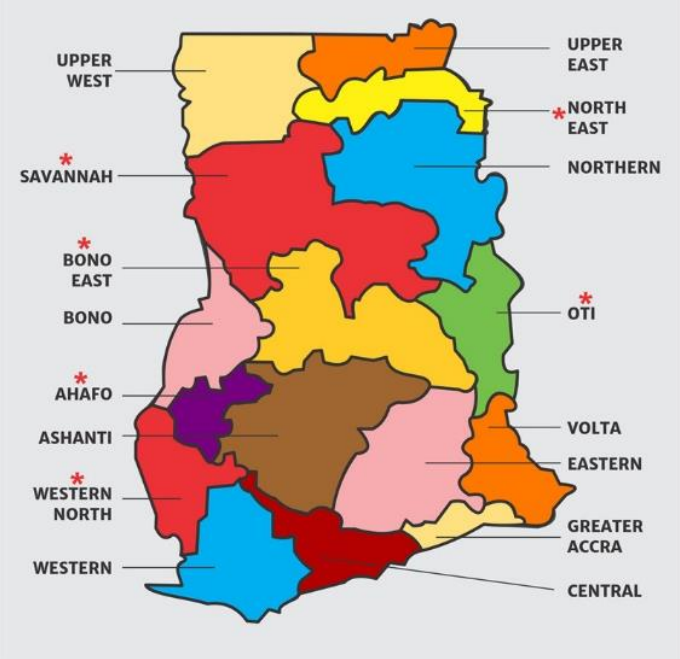

Figure 11. Administrative regions in Ghana

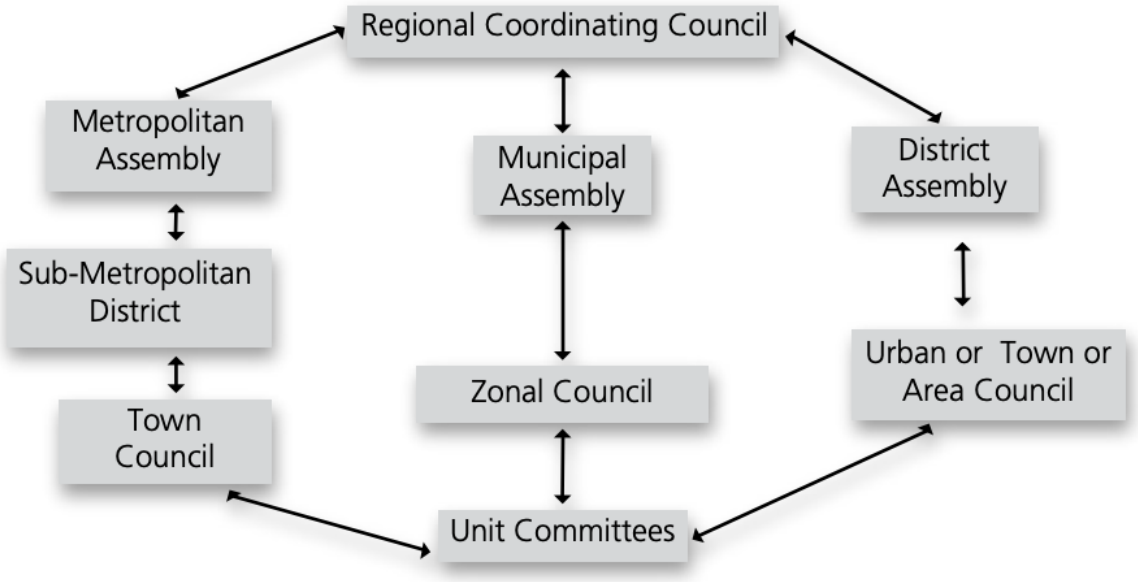

Figure 12. Structure of the local government system (ILGS-FES, 2014)

4.3 Institution in charge of Early Warning Systems

Given the multi-sectorial and multi-disciplinary aspects of disaster management, the government has implemented an integrated approach, identifying the key agencies involved in Disaster Knowledge, Awareness and Response (see Annex 1 for institutions identified by NADMO to be trained in DRM and Annex 2 for institutions involved in response and relief) and defining cross-sectoral collaborations between local and national levels (Figure 13). For each identified stakeholder, the National Disaster Management Organisation (NADMO) has defined roles and responsibilities according to above disaster management phases (e.g. Table 3), reported in the National Disaster Management Plan (NDMP) reviewed by NADMO in 2010. Some of these stakeholders are grouped under different commissions and committees such as the Technical Advisory Commission and the National Disaster Management Committee. The roles of key agencies and commissions are further explained in the sub-paragraph below.

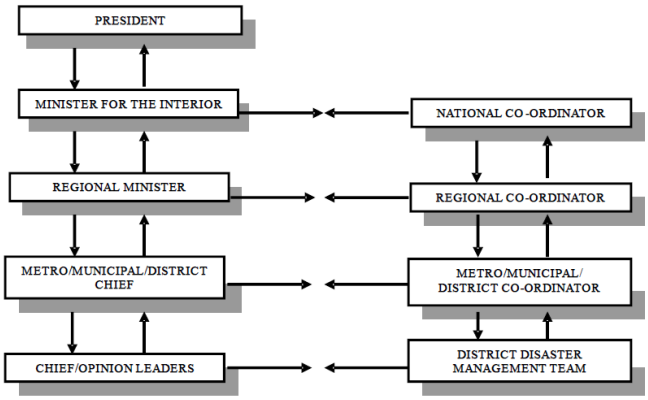

Figure 13. Organogram of Disaster Management in Ghana

Table 3. Institutional Arrangements for Hydro-meteorological Disaster

Disaster Type	Activities	Inputs	Lead Agencies	Collaborating Agencies
Hydro-meteorological	Mapping of flood prone areas	Base maps, consultancy services	GMet	TCPD, MMDAs, Water Research Institute, Department of Urban roads, Department of Forestry, EPA
	Reading and recording of rainfall and water levels	Rain gauges and automatic water levels recorded	GMet, Hydrological Services Department, WRC	MMDAs, NADMO
	Preparation of drainage master plans	Consultancy services	Hydrological Services Department	MMDAs, TCPD, GHA, NADMO
	Preparation of Flood insurance risk maps	Consultancy services	National Insurance Commission	Hydrological Services Department, MMDAs, NADMO
	Installation of Early Warning Systems	Consultancy services	GMet, Hydrological Services Department	MMDAs, WRC, NADMO

4.3.1 Key actors

Below, the key institutions involved in flood and drought EWS.

- **Ministry of Interior**

The Ministry of the Interior is mandated to ensure internal security, and the maintenance of law and order in the country. Among its many objectives, this ministry aims to strengthen disaster prevention, management and social mobilisation.

- **National Disaster Management Organization (NADMO)** http://www.nadmo.gov.gh/

NADMO was established by the Act of Parliament N. 517 of 1996. It is structured under the Ministry of the Interior in order to coordinate all the relevant civil authorities at the national, regional and district levels (UNISDR, 2010). Its mission is to manage disasters by coordinating the resources of government and non-governmental agencies, developing the capacity of voluntary community-based organizations and improving livelihood through social mobilization, employment generation and poverty reduction projects(NADMO, 2010).

NADMO's role was primarily on reactive disaster management, according to the National Disaster Management Plan (NDMP) and the National Standard Operational Management Plan (NSOP). These plans define, in detail, NADMO's role in responding and assisting with recovery during emergency events. With the issuing of law no. 927 of 2016, the government tried to promote, instead, more proactive disaster risk

management. However, NSOP and NDMP have not been revised accordingly, without further specification of the role of NADMO in the prevention and mitigation.

NADMO's general organizational structure is shown in Figure 14. It functions under a National Secretariat, ten Regional Secretariats, 243 Metropolitan, Municipal and Districts secretariats and 900 zonal offices. Within NADMO, there is a *National Emergency Operation Centre* (EoC) formed by the Municipal and District Assemblies (MDA) and the Regional Coordinating Councils (RCCs) which support NADMO in public awareness programs and in the management and release of resources during the operations. NADMO committees at the National, Regional and District levels are in charge of implementing the policies and are supported by the *Technical Advisory Committees*. The technical committees consist of meteorologists, hydrologists, health specialists and engineers. The hydro-meteorological departments function as secretariats of the committee. The committee is meant to meet at least four times a year. However, due to lack of financial resources, they can only meet two times a year. NADMO also manages the *Disaster Management Committees* made up of staff, local representatives and volunteers at municipal levels. These are established only in some municipal areas.

NADMO works closely with many different agencies, especially with the meteorological agency (GMet), which shares both daily and seasonal forecasts with them. The Hydrological Service Department (HSD) shares, instead, hydrographs obtained from the stream gauges. GMet and in some cases HSD are, hence, the first agencies to issue warning information to NADMO in the event of floods.

The warning message is issued by NADMO consolidating the information received by GMet and HSD with the hazard maps and matching the results with their local knowledge of disasters and historical impacts. Accordingly, it sends warning information to the media, in order to reach and alert the communities. In urban areas, the warning is disseminated mainly through social media. In rural areas, NADMO alerts the head of the community through radiophone.

If the role of NADMO is well defined during flood events, the same does not apply to drought events. Currently, drought is not yet included in the disaster management plan (NDMP), but according to the stakeholders interviewed it will be included in the next version. According to the National Contingency Plan (2010), NADMO plays a major role in reducing the impact of droughts by helping small farmers buy risk insurance. They also attempt to increase the farmers' resilience suggesting possible best farmer practices, identified together with the ministry of Food and Agriculture.

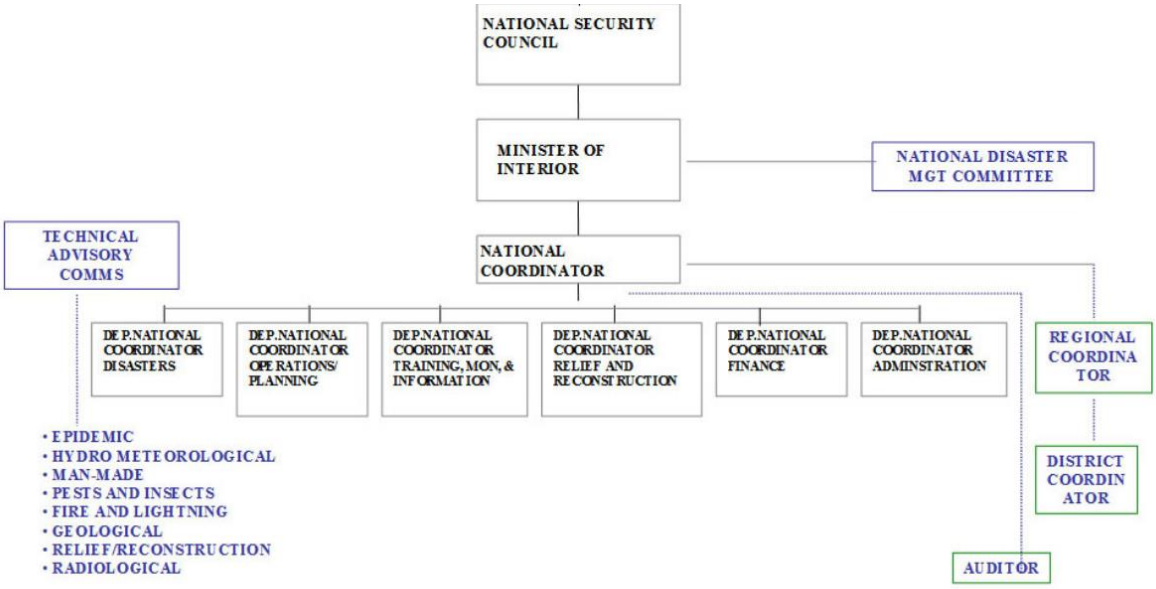

Figure 14. NADMO organizational Structure (NADMO, 2020)

- **Meteorological agency of Ghana (GMet)** https://www.meteo.gov.gh/gmet/

GMet was formed by law in 1957 and the consequent Act of Parliament, and it is now under the Ministry of Communication. It is a semi-autonomous organization comprised of seven departments: engineering, synoptic meteorology and forecasting, support services, applied research and meteorology, basin network and data processing. In the context of EWS, GMet is responsible for providing daily and seasonal weather forecasts.

GMet has an office in ten regions out of sixteen, with a total staff of 364 people. The role of the regional offices is only to collect data and then, transmit them to the central office in Accra, which will further elaborate them through modelling. The transmission takes place mainly by phone or email due to frequent connection problems that do not guarantee the use of automatic tools.

The agency issues daily weather bulletins, with information on precipitation, wind, lightning, rain and floods. The bulletins are shared via e-mail to different institutions (e.g. NADMO, HSD, included Water River Authorities, Private Sector). Additionally, GMet issues a weekly agro-meteorological bulletin and seasonal weather forecasts (published every March and updated in June), without any outlook on possible droughts. Seasonal forecasts are divided into weather forecasts (climate and agro-meteorological) and hydrological forecasts. The seasonal weather forecast is used actively in the northern regions and is based on a locally adjusted weather forecast from the global NOAA CFS model. GMet disseminates the seasonal weather forecast to several key stakeholders such as the Ministry of Food and Agriculture, who is responsible for the further dissemination to local farmers and local organizations through extension officers. The latter also has the responsibility to alert farmers in case of warnings and to collect feedback concerning the accuracy of the forecast. Currently, GMet does not disseminate other drought related information.

Early warnings due to severe weather conditions are also part of GMet's mandate. Extreme weather events are forecasted by comparing the weather forecast with standard average values expected in the area and time of year under analysis. In its study, GMet also provides information about the communities that will be impacted, by using the flood prone areas maps they have developed. Currently, they are in the process of developing a script for forecasting meteorological floods.

Warnings are generally broadcasted to the population via radio, Facebook and other social media. However, only national channels that are currently not popular among the population are used. Private media require indeed an expensive fee to send warning messages on their channels. This is one of the reasons why the alerts don't arrive on time. Warnings are usually issued 2 hours before the event. In addition, no customised messages or color-coded systems are used, except for the warning sent to fishermen.

GMet has no cross-border agreement with neighbouring meteorological agencies. Therefore, they carry out an overall global assessment of current events in the areas surrounding the borders of Ghana, using global satellite data.[2]

- **Hydrological Services Department of Ghana (HSD)**

The HSD under the ministry of Works and Housing (MWH) is mandated to operate and manage primary storm drains and is responsible for programming and coordinating coastal protection works and monitoring and evaluating surface water bodies with respect to floods. Its multi-functional department is divided into six sections:

- Operational Hydrology: establish and maintain hydrological stations. It is also involved in the flood forecasting and the Early Warning;
- Drainage Engineering: design and implementation of storm drainage system;
- Sewage Engineering: design and implementation of sewage systems;
- Coastal Engineering: design and implementation of construction and coastal flood control works;
- Land and Hydrographic Surveying;
- Quantity surveying.

HSD does not issue any warnings, but during the rainy season (June-October) it issues a bulletin three days per week (Monday, Wednesday and Friday before 12:00). The bulletins report the results (hydrographs) of the Sobek model (component of the Flood Early Warning System installed in the White Volta). For the other basins, the bulletins report the hydrographs obtained from the water level measures in the installed stream gauges. HSD assesses the likelihood of a flood event by comparing the water levels with threshold values

[2] In relation to the meetings that CIMA held with the authorities involved in the EWS in Ghana, it is known that "There are no platforms or agreements for sharing information among countries".

established for each gauge according to the vulnerability and exposure of the surrounding villages (threshold-based warning). Due to missing forecasts on the water level (with the exception for the White Volta), the information presented in the bulletin is not time effective.

At present, HSD does not have any formal national or international agreements for data exchange with the exception of the water spilling and level information shared by Sonabel in the Bagré dam, which is regularly shared by the respective organization in Burkina Faso and the Oti river basin. The lack of formal agreements in data exchange, especially with GMet, results in the use of global data as inputs of the Sobek model. Additionally, data owned by HSD can be exchanged only under a formal request.

Currently, GMet and HSD are in the process of setting up a data sharing procedure (MoU). This will allow HSD to regularly receive Meteorological data and severe weather warnings. Additionally, there is an ongoing discussion for the possibility of having a joint bulletin.[3]

- **Water Resource Commission (WRC)** http://www.wrc-gh.org/

The Water Resources Commission (WRC) was established by an Act of Parliament (Act 522 of 1996) and it is under the ministry of Sanitation and Water Resources. The commission has the mandate to regulate and manage Ghana's Water Resources and co-ordinate government policies in relation to them. The institution develops policies for the protection of water bodies in Ghana (e.g. riparian buffers) and regulate their water activities. Additionally, it regulates the use of flood plains for agriculture.

The Board of WRC is made up of 15 members including the Chairman, the Executive Secretary, a Chief and two other persons, one of whom shall be a woman. The rest are representatives of key institutions in the water management sector (WRC, 2020):

- Ghana Water Company Limited;
- Organizations producing potable water;
- Hydrological Services Department;
- Volta River Authority;
- Irrigation Development Authority;
- Water Research Institute;
- Ghana Meteorological Agency;
- Environmental Protection Agency;
- Forestry Commission;
- Minerals Commission.

[3] In relation to the meetings that CIMA held with the authorities involved in the EWS in Ghana, it is known that an "Agreement on data exchange (MoU) with VBA is in place".

The commission coordinates the implementation of early warning systems, whose operational part is under the responsibility of other national organizations (e.g. Hydrological and Meteorological Agency). In addition to its coordination role in several projects, WRC provides support on resources and capacity building. For example, they support data collection by providing equipment and technical training. Previously, the budget they managed depended entirely on donor support. Currently, WRC generates an internal fund for operational activities supported partially by the Ghana Government.

Extreme events, such as drought, are not directly mentioned as part of the functions of WRC. However, knowledge of drought situations is taken into account when preparing IWRM plans, issuing water permit and designing water resource monitoring system.

- **Volta River Authority (VRA)**

The Volta River Authority (VRA) is the principal energy infrastructure development agency for the generation of electrical power in Ghana (IHA, 2019). This agency manages the Akosombo dam. When the level of Lake Volta is too high, VRA issues a warning that they might start spilling. This has happened only twice since the construction of the dam, in 1990 and 2010 (CREW project, 2015).

- **WASCAL**

The objectives and activities of WASCAL in Ghana are:

- Climate service: strengthen capacity in climate change adaption in scientists, policy makers, IT- and data experts, farmers and citizens.
- Set up of WADI data portal (WAscal Data Infrastructure) including standardization of data formats, meta data and protocols to facilitate the acquisition, provision, integration, management and exchange of data resources and links to relevant data sources;
- Capacity building: WASCAL supports and facilitates academic education amongst six West African universities.
- WASCAL provides no operational data. So WASCAL will not provide relevant input data for the EWS.

4.3.2 Other important actors

The key additional stakeholders that are or should be involved in the design, development and implementation of an early warning system are as follow:

- **Ghana Irrigation Development Authority** (GIDA): Responsible for the formulation and execution of policies and plans to promote the sustainable development of land and water resources in Ghana for crop production, livestock watering, aquaculture, agricultural related industries and institutions while

ensuring plans for all year-round agriculture production in Ghana. Hence, IFM is an integral part of their core activities.

- **Environmental Protection Agency** (EPA): Responsible for the implementation of environmental policies ensuring that the environment is protected through sustainable use of natural resources. With respect to drought, EPA provides the link between the technical aspects and warnings with the practical implementation at the farmers' level.

- **Ghana Water Company Limited**: Responsible for the planning and development of water supply systems in urban communities in the country.

- **Community Water and Sanitation Agency**: Responsible for the planning and development of water supply and sanitation systems in rural communities in the country.

- **Metropolitan, Municipal and District Assemblies** (MMDAs): Support with the implementation of flood management plans in their districts and to help coordinate flood rescue operations with NADMO and other state institutions.

- **Ministry of Sanitation and Water Resources**: Responsible for initiating, formulating, implementing and co-ordinating of policies and efficient implementation of programmes on Water Supply and Sanitation, Hydrology and Flood Control Systems in the country.

- **Ministry of Food and Agriculture** (MOFA): MOFA is responsible for the formulation of appropriate agricultural policies, planning & co-ordination, monitoring and evaluation within the overall national economic development. In relation to drought, they convey weather information received from GMet to the local and regional offices and provide guidance and support to the farmers in relation to farming and agricultural sector. No drought forecast or warnings to the agricultural sector are provided.

- **Centre for Remote Sensing and Geographic Information Services** (CERSGIS): is a governmental institution under the land commission which provides GIS survey and mapping service (https://cersgis.org/services/).

- **Land use and spatial planning authority** (LUPSA) is a governmental institution which aims to plan, manage and promote sustainable and cost-effective development of human settlements in the country,

in accordance with sound environmental and planning principles (http://www.luspa.gov.gh/index.html)

- **Ghana Statistical Service** (http://www.data4sdgs.org/partner/ghana-statistical-service)

- **Water Research Institute** (WRI) **https://www.csir-water.com/:** operates under the Council for Scientific and Industrial Research (CSIR) of Ghana, with the mandate to research into water and related resources, providing scientific information, strategies (decision support) and services towards the rational development, utilization and management of water resources. Through consultation, it collaborates with different institutions to accomplish their mandate. They have a total staff of 280 people divided into six technical divisions. Currently, they are collaborating with the Volta Basin Authority for the establishment of a disasters database (amount of rainfall leading to disaster, river level, impact, location etc.).

- **THAMO** (Trans African Hydro Meteorological Observatory - Technical University of Delft)
  Its objective is to develop a dense network of hydro-meteorological monitoring stations in sub-Saharan Africa with stations spaced at approximately 30 km. For Ghana, about 230 of these stations are foreseen. Currently TUD is working on a pilot to install 30 of these stations throughout Ghana. Transmission of data from these stations is likely to be done on a daily basis, through GSM / GPRS. Once this is up and running, TUD wants to connect this to a WARP model for weather forecasting. TUD thinks it is possible to make a (reliable) weather forecast for the next 3 days. It is not yet clear how TUD will store the data or when data (measured or forecasted) might become available.

4.4 Policy and Plans

In the last 20 years, the government has drafted Disaster Management and Disaster Preparedness Plans at national, regional and district levels. Main plans for effective disaster management in Ghana are:

- **The National Disaster Management Plan** (**NDMP**)

First drafted in 1997 and then reviewed in 2007, the NDMP serves as a framework for managing disasters during the three phases of disaster management: Pre-disaster phase (prevention, mitigation), disaster or emergency phase (response), and post disaster phase (recovery);

- **National Standard Operating Procedures for Emergency Response 2010** (**NSOP**)

The NSOP states the tasks or roles required to implement an effective response to any disaster event. The responsibilities of the Government and its key Ministries, Departments and Agencies, as well as Non-Governmental Organizations (NGOs) and Volunteers have also been defined. The NSOP is the emergency operational component of the NDMP;

- **Ghana Plan of Action on Disaster Risk Reduction and Climate Change Adaptation (for 2011-2015)**

The plan constitutes a first effort from the government to shift the national agenda from a disaster response to disaster prevention and risk reduction approach. The plan is articulated according to the 5 pillars of the Hyogo Framework of Action.

- **National Contingency Plan (NCP) for emergency preparedness and response**

The plan provides the basis for each key organization to carry out an effective and coordinated response to natural disasters. It covers preparedness for floods, earthquakes, and post-election/ethnic conflicts.

5. Analysis of National Hydro-Meteo Capabilities

Hydrological Services Department of Ghana (HSD)

n. stream gauges	261 stations (only 172 operational) among which 91 stations are within the Volta basin (only 55 operational) How many manual, automatic and tele-transmitted?
models	Sobek
staff	60 staffs (hydrologists and technicians)
Revenue	Self-generated but owned by the government
Challenges and gaps	• Under-staff; • Loss of knowledge: 1. Staff leave after retirement and their knowledge is lost; 2. People that are trained leave for better paid jobs in private companies or projects. They were supposed to be 200, but currently they are only 60. The reason is the lack of funding.

Previously, the number of stream gauge stations was 300. Now it is reduced to 261 stations among which 172 stations are currently operational. The main problem of the shut-down of the stations is the maintenance and operational cost. For the automatic stations, the main challenges are in data transmission and in their maintenance. The data acquired from the stations pass through a quality check. HSD has water level and discharges data for a period of around 30-40 years. Finally, HSD uses the flood and drought portal (https://www.flooddroughtmonitor.com/home) for the analysis of several satellite data. For flood forecasting, HSD runs "Sobek" at a coarse resolution, which hinders the formulation of adequate flood risk warnings. However, the use of a model with a finer spatial resolution is limited by the low computing capacity and data availability.

Ghana Meteorological Agency (GMet)

Weather Station	● 20 synoptic stations that are communication automatically, 22 semi-automatic (22 manual synoptic stations); ● 103 stations: 24 manual (working); 69 automatic (not functional); ● 56 rainfall stations (synoptic transmit data every 3 hours); ● 10 agrometeorological stations; The automatic stations send data every hour.
Models	● Meteo France; ● ECMWF; ● WRF (running operational by them). It runs every Monday. ● UK MET office
Staff	364 people in 10 regional offices
Revenue	Self-generated but owned by the government
Challenges and gaps	● Internet connection not always works (transmission issue); ● Challenges in maintenance (e.g. replacement of the butteries); ● The computers used for running the models have a low capacity.

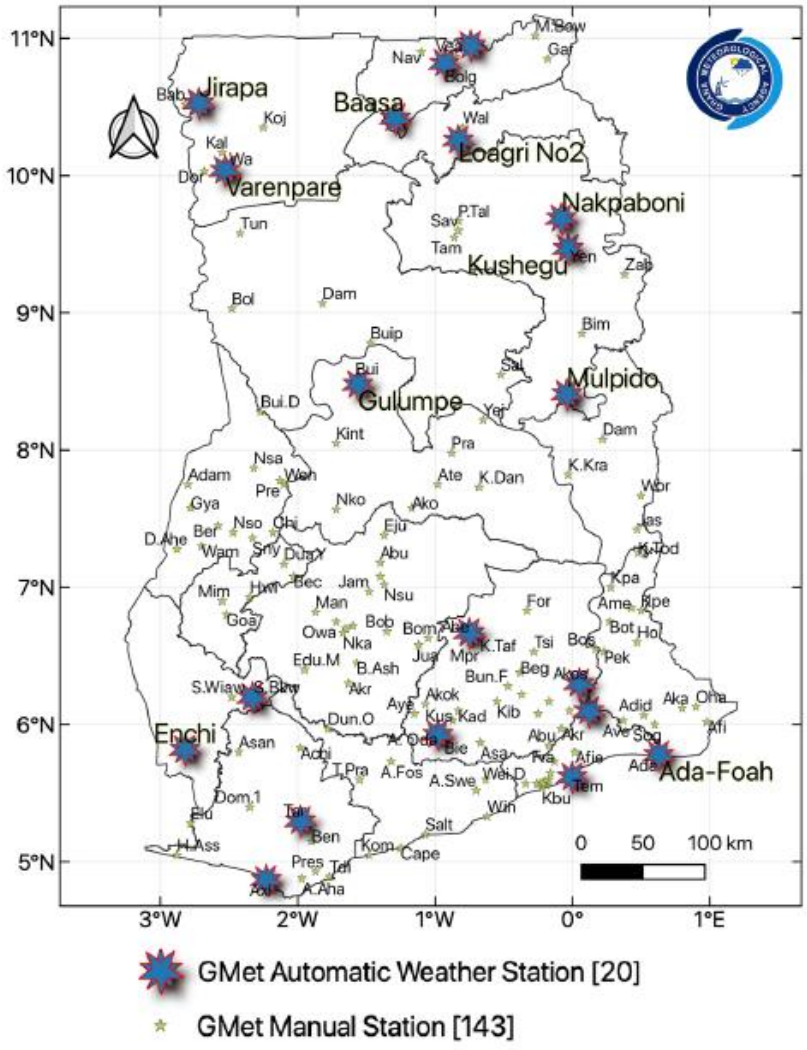

Figure 15. GMet Meteorological Station Distribution

Water Resource Institute

Models	• SWAT; • HEC-RAS; • WEAP.

The institution runs water allocation models and hydraulic models like SWAT, WEAP and HEC-RAS. Their work mainly focuses on the management and utilization of water resources. In the field of disaster management, they are currently collaborating with the Volta Basin Authority for the establishment of a disaster events database. Concerning drought, they focused on the hydrological drought for investigating the impacts of river flow decrease on the hydropower production.

Global models and products available and not yet used

- https://earlywarning.usgs.gov/fews/search/Africa/West%20Africa (for FEWS drought monitoring)
- https://fews.net/agroclimatology (The USGS FEWS NET Data Portal provides access to geo-spatial data, satellite image products, and derived data products in support of FEWS NET drought monitoring efforts throughout the world);
- Global NOAACFS model for weather forecast in the northern regions.

IT infrastructure supporting Hydro-Meteo data and models

- The Trans-African Hydro-Meteorological Observatory (https://tahmo.org/) has around 96 Hydro-Meteorological Stations in Ghana;
- CERSGIS data:

  Data set available for the scale of 1:50000. For Urban areas, data and maps are available with a scale of 1:2500 (Street level data for the major urban areas 1:2500)

  - Land Cover/Land Use information is available for the year 2010 (30m resolution) – currently it has been updated and will be made available for 2017 (June 2020)
  - Water bodies (lagoon, open water surfaces) – will be made available under the new LC/LU
  - Detailed map of the buildings' location in certain areas. For the 1990, 2000, 2010, they have maps for the all countries using Landsat imageries (30-meter resolution). They are currently working on maps for 2017 (info contained: build-up areas, per urban and agriculture areas).

6. National analysis of the EWS for floods and drought

6.1 Methodology

Early Warning Systems (EWS) have a prominent role for mitigation and adaptation to natural hazards and climate change, as recognized by the Sendai Framework for Disaster Risk Reduction (target g) (United Nations, 2015). An effective EWS encompasses not only data and technological apparatus, but also the use of disaster risk information, policies and legal frameworks, contingency planning and involvement of population in communication and education.

The definition of a road map to drive the EWS towards a better alignment to international standards requires a preliminary evaluation of the existing system. In the following is described the method adopted to assess the elements of efficient, people-centred EWS. The method follows the World Meteorological Organization checklist for multi-hazard early warning (WMO, 2018) and the guiding principle for community early warning by the International Federation of Red Cross (IFRC, 2012).

The checklist (WMO, 2018) is translated into a survey composed by 80 questions which encompass the four elements of people-centred EWS (20 questions per element). They are: A) disaster risk knowledge, B) monitoring and forecasting, C) warning dissemination and D) communication, preparedness and response (Figure 16). The survey is intended to be partly filled as a desk review based on available documents and completed with the help of country representatives during consultation activities.

Figure 16. The four elements of people-centered EWS (WMO, 2018).

Section A of the survey evaluates the state of disaster risk knowledge in terms of (1) identification of key hazards and related threats; (2) identification of exposure, vulnerability, capacities and risks; (3) identification of roles and responsibilities of stakeholders; (4) consolidation of risk information and (5) incorporation of risk information into EWS. This section investigates if a systematic collection, analysis and revision of data regarding hazards, vulnerabilities and exposure is in place and if the capacity to cope is evaluated.

Section B of the survey appraises the monitoring and forecasting capabilities in terms of (1) availability of monitoring systems; (2) forecasting and warning services; (3) institutional mechanisms. This section checks the availability of warning services with a sound scientific basis, reliable technology, qualified personnel and continuous operativity.

Section C of the survey assesses the warning dissemination and communication in terms of (1) roles, functions, organization and decision-making processes; (2) communication systems and equipment and (3) impact-based EW (WMO, 2015). This section analyses the existence of operating procedures to coordinate different levels (e.g. national to local), verify, maintain and ensure redundancy of equipment and trigger appropriate reactions to the warnings.

Section D evaluates preparedness and response capabilities in terms of (1) existence and effectiveness of disaster response plans and (2) public awareness and education campaigns. This section investigates how the

warnings actually reach last-mile operators and citizens and if awareness campaigns are targeting different sectors of civil society.

A score from 0 to 3 is assigned to each response, according to the answers to the questions in the survey. As general evaluation criteria, a score equal to 0 indicates that at the current state the answer is totally insufficient, score 1 shows is again not sufficient but some partial attempts have been made, 2 is sufficient/quite good, 3 means very good, i.e. exceeding the recommendations (Figure 17). Evaluation criteria are declined specifically for each question (Figure 18). The sum of the scores in each section is used to identify opportunities to improve the current situation, a sufficient section score is given by at least 40. The maximum score for a section is 60.

The final roadmap will aim to fill the identified gaps and reach at least a sufficient/quite good score for each element.

Grading scale	**Score**	**Description**
The principle is not met: there is no evidence of required elements nor there are ongoing initiatives.	**0**	The current state of the system does not comply with international standards and good practices. Ongoing initiatives to strengthen it do not exist or will not suffice to make it compliant.
The principle is partially achieved: some efforts to achieve the criteria are observed but additional initiatives need to be implemented.	**1**	The current state of the system does not comply with international standards and good practices. Ongoing initiatives could suffice to make it compliant.
The principle is achieved: there is consistent evidence that the standards have been successfully reached.	**2**	The current state of the system complies with international standards, recommendations and reference good practices.
The principle is exceeded. There is evidence that a variety of methods is used to go beyond the minimum expectations and ensure an exceptionally high level of quality.	**3**	The current state of the system exceeds with international standards, recommendations and reference good practices.

Figure 17. General evaluation criteria for the survey

Questions	**Response (0-3)**	**Response description**	**References**	**Evaluation criteria**
Are people educated on how warnings will be disseminated and how to respond?				0 Non 1 Partly in some pilot tests 2 Yes, there are education program for students and adults 3 yes, there are education program for students and adults, and they are repeated each year before the hazard season

Figure 18. An example of question in section D "Preparedness and response" (green) and specific evaluation criteria (blue)

6.2 Overall score

Ghana's strengths in EWS are in the disaster risk knowledge and monitoring and forecasting. Over the last twenty years, many projects on flood forecasting and flood risks were carried out in the country, increasing knowledge on the probability and impact of this weather-related hazard. The implementation of pilots EWS in the White Volta and Oti basins has increased the monitoring and forecasting capacity of the hydro-meteorological agencies, providing new tools and models to forecast floods. However, knowledge of disaster risk is often project-related, limiting the possibility of extending linked pilot projects to the entire country. This does not allow for the development of financial, technical and human capacities that would increase the sustainability of the pilot projects, which too often end once donors' funding stops, without any follow-up or up scaling. Until now, only a few projects have focused on drought, leading to few available systematic studies on the current and future risks of drought in the country.

The country's institutional procedures are fully in place. With the establishment of a Technical Advisory Committee, the government fosters intra-sectorial coordination and the consolidation of disaster information. The government has identified key stakeholders in the early warning system and clearly defined their roles and responsibilities. Additionally, its effort to shift the attention from response to preparedness interventions is reflected in recent acts and revision of plans. However, the lack of financial investment does not allow for the enforcement of established procedures and plans. For the same reason, the Technical Advisory Committee does not meet often during the year. Institutions like the Hydrological Service Department do not have an internal budget and strongly depend on government investment in its services. The lack of funding also affects maintenance interventions and the operations of monitoring systems with a consequent reduction in the reliability of real-time forecasts. Therefore, the warnings are not timely and little can be done before the events happen. This, combined with a weak coordination between the national and local levels, leads to the implementation of reactive rather than proactive interventions.

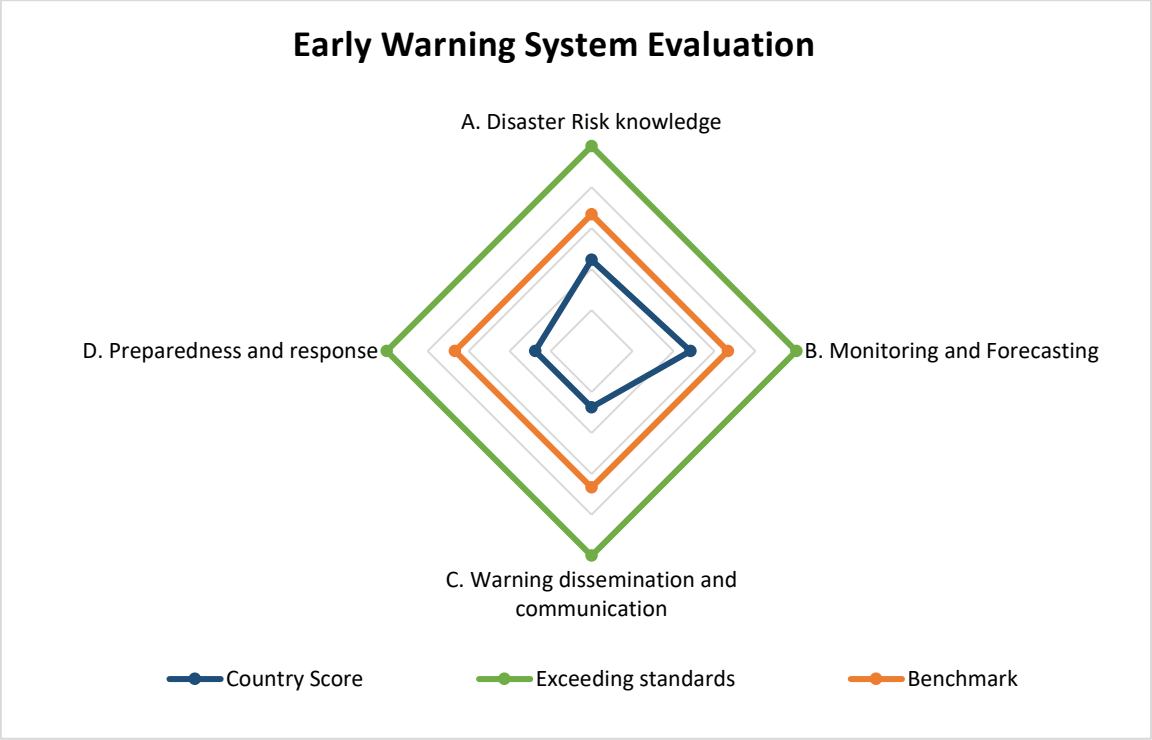

Figure 19: EWS overall score.

6.3 Risk Knowledge

Disaster risk knowledge is one of the components that is best achieved in Ghana. Over the last 20 years, many donors' projects focused on flood risk in the country, broadening the knowledge about spatial distribution of current and future flood hazards.

The disaster risk knowledge is quantitative: there are quite recent (2010) hazard maps for floods and droughts that cover the whole country. The maps were developed by HKV and Royal HaskoningDHV, within the CREW project. Flood hazard maps were developed considering current and future climate scenarios (Figure 5). However, the map's reliability is uncertain due to the use of global satellite data (SRTM 90 DTM) as inputs. Additionally, they have a quite coarse resolution (90m) for analysis in urban areas and hotspots. The drought hazard map was developed by computing the maximum precipitation deficit with the Tropical Rainfall Measuring Mission (TRMM) and the Global Potential Evapotranspiration at a resolution of around 30 km (Figure 8b). Although, the resolution is coarse, the map is consistent with historical drought events.

Currently, both NADMO and GMet are collecting historical data in a database. Historical weather data is used by GMet to identify possible meteorological anomalies, while historical information on disasters is used by NADMO to validate warnings and calibrate a possible response in relation to previous impacts. A more detailed understanding of weather disaster risks at the local level is reached only in some areas within the Volta Basin thanks to pilot projects carried out within the CREW project.

Another weakness in identifying key hazards is the lack of assessment of possible cascading events. This assessment is not carried out although there are many cases of landslides during floods, or fires in drought conditions.

Exposure and vulnerability are qualitatively and locally assessed. Community leaders are usually aware of vulnerability levels, based mainly on their past experiences. Additionally, local government authorities in some urban areas conduct GIS and census surveys. However, this assessment is not carried out frequently and therefore, is not able to capture the dynamism of the analysed areas.

Cultural practices are quite frequent, especially in the rural northern areas. Although the Ghana National Adaptation Plan (EPA, 2018) encourages the integration of indigenous local knowledge into the early warning system, there is no mention of the impact that those local practices could have in increasing or decreasing the vulnerability of the communities. Local communities often rely more on their local knowledge than on the warnings issued.

Institutional mechanisms for managing forecasting and warning are well defined by the National Disaster Management Plan (NADMO, 2010), which for each disaster identifies the actions, the lead agencies and collaborating agencies in charge. The responsibility for developing flood prone area maps is under GMet, while risk information is collected by NADMO. General coordination is managed by NADMO, which however has limitations in coordinating the exchange of information between different national institutions and in reaching the local communities. There is no active engagement of the rural and urban communities in assessing local hazards and risk, with the exception of few projects carried out especially in the White Volta Basin (GFDRR, 2014).

As mentioned above, flood hazard warnings are consolidated both through historical information and through local (mainly volunteer) officials. On the other hand, vulnerability and exposure data are not assessed for the whole county and rare updates are only made for some pilot sites. This results in an incomplete picture of the flood and drought risks across the country. In this regard, the flood and drought risk profile for Ghana developed by UNDRR and CIMA (UNDRR, 2019) could be a valid support. However, the results obtained are not validated due to the lack of local commitment and the resolution is rather coarse due to the exclusive use of global data. Furthermore, many institutions are unaware of this work which is not at all incorporated together with the hazard maps available in the development of ad hoc mitigation measures.

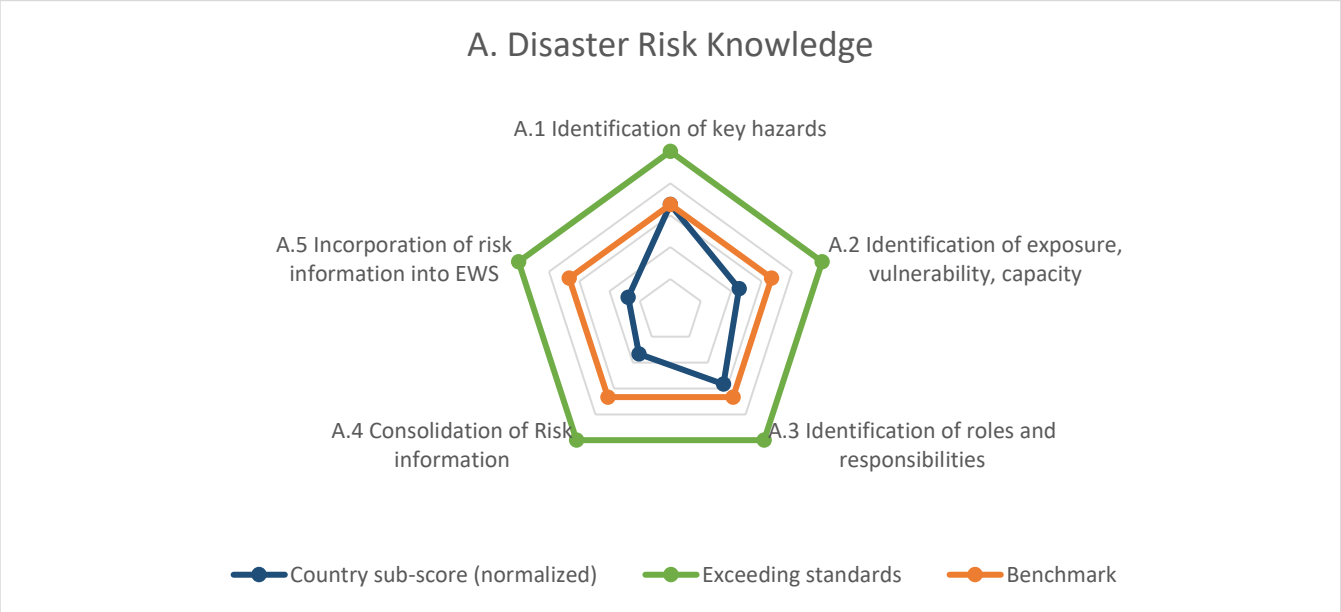

Figure 20: Score of Component A "Disaster Risk Knowledge".

6.4 Monitoring and Forecasting

The monitoring network for hydro-meteorological data has a low spatial coverage in the country, with only a few automatic stations and many currently not operational due to the lack of funds for maintenance. This applies, in particular, to the stream gauge network, in which only half of the available stations are functioning. The lack of financial resources for maintaining the monitoring system and hardware or software also adds to the lack of trained people. This is both the result of few training opportunities especially for HSD staff and the loss of knowledge: the elderly people leave the agency without training the younger ones and the trained people leave due to better job opportunities.

For the functioning stations, GMet collects and processes the data in real-time. However, the same data are not currently shared with HSD and hence, not used to feed the hydrological model for flood forecasting. Local data are, hence, mainly used as a validation of the results obtained from global models. Flood early warning systems are only operative in a few basins (e.g. White Volta and Oti basins) and the issued warnings are not linked to response actions.

Concerning drought, reliable near real-time observations are missing in some parts of Ghana, which makes it difficult to overview the current conditions and predict how drought events will evolve. The issues are mainly related to a missing institutional framework. Drought is not included, both in the National Contingency Plan (2010), and in the Standard Operational Procedure (2010) developed by NADMO. GMet has a major role in providing and disseminating information/recommendations concerning drought through weekly agrometeorological bulletins and a seasonal forecast report disseminated locally by extension officers.

GMet is providing tailored weather information through specialised services to public and private sectors. Furthermore, it is currently developing an integrated weather dissemination system (WIDS) which will include user specific needs, area specific and language specific.

In general, the warning systems are rarely subject to tests and exercises. Additionally, there are no established procedures to ensure that warnings have reached the principal stakeholders and the population at risk, not even to inform the population of the end of a threat.

The pilot FEWS in the White Volta basin has a backup system. Concerning the inputs needed for forecasting, in the event of a blackout or transmission problems, the data is entered manually. In the case of warnings, messages are sent by phone or walkie-talkie in order to minimize the possibility of failure as much as possible.

Concerning the institutional mechanisms, there are no agreement and interagency protocols to ensure the consistency of the warning language. Currently, more than one bulletin is issued (from GMet and from HSD); however, there is an ongoing initiative for unifying the bulletin. Agreements for data exchange are also missing, both at the national and international levels. The only cross boarder exchange is with Burkina Faso through a bilateral management committee of the Bagré dam (Almoradie, et al., 2020). However, there are still limitations in disseminating warning information in a timely manner and spillages from the dam often results in significant damages for the communities in the north Ghana. Despite these gaps, there is a clear understanding from media, partners and population of who is responsible for issuing warnings.

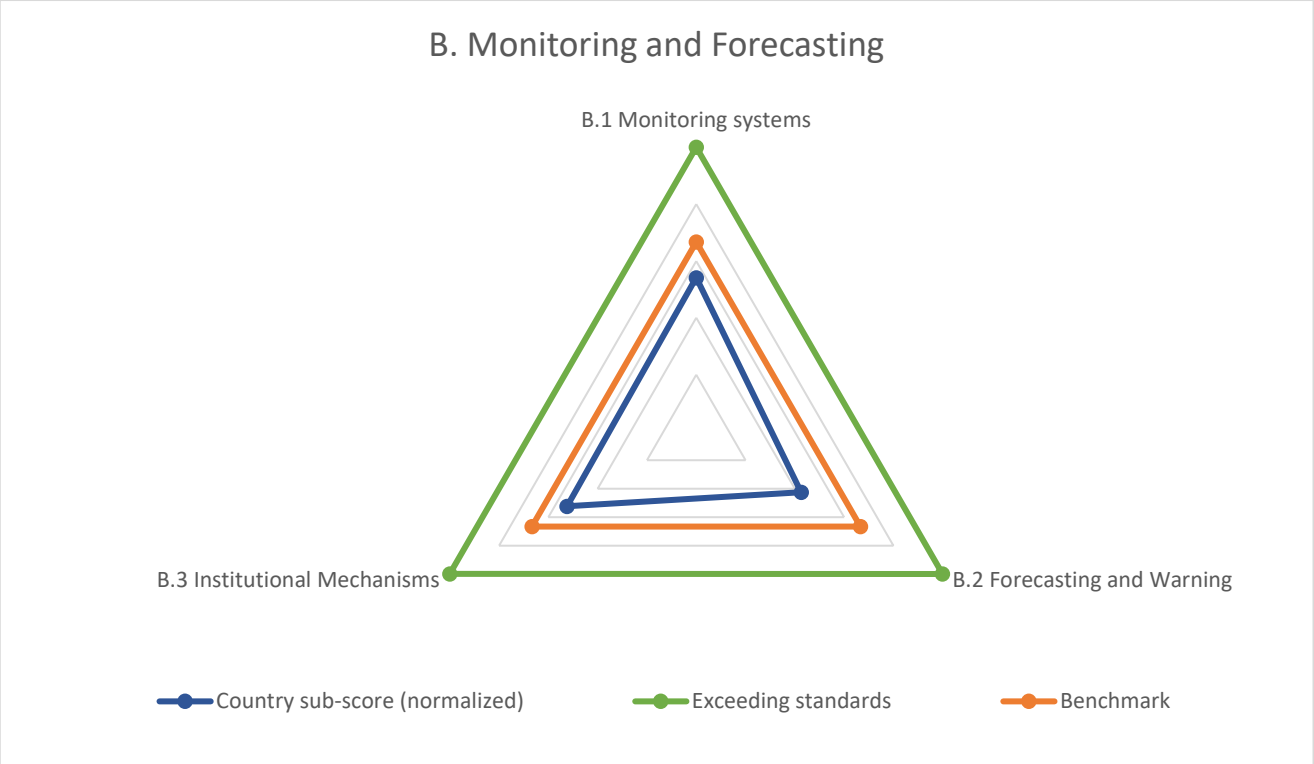

Figure 21: Score of Component B "Monitoring and forecasting".

6.5 Warning dissemination and communication

Warning dissemination and communication is the component that would benefit for a more systematic improvement in the national early warning analysis.

The National Standard Operational Management Plan -NSOP states the tasks and the roles at national and local levels, required of responders in any disaster event. However, the document is lacking in identifying roles and responsibilities of the 'last mile' operators and citizens. Based on the consultations carried out in December 2019, local procedures appear to be lacking and not effective in some cases. The NDMP and the NSOP set up committees at national and local levels responsible for drawing national and local plans while improving coordination among the different agencies involved. At the national level, the committee is expected to meet four times a year. However, they currently meet only two times a year due to limited financial resources and the same is likely to happen locally.

NADMO has a country-wide structure with representation at regional, district, and zonal levels. The decentralized structure over different levels should place NADMO in a key role in the warning dissemination. However, due to the limited (mainly financial) resources of the Zonal offices, emergency warnings at the local level often rely on messages from community volunteers, and/or District Assembly representatives with contacts in a rural location. These same people are also responsible for collecting feedback from end-users concerning the reliability and accuracy of the warning messages (GFDRR, 2011).

There are no feedback mechanisms to verify that warnings have been received from the whole population with particular attention to vulnerable categories. Warning messages are not tailored to different end-users, do not provide guidance to potential impacts and needed actions, and, finally, do not always reach the affected population, including those in remote locations. The established communication strategy is not effective both because messages are not transmitted in the local languages and because the channels used are not popular with the population (there are no agreements with private sectors to disseminate warnings). If the early warning system is in place in the potentially affected area, the warning message is received at the earliest two hours before the event, which does not give much time for the implementation of preparedness actions. When NADMO activates, the emergency is already ongoing. This results in very little coordination between the different actors. The affected population then reacts to the expected hazards based on their knowledge acquired through historical events.

For communicating warning messages, NADMO uses basic equipment, which does not require much maintenance, reducing the overall operational cost. As part of donors' projects, recent technological equipment has been provided. However, it is currently unused due to the lack of financial resources necessary for its use and maintenance. Finally, rehearsals and simulation exercises are performed only rarely and only in some cities.

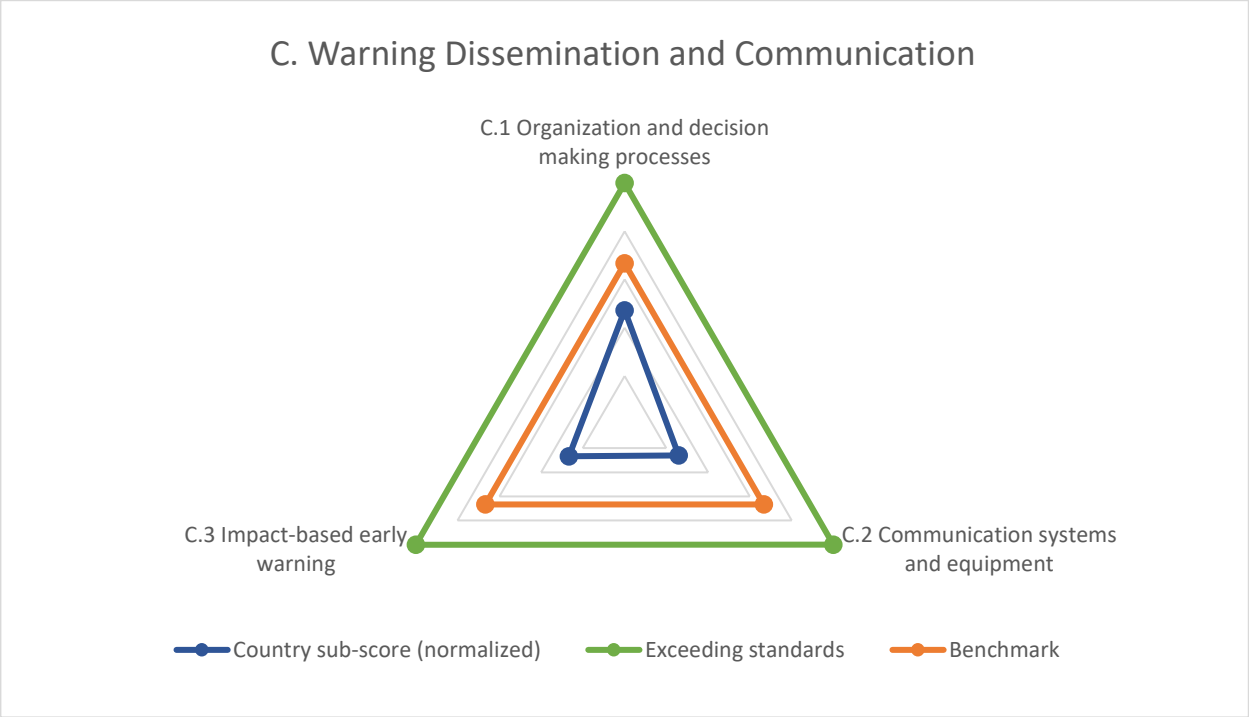

Figure 22: Score of Component C "Warning dissemination and communication".

6.6 Preparedness and Response

The system of logistics and equipment for effective disaster response is weak, particularly at the regional and district levels. At sub-national level, and especially in rural areas, a more integrated approach to disaster risk management planning should be adopted. This results from low human resources capacity, lack of training opportunities, low remuneration, and weak coordination power, which fails in engaging relevant sector agencies. Therefore, early actions and response mechanisms appear to be missing or unrelated to the severity of the expected event and its impact. This is also the result of unsecured funding for different disaster scenarios. At the national level, NADMO is responsible for the development of contingency plans based on several scenarios (best case, most probable and worst-case scenarios).

There is growing attention on the issue of disaster and risk management by academic institutions or research centres. Attention is paid in particular to the economic sectors mainly affected, such as the production of hydroelectric energy. However, there is little research into the risk of drought in future climate scenarios and its impact on other economic sectors.

There are currently no educational programs for students and adults on hydro-meteorological hazards, dissemination of warnings, preparation and response actions. Furthermore, the population is not aware of the risks that might incur, which is evident from the frequent occupation of flood plains or waterways. Further progress in this regard is being made by NADMO through the establishment of Operation ThunderBolt 2020 which focuses on alerting and preparing the population for any disaster that will result from the heavy rains

and the Bagre dam spill that usually affects the Black and White Volta, as well as the Oti River (GhanaWeb, 2020).

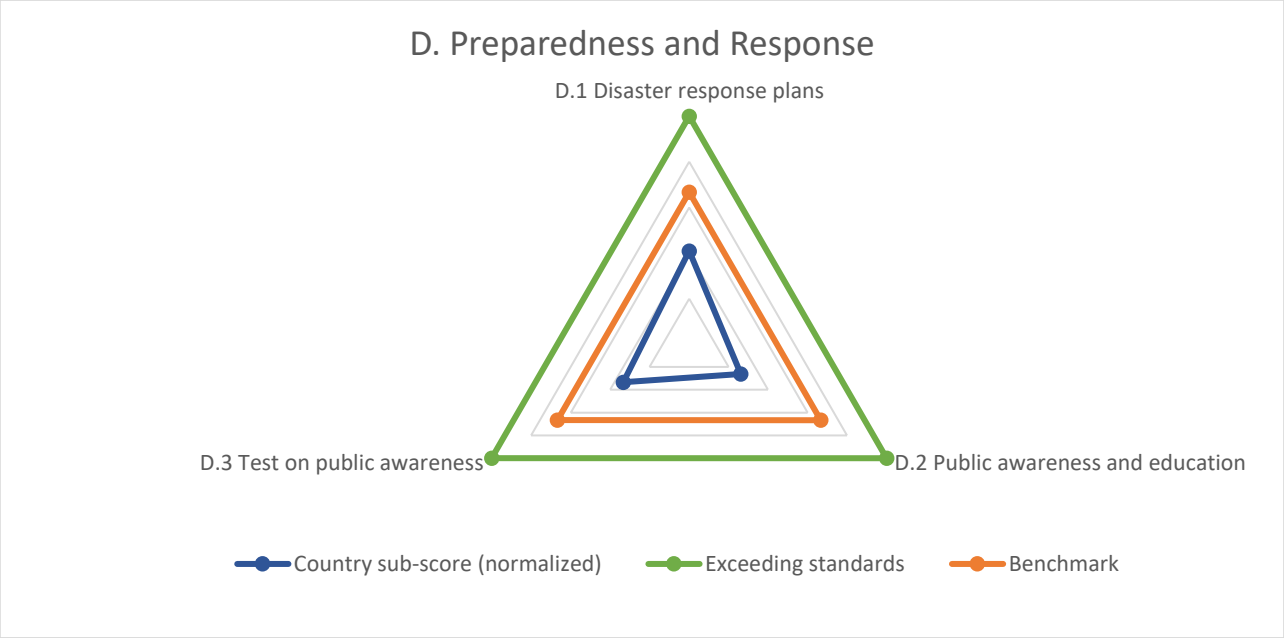

Figure 23: Score of Component D "Preparedness and response".

7. Review of programs, projects or initiatives (completed, under implementation or in the pipeline) related to flood and drought forecasting and EWS

- **Drought Early Warning System for Ghana** (2014 – 2018)
  https://www.dhigroup.com/global/news/2018/04/implementing-a-drought-early-warning-system-in-ghana

Within the Flood and Drought Management Tools project, UNEP-DHI Partnership supported by the Climate Technology Centre & Network and the Ghana Water Resource Commission designed and implemented a web-based Drought Early Warning System for Ghana. The web-based portal allows the access to near real-time data related to drought and to assess the occurrence of drought according to a range of drought indices (CTCN, 2017). The drought assessment can be carried out through different applications contained in the platform.

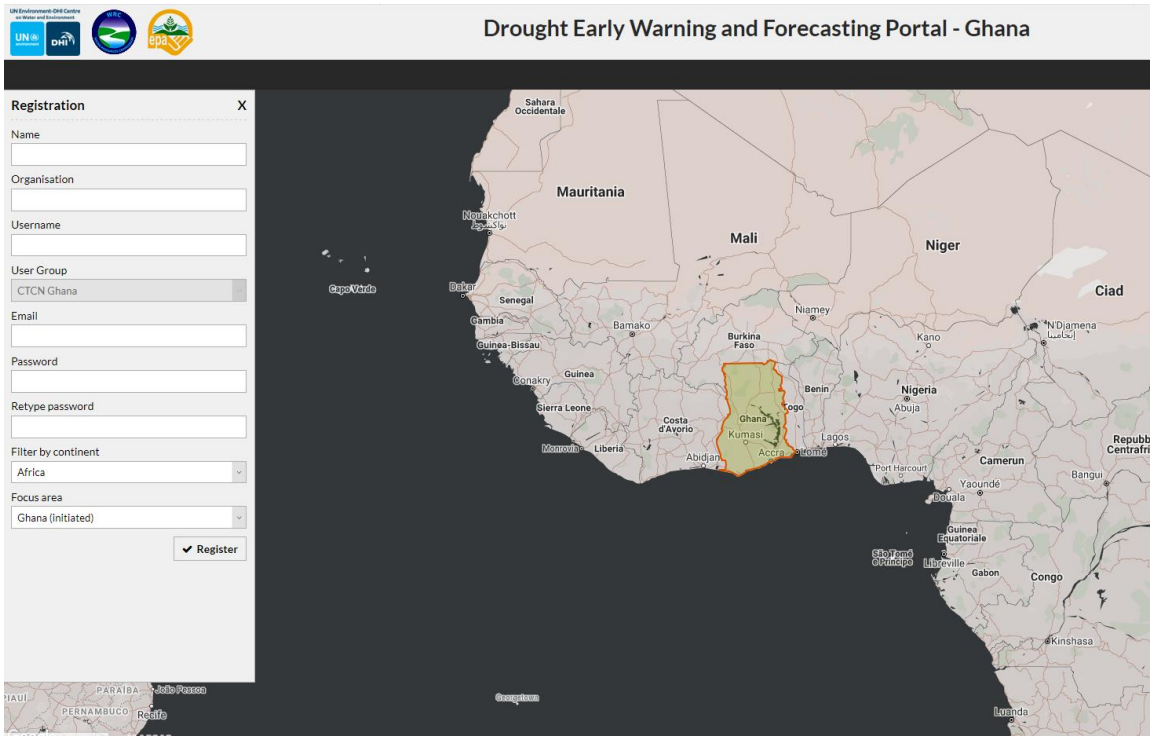

*Figure 24. Drought Early Warning and Forecasting Portal (*http://www.flooddroughtmonitor.com*)*

- **Financing Climate Resilient Agricultural Practices in Ghana** (under proposal – 2020/2024)

https://www.greenclimate.fund/documents/20182/574760/Funding_Proposal_-_FP114_-_AfDB_-_Ghana.pdf/8a5a21f4-9c1b-0cbf-1e70-7cf1832b2df1

The project aims to empower groups of women located in vulnerable agro-ecological zones (e.g. Savannah regions) through Line of Credit and Technical Assistance to implement climate resilient agricultural practices in Ghana. In detail, the program promotes the use of solar pumps and efficient irrigations systems to address scarcity and variability of rainfall. Furthermore, it enhances the access to inclusive loan product to increase efficiency and profitability while reducing vulnerability to climate risks.

- **The Oti River flood hazard assessment in Ghana and Togo** (2016 –2019)

https://www.worldbank.org/en/news/feature/2016/08/08/expanding-flood-resilience-in-the-volta-basin-with-expertise-and-support-from-japan

https://www.worldbank.org/en/news/feature/2014/10/01/drmhubtokyo-country-program-ghana-strengthening-flood-management-in-volta-basin

Supported by the World Bank and GFDRR and Japan, the project aims to increase flood preparedness by setting up a Flood Early Warning system, developing flood hazard and risk maps, capacity development of local experts, and basic input into Emergency Preparedness Plans.

The partners identified the water level thresholds at the different stream gauges. These thresholds are set in the Sobek software (refer to the Appendix 3 for an example of the bulletin issued).
However, perception and acceptance of risk vary between Ghana and Togo. Therefore, it is necessary to harmonize the water level thresholds which should differ according to the country under consideration.

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- **Operational flood forecasting system for the White Volta in Ghana** (2012-2016)

https://www.gfdrr.org/en/state-art-flood-forecasting-model-launched-white-volta-river-ghana

Led by the World Bank's Africa Disaster Risk Management, with technical and financial support from the Global Facility for Disaster Reduction and Recovery, a flood early warning system was created for the White Volta River in Ghana. The EWS uses a coupled hydrologic and hydraulic model and provides a daily forecast with a 5-day lead time based on satellite precipitation data. The system is implemented from the border with Burkina Faso to the mouth in Lake Volta, including parts of its main tributaries. The boundaries of the model are Yarugu-Kobori river gauging station and Lake Volta. The system automatically downloads rainfall (satellite) and river gauging station data (water levels/discharges) at fixed intervals. All downloaded data and forecasts are visualized in a Delft-FEWS interface.

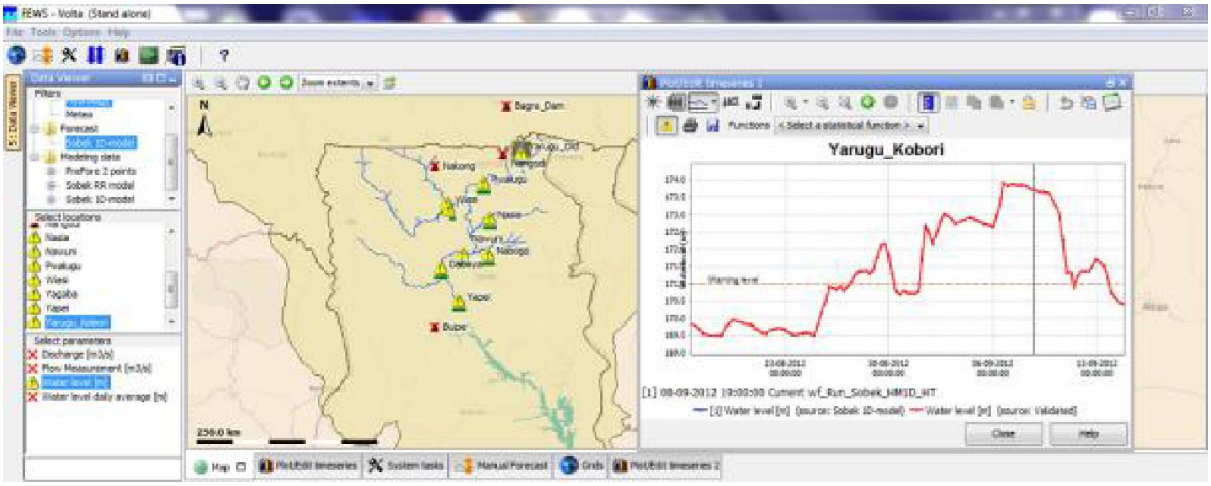

Figure 25. FEWS System in the White Volta Basin

The system is installed on a server at the Hydrological Services Department of Ghana in Accra (HSD). The HSD is responsible for its operation and maintenance and uses the system to create a daily forecast. The HSD is also responsible for the data input to the system from the automatic river gauging stations along the White Volta River. A new simulation is automatically executed twice per day. The HSD should provide a forecast report once per day to the main stakeholders.

The used hydrological model is Sobek and its inputs are the GPM and TRIMM satellite data. The implementing partner was HKV Consultants.

- **Community Resilience through Early Warning - CREW** (2013 -2016)

https://www.gh.undp.org/content/ghana/en/home/operations/projects/environment_and_energy/crew.html

The CREW project was led by UNDP with Norwegian fund. The project developed drought and flood hazard, vulnerability and risk maps at the national level and for 10 pilot areas throughout Ghana. HKV Consultants developed national maps with open-source data sets for the current situation and a future scenario in 2050. District maps were developed with a digital terrain model. A drought and flood early warnings system was developed in the 10 pilot areas. Training at the national and community level was organized to raise the capacity of stakeholders in reading the maps and in integrating the results in the EWS. Within the project, historical information on major hydro-meteorological disasters in the country was collected and stored in a database. Currently, the results of the models are displayed on the NADMO websites: http://crew.nadmo.gov.gh/ewsghana/#dashboard/1

- **Greater Accra Resilient and Integrated Development Project (GARID**) (under proposal – 2020/2025)

http://documents.worldbank.org/curated/en/675901559440929710/pdf/Ghana-Greater-Accra-Resilient-and-Integrated-Development-Project.pdf

https://www.worldbank.org/en/news/loans-credits/2019/05/29/ghana-greater-accra-resilient-and-integrated-development-project

The project aims to improve flood risk management and solid waste management in the Odaw River Basin of the Greater Accra Region and improve access to basic infrastructure and services in the targeted communities within the Odaw River Basin.

- **Open Cities Accra** (2018 – ongoing)

https://opencitiesproject.org/accra/

The initiative aims to support the GARID project by creating maps which inform about participatory solid waste management and informal settlement upgrading, in flood prone areas of Accra. Open Cities Accra will create a detailed and accurate map of these areas, as well as build the capacity of stakeholders within government institutions (such as: NADMO and the Ghana Statistical Service). This project scope is to help government stakeholders to make data-driven decisions enhancing effective informed planning decisions and improved disaster response capabilities.

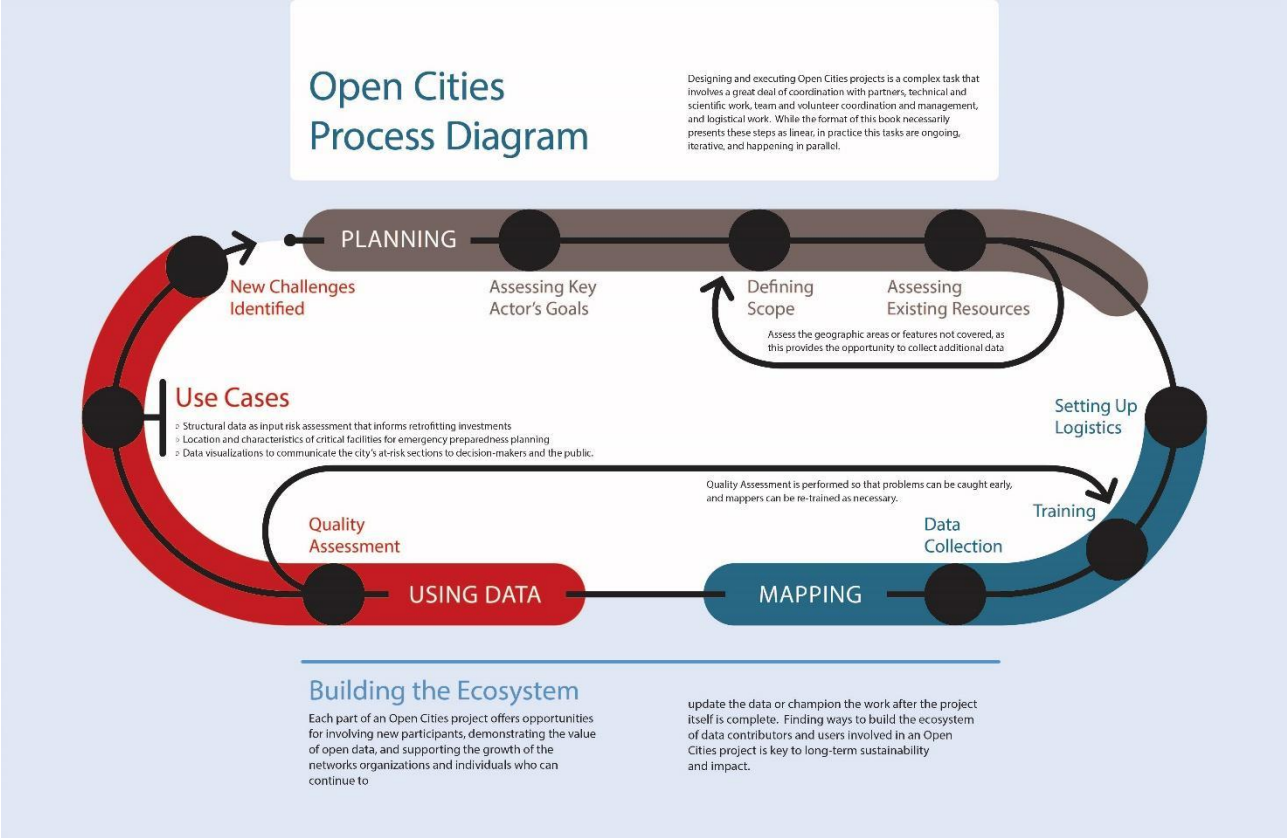

Figure 26. Open Cities Process Diagram (Source: https://opencitiesproject.org/accra/)

- **FANFAR (Operation Flood Forecasting and alerts in west Africa) (2018 – ongoing)**

https://fanfar.eu/about/

The European Union-financed project seeks to enhance an effective flood management in West Africa, through a reliable and timely operational forecasts and alerts that are operated by West African institutions. The project consortium, led by the Swedish Meteorological and Hydrological Institute, involves several European institutions, the AGRHYMET Regional Centre and around 30 governmental institutions of the interested nations (e.g. the Ghana Hydrological Service Department and NADMO)

- **Flood and Drought Management tool (FDMT) (2014-2018)**

https://fdmt.iwlearn.org/about

A methodology will be developed for enhancing the transboundary river basin management in the Volta Basin. With the development of flood and drought management tools for both regional organizations and local users, the project aims to improve water resources management at the basin level. The tools will integrate information on climate variability and change.

- **REWARD (2018 – ongoing)**

https://www.thegef.org/project/reversing-ecosystem-and-water-degradation-volta-river-basin-reward-volta-river-basin

The project aims to implement key Strategic Priority Actions for the development of ecosystem-based management tools. The tools will be used for identifying stress reduction measures aimed at the establishment of sustainable management and use of the Volta basin's resources.

- **Develop Insurability Project for the Greater Accra** (2018 – ongoing; expected end date:2021)

https://www.newsghana.com.gh/greater-accra-flooding-identified-as-main-climate-effect/

https://www.marketscreener.com/ALLIANZ-436843/news/Allianz-Stakeholders-meet-over-perennial-flood-disaster-in-district-assemblies-28685865/

The German Development Agency (GIZ) and Allianz Ghana are spearheading a project to develop insurance models for extreme climatic events in three municipalities of the Greater Accra Area. The project seeks to help the municipalities in the development of contingency plans, reducing the impact of forecasted hazards.

The implementing partner is HKV Consultants, which is responsible for collecting data concerning damages and exposure (e.g. roads, industry, housing). Ten different levels of assets are considered (school, marketplace, bus stations, health facilities, etc..). The data was collected together with the Metropolitan, Municipal and District Assemblies (MMDA's). The MMDA's identified 632 assets in the three explored municipalities (GA West, GA East and AMA), taking surveys and mapping their geo-location. The surveys included questions on the number of floors in the building, construction dates, building materials, value of the building, and historical flood events. This resulted in the development of vulnerability curves showing average damage as a function of inundation depth per type of assets.

- **My Flood Risk Accra App**

https://www.hkv.nl/en/products/apps/

HKV developed an app to inform citizens about their exposure to flood risks. The app has multiple layers of flood maps, for different statistical return periods and provides the water level rise in the area of interest for fixed time period.

Figure 27. My Flood Risk App Interface

- **Rainsat Ghana**

http://www.rainsat.net/index.html?country=Ghana

https://play.google.com/store/apps/details?id=com.hkv.dashboard.rainsatghana&hl=en

HKV developed an app for the visualization of weather condition using Nowcasting. The rainfall information is received from satellite observations, collected every 15-minutes. Rainsat shows the rainfall intensity from the previous 4 hours up to now and helps the user to see if more rain can be expected or not.

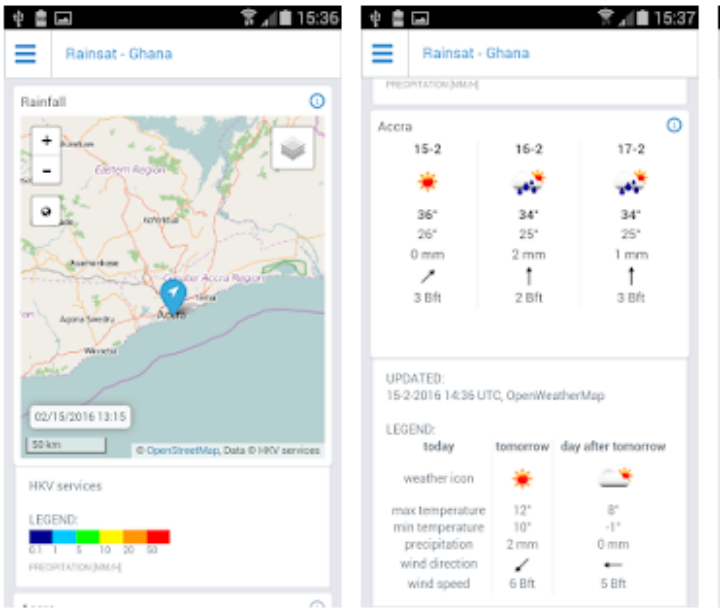

Figure 28. Rainset Ghana App Interface

- **GLOWA Volta project** (2000 – 2009)

https://www.geographie.uni-wuerzburg.de/en/fernerkundung/research/completed-projects/glowa-volta/

https://www.zef.de/fileadmin/template/Glowa/Downloads/SDRC-Report_GLOWA-VBAGeoPortal_Ghana.pdf

https://link.springer.com/chapter/10.1007/978-1-4020-5591-1_18

The project aimed to establish a scientifically sound Decision Support System (DSS) for water resource management in the riparian countries of the Volta Basin in West Africa. The project was financed by the Federal Ministry for Education and Research, with additional funding from the Ministry of Science and Research of North Rhine - Westphalia.

- **Global Environmental Monitoring Service (GMES) for Volta**

https://africanews.space/institutions-from-45-african-countries-are-implementing-earth-observation-projects-through-gmes-africa/

Together with VBA, WRI is contributing to a regional flood EU project (GMES) lead by the Nigerian Centre for Space Science and Technology Education (CSSTE). The purpose of the project is the development of Historical Flood Database for the Volta, under the partnership of NADMO and the Water Resource Institute (Ghana national coordinators) and VBA (regional coordinator). The database will be operational by 2020 and will be compliant with the Sendai Framework, including also the specific country needs.

The project includes 5 countries (Nigeria as lead partner, Cote d'Ivoire, Benin, Burkina Faso and Ghana) among which four countries are within the Volta basin. For each country, the national operational database will be linked to the regional database. This database is important particularly at national level, where the few available information on floods and related impacts are reconstructed from old newspapers.

The national historical database will be updated at each event. The level of disaggregation of the collected data is at discretion of the country. There will be no constraint to comply with specific standards. The project does not aim to improve the data collection, but just to group existing data in a shared database. However, it is important to harmonize the data collected by the different countries, precisely because each country will have its own protocol for data collection. Standardized indicators will not be used because in some countries some events can have a significant impact, while for others the same event does not cause any threat. The database will be operational by mid-2020.

- **Strength Disaster Risk Reduction in West Africa** (2016-2019)

https://www.ecowas.int/ecowas-commission-organises-regional-training-workshop-on-disaster-risk-reduction/

The ECOWAS Commission and the World Bank Global Facility for Disaster Risk Reduction (GFDRR) entered into a four year "Grant" Agreement (2016-2019) to support ECOWAS in the development and implementation of programmes to strengthen disaster risk reduction coordination, planning and policy advisory capacity in West Africa. The Water Resource Institute is currently joining the WASCAL (https://wascal.org/) team to support the ECOWAS project in the flood mapping and the forecasting. One of the final products will be the production of risk maps at big scale. The problem of this risk map is their validation, due to their coarse resolution.

- **Supporting Evidence-based Decision-making for a Clean, Resilient and Inclusive Greater Accra (12/2017 – 09/2020)**

https://www.gfdrr.org/en/ghana-supporting-evidence-based-decision-making-clean-resilient-and-inclusive-greater-accra

The project is funded by the European Union (EU) and the African, Caribbean, and Pacific (ACP) Region Disaster Reduction Partnership Trust Fund. It contributes to studies on the climate risks for the Greater Accra region, identifies possible risk mitigation measures, and builds capacities of and develops tools for central and local governments to be better prepared for disaster risks.

- **National Web Emergency Operations Center** (Web-EOC)

https://www.juvare.com/request-a-demo-webeocx/

The project aimed to install the Web-EOC to facilitate disaster risk management operations. The platform is managed by NADMO.

- **Programme of Work with the African Risk Capacity**

https://www.africanriskcapacity.org/2019/02/18/ghana-hosts-african-risk-capacity-joint-board-meeting-signs-programme-of-work-to-improve-responses-to-extreme-weather-events-and-natural-disasters/

The Government of Ghana has signed a Programme of Work with the African Risk Capacity (ARC). The Programme will help the Government of Ghana to improve responses to extreme weather events and natural disasters as well as prepare the country to possibly take out insurance from ARC Ltd.

Within this project NADMO is building capacity for the development of a database on disasters. Currently, they were able to aggregate information from 1983 to 2018. They also started to establish the DesInventar database (Sendai Framework).

- **PARADeS -Participatory assessment of flood related disaster prevention and development of an adapted coping system in Ghana** (2019-2023)
  http://ewa.uni-bonn.de/parades/?PARADeS_project

The aim of the PARADeS project is to contribute to enhancing Ghana's national flood disaster risk reduction and management strategy by investigating key mechanisms (drivers, pressures, state, impact, response), existing flood risk management, human-water interaction, and development of scenarios, action plans and feasible measures. This will be carried out through innovative socio-technical participatory approaches. The resulted action plans for reducing the risk and increase the security of the society, will be then tested in three case studies: (1) Accra - pluvial and coastal floods, (2) Kumasi - pluvial and fluvial floods, and (3) Volta river Basin – fluvial floods.

The consortium partners are the University of Bonn, University of Freiburg, University of applied sciences in Magdeburg and the Hochwasser Kompetenz Centrum of Germany. And from Ghana, the West African Science Service Center on Climate Change and Adapted Land Use (WASCAL), Water Resources Commission (WRC) and National Disaster Management Organization (NADMO).

- **Youth map initiatives in Cape Town**

https://www.youthmappers.org/
https://www.youthmappers.org/single-post/2019/04/09/My-encounter-with-the-University-of-Ghana-YouthMappers-and-its-journey-so-far
https://www.youthmappers.org/single-post/2019/03/26/Feeding-Ghana-through-the-eyes-of-female-farmers-and-efforts-of-open-data

Young students from the university of Cape Coast are involved in data collection and analysis for humanitarian purpose. They do not have a particular specialization or focus on what will be mapped, but mainly depends on the needs of the client. For example, one of the project in which they were involved was the impact of droughts on the farmers. They use mainly open sources tools for collecting data. This data is confidential and hence, only available to the institutions that have requested them. These students' groups are also in Burkina Faso, Togo, Mail and Cote d'Ivoire.
Other similar initiatives can be found: www.girlsmap.org and www.urbansen.org

- **Servir West Africa**

http://servir.cersgis.org/

Geospatial data-frame to support development programs. The initiative seeks to support regional institutions in improving their capabilities for applying geospatial and analytical techniques. The project is implemented through AGRHYMET Regional Center. Ghana national partner is the Geographic Institute.

- **Enhancing Resilience to Climate and Ecosystem Changes in Semi-Arid Africa (CECAR-Africa) 2011-2016**

http://sdg.iisd.org/news/unu-and-ghana-collaborate-on-enhancing-resilience-to-climate-and-ecosystem-change/

The project contains three themes:

- Forecast and assessment of climate change impact on agro-ecosystems;
- Risk assessment of extreme weather hazards and development of adaptive resource managements and methods;
- Implementing capacity

- **SWIFT**

https://africanswift.org/2020/01/13/the-ghanaian-users-policy-brief-is-ready/
https://iopscience.iop.org/article/10.1088/1748-9326/ab4dfe

Project coordinated by Leeds University has the objective of integrating weather and climate information into societal decision-making.

- **ASPIRE (Adaptive Social Protection - Information for Enhanced Resilience) 2019-ongoing**

https://www.metoffice.gov.uk/about-us/what/working-with-other-organisations/international/projects/wiser/aspire

The project is based on three main objectives:

- Enhance seasonal forecasting - regional and national levels;
- Social protection stakeholder training;
- Explore how forecast information can support resilience mechanisms in the Sahel (joint activity with Red Cross Climate Centre).

Other projects:

- https://www.weatherimpact.com/fall-armyworm-early-warning-system-operational-in-ghana/
- https://www.dhigroup.com/global/news/2018/04/implementing-a-drought-early-warning-system-in-ghana
- https://www.thebritishacademy.ac.uk/sites/default/files/JBA-7s2-08-Kasei-Kalanda-Joshua-Tutu-Benefor.pdf

8. General Recommendations

The following recommendations refer to general nationwide observations based on a desk review and consultations held in November and December 2019 and during the national workshop carried out in January 2021. The assessment is very broad and exceeds the workforce scope of the Volta project, which is a regional project focused primarily on the portion of the territory of Ghana that is part of the Volta basin. Since the institutions involved in the Volta project are national agencies, the assessment should clearly be done at this level, but the Volta project, due to its nature, will only be able to respond to some of the recommendations presented in this report.

In recent years, Ghana's government has greatly increased its knowledge on the potential risk of floods thanks also to the recent involvement of research institutes and hence, to an increased number of publications on the topic. However, the government does not yet have a comprehensive understanding of flood events and their impacts across the country, given the fragmented approach and the narrow focus of many implemented projects. This issue is more evident with regard to drought events, where investigations on related risk and impacts to the economic sector have only recently been conducted. Better synergy between projects and the integration of available information can overcome this problem. Targeted investments on the geographic areas and sectors hitherto neglected could help the government in acquiring a national picture on the flood and drought risks. The establishment of standardized procedures and methodologies, which will enable the analysis and comparison of acquired data and obtained results, should support this process. Additionally, successful projects could be up-scaled to provide a full coverage of the country.

Collecting information about past weather events and their impacts can consolidate risk analysis by providing the information needed to develop preparedness and response strategies. The creation of a centralized database in which different agencies could store and consult information on risks can improve a transversal knowledge on the risks of meteorological disasters. National agencies should pay particular attention to the collection of information on the vulnerability and exposure that the country currently lacks most. This information needs to be updated regularly, following/depicting the growth rate of the community in analysis.

A major challenge for Ghana's government is the mobilization of financial resources for investing in the monitoring and forecasting system. This negatively affects the generation of timely and accurate warnings. The lack of financial resources mainly affects the national hydrological department. The internal budget could be increased by developing hydrological products tailored to specific socio-economic sectors. This will attract investment from private sectors, improving the agency's capacity development. The development of these products should be supported by organizing staff training and by establishing inter-agency agreements for data exchange. This will also allow for the creation of inter-sectorial products.

Currently, the meteorological agency is in the process of establishing a MoU for creating data exchange procedures with the hydrological agency and for the establishment of a joint bulletin. This is an initiative that should be strongly encouraged and promoted by many other agencies.

The improvement in the reliability of the forecasts also depends on the institutional framework in place. The Ghanaian government has clearly identified the main stakeholders for the various risks related to weather conditions, with the exception of drought, which is in the process of being integrated into the national disaster management plan. The establishment of national and local committees for the consolidation and validation of risk information is a strength of the current DRM policy. However, committees should meet regularly to enable effective preparedness and response mechanisms. Therefore, coordination between different sectors and between the national and the local level should be promoted by ensuring regular meetings to share experiences of past events, design strategies and adequate financial resources to implement the identified measures. Improved coordination should also be promoted within the six NADMO technical committees (eg fire, hydro-meteorological, etc.) with also a better definition of roles to avoid overlapping during response actions.

NADMO has a countrywide structure with representation at the regional, district, and zonal levels. Although its decentralised structure, warnings and response interventions does not effectively reach the entire population. Agreements with private sectors need to be established, allowing for a broadening of the channels used for transmission. In addition, warning messages need to be clear, consistent and tailored to the needs of the end-users, thus being able to reach the 'last-mile' connectivity. In order to strengthen the role of different agencies in preparing rather than in responding, the government needs to better frame current national and local plans by identifying specific roles. Finally, contingency plans need to be reviewed periodically, in line with updated information on the vulnerability and exposure of the communities under analysis.
Raising awareness of disasters and population forecasts should be another government priority. The government should invest more in awareness campaigns and in community's engagements for identifying flood and drought risks. People must be trained in recognizing the signs of hydro-meteorological hazards and on the basic concepts of hydrological forecasting and its uncertainty, in order to create trust in institutions even when false alarms are issued.

The list of recommendations and related actions presented below was prepared according to information provided by all the stakeholders and collected through a desk review during last year. It corresponds to the results of the general evaluation carried out at national level.. The Volta project will address some of the gaps identified with a focus on the portion of the Ghanaian territory which belongs to the Volta basin. The recommendations that will be addressed within the framework of the Volta project are associated in the following table with the project activities that could respond to them (fourth column) and the expected results of such activities (fifth column).

EWS Component	Recommendations	Actions	N. output/activity of the Volta project responding to recommendations and actions	Description of the expected results of the project Volta responding to recommendations and actions
A Consolidate **Disaster Risk Knowledge**	Incorporate risk information into EWS	Complement risk information with mitigation measures for minimizing losses once warning are issued	2.2.3	For pilot communities, the community-based flood or drought management plan or guidelines will be developed. This will help in implementing similar methodology and approach in other communities through other projects or National funding.
		Use hazard maps and information on vulnerable groups to define safe areas and evacuation zones		
	Consolidate risk information	Create standards, procedures and methodologies for the collection of data related to flood hazards, vulnerability, exposure, capacity and for assessing disaster risks	1.1.2 1.1.3 1.1.4	The development of flood and drought risk maps in the Ghanaian Volta Basin will provide a possible methodology, procedure and standards that could be adopted in future for other areas of the country

		Establish a central standardized repository for storing historical disasters and impact information	1.1.2	The development of Dewetra (integrated system for real-time monitoring and prediction) and the activities on the pilot sites could support the specification of the platform for historical and recent events
		Carry out impact assessments through gender inclusive approach, including post-crisis assessments	-----	-----
	Identify exposure, vulnerability, capacity and risks	Asses the vulnerability to flood and drought of social groups and key sectors at national and local level	1.1.1.4 1.1.2	National and local data and information on vulnerabilities, exposure, capacities within the Volta Basin will be identified, collected and stored with the support of National Agencies
		Develop detailed flood and drought risk maps with a National coverage	1.1.1 1.1.2 1.1.3 2.1.3	Establishment of drought and flood risk maps in the not yet covered part of the Ghanaian Volta basin, using available local, national and satellite data. Existing information from available risk maps will be validated and reused.

	Identify key hazards and related threats	Specify the reliable topographic information needed for supporting flood and drought mapping (and other natural risks), forecasting models, crisis preparedness and response, as well as post-crises evaluations	1.1.2	Some of the recommendations will be covered for the National part of the Volta Basin
		Develop drought hazards maps with a National coverage, considering different climate change scenarios	1.1.2 1.2.1	Drought risk maps will be developed for the National part of the Volta Basin using Global, National and local data
B Improve **Monitoring and Forecasting**	Improve Forecasting and Warnings	Implement hydro-meteorological models for all basins crossing the country	2.1.5	Under the project, the existing White Volta and Oti Basins models will be assessed and implemented into the Dewetra platform if possible (based on availability of data and information from Global, National and local level). Additionally, the use of meteorological data into the hydrological model for the White Volta Basin will be enhanced

				For the Black Volta, development of new models will be evaluated.
		Develop tailored hydrological products for specific socio-economic sectors	-----	-----
		Create a database with climate-information for long-term planning	1.1.2	National database will be established to collect and store Hydrological, Meteorological, Climatological and other social and structural information. Also capacity development will be provided to the National staffs on the use of database including migration of information from existing sources.
		Create a center (real or virtual) or a mechanism to produce and coordinate operational flood and drought forecasting and the dissemination of warnings to the decision-makers and the stakeholders	2.2.1 2.2.2	During the pilot testing of the EWS in 10 sites over the whole basin, mechanisms to produce and coordinate operational flood and drought forecasting and warning system (VOLTALARM at the

				transboundary system) will be tested
		Develop national standard operational procedures for impact-based forecasting	2.2.1 2.2.2	The integration into VoltAlarm of existing national and local data and products available for flood and drought, including also social vulnerability and environmental information, with a focus on the area under the Volta basin, will be facilitating impact-based forecasting.
	Strengthen the institutional mechanism	Establish agreements and protocols to ensure consistency of warning messages	-----	-----
		Improve coordination between key EWS actors by promoting the mainstreaming of national DRR strategies into different sectors and at different scales (national and local). On this line, establish regular meetings of the Technical	2.2.1	The involvement and participation of National services professionals in the pilot testing activities of EWS (three sites selected in the Volta Basin of Ghana) will help improve coordination with key EWS actors.

		Advisory Committees and the Zonal DRR Committees		
		Improve and strengthen the sharing and the consolidation of data/products among different national institutions and with cross-border countries	2.1.2 1.1.2.3 1.1.2.4	Dewetra platform will integrate existing national and local data and products available for flood and drought management in the country, with a focus on the area under the Volta basin. Information sharing across countries within the Basin will be also promoted
		Develop national consensus on climate models	-----	-----
	Improve monitoring system	Promote a financial advocacy increasing awareness at government level on the importance of investing in monitoring and forecasting	3.1.1 3.1.2 3.2.1 3.2.2	Existing national and regional policies and action plans will be reviewed and suggestion will be made to promote a financial advocacy for investing in monitoring and forecasting systems for flood and drought
		Increase human resource capacity in the hydrological institution	-----	-----
		Increase coverage of weather and hydrometric stations	-----	-----

		Increase hydro-meteorological products and services and their quality in order to gain added value and end-users interests	2.1.6, 2.1.7	The development of flood and drought risk maps and an early warning system for the entire Volta Basin region will provide an incentive for more exchanges with end-users and to specify their expectations.
		Promote capacity development and trainings for the national meteorological and hydrological services	1.1.1 2.1.1 2.1.2 2.1.3 2.1.4 2.1.5 2.1.6 2.1.7 2.2.1 2.2.2	The involvement and participation of National services professional in the management of floods and drought will be improved through several capacity development and pilot testing activities. They will be consulted in the implementation of the activities to provide feedback and suggestions and at the end, the National services will have knowledge and skills to use the services and tools.

				Training will be provided to migrate the National and local level data to a new proposed database and for using it for products and services.
C Expand **Warning and Dissemination**	Improve communication systems and equipment	Customize communication systems to the needs of different groups in order to reach the 'last mile' connectivity	2.2.1 2.2.3	The EW pilots tested during wet and dry period will help in understanding the mechanism for issuing clear and consistent warning messages from National to local level. Also, community-based flood and drought management activities are planned in six communities for the entire Volta Basin countries (one community in Ghana)
		Increase communication channels and assess their resilience during disaster events. On this line, establish agreements with the private sector	2.2.1 2.2.2	
	Establish impact-based early warnings	Issue clear and consistent warning messages that take into account the population vulnerabilities and that can be linked to possible actions	2.2.1	The pilot testing during wet and dry period will help in understanding the mechanism for issuing clear and consistent warning messages from National to local level.

		Establish color code warnings and develop appropriate response actions	2.1.4 2.1.5 2.1.6 2.1.7	The review/definition of thresholds for flood events and for drought period in the Volta basin will be based on the current vulnerability, capacity, exposure and risk maps and according to Global/National standards and in consultation with the National agencies. The impact-scenarios thresholds will then be translated in color-coded warnings.
	Improve organization and decision making process	Organize regular meetings within the National Platform for Disaster Management and Reduction	2.2.2	The pilot testing during monsoon and dry period will help to understand the mechanism for coordination between agencies, issuing clear and consistent warning messages from National to local level.
		Define a proper coordination responsibility for the information dissemination	2.2.2.	
		Establish strategies to build trust on warning messages	2.2.2	
		Establish feedback mechanisms to verify that warnings have been received and to correct potential failure	2.2.2	

		Establish mechanisms to update the information in place on the ongoing event. Mechanisms need to be resilient to the disaster events	2.2.2	
D Increase **Preparedness and Response**	Promote public awareness and education campaigns	Promote gender mainstreaming: participations of vulnerable groups to risk mapping, to post-disaster evaluations, to specification of warnings and to warning dissemination	2.3.2	Capacity building activities on mainstreaming gender in floods forecasting and EWS is planned at the National level
		Integrate modules on disaster risk in the school and university curricula	-----	-----
		Educate people in recognizing the hydro-meteorological hazard signs	-----	-----
	Enforce disaster response plans	Develop local and national preparedness plans in a scenario-based manner which are implemented/enforced through an allocated budget	2.2.3	Community-based flood and drought management activities are planned in total six communities in the Volta Basin countries (one community in Ghana)
		Actively engage the communities in the development of disaster preparedness and response plans	2.2.3	

		Assess the community's ability to cope to disasters and respond to warnings	2.2.3	
		Create an emergency fund based on forecasting of any floods events	2.2.1 2.2.2	Support to the specification of this emergency fund could be provided when the flood risk maps will be developed
		Regular testing of disaster response plans	-----	-----
		Review periodically the contingency plans according to risk information and integrate response actions to warnings for flood and drought	2.2.1 2.2.2	Support to pilot communities in developing or reviewing contingency plan according to Risk Map and EWS information (color code)
	Test public awareness	Update and review public awareness strategies and programs regularly, according to changes in hazards and vulnerability	1.1.3.2	The update of flood and drought risk maps in the national part of the Volta basin can support the review of public awareness strategies
Crosswise	Adopt an integrated IT system over multiple levels for improving availability	Establish an integrated system for monitoring, prediction and prevention of natural disasters.	1.1.2.1 1.1.2.2 1.1.2.3	The Dewetra platform will be installed for the Volta basin. In this context, a national database

	and accessibility to risk information and Early Warning systems in general	Enhance data consolidation and data sharing between local and national levels and among different stakeholders for monitoring and forecasting		will be set-up to collect climatology, hydrological and meteorological data including also social vulnerability and environmental information.

One of the main activities of the Volta project aims to respond to the need to have an integrated IT system that can support all national agencies involved in an early warning system for floods and drought with regard to data sharing, real-time monitoring and forecasting with local and global information, and also the development and dissemination of alerts and warnings. A technological tool with these characteristics could strengthen the entire early warning system in all its aspects. A first presentation of the functionalities of the VoltAlarm platform was made during the national workshop on January 27th-28th, 2020, to show the platform's capacity to be an empty box which can adapt and be configured according to the needs of the context and the structures involved. Then, a survey was submitted to the participants who, grouped by structure, gave their opinion concerning: (i) the use that they would make of this platform, (ii) which data they would like to visualize and share on the platform, (iii) which role they would have in relation to warnings, (iv) format and frequency of emission and (v) the possibility of having bulletins shared with other countries of the Volta basin. The analysis of the survey's results is presented in the workshop report (Annex 8); however, in general, each actor involved in the early warning system, in accordance with its mandate and needs, would like to have a technological tool allowing to exchange and analyse data, as well as prepare or receive warning bulletins.

9. Action plan for ongoing and future activities (update to be done in July 2022)

An operational action plan concerning ongoing and future activities of the Volta project is presented. The plan is a proposal that can be adapted over time according to the needs of the structures involved and in the event of external or unforeseen situations. The first two columns of the table refer to the EWS components and the general recommendations presented in detail in the previous pages in order to further highlight the relationship of the project activities as a strengthening process of the national early warning system.

EWS component	Recommendations	Project activity	Description	Implementation period	Other structures involved with the National Working Group	Expected results
A Consolidate **Disaster Risk Knowledge**	Identify exposure, vulnerability, capacities and risks	Development of risk maps for the Volta Basin region	The risk mapping will be based on the identification of vulnerabilities and exposure through national data and information (jointly to global available information) for the part of the Volta basin relating to each country. National agency staff will be engaged in a context of active participation through training related to GIS for the development of vulnerability and exposure maps. The hazard maps will be developed with modeling based on the return period (100 years, etc.)	November 2020 - August 2021	NADMO CERSGIS WRC WRI	Hazard, vulnerability, exposure and risk maps for floods and drought will be produced covering the portion of Ghana territory which is part of the Volta basin.
	Consolidate risk information					
	Identify key hazards and related threats					
A Consolidate **Disaster Risk Knowledge**	Consolidate risk information	Implementation of the VoltAlarm EWS platform and establishment of	1. Data collection and establishment of a database management system	January 2021 - December 2022	GMet HSD NADMO	The VoltAlarm platform, based on the myDewetra system (integrated system for monitoring and forecasting in real time) will be installed as a

B Improve **Monitoring and Forecasting** **C** Expand **Warning and Dissemination**	Strengthen the institutional mechanism Improve the monitoring system Improve forecasting and warnings Establish impact-based early warnings Improve communication systems and equipment Improve organization and decision-making process	a centralized national database	2. Installation of IT components in a cloud server service (purchased by the project) 3. Configuration of the platform for the data sharing and visualization at regional level (Volta basin) 4. Configuration of the tool for the semi-automatic production of flood and drought warning bulletins for the part of the Ghana territory that is part of the Volta basin, at national and regional level 5. Training and transfer of skills to the national agencies involved 6. Technical assistance in using the platform		WRC CERSGIS	technological tool in support of EWS. It will integrate national and local data and products available for flood and drought management in the country, focusing on the Volta Basin area. The tool for the semi-automatic production of bulletins will be integrated in the same platform and the sharing of information, as well as warning bulletins, among the countries of the basin, will be carried out through the same platform.
B Improve **Monitoring**	Strengthen the institutional mechanism Improve forecasting and warnings	Pilot tests of the EWS VoltAlarm during the monsoon and the dry pseason in	The planning of the pilot tests will be carried out in coordination with stakeholders at national	January 2022 - December 2022	GMet HSD NADMO	During the EWS tests on the 10 pilot sites of the basin (three sites selected in the Volta Basin of Ghana), mechanisms

and Forecasting		10 areas of the Volta basin.	level and local authorities. The tests will be carried out in the monsoon period and in the dry period to test the effectiveness of the EWS VoltAlarm and also the national and regional coordination mechanisms.		WRC MMDAs Local authorities	aiming at producing and coordinating operational forecasts for floods and drought will be elaborated. These pilot tests could provide the opportunity to demonstrate and understand the added value of exchanging and coordinating transboundary alerts at all levels and assist in the development of transboundary agreements in the shared river watersheds of the Volta basin region. The tests will help to understand the mechanism for disseminating clear and consistent warning messages from national level to local level.
C Expand **Warning and Dissemination**	Establish impact-based early warnings					
	Improve communication systems and equipment					
	Improve organization and decision-making process					
D Increase **Preparedness and Response**	Enforce disaster response plans					
	Test public awareness					
	Promote public awareness and education campaigns					
A Consolidate **Disaster Risk Knowledge**	Identify exposure, vulnerability, capacities and risks	Mapping of vulnerability and local capacities	The study and mapping of vulnerability and local capacities is based on the consultation of social / local actors about recent hazards, through focus groups and interviews. Specific	July 2020 - March 2021	NADMO MMDAs Local authorities	The results of local vulnerability and capacity maps from 60 sites in the Volta basin (including 15 in Ghana) will also be presented as a report and will be included in the EWS VoltAlarm and in

			tools, as well as guidelines, for data and information collection, are developed to support the fieldwork. Areas affected by the most frequent floods, as well as by the worst flood, and the main infrastructures affected, are mapped over 60 sites in the Volta basin.			local disaster response plans.
C Expand **Warning and Dissemination**	Establish impact-based early warnings	Community-based flood and drought management at the local level in a total of 6 sites in the Volta Basin	Community-based local flood and drought management activities are planned in a total of 6 sites in the Volta Basin. Implementation of preparedness and resilience measures in the 6 identified sites.	March 2021 - July 2022	Local authorities Local communities (others to be defined)	6 communities in total in the Volta basin (including 1 in Ghana) will put in place local preparedness and resilience measures (self-help capacities)
	Improve organization and decision-making process					
D Increase **Preparedness and Response**	Enforce disaster response plans					
A Consolidate **Disaster Risk Knowledge**	Identify exposure, vulnerability, capacities and risks	Ecosystem services	1. Data collection and processing 2. Ecosystem risk assessment 3. Development of integrated guidelines for wetlands at basin	July 2020 - December 2020	EPA HSD WRC WRI	At least five environmental indicators (primary data) will be integrated into the EWS VoltAlarm and integrated guidelines for wetlands at basin scale will be ready to be used in planning at basin scale.

	Consolidate risk information		scale to promote the sustainability of ecosystem services 4. Facilitate a regional workshop whose main objective is to accelerate the adoption and use of the integrated guidelines for wetlands at the basin level.			
C Expand **Warning and Dissemination**	Establish impact-based early warnings					
B Improve **Monitoring and Forecasting**	Strengthen the institutional mechanism	End-to-end EWS training	1. Development of the training program and sepcific e-learning capacity development courses for staff of national agencies (meteorologist, hydrologist and hydrological technician, civil protection and disaster managers, etc.); 2. E-learning program on EWS system for floods and drought. 3. Regional workshops for demonstration and implementation of practical trainings	October 2020 - July 2022	GMet HSD NADMO WRC	Staff from different structures will be certified as end-to-end EWS expert through online training (e-learning).
	Improve forecasting and warnings					
C Expand **Warning and Dissemination**	Improve communication systems and equipment					
	Improve organization and decision-making process					
D Increase **Preparedness and Response**	Enforce disaster response plans					

Annexes

1. Institutions identified for Education and Training in DRM (NDMP, NADMO 2010)

Table 9 Institutions Identified for Education and Training

Target Group	Topics	Inputs	Responsible Agencies
Political leaders, decision-makers, opinion leaders and development planners, teachers and general public, especially vulnerable groups.	• Types of disasters, causes, effects, prevention and mitigation and response • Information on disaster prone areas • Public response to disasters when they occur • Roles and responsibilities of stakeholders • Contingency planning • Legislation and regulations	Educational materials and consultants	NADMO, Ministry of the Interior, Information Services Department, Ghana Education Service, Assemblies, Security Services, Religious Bodies, Ghana Health Service, Opinion Leaders etc.
Train –the –trainers: agriculturists, planners, medical personnel, architects, engineers, geologists, seismologists, security personnel, media practitioners, selected members of the community, teachers etc.	• Disaster types and their characteristics • Risk reduction and response • Search ,rescue and evacuation of victims • Relief , Recovery and reconstruction • Needs assessment (before, during and after disaster) • Disaster evaluation and reporting • Restoration of essential services • Medical Response • Exercises and Drills	ogistics Training materials Consultants	NADMO, Ministry of the Interior, Information Services Department, Ghana Education Service, Assemblies, Security Services, Religious Bodies, Ghana Health Service, Opinion Leaders etc.

2. Institutions and related roles in response and relief (NDMP, NADMO 2010)

Table 13 : Institutional Collaboration

Action to be Taken	Collaboration Institutions	Lead Institution
Identification and registration of victims	NADMO, NGO Consortium, District Assemblies, WFP, GRCS	NADMO
Provision of cooked food	NADMO, Women's Organizations	NADMO
Counselling	Religious Organisations, NGOs, GHS, GRCS, UNICEF, NADMO	GHS
Provision of dry rations	NADMO, CRS, ADRA, NGO Consortium, GRCS, WFP,	NADMO
Provision of non-food items e.g. tents, blankets, clothing	NADMO, NGO Consortium, UNHCR, UNICEF, WFP	NADMO
Provision of fire fighting equipment	GNFS, NADMO, Ghana Armed Forces, VALCO, TOR, GPHA, GCAA, GWCL, PWTOA, NGO Consortium,	GNFS
Provision of Potable water	GWCL, PWTOA, GAF, CWSA, MMDAs, Water Resources Commission, UNICEF, NADMO	GWCL
Provision of mobile water purifiers	NADMO, MMDAs, GAF, GRCS, EPA, CWSA, GWCL, UNICEF	MMDAs
Maintenance of sanitation	Waste Management Services, CWSA, MMDAs, NADMO	MMDAs
Construction of toilets	48 Engineer Regiment, Department of Rural Housing, NADMO	Department of Rural Housing
Training in the construction of provisional field toilets, *etc*	NADMO, 48 Engineer Regiment, Department of Rural Housing, Local Communities World Vision International	Department of Rural Housing
Waste Disposal	Waste Management Services, CWSA, MMDAs, EPA, NADMO	MMDAs
Provision of warehouse and other storage facilities	RCCs, MMDAs, GAF, Private Warehouses, WFP, *etc*	RCCs
Public education & information dissemination	NADMO, MMDAs, Media (Print & Electronic), GES, ISD, NCCE, UNICEF, OCHA	NADMO
Provision of first aid/medical care	GHS, GRCS, St John Ambulance, WARA, GAF Health Institutions, WHO, UNICEF	MOH
Logistics support	EU, UNDP, other Bilateral & Multilateral Agencies, MMDAs, NGOs, NADMO	NADMO
Control of pest & insect infestation	MOFA, MMDAs, DVGs, COCOBOD, NADMO,	MOFA
Protection	Min. of Interior, Security Agencies, GRB, DOVVSU, CSO's, GRCS, MOWAC, DSW, UNICEF, UNHCR	Ministry of the Interior
Emergency Sheltering	NADMO, MMDAs, Religious Bodies, GES, UNHCR	NADMO
Search, Rescue and Evacuation	GNFS, Security Agencies, GRCS, GPRTU, DVGs, NAS, GHS, NADMO,	NADMO, GNFS
Iodine prophylaxes	NAMDO, GHS, GAEC, WHO	GHS
Food restriction	MOFA, GAEC, MMDAs, FDB, WFP, NADMO	MOFA
Decontamination	GNFS, GAEC, MMDAs, NADMO	GNFS,NADMO
Relocation and resettlement	NADMO, Ministry of Finance, MMDAs, UNHCR	NADMO

3. Agrometeorological bulletin – Gmet

GHANA METEOROLOGICAL AGENCY

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Agrometeorological Bulletin No.8, Dekad 2, March (11-20)2020

GMET/AGROMET/200719 ***FORM190***

SUMMARY:

Rainfall activities, during the dekad, extended to parts of the north as the season progresses towards the transition belt of the country. Quite a number of stations around the forest belt experienced over 50mm of rain within the period. The forest zone also witnessed, mostly, between two (2) and five (5) rainy days, while the rest of the country had less than two (2). Most parts of the country experienced deficit rain condition with only pockets of some locations witnessing surplus rains. Average day temperatures were relatively higher over the north, where most stations witnessed temperature values of over 39^{o}C. The average night time temperatures were also relatively warm along the extreme south-eastern portions through to the north-eastern parts of the country.

Figure 1. Total Rainfall

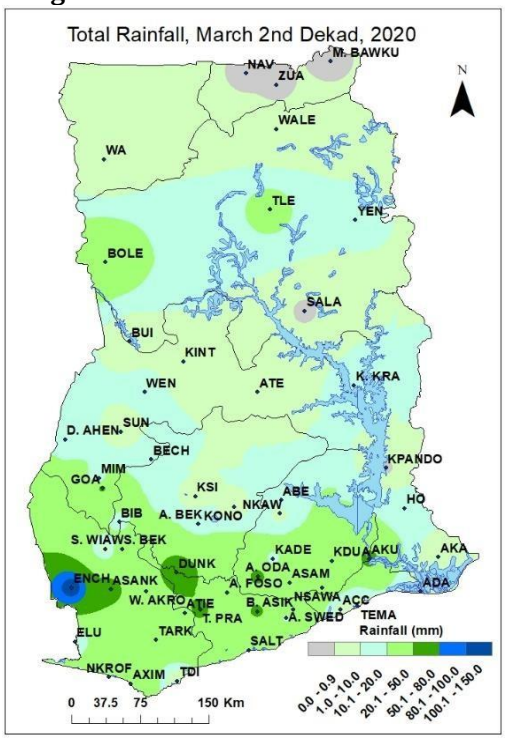
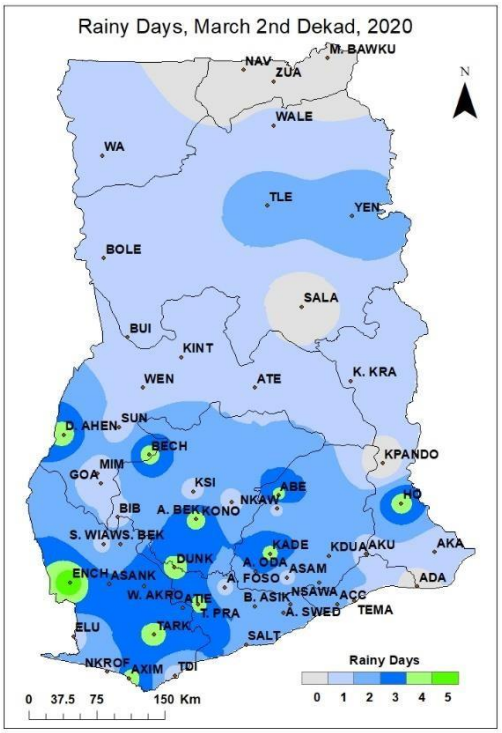


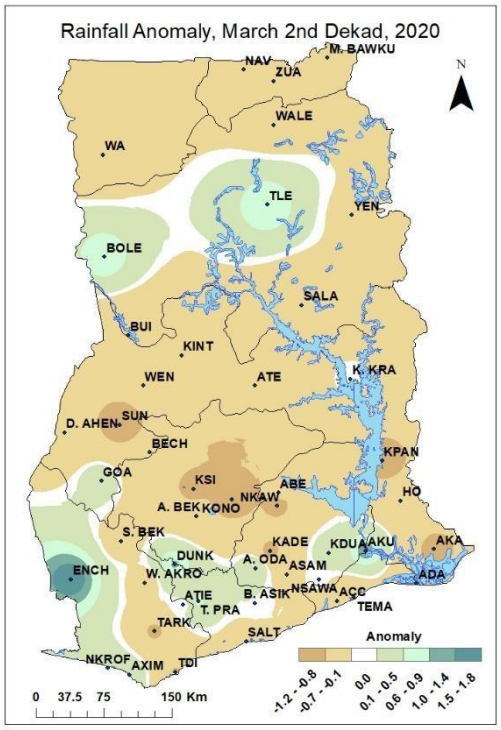
Figure 2. Rainy Days



The rains continue to dominate within the southern portions of the country, (figure 1 above) with over 50mm of rainfall recorded at stations such as Enchi, Dunkwa, Asankragwa, Akuse, Akim Oda, Goaso, Breman

Asikuma and Twifo Praso. Bole, Tamale and Yendi in the northern part of the country also received over 10mm of rain with the highest of 38.8mm over Bole. The number of rainy days experienced during the dekad (figure 2 above) were mostly pronounced over the south, where Enchi recorded the highest of five (5) number of wet days.

Figure 3. Rainfall Anomaly



The dekad had experienced deficit rain condition over most parts of the country, with Sunyani, Kumasi, Kade, Kpando and Akatsi mostly affected. Surplus rains were witnessed over Enchi, Nkroful, Goaso, Dunkwa, Axim, Atieku, Twifo Praso, Breman Asikuma, Akim Oda, Koforidua and Akuse in the southern portions, and over the north, Bole and Tamale also experienced surplus rain condition.

The average day temperatures, within the dekad (figure 4 below) were relatively higher over the northern half with values ranging between 38.1^{o}C at Bole and 41.5^{o}C over Navrongo. Towards the southern portion, the day temperatures significantly reduced to the lowest of 31.7^{o}C over Axim around the western coast and Abetifi over the middle portion of the country. The average night time temperatures (figure 5 below) were, however, relatively warmer over Tamale, Kete Krachi, Navrongo around the northern part and Accra, Tema and Ada over the south-east coast of the country with temperature range between 26.7^{o}C at Navrongo and 28.0^{o}C over Tamale. Relatively cool nights were experienced over the middle portions, where the least temperature of 22.9^{o}C was experienced over Abetifi.

Figure 4. Maximum Temperature

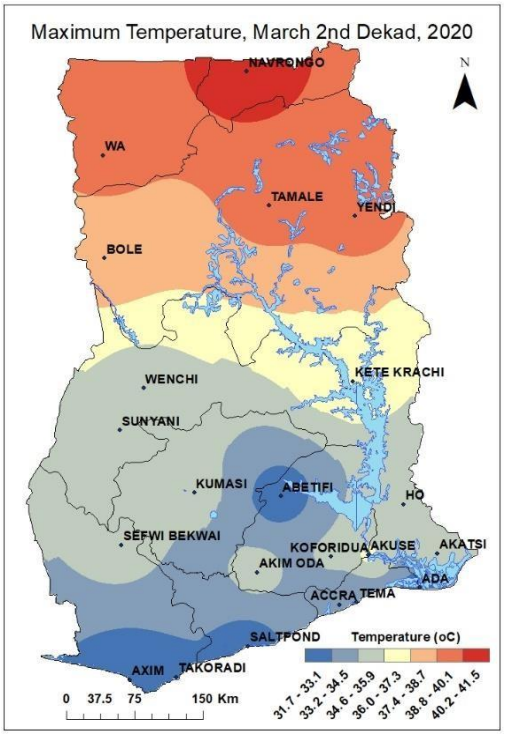
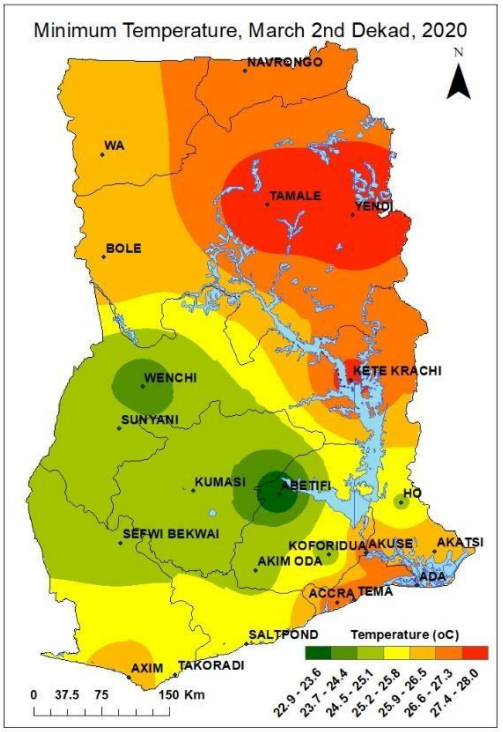


Figure 5. Minimum Temperature



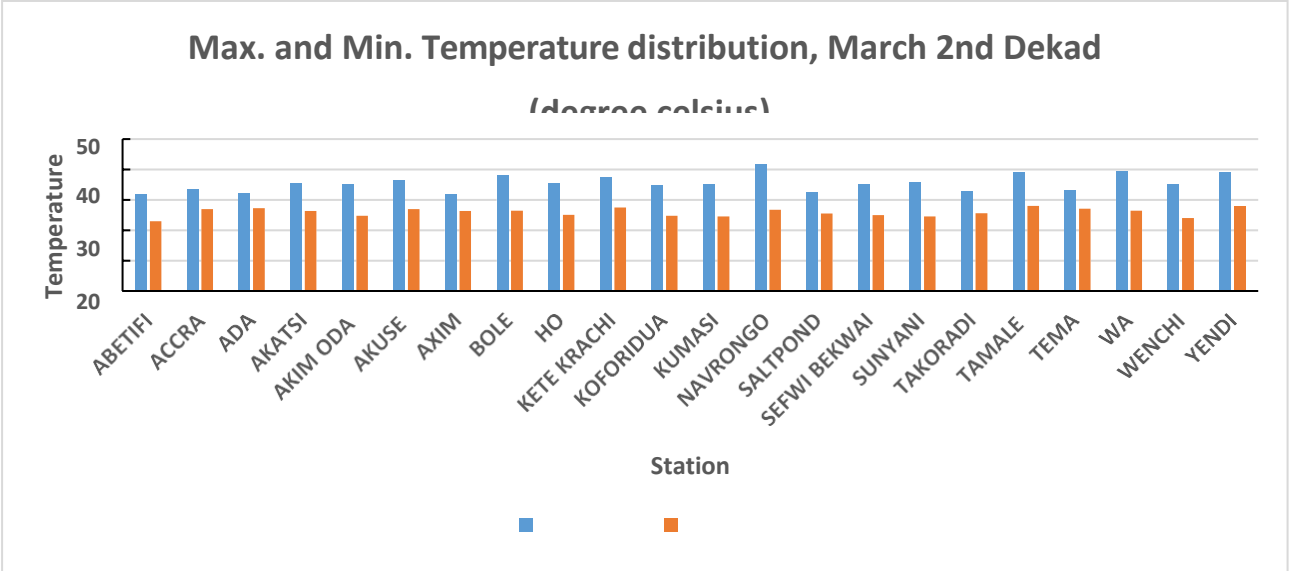


TABLE OF STATIONS					
STATIONS	Abrevation	STATIONS	Abrevation	STATIONS	Abrevation
Abetifi	ABE	Bui	BUI	Salaga	SALA
Accra	ACC	Cape Coast	C. COAST	Saltpond	SALT
Ada	ADA	Damongo	DAM	Sefwi Bekwai	S. BEK
Agona Kwanyako	AG. KWA	Dorma Ahenkro	D. AHEN	Sefwi Wiawso	S. WIAW
Agona Swedro	AG. SWE	Duayaw Nkwanta	D. NKWA	Sunyani	SUNY
Akatsi	AKA	Dunkwa	DUNK	Techiman	TECH
Akim Oda	AK. ODA	Goaso	GOA	Tafo	TAFO
Akropong Akwapim	A. Akwap	Ho	HO	Takoradi	TADI
Akuse	AKU	Kade	KADE	Tamale	TAMA
Asamankese	ASAM	Kete Krachi	K. KRA	Tarkwa	TARK
Asankragwa	ASANK	Kintampo	KINT	Tema	TEMA
Atebubu	ATE	Koforidua	KOF	Twifo Praso	T. PRA
Atieku	ATIEKU	Kpando	KPAN	Vea Dam	VEA
Axim	AXIM	Kumasi	KSI	Wa	WA
Babile	BABILE	Manga Bawku	M. BAWKU	Walewale	WALE
Bechem	BECH	Mim	MIM	Wamfie	WAMF
Bibiani	BIB	Navrongo	NAV	Wassaw Akropong	W. AKR
Bimbila	BIMB	Nsoatre	NSOA	Wenchi	WEN
Bole	BOLE	Obuasi	OBUASI	Winneba	WINN
Bolgatanga	BOLGA	Pong Tamale	P. TAM	Yendi	YEN
Bompata	BOMPA	Prang	PRANG	Zuarungu	ZUA
Breman Asikuma	B. ASIK				

Kindly send feedback to:
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Research &Applied Meteorology
Ghana Meteorological Agency
P.O.Box Lg 87, Legon, Accra-Ghana.

Email:info@meteo.gov.gh

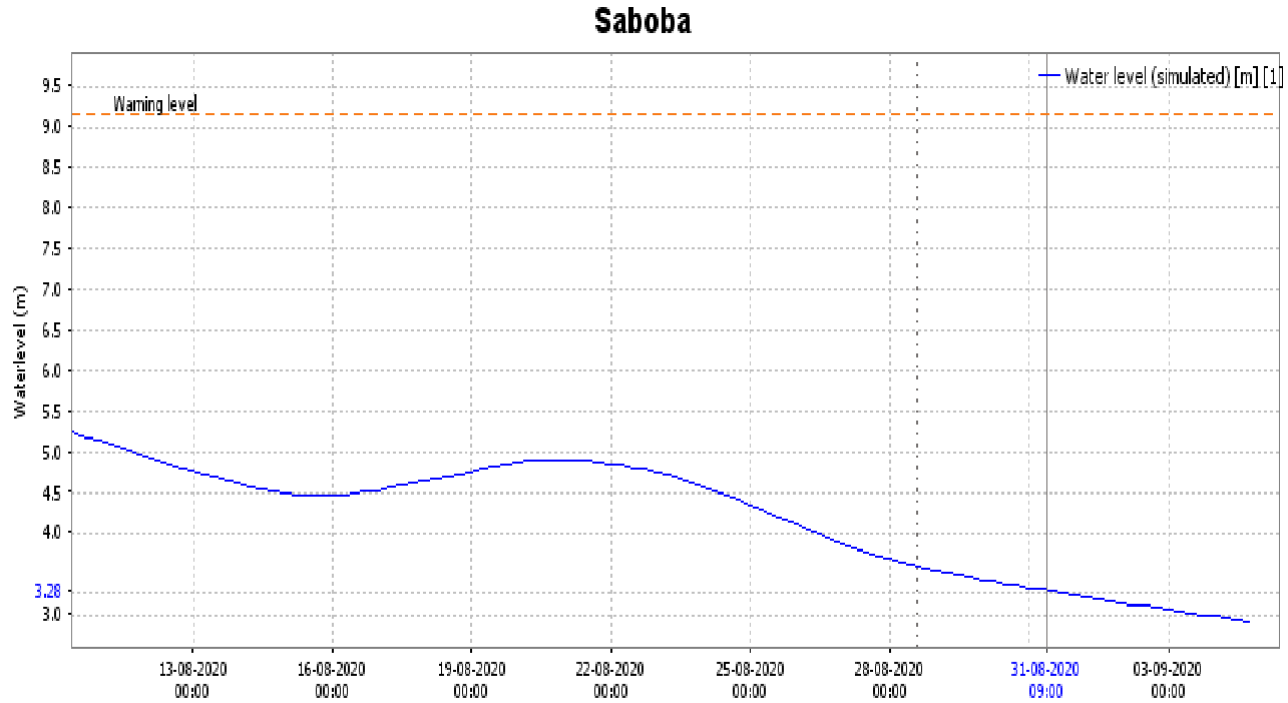
4. Oti river basin forecast - HSD

DATE (31-08-2020) TIME
(10:00AM)

RESPONSIBLE ORGANIZATION: HYDROLOGICAL SERVICES DEPARTMENT

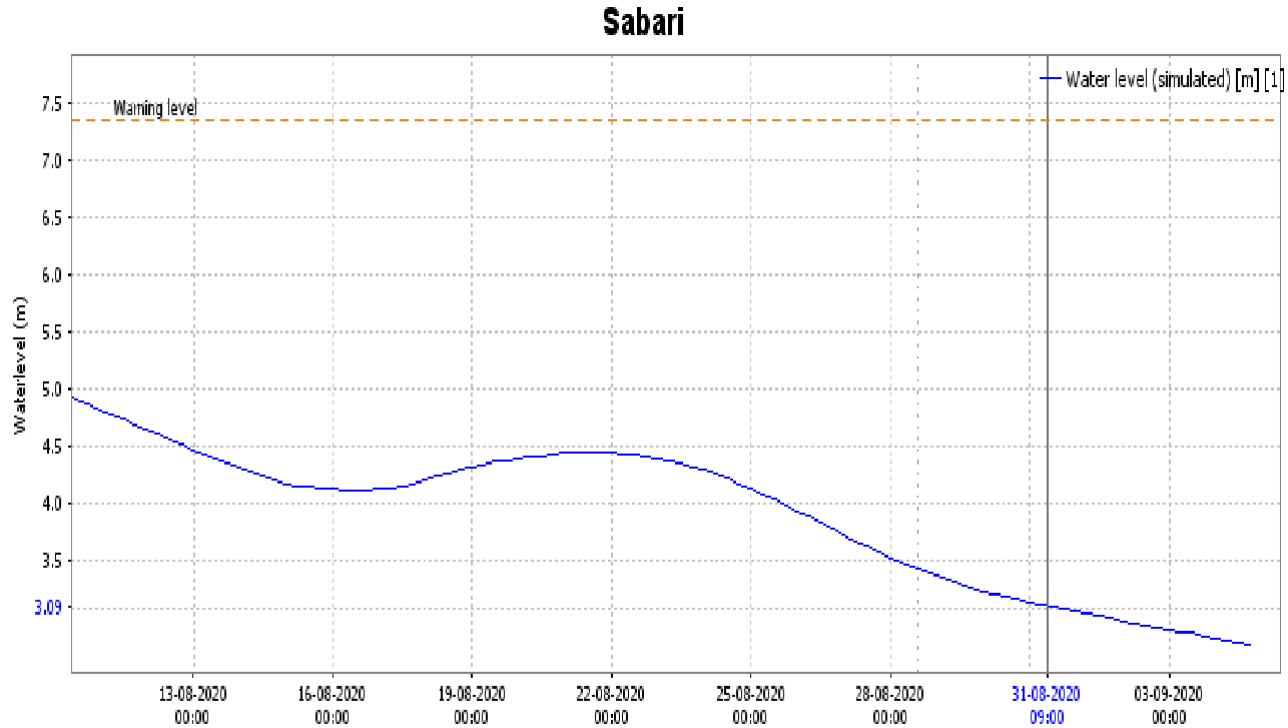
OBSERVATION	
Meteo forecast	
Saboba low: < 3.95 high: > 3.95 < 8.95 warning: > 8.95	Forecast: ☒ low ☐ low but rising ☐ high and rising ☐ high and falling ☐ Critical and rising ☐ Critical and falling Simulated water level (GPM): 3.28m Date: 31/08/20
Info from gauge reader at Saboba	None
Sabari low: < 1.96 high: > 1.96 < 6.96 warning: > 6.96	Forecast: ☐ low ☐ low but rising ☐ high and rising ☒ high and falling ☐ Critical and rising ☐ Critical and falling Simulated water level (GPM): 3.09m Date: 31/08/20
Info from gauge reader at Sabari	None
Action taken	None

FIGURE OF FORECAST AT SABOBA (UPSTREAM) AND SABARI (DOWNSTREAM) – 31/08/20



wf_FullForecastRun_GPM: [1] Run model train base... 28-08-2020 14:15:01 GMT Current

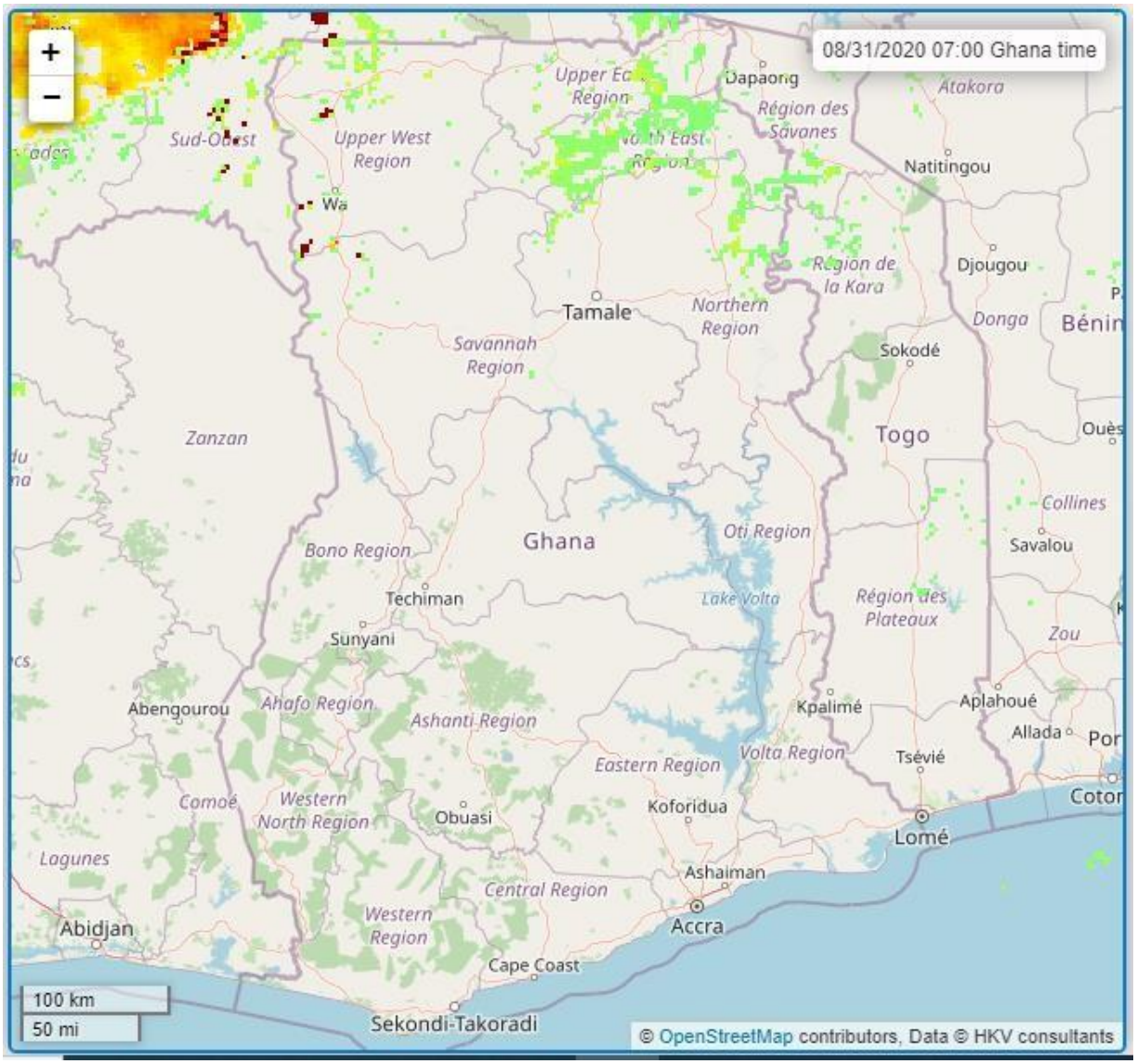
---

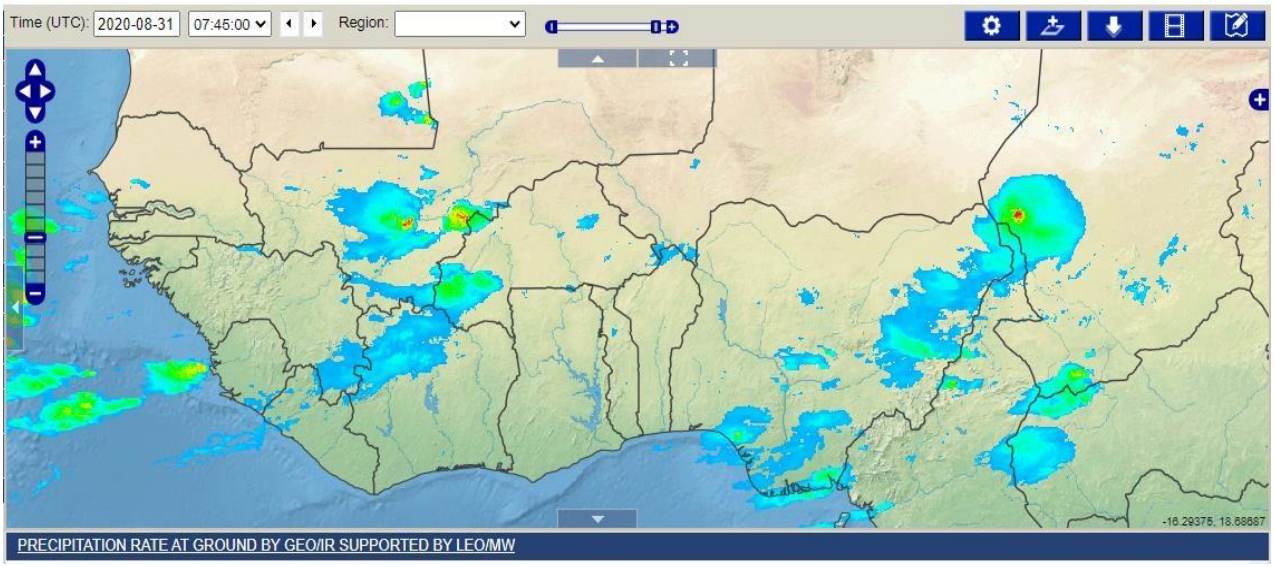


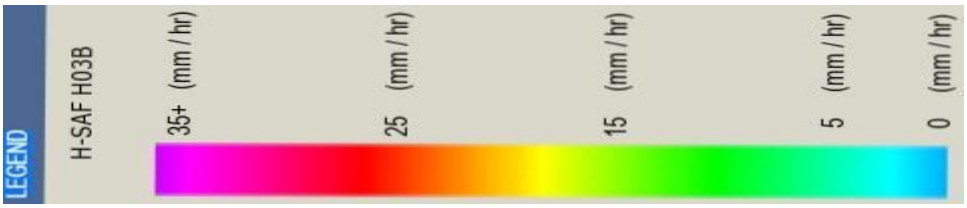
wf_FullForecastRun_GPM: [1] Run model train base... 28-08-2020 14:15:01 GMT Current

---

TODAY'S RAINFALL MAPS – 31/08/20

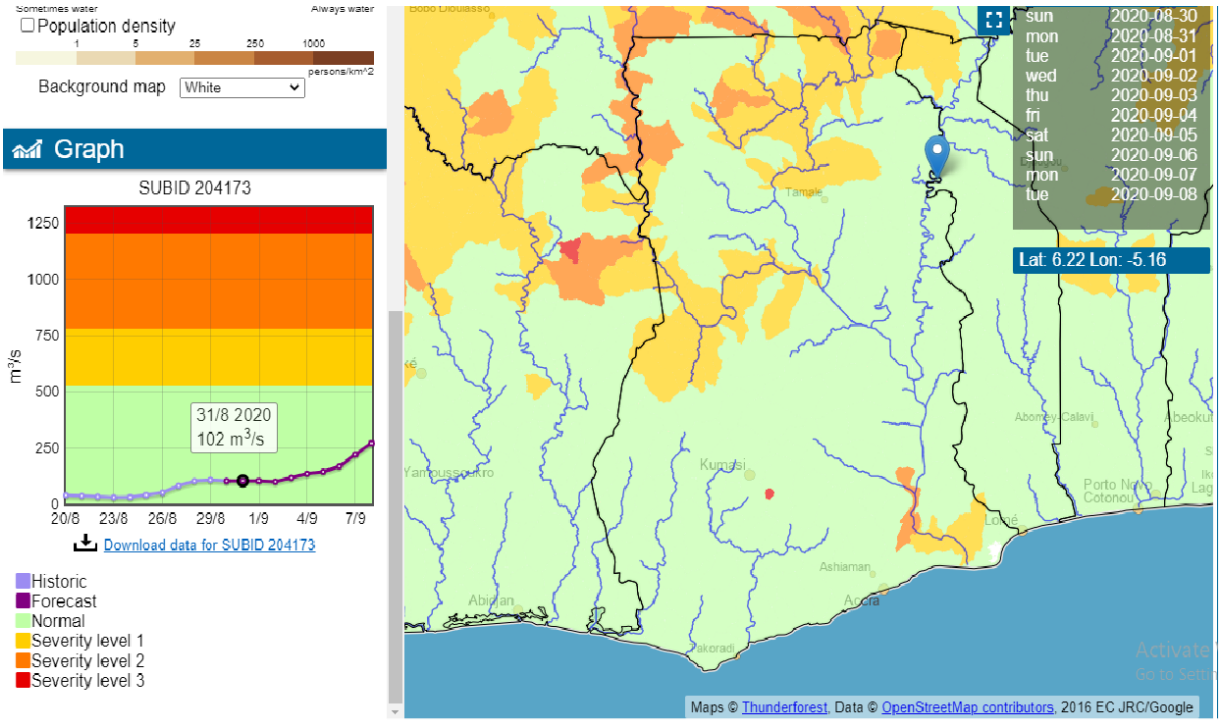




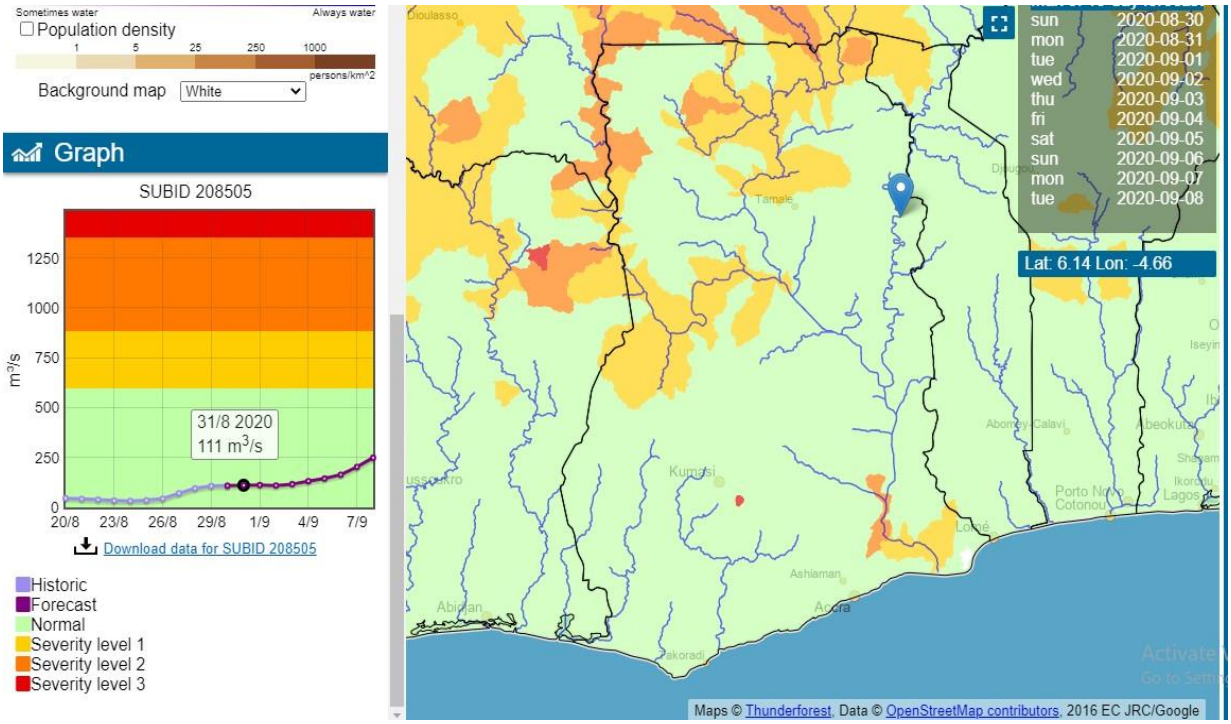


SIMULATED DISCHARGE AT SABOBA (UPSTREAM) AND SABARI (DOWNSTREAM) – 31/08/20

Saboba = 102 m3/s (Warning level = 550 m3/s)



Sabari = 111 m3/s (Warning level = 600 m3/s)



5. White Volta river basin forecast - HSD

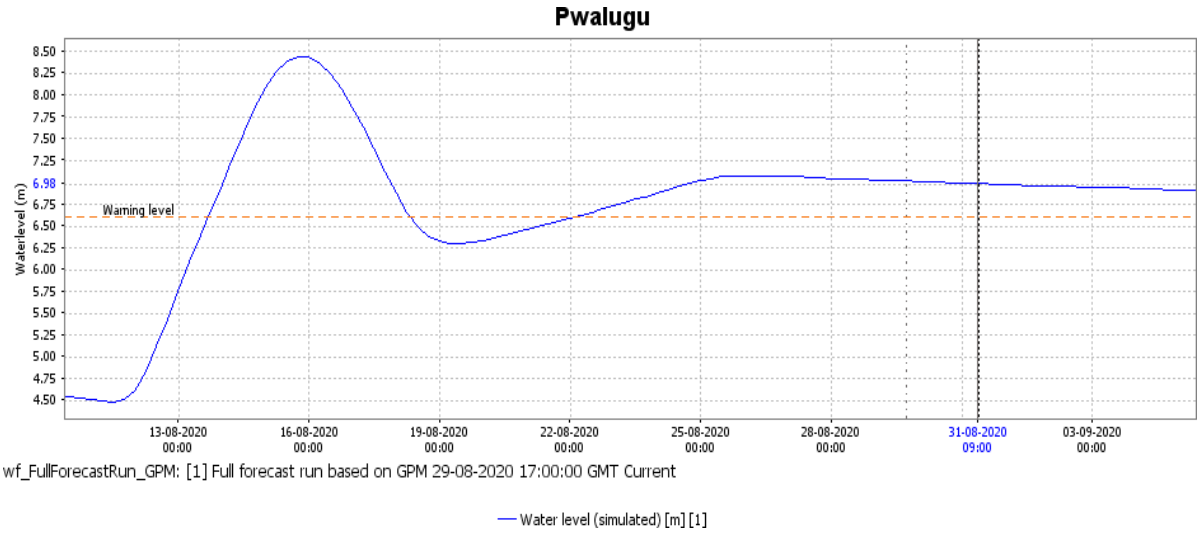
HYDROLOGICAL SERVICES DEPARTMENT (HSD) WHITE VOLTA RIVER BASIN FORECAST REPORT

Note: Recommendations on the content and format are welcome. The forecast report will also be used to calibrate and improve the forecast accuracy. Field observations and verifications are therefore much appreciated

Below are water level forecasts for the White Volta river basin valid from today, 31/08/2020 to 06/09/2020 @ midnight.

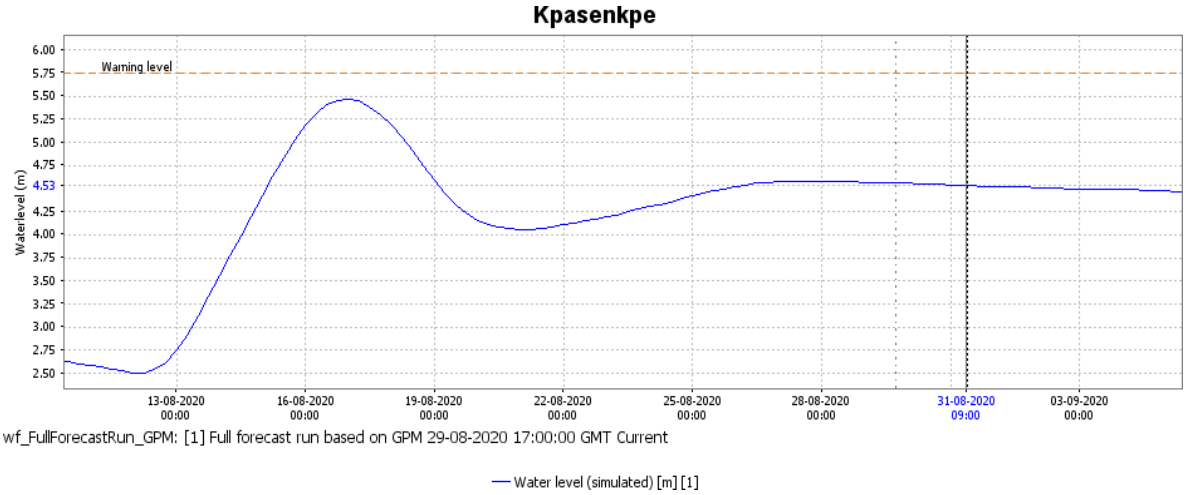
- **Pwalugu - White Volta river:**

Warning level = **6.60m**
Current water level = 6.98m
Forecast range = 6.98m – 6.91m



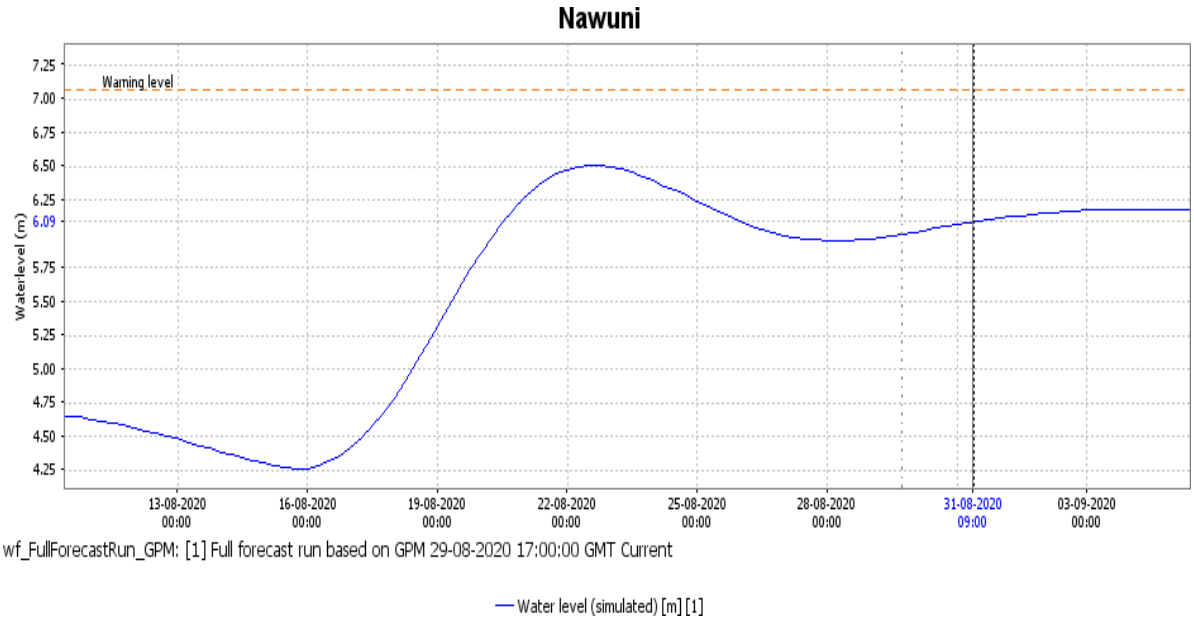
- **Kpasenkpe - White Volta River**

Warning level = **5.75m**
Current water level = 4.53m
Forecast range = 4.53m – 4.46m



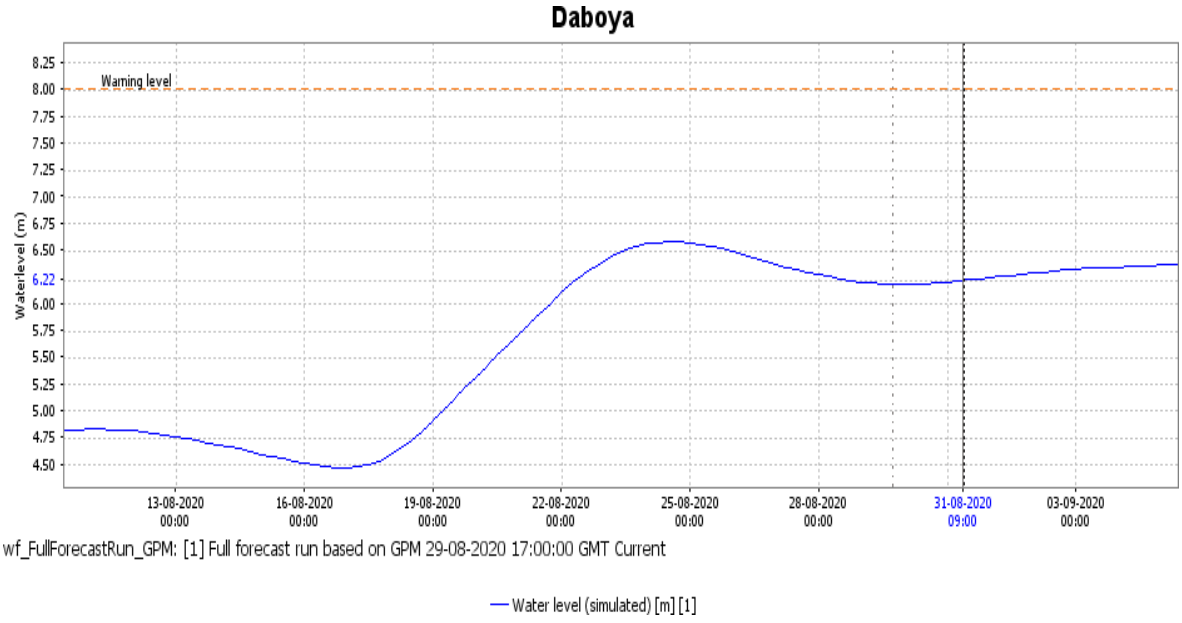
- **Nawuni - White Volta river:**

Warning level = **7.10m**
Current water level = 6.09m
Forecast range = 6.09m – 6.17m



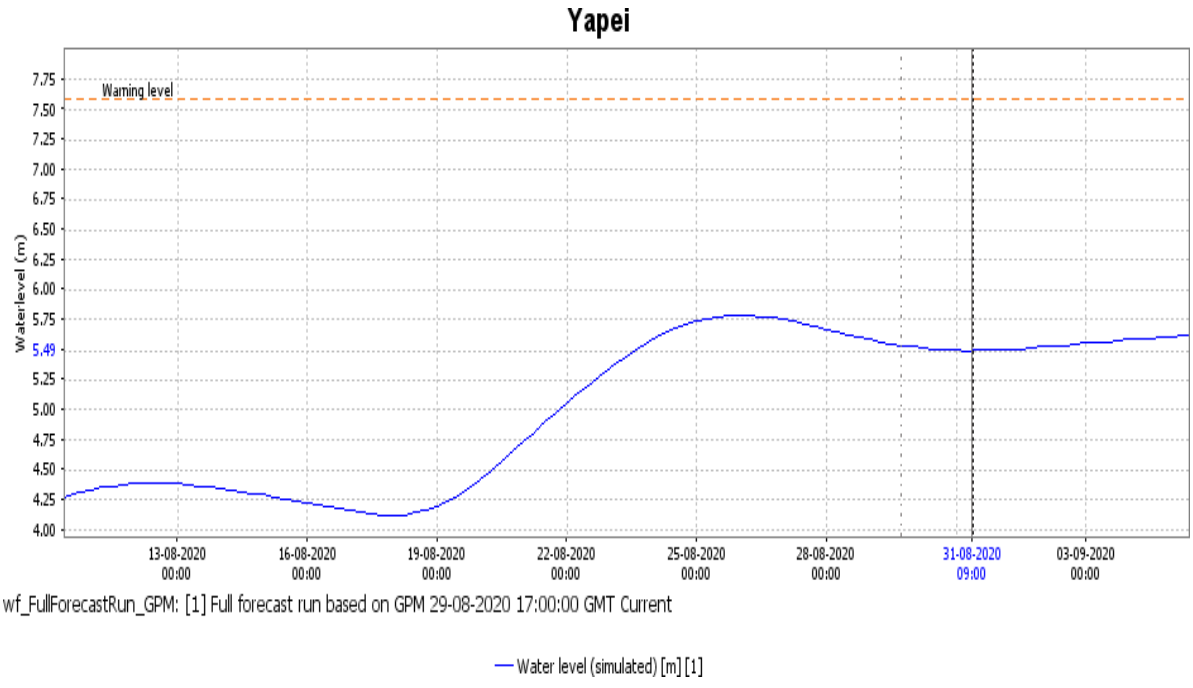
- **Daboya - White Volta River**

Warning level = **8.00m**
Current water level = 6.22m
Forecast range = 6.22m – 6.36m

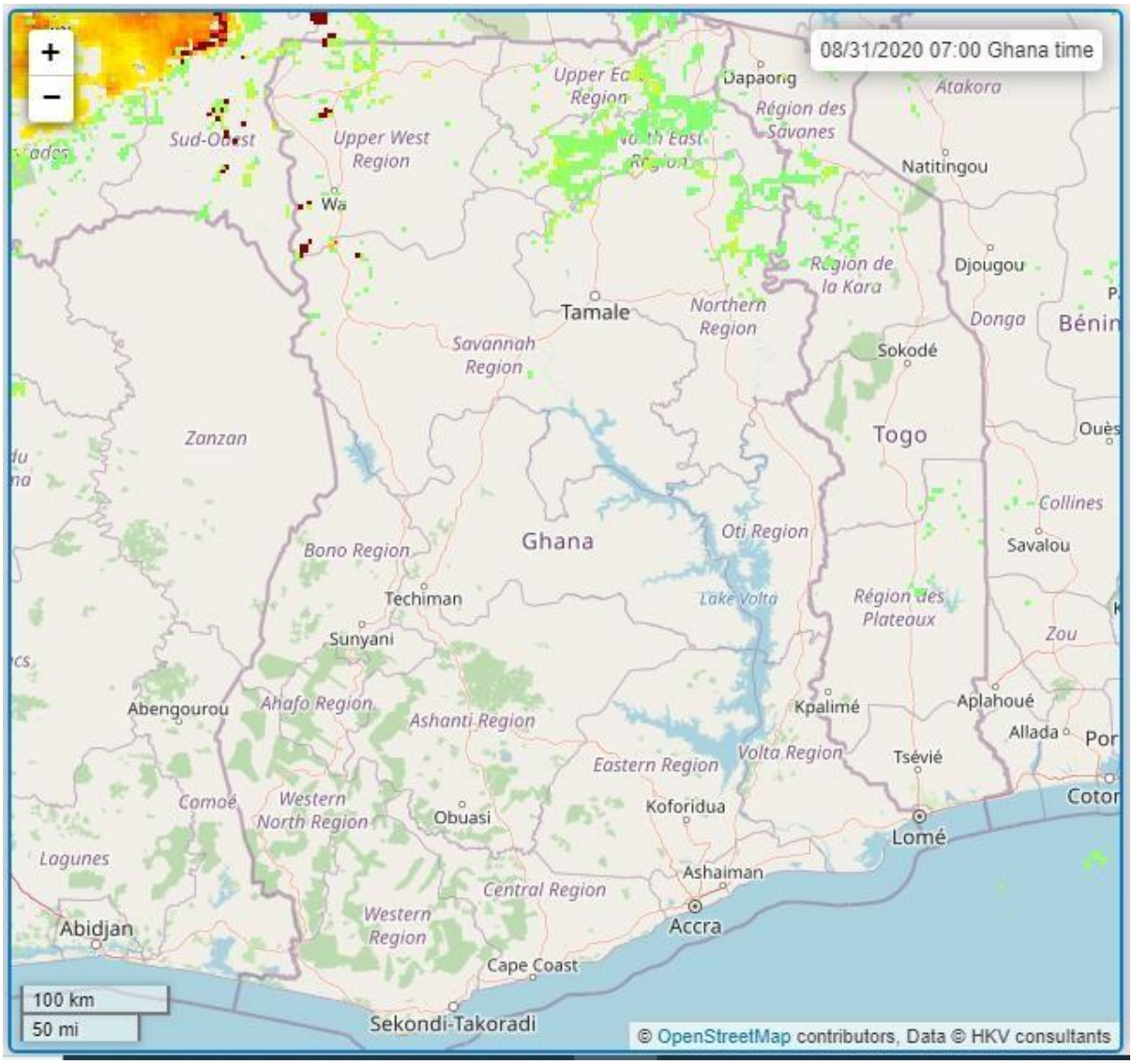


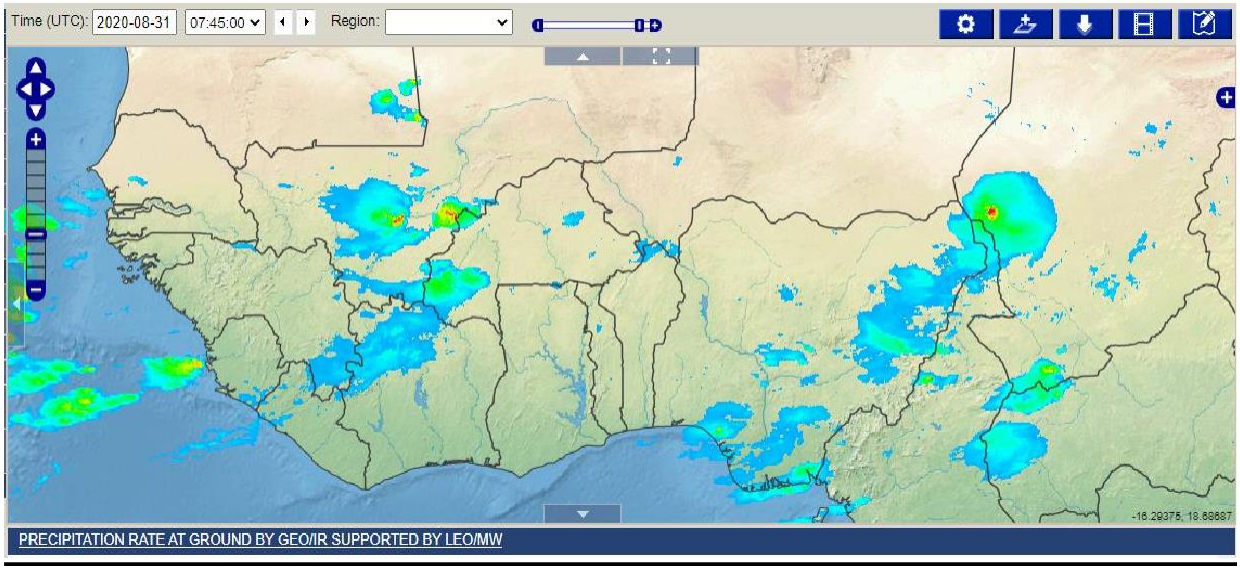
- **Yapei – White Volta River**

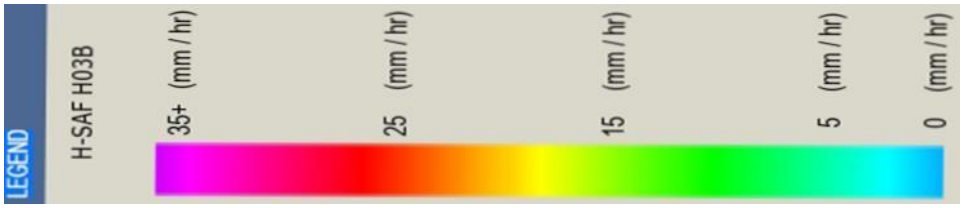
Warning level = **7.60m**
Current water level = 5.49m
Forecast range = 5.49m – 5.61m



TODAY'S RAINFALL MAPS – 31/08/20

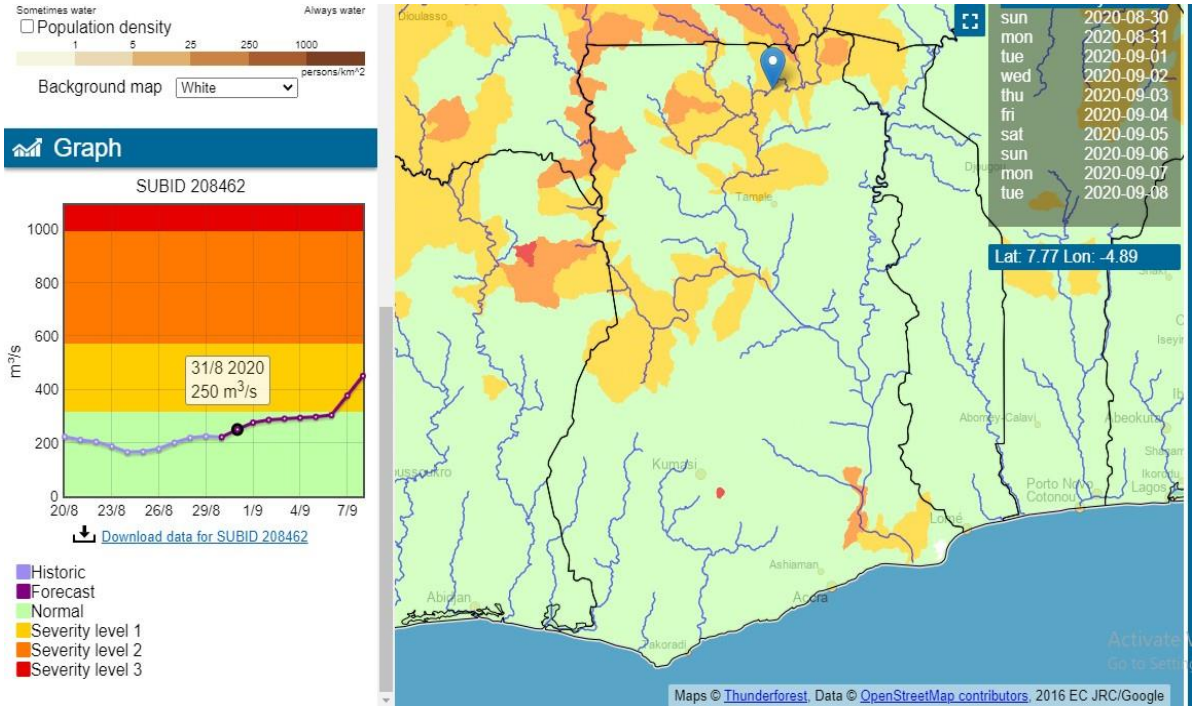




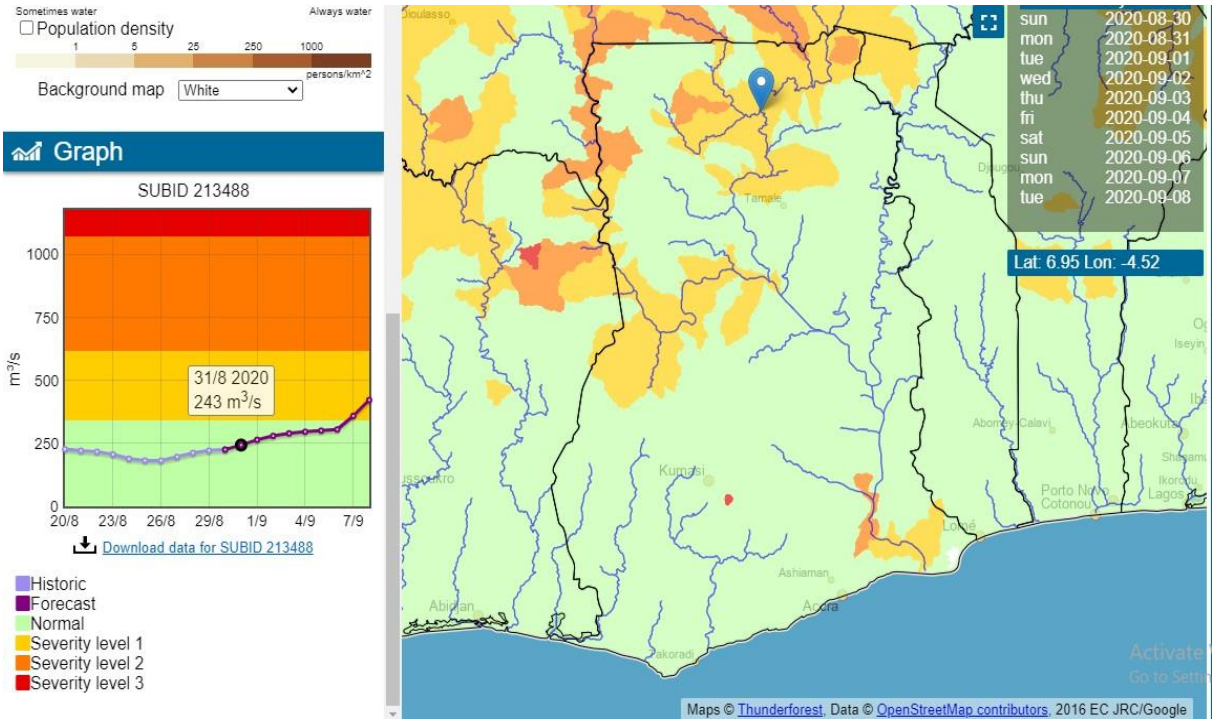


SIMULATED DISCHARGE – 31/08/20

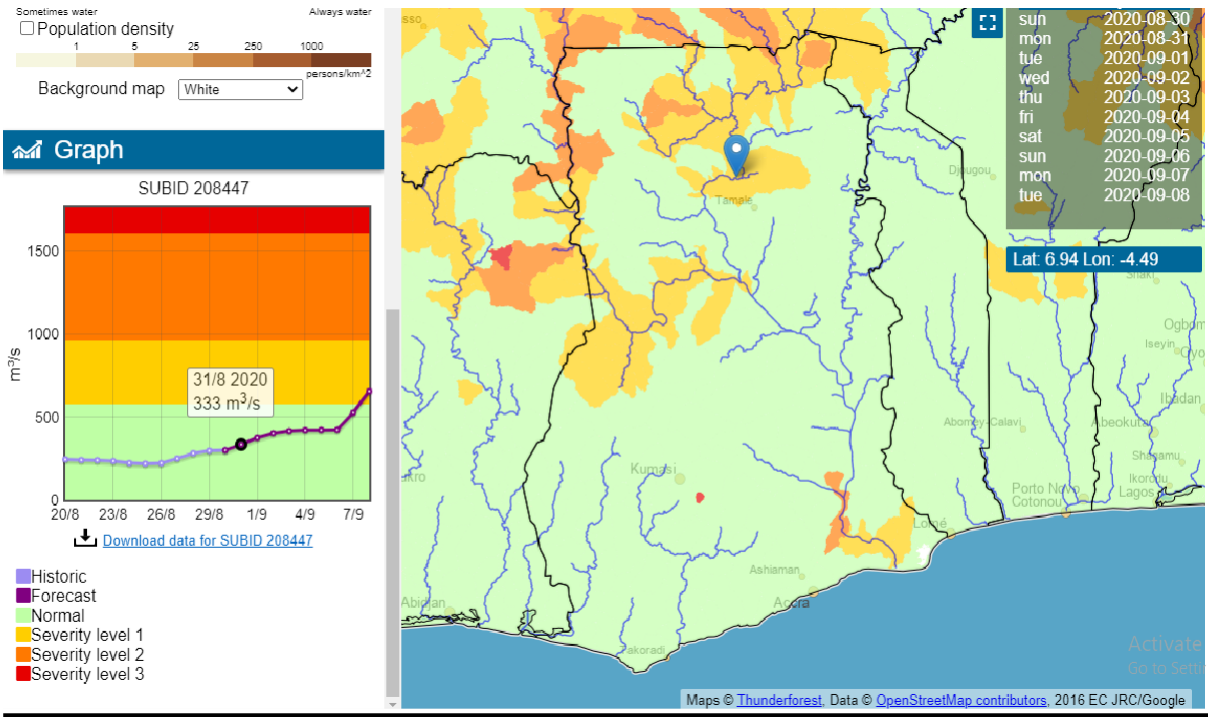
- **Pwalugu = 250 m^3/s (Warning level = 310 m^3/s)**



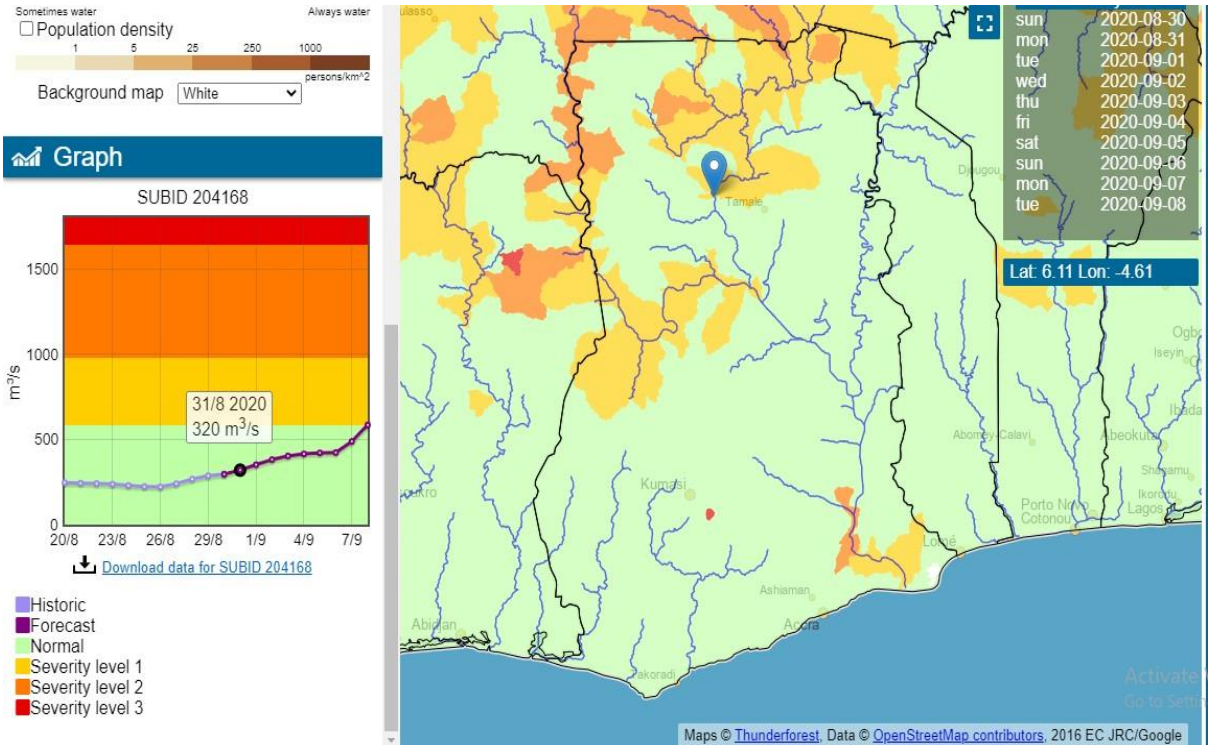
- **Kpasenkpe = 243 m^3/s** **(Warning level = 350 m^3/s)**



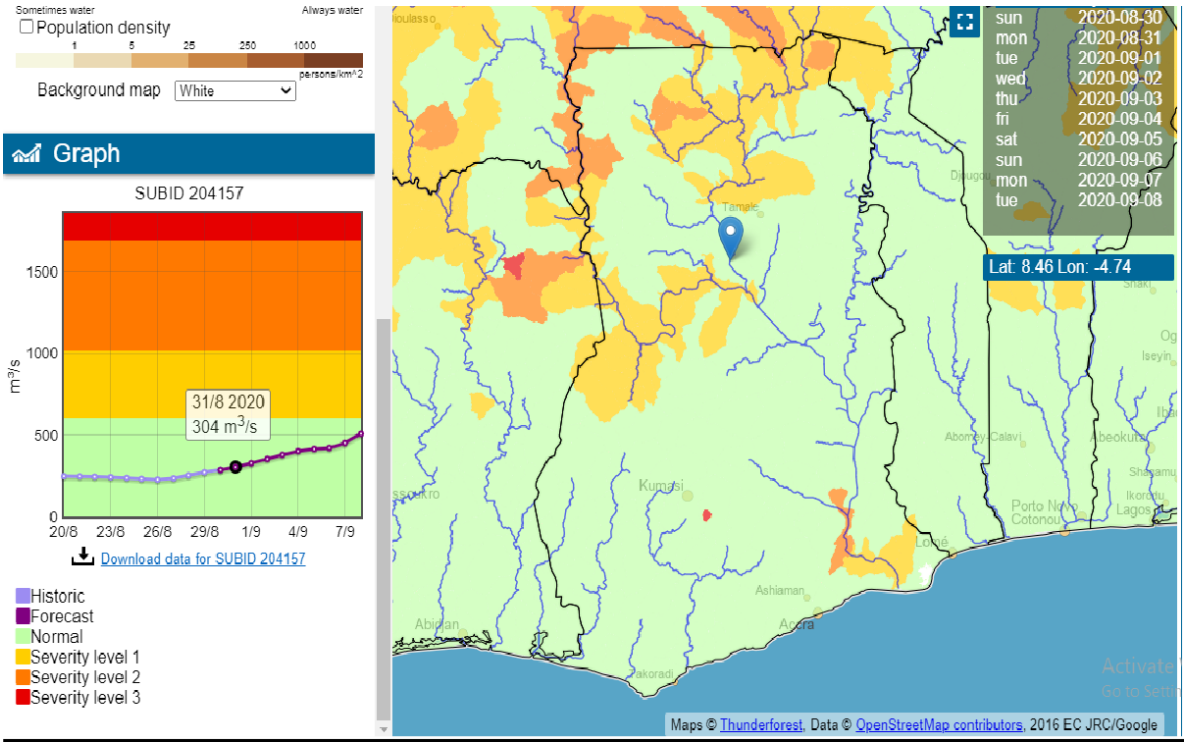
- **Nawuni = 333 m^3/s** **(Warning level = 600 m^3/s)**



- **Daboya = 320 m^3/s** **(Warning level = 600 m^3/s)**



- **Yapei = 304 m^3/s** **(Warning level = 600 m^3/s)**



Recommended action: The simulated water level at Pwalugu has passed its warning level, hence inundation is likely to occur. Discharge map also shows that there are inundations occurring in the following areas: Pwalugu, Yarugu, Zebilla and Bawku in the Upper East Region due to the spillage from the Bagre Dam.

Inundation are also expected to occur at Wiasi, Yagaba, Kpasenkpe, Nawuni and Daboya all within the White Volta River Basin.

There also inundations likely to occur at the following areas (Hamile, Nandom, Lawra, Chache, and Bui,) along the Black Volta River.

The following communities (Akosombo, Kpong, Adidome, Battor, Tefle, Sokagope and Ada) within the Lower Volta Basin are also expected to have some inundations.

NADMO regional, district and zonal officers/offices are to continue monitoring in the field and possibly alert and sensitize inhabitants of the under-listed local communities in the White Volta River Basin in the Northern and Upper East Regions to move to higher grounds and safe havens.

6. Terms of Reference for the consultation meetings

National Consultations/Assessments on Capabilities and Needs on Forecasting and Early Warning System for Flood and Drought

Introduction

This document outlines the methodologies and tools for conducting a National Consultation on Hydrological Capabilities for Flood and Drought Forecasting in the Volta Basin countries, in the framework of the Volta Flood and Drought Management (VFDM) project entitled 'Integrating Flood and Drought Management and Early Warning Systems in the Volta Basin'.

Objectives and Scope of the national consultation

Assess the national capabilities and needs for developing forecasting and early warning system for flood and drought events and provide integrated, tailored, basin-wide and sustainable solutions for building climate change resilience at local, national and regional level.

Methodology and tool

The National Early Warning System Assessment (NEWSA) methodology and tool prepared by CIMA Research Foundation will be used as the main tool to assess the capabilities for flood forecasting and warning in the country. In addition, the consultation team may use additional evaluation tools as needed, such as the World Meteorological Organization (WMO) Assessment Guidance tool prepared by the task team of the WMO Commission for Hydrology (CHy) or other tools, mainly for collecting information on drought indicators and warnings. The consultation team is composed of two consultants from the CIMA Research Foundation and three WMO representatives (the VFDM project leader, the WMO representative for West Africa and one consultant in operational hydrology).

The consultation team should perform the following tasks:

i. Collect information about the main flood and drought risk areas, globally available datasets on vulnerabilities, exposure and hazards) in the country, and combine with existing knowledge on available hydro-meteorological services as well as flood impacts on the population and socio-economic sectors;
ii. Examine the Hydrological-meteorological (and other sectors) data management mechanism (collected, transmitted, storage, monitoring and sharing) and possible approach for integrating with the transboundary open-source platform for early warning system.
iii. Examine the current hydrological and meteorological forecasting and warning (dissemination and communication) capabilities and needs, applying the assessment tools to the national directorate and agencies mainly responsible for operational hydrology and meteorology and early warning communication (Civil protection, disaster management, etc.);
iv. Collect information related to the institutional framework, policies, legal mandates, infrastructures, tools and human resources capabilities (skills acquired and trainings) for flood and drought management.
v. Review programs, projects or initiatives (completed, under implementation or in the pipeline) related to flood and drought forecasting and warning system and propose an approach to enhance linkages or complementarities of these initiatives to the future transboundary level Hydro-Meteo VoltAlarm system.
vi. Gather recommendations and action plans with different options, from the national agencies, for the design and implementation of a flood and drought forecasting and early warning system for the transboundary Volta Basin region taking into account the relevance, efficiency, effectiveness, impact and sustainability, and also any relation with other resources available.

Prior to the consultation meetings

The consultation team will review the existing literature, tools or products available in the country as well as information about the National Services involved in flood and drought forecasting, warning and response. The National agencies are requested to share additional documents with the consultation team, information sheets or web-links providing information on their activities or work area.

Consultation approach

The consultation team will meet several agencies that are involved in the management of climate change events such as Floods and drought and are based in National Capital city. The draft list of Agencies to meet is available in the Annex. The Agencies were requested to add their availability to meet with the consultation team.

Expected Outcomes

The consultation team will provide Consultation meeting report, in French (for the French speaking countries) and English for Ghana, summarizing the information gathered with the most significant results, and the critical comments in line with the CIMA and WMO AG Matrix. The Country National Consultation report will include general **recommendations and will be** proposed to the National stakeholders in the National Workshops planned in 2020, for the design and implementation of a future transboundary integrated Flood and Drought Forecasting and Warning System (VoltAlarm) under the framework of the VFDM project especially Components 1 and 2.

The consultation meeting report will be drafted and shared with the National agencies before 25 March 2020 and a national workshop will be organized with the agencies to present the findings and recommendations for validation and ownership, most probably in June 2020.

Sample questionnaire to various agencies

METEOROLOGICAL (Meteorological Agency) and HYDROLOGICAL SERVICES (Direction in charge of Water Resources)

- Institutional framework (from national to local)
- Data management mechanism for both floods and drought
- Agreements and interagency protocols for data exchange
- Existing approach for modeling and forecasting for floods and drought monitoring
- Global products (ECMWF, GLOFAS, NOAA) or services used if any
- Issue for warning at National and local levels
- Cross-border exchange of warnings
- Availability of repository established to store all events
- Stations and barrages
- Collaboration with other services
- Gaps and opportunities

Disaster Management Agency

- Institutional framework (from national to local)
- Warning messages
- Drill and simulation exercise on field
- How they work in real time
- Technical equipment (provide some guidance on types)
- Standard operating procedures
- Coordination arrangements between the warning issuers, media and other stakeholders
- Availability of contingency plan
- Public awareness and education campaigns
- Collaboration with other services
- Gaps and opportunities

INSTITUTIONS in charge of SOCIO-ECONOMIC DUTIES

- How data are organized and shared (freely available, platform used, etc.)
- Availability of exposure data
- Availability of vulnerability data
- Hazard maps
- Mitigation measures
- Land-use and land cover maps
- Repository established to store all event
- Involvements in project related to flood and drought management
- Collaboration with other services
- Gaps and opportunities

CIVIL PROTECTION (other than NADMO)

- Institutional framework (from national to local)
- Receiving warning messages
- How they work in response time
- Technical equipment (…)
- Standard operating procedures
- Collaboration with NADMO
- Last mile connectivity (reach the entire population, including seasonal population and those in remote locations)
- Public awareness and education campaigns
- Collaboration with other services
- Exercises and training activities
- Gaps and opportunities

AGENCIES in charge of WATER, ENVIRONMENT AND ECOSYSTEM

- Information related to environment indicators (vegetation cover)
- Protected and conserved lands
- Bio-diversity (threatened species)
- Availability of Database with information
- Projects currently on-going, completed or in pipeline
- Gaps and opportunities

COUNTRY WATER PARTNERSHIP

- Collaborations with operational services
- Other Stakeholders in the country working on Flood and Drought Management
- On-going, completed or future projects in the Volta Basin region
- Activities at community-level
- Means of actions to support the project

NATIONAL DESIGNATED AUTHORITY FOR THE ADAPTATION FUND

- Other related regional or National projects or in the Volta Basin region
- Possible follow up for the activities
- Recommendations for fulfilling the activities of the VFDM project

WASCAL

- Projects/Activities implemented on Flood and Drought Management

- Availability of data on Hydrology, Meteorology and Climatology
- Risk maps, hazard maps, vulnerability maps etc.
- Hydrological or Meteorological Stations
- Trainings and Capacity development
- Community-based activities

GEOGRAPHICAL INSTITUTE OR ACADEMIA

- Past, current and forthcoming studies in the field of forecasting and early warning for flood and drought
- Existing approaches, equipment, IT and tools
- Topographic maps with demographic data
- Relationships with operational services and civil security
- Partnerships through student research or research projects
- Recommendations

7. List of participants consulted during the National Consultation mission

Flood and Drought Management in the Volta basin

Country: Ghana **Organisation:** Water Resources Commission

Date: Dec 3, 2019

N°	Family name/First Name	Organisation/Position	Contact (email, phone)	Signature
1	Wittmer Caroline	consultant OMM	wittmer-borne@orange.fr +33 6 44 30 38 16	
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3	Rakesh Tripathi	World Meteorological Organization	rtripathi@wmo.int +41 77922 3020	
4	Alessia Matano	CIMA Research Foundation	alessia.matano@cimafoundation.org +39 338 491 6338	
5	MARCO MASSABO	CIMA	MARCO.MASSABO@CIMAFOUNDATION.ORG +39 348 7748016	
6	Dr. Bob Alfa	WRC	bobalfa@yahoo.com	
7	Dr. Mawuli Lumor	WRC	mawlumor@yahoo.com	
8	Maxwell Bentag-Gymah	CWP - GH	bentagmax2@gmail.com	
9	Eric Mualo	WRC	ericmualo25@gmail.com	
10				

Flood and Drought Management in the Volta basin

Country: Ghana Organisation: Hydrological Service Department

Date: Dec 3, 2019

N°	Family name/First Name	Organisation/Position	Contact (email, phone)	Signature
1	ADDAE-MENSAH BENEDICT	HYDROLOGICAL SERVICES DEPT.	0249348012 pkwaxy@yahoo.com	
2	SYLVESTER DARKU	✓	Skylw esi@yahoo-com 0244177110	
3	Wittwer Caroline	consultant OMVS	wittwer-boanergues@orange.fr +33 6 77 30 38 26	
4	MARCO MASSABO	CIMA	MARCO.MASSABO@CIMAFOUNDATION.ORG +39 348 774 70 16	
5	ALESSIA MATANO	CIMA	ALESSIA.MATANO@CIMAFOUNDATION.ORG +39 348 892 6808	
6	TRIPATHI RAMESH	WMO	RTRIPATHI@WMO.INT +41 779 22 3020	
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9				
10				

Flood and Drought Management in the Volta basin

Country: Ghana Organisation: Ghana Hekorological Agency

Date: Dec 3, 2019

N°	Family name/First Name	Organisation/Position	Contact (email, phone)	Signature
1	Wittwer Caroline	Consultant WMO	wittwer-bonnefoy.caroline@wmo.int +33 6 44 30 38 76	
2	TRIPATHI RAMESH	WMO	RTRIPATHI@WMO.INT +41792230210	
3	Bernard E. Gomez	WMO	begomez@wmo.int +2347083598874	
4	ALESSIA MATANÒ	CIMA	ALESSIA.MATANO@CIMAFOUNDATION.ORG +39 348 89 16 308	
5	Joseph Portuphy	GMet	j.portuphy@meteo.gov.gh +233 277 413938	
6	Eric Asuman	GMet	e.asuman@meteo.gov.gh	
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9	ELIKEM SETSOAFIA	GMET	elikem_s@yahoo.com	
10	MARCO MASSABÒ	CIMA	MARCO.MASSABO@CIMAFOUNDATION.ORG +393487747016	

Flood and Drought Management in the Volta basin

Country: Ghana **Organisation:** Water Research Institute

Date: December 4, 2019

N°	Family name/First Name	Organisation/Position	Contact (email, phone)	Signature
1	Wittwer Caroline	Consultant WMO	wittwer-bonnefoux@orange.fr +33647303816.	
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5	Emmanuel Obuobie	CSIR-WRI	obuobie@yahoo.com 0241441038	
6	Alia Baibie	" "	alia.baibie@gmail.com	
7	Franz Alex Gaisie-Essilfie	CSIR-WRI	franzalex@csir-water.com	
8				
9				
10				

Flood and Drought Management in the Volta basin

Country: Ghana **Organisation:** NADMO

Date: Dec 4, 2019

N°	Family name/First Name	Organisation/Position	Contact (email, phone)	Signature
1	Wittwer Caroline	consultant WMO	wittwer-bonnefoux@orange.fr +33 6 44 30 38 46	
2	KEKLY KEKELY DEGBOE	NADMO	Kekely77@hotmail.com 0243155964	
3	Frank Nansam-Aggrey	NADMO	frank_aggrey@yahoo.com 0555301853	
4	Bernard B Gomez	WMO	begomez@wmo.int +234 708 359 8874	
5	Alessia Matarò	CIMA	ALESSIA_MATARO@CIMAFOUNDATION.ORG +39 348 89 46 868	
6	Marco Mazzola	CIMA	MARCO.MASSABO@CIMAFOUNDATION.ORG +39 340 7747016	
7	Caroline → (1)			
8	RAMESH RIPATHI	WMO	RTRIPATHI@WMO.INT +41779223020	
9				
10				

Flood and Drought Management in the Volta basin

Country: Ghana Organisation: CERSGIS

Date: Dec 5, 2019

N°	Family name/First Name	Organisation/Position	Contact (email, phone)	Signature
1	W. Hwer Coulie	consultant WMO	w.hwer-benefour@diplo.fr +33 6 XX 30 38 16	
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4	George Quansy	CERSGIS/TECHNICAL SERVICES MANAGER	georgeseny@gmail.com +233-243053574	
5	Bernard E. Gomez	WMO	begomez@wmo.int +234 708 359 8874	
6	Eric Muda	WRC	ericmuda25@gmail.com +233 (0) 3450 22258	
7				
8				
9				
10				

8. Final report of the national workshop held in Accra (27th and 28th January 2021)

Please see the document “Final report of the national workshop in Ghana (27th and 28th January 2021)“

Bibliography

Abbam, T., Johnson, F. A., Dash, J. & Padmadas, S., 2018. Spatiotemporal Variations in Rainfall and Temperature in Ghana Over the Twentieth Century, 1900–2014. *Earth and Space Science,* 5(4), pp. 120-132.

Aboagye, D., Dari, T. & & Koomson, J., 2013. Risk Perception and Disaster Management in the Savannah Region of Ghana. *International Journal of Humanities and Social Science,* 3(3), pp. 85-96.

Almoradie, A. et al., 2020. Current flood risk management practices in Ghana: Gaps and opportunities for improving resilience. *Journal of Flood Risk Management,* 13(4).

Ansah, S. O. et al., 2020. Meteorological Analysis of Floods in Ghana. *Advances in Meteorology.*

Bond, H., Cross, K., Glotzbach, R. & Richaud, B., 2018. *Flood and Drought Management Tools Case Study*, s.l.: s.n.

CREW project, 2015. *Risk Assessment and Mapping – HKV Technical Report.* s.l.:s.n.

CTCN, 2016. *Improving Resiliency of Crops to Drought through Strengthened Early Warning within Ghana - Needs assessment report* , s.l.: s.n.

CTCN, 2017. *CTCN Ghana - Technology validation report.* [Online]
Available at:
https://www.flooddroughtmonitor.com/handler/extradocumenthandler.ashx?request=user_guide&file=User_guide_CTCN_Ghana.pdf

EPA, 2018. *Ghana's National Adaptation Plan Framework,* s.l.: s.n.

FAO, 2005. *AQUASTAT Country Profile - Ghana*, s.l.: s.n.

GFDRR, 2011. *Disaster Risk Management Programs for Priority Countries,* s.l.: s.n.

GFDRR, 2014. *State of art of the flood forecasting model launched for the White Volta river in Ghana.* [Online]
Available at: https://www.gfdrr.org/en/state-art-flood-forecasting-model-launched-white-volta-river-ghana

Ghana Maritime Authority, 2001. *Profile of major rivers in Ghana*, s.l.: s.n.

GhanaWeb, 2020. *NADMO issues alert as Burkina Faso prepares to spill dams.* [Online]
Available at: https://www.ghanaweb.com/GhanaHomePage/NewsArchive/NADMO-issues-alert-as-Burkina-Faso-prepares-to-spill-dams-1026982

IFRC, 2012. *Community early warning systems: guiding principles,* s.l.: s.n.

IHA, 2019. *Volta River Authority.* [Online]
Available at: https://archive.hydropower.org/companies/volta-river-authority

ILGS-FES, 2014. *A Guide to District Assemblies in Ghana,* s.l.: s.n.

IWMI, 2005. *The Volta River Basin: Comprehensive Assessment of Water Management in Agriculture - Comparative study of river basin development and management*, s.l.: s.n.

Kusimi, J. M., 2018. *Natural Disasters of Ghana.* [Online]
Available at: https://www.bristol.ac.uk/media-library/sites/research/documents/gcrf-presentations-hazards/kusimi-global-partnerships-symposium-presentation.pdf
[Consultato il giorno 2020].

Logah, F. Y., Obouble, E., Ofori, D. & Kankam-Yeboah, K., 2013. Analysis of Rainfall Variability in Ghana. *International Journal of Latest Research In Engineering and Computing (IJLREC),* 1(1).

Madu, C. N. & Kuei, C.-H., 2017. *Handbook of Disaster Risk Reduction & Management: Climate Change and Natural Disasters.* s.l.:s.n.

NADMO, 2010. *National Disaster Management Plan.* s.l.:s.n.

NADMO, 2020. *Organisational Structure of NADMO.* [Online]
Available at: http://www.nadmo.gov.gh/

Siaw, D. E., 2001. *State of Forest Genetic Resources in Ghana,* s.l.: s.n.

Statista, 2020. *Ghana: Distribution of employment by economic sector from 2008 to 2018.* s.l.:s.n.

UNCCD, 2016. *Ghana National Drought Plan.* [Online]
Available at: https://knowledge.unccd.int/sites/default/files/inline-files/1%20FINAL_NDP_Ghana.pdf

UNDP, 2008. *Climate Change Country Profile: Ghana.* [Online]
Available at: https://web.archive.org/web/20130921055503/http:/ncsp.undp.org/document/undp-climate-change-country-profile-11
[Consultato il giorno 2020].

UNDRR, 2019. *Ghana Disaster Risk Profile - Floods & Drought (2019),* s.l.: s.n.

UNISDR, 2010. *Inventory of National Coordination Mechanisms, Legal Frameworks and National Plans for Disaster Risk Reduction in Africa,* s.l.: s.n.

United Nations, 2015. *Sendai Framework for Disaster Risk Reduction 2015 - 2030,* s.l.: s.n.

UNW-AIS, 2015. *Drought conditions and management strategies in Ghana.* [Online]
Available at: https://www.ais.unwater.org/ais/pluginfile.php/629/mod_page/content/6/Ghana.pdf

WMO, 2015. *WMO Guidelines on Multi-hazard Impact-based Forecast and Warning Services - N. 1150,* s.l.: s.n.

WMO, 2018. *Multi-hazard Early Warning Systems: A Checklist,* s.l.: s.n.

WorldPopulationReview, 2020. *Ghana population.* [Online]
Available at: https://worldpopulationreview.com/countries/ghana-population/

WRC, 2020. *Water Resources Commission - About us.* [Online]
Available at: https://www.wrc-gh.org/about-us/

WRC, 2020. *Water Resources Managemente & Governance - River Systems.* [Online]
Available at: https://www.wrc-gh.org/water-resources-management-and-governance/river-systems

Yiran, G. A. & Stringer, L. C., 2016. Spatio-temporal analyses of impacts of multiple climatic hazards in a savannah ecosystem of Ghana. *Climate Risk Management,* Volume 14, pp. 11-26.