2019

DISASTER RISK PROFILE

Flood Drought

Ghana

Building Disaster Resilience in Sub-Saharan Africa

Building Disaster Resilience to Natural Hazards in Sub-Saharan African Regions, Countries and Communities

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INTRODUCTION

Disasters are on the rise, both in terms of frequency and magnitude. From 2005-2015, more than 700.000 people worldwide lost their lives due to disasters that affected over 1.5 billion people, with women, children and people in vulnerable situations disproportionately affected. The total economic loss amounted to more than US$ 1.3 trillion. Disasters inordinately affect lower-income countries. Sub-Saharan Africa, where two-thirds of the world's least developed countries are located, is prone to recurrent disasters, largely due to natural hazards and climate change.

The Sendai Framework for Disaster Risk Reduction 2015 – 2030 emphasises the need to manage risk rather than disasters, a theme already present in its predecessors, the Yokohama Strategy and the Hyogo Framework for Disaster Risk Reduction. Specifically, the Sendai Framework calls for the strong political leadership, the commitment, and the involvement of all stakeholders, at all levels, from local to national and international, to *"prevent new and reduce existing disaster risk through the implementation of integrated and inclusive economic, structural, legal, social, health, cultural, educational, environmental, technological, political, and institutional measures that prevent and reduce hazard exposure and vulnerability to disaster, increase preparedness for response and recovery, and thus strengthen resilience"*.

Understanding disaster risk is the Sendai Framework's first priority for action: *"policies and practices for disaster risk management should be based on an understanding of disaster risk in all its dimensions of vulnerability, capacity, exposure of persons and assets, hazard characteristics and the environment"*. The outputs of disaster risk assessment should be the main drivers of the disaster risk management cycle, including sustainable development strategies, climate change adaptation planning, national disaster risk reduction across all sectors, as well as emergency preparedness and response.

As part of the "Building Disaster Resilience to Natural Hazards in Sub-Saharan African Regions, Countries and Communities" programme, UNDRR hired CIMA Research Foundation for the preparation of 16 Country Risk Profiles for floods and droughts for the following countries: Angola, Botswana, Cameroon, Equatorial Guinea, Gabon, Gambia (Republic of The), Ghana, Guinea Bissau, Kenya, Eswatini (Kingdom of), Côte d'Ivoire, Namibia, Rwanda, São Tomé and Príncipe, Tanzania (United Republic of), and Zambia.

The Country Risk Profiles provide a comprehensive view of hazard, risk and uncertainties for floods and droughts in a changing climate, with projections for the period 2050-2100. The risk assessment considers a large number of possible scenarios, their likelihood, and associated impacts.
A significant amount of scientific information on hazard, exposure, and vulnerabilities has been used to simulate disaster risk.

The EU PROGRAMME "Building Disaster Resilience to Natural Hazards in Sub-Saharan African Regions, Countries and Communities"

In 2013, the European Union approved 80 million EUR financing for the *"Building Disaster Resilience to Natural Hazards in Sub-Saharan African Regions, Countries and Communities"* programme. It is being implemented in Africa by four partners: the African Union Commission, the United Nations Office for Disaster Risk Reduction (UNDRR), the World Bank's Global Facility for Disaster Reduction and Recovery (WB/GFDRR), and the African Development Bank's ClimDev Special Fund (AfDB/CDSF). The programme provides analytical basis, tools and capacity, and accelerates the effective implementation of an African comprehensive disaster risk reduction and risk management framework.

PROBABILISTIC RISK PROFILE: METHODOLOGY

PROBABILISTIC RISK ASSESSMENT

Understanding disaster risk is essential for sustainable development. Many different and complementary methods and tools are available for analysing risk. These range from qualitative to semi-quantitative and quantitative methods: probabilistic risk analysis, deterministic or scenario analysis, historical analysis, and expert elicitation.

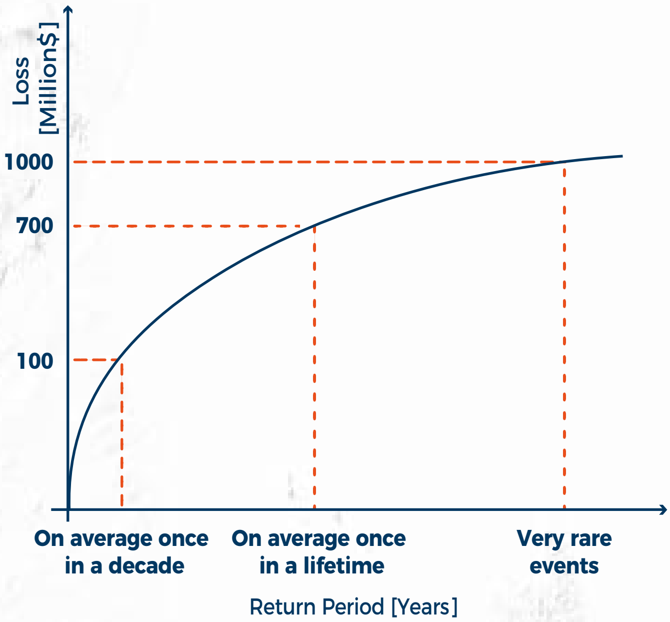
This disaster risk profile for floods and droughts is based on probabilistic risk assessment. Awareness of possible perils that may threaten human lives primarily derives from experience of past events. In theory, series of historical loss data long enough to be representative of all possible disastrous events that occurred in a portion of territory would provide all of the necessary information for assessing future loss potential. Unfortunately, the availability of national historical information on catastrophic natural hazard events is limited, and data on the economic consequences is even less common.

In the absence of extensive historical data, a modelling approach is needed to best predict possible present and future scenarios, taking into consideration the spatial and temporal uncertainties involved in the analysed process.
This profile simulates a realistic set of all possible hazardous events (scenarios) that may occur in a given region, including very rare, catastrophic events. Potential impacts were computed for each event, taking into consideration associated economic losses or the number of people and assets affected. Publicly available information on hazard, exposure, and vulnerability was used in the analysis. Finally, statistics of losses were computed and summarised through proper quantitative economic risk metrics, namely Annual Average Loss (AAL) and Probable Maximum Loss (PML).
In computing the final metrics (PML, AAL), the uncertainties that permeate the different steps of the computations have been explicitly quantified and taken into account: uncertainties in hazard forcing, uncertainties in exposure values and their vulnerabilities.

Average Annual Loss (AAL) is the expected loss per year, averaged over many years. While there may actually be little or no loss over a short period of time, AAL also accounts for much larger losses that occur less frequently. As such, AAL represents the funds which are required annually in order to cumulatively cover the average disaster loss over time.

Probable Maximum Loss (PML) describes the loss which could be expected corresponding to a given likelihood. It is expressed in terms of annual probability of exceedance or its reciprocal, the return period. For instance, in the figure below, the likelihood of a US$ 100 million loss is on average once in a decade, a loss of US$ 1 billion is considered a very rare event. Typically, PML is relevant to define the size of reserves which, insurance companies or a government should have available to manage losses.

The methodology is also used to simulate the impact of climate change [SMHI-RCA4 model, grid spacing 0.44° - about 50 km - driven by ICHEC-EC-EARTH model, RCP 8.5, 2006-2100 and, future projections of population and GDP growth (SSP2, OECD Env-Growth model from IIASA SSP Database)].
Results are disaggregated by different sectors, using the categories of Sendai Framework indicators: direct economic loss (C1), agricultural sector (C2), productive asset and service sector (C3), housing sector (C4), critical infrastructures and transportation (C5).



PROBABILISTIC RISK PROFILE: RISK COMPONENTS

HAZARD

process, phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation.

In order to best predict possible flood and drought scenarios, a modelling chain composed of climate, hydrological, and hydraulic models combined with available information on rainfall, temperature, humidity, wind and solar radiation, has been used. A set of mutually exclusive and collectively exhaustive possible hazard scenarios that may occur in a given region or country, including the most catastrophic ones, is generated and expressed in terms of frequency, extension of the affected area and intensity in different locations.

Flood hazard map for 1 in a 100 years probability evaluated under current climate conditions, the scale of blues represents different water depth values.

VULNERABILITY

conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of an individual, a community, assets or systems to the impacts of hazards.

Direct losses on different elements at risk are evaluated by applying vulnerability functions. This links hazard intensity to the expected loss (economic loss or number of affected people) while counting for associated uncertainty. Vulnerability functions are differentiated by the typology of exposed elements, and also take into account local factors, such as typical constructive typologies for infrastructures or crop seasonality for agricultural production. In the case of floods, vulnerability is a function of water depth. For agricultural production, the vulnerability is a function of the season in which a flood occurs. In the case of agricultural drought, losses are computed in terms of lack of production for different crops from a nominal expected production. A similar approach is used for hydrological drought, the evaluation of which focuses on loss of hydropower production.

EXPOSURE

people, property, systems, or other elements present in hazard zones that are thereby subject to potential losses.

Losses caused by floods and droughts are assessed in relation to population, GDP and a series of critical sectors (education, health, transport, housing, and the productive and agricultural sectors). The sectors are created by clustering all of the different components, which contribute to a specific function (e.g. the health sector is comprised of hospitals, clinics and dispensaries). Publicly available global and national data, properly generated, enables the location of these elements at high resolution, e.g. 90 metres or lower, for the whole country. The total number of people and the national GDP (in US$) are considered in both current (2016) and future (2050) scenarios. The critical sectors are characterised in terms of their economic value (in US$), using the most updated information available.

Exposure distribution, the different colors represent different types of assets.

AGRICULTURAL SECTOR [C2] | SERVICE SECTOR [C3] | PRODUCTIVE ASSETS [C3]

HOUSING SECTOR [C4] | TRANSPORTATION SYSTEM [C5] | OTHER CRITICAL INFRASTR.[C5]

UNDRR terminology on Disaster Risk Reduction: https://www.unisdr.org/we/inform/publications/7817

A SENDAI ORIENTED RISK PROFILE

The Sendai Framework guides the organisation of the results of the risk profile. Sendai introduced seven global targets and several indicators for monitoring their achievements. The indicators are common standards for a consistent measurement of progress towards the global targets across countries and over the duration of the Sendai Framework and Sustainable Development Goals. The Risk Profile presents the results of the assessment, mostly referring to indicators for the Target B on the affected people, Target C on direct economic losses and Target D on damage and disruption of basic service. Seven additional indicators are included in the risk profile in order to obtain a more comprehensive understanding of risk from floods and droughts. The table below summarises the indicators used in the risk profiles, as well as the climatic and socio-economic conditions considered in the estimation of the different risk metrics.

	INDICATORS			FLOOD			DROUGHT			
				P	F	SEp	P	F	SEp	RISK METRICS
SENDAI INDICATORS	B1		Number of directly affected people	Y	Y	Y	Y	Y	Y	Annual Average
SENDAI INDICATORS	C1 Direct economic loss attributed to disasters	C2	Direct agricultural loss (Crops)	Y	Y		Y	Y		AAL (Average Annual Loss) / PML (Probable Maximum Loss)
		C3	Direct economic losses to productive asset (Industrial Buildings + Energy Facilities)	Y	Y		Y	Y		
		C3	Direct economic losses in service sector	Y	Y					
		C4	Direct economic losses in housing sector	Y	Y					
		C5	Direct economic losses to transportation systems (Roads + Railways)	Y	Y					
		C5	Direct economic losses to other critical infrastructures (Health + Education Facilities)	Y	Y					
SENDAI INDICATORS	D1 Damage to critical infrastructure attributed to disasters	D2	Number of destroyed or damaged health facilities	Y	Y					Annual Average
		D3	Number of destroyed or damaged educational facilities	Y	Y					
		D4	Number of other destroyed or damaged critical infrastructure units and facilities (Transportation systems)	Y	Y					
* No official Sendai indicators	Agricultural & Economic Indicators		GDP of affected areas*	Y	Y	Y	Y	Y	Y	Annual Average
			Number of potentially affected livestock units*				Y	Y		
			Number of working days lost*				Y	Y		
* No official Sendai indicators	Hazard Index	SPEI	Standardised Precipitation-Evapotranspiration Index*				Y	Y		
		SSMI	Standardised Soil Moisture Index*				Y	Y		
		SSFI	Standardised StreamFlow Index*				Y	Y		
		WCI	Water Crowding Index*				Y	Y		

P Present Climate | **F** Future Climate | **SEp** Socio Economic projection

GHANA DISASTER RISK PROFILE

COUNTRY SOCIO-ECONOMIC OUTLOOK

OVERVIEW

Ghana sits on the Atlantic Ocean and borders the Republic of Togo, Cote d'Ivoire, and Burkina Faso. Ghana, with a total population of 28.2 million people, has a young age structure, with approximately 57% of the population under the age of 25 [1]. More than half of the country's population (54.4%) is urban [2]. After a difficult year in 2016, Ghana's economic performance improved significantly in 2017. Underpinned by serious fiscal consolidation efforts, the fiscal deficit dropped from 9.3% of gross domestic product (GDP) in 2016 to 6% in 2017 [3]. Agriculture accounts for some 20% of GDP and employs approximately 40% of the workforce, mainly small landholders. Exports in gold, oil, and cocoa as well as individual remittances are major sources of foreign exchange [1]. Expansion of Ghana's nascent oil industry has boosted economic growth, but the fall in oil prices since 2015 reduced Ghana's oil revenue by a half. Nevertheless, based on reports released in April 2018 by the Ghana Statistical Service, the country's economy, driven by the mining and oil sectors, expanded from 3.6% in 2016 to 8.5% in 2017 [3].Continued sustained growth and development is at risk of being thwarted by climate change. The flooding and drought risk assessments presented in this report show the various potential economic and social impacts of floods and droughts in a changing climate. Thus, they offer an important understanding of risk, essential to the healthy future development of the country.

SOCIO-ECONOMIC PROJECTIONS

Climate scientists and economists have recently built a range of new "pathways" which examine ways in which over the next hundred years national and global societies, demographics and economics may lead to alternative plausible future development scenarios [4,5]. Such scenarios range from optimistic trends for human development, with "substantial investments in education and health, rapid economic growth and well-functioning institutions" [6], to more pessimistic outlooks for low-income countries, indicating low levels of economic and social development, limited investment in education or health, coupled with a fast-growing populations and increasing inequalities.

PROJECTIONS USED IN THE RISK PROFILE

The "middle of the road" scenario used in this risk profile envisages that the historical patterns of development are continued throughout the 21st century. Following this projection, Ghana's population will increase by 64% between 2016 and 2050 (World Bank Data), and its GDP will increase almost tenfold.

POPULATION	GDP
2016 Projection	2016 Projection
28.2	**42.8**
[Million People]	[Billion$]
46.3	**414.3**
2050 Projection	2050 Projection

GHANA

AREA : 238.540 km² *(GHANA.COUNTRYSTAT.ORG)*

POPULATION DENSITY : 129 people/km²

MEDIAN AGE : 20 years *(DATA.GOV.GH)*

HDI - HUMAN DEVELOPMENT INDEX : 0.592 *(UNDP - 2017)*

LIFE EXPECTANCY AT BIRTH : 63 years *(UNDP - 2017)*

MEAN YEARS OF SCHOOLING : 7.1 years *(UNDP - 2017)*

EMPLOYMENT TO POP. RATIO (AGES > 15) : 75.1% *(WB - 2017)*

EMPLOYMENT IN AGRICULTURE : 40.7% *(WB - 2017)*

EMPLOYMENT IN SERVICES : 45.2% *(WB - 2017)*

data from:
http://hdr.undp.org/en/countries/profiles/
https://data.worldbank.org/indicator/
http://ghana.countrystat.org - https://data.gov.gh/

COUNTRY CLIMATE OUTLOOK

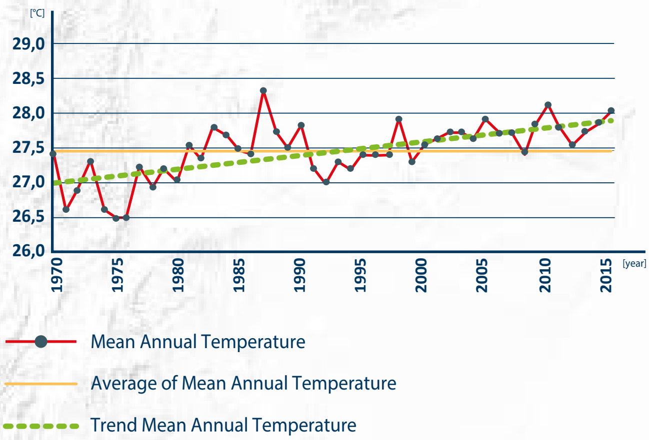
OVERVIEW

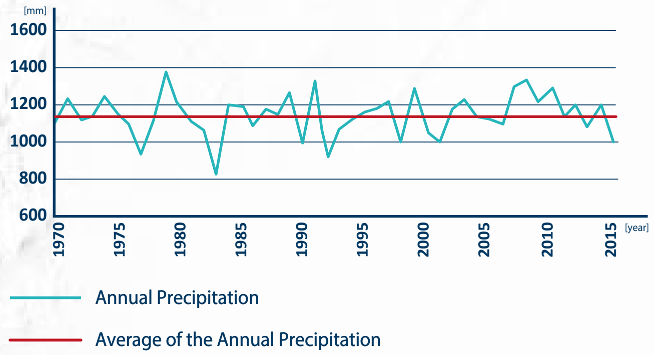
Ghana's climate is warm and humid, with a mean annual temperature ranging from around 26˚C near the coast to almost 29˚C in the north. The country is tropical, with two main seasons: wet and dry. Northern Ghana's rainy season goes from April to mid-October whereas in southern Ghana it goes from March to mid-November. Ghana's tropical climate is relatively mild for its latitude. The harmattan, a dry desert wind, blows in north-eastern Ghana from December to March, lowering the humidity and causing hotter days with cooler nights [7, 8].

CLIMATE TRENDS

Similarly to other west African countries, temperature observations from recent years indicate that Ghana's temperature has increased considerably. An analysis of climate data from 1970 to 2015 [9] shows an average rise of around 1.0˚C. Trends for precipitation are not as clear as those for air temperature, and are variable in time and space. Average annual precipitation in Ghana is approximately 1140 mm, while the mean number of wet days is around 140.

TEMPERATURE AND PRECIPITATION TRENDS IN CURRENT CLIMATE





RIVERS OF GHANA

There are three main river systems in the country:

- The Volta river system consists of the Oti and Daka rivers, the White and Black Volta rivers, and the Pru, Sene and Afram rivers. The basin covers 70% of the country's area.

- The south-western river system is comprised of the Bia, Tano, Ankobra and Pra rivers and covers 22% of the country's area.

- The coastal river system is comprised of the Ochi-Nakwa, Ochi Amissah, Ayensu, Densu and the Tordzie rivers, covering 8% of the country's area. Wetlands constitute about 10% of Ghana's total land area and remain highly productive. Ghana is a signatory to the Ramsar Convention, and boasts five Ramsar sites of international importance: the Densu Delta, the Songor, the Keta Complex, the Muni-Pomadze, and the Sakumo Lagoons. These are protected areas and have been gazetted as such. Other wetlands located in the forest and in the wildlife reserves of the Mole National Park, Black Volta, Sene, Bia and Owabi Wildlife Sanctuaries are equally protected. Some wetlands such as the Ankobra and Pra rivers, which fall outside the conservation wetland areas, are subject to traditional conservation practices. Lake Volta and Lake Bosomtwi in the Ashanti region [10] are the two most important lakes in the country.

Photo Credit: ZSM - https://commons.wikimedia.org/wiki/File:Ankobra_River,_Ghana.JPG

CLIMATE PROJECTIONS FOR GHANA

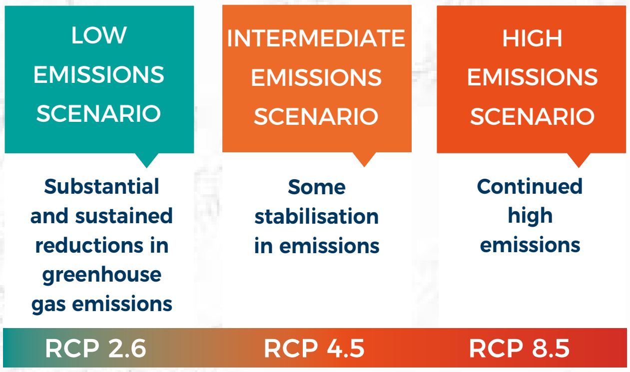
Climate projection studies are abundant for multiple different time spans and with various scales. Climate models are tools that the scientific community uses to assess trends in weather conditions over long periods. In a recent study [9] Alder, et al., compared the observed temperature and precipitations of the 1980-2004 period with the estimations of a set of global climate models provided by the Coupled Model Intercomparison Project Phase 5 (CMIP5). Three future periods (2025-2049, 2050-2074 and 2071-2095) were then analyzed for different greenhouse emission scenarios (see IPCC's Emissions Scenarios). In all periods and in all emission scenarios, models showed an increase in temperature. The increase of temperature was more evident in high emissions scenarios and long term period projections. In high emission scenarios (RCP8.5), model projections showed an increase of between about 2˚C and 4˚C for the mid-term period (2050-2074) and an increase of between about 2˚C and 6˚C for the long term period (2071-2095). Future changes in precipitation are much more uncertain, and the models predicted on average no change in precipitation for both medium and long term period and for all different emission scenarios.

Time Frame	Climate Projections (RCP 8.5 - High emission scenario)
Mid-term Future (2050-2074)	Increase in temperature from 2˚C to 4˚C Divergent change in precipitation (from -20% to +15%)
Far Future (2071-2095)	Increase in temperature from 2˚C to 6˚C Divergent change in precipitation (from -15% to +15%)

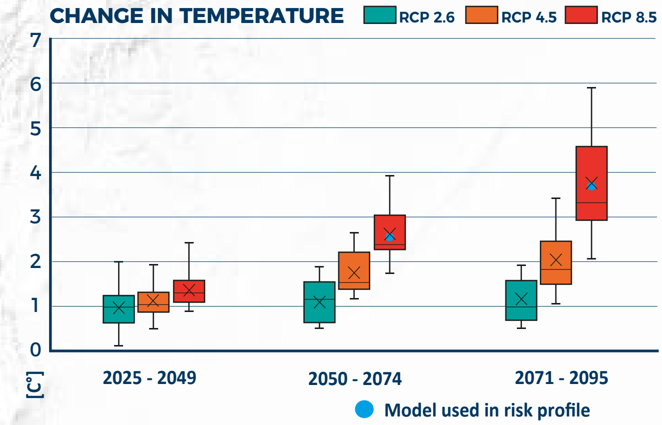
CLIMATE PROJECTIONS USED IN THIS RISK PROFILE

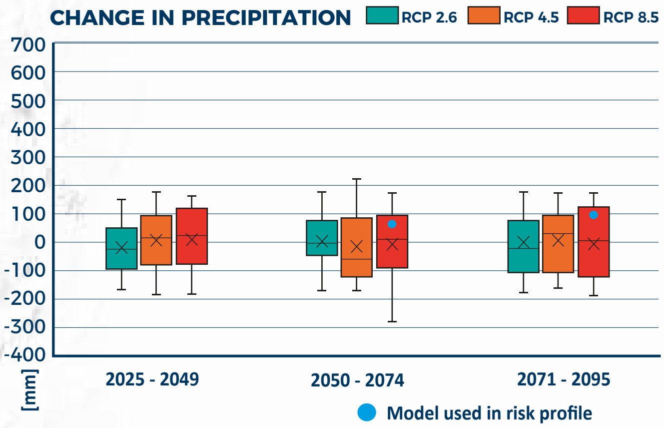
Results presented in the Risk Profile which refer to climate change were obtained using a climate projection model based on a high emission scenario (SMHI-RCA4 model, grid spacing 0.44˚ about 50 km - driven by the ICHEC-EC-EARTH model, RCP 8.5, 2006-2100) [12, 13, 14].

This study uses a high-resolution model which has been accurately calibrated for the African domain. This allows for a better capture of climate variability, which is key in assessing extremes. Regional model projections were checked for consistency against a full ensemble of global models available for the area. The Regional model forecasts changes in temperature and annual precipitation that are in line with the range of variability of global models analyzed in the study by Alder et al.[11].



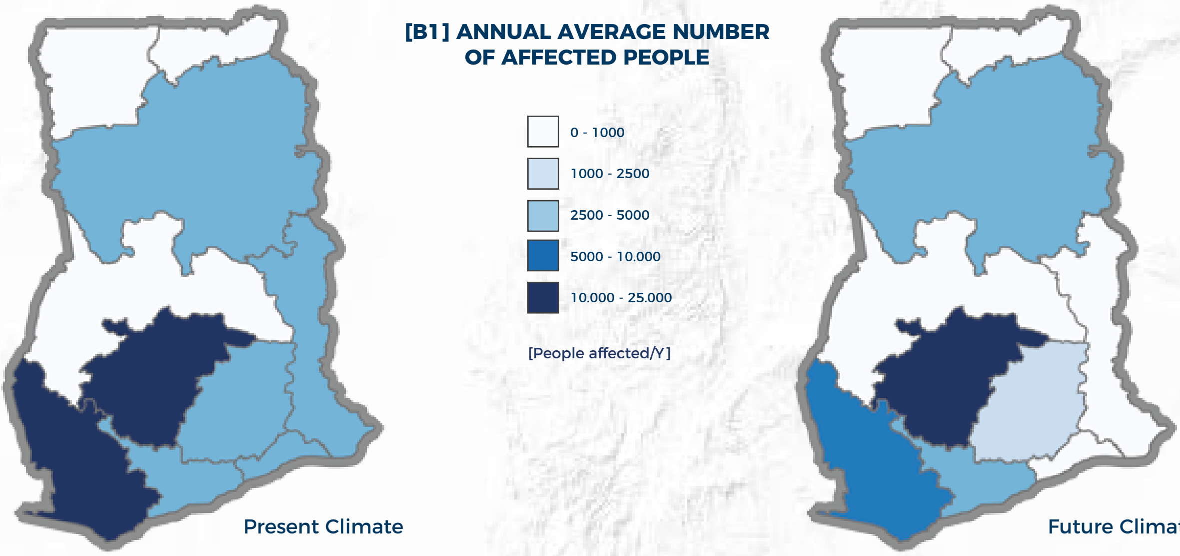
IPCC's Emissions scenarios for Climate Projections





In the specific case of the high emission scenario, the regional model predicts a comparable increase in temperature (close to 3.5˚C in the long term period) compared to the global ensemble. With regard to annual precipitation at the country level, an increase of 100 mm is predicted by the regional model for the long-term period (almost +10%).

RESULTS | FLOODS



KEY MESSAGES

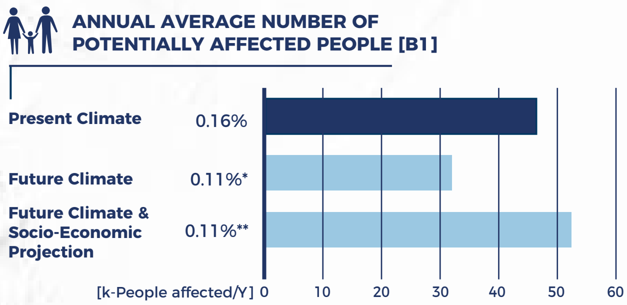
- Flooding affects on average more than 45.000 people, approximately 0.16% of the total population of the country.

- A majority of the effected people are concentrated in the south-western part of the country and along the coast, one of the most populous regions of Ghana.

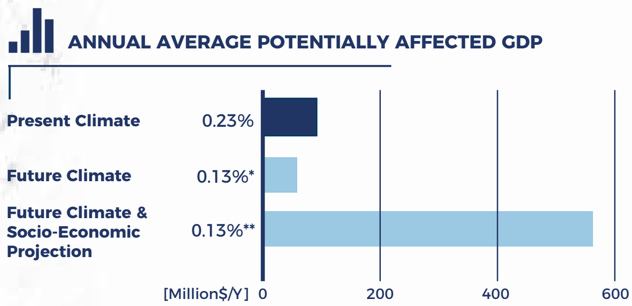
- Annually, on average about 100 million USD of the country's GDP is potentially affected by floods. This corresponds to about 0.23% of the national GDP.

- Under future climate conditions, as climate models predict a significant increase in temperature and a small increase in precipitations, the flood-affected population and potentially flood-affected GDP are likely to decrease slightly. However, climate projections remain inherently uncertain and caution is required when considering the above estimations for use in policy.

- When climate change projections are paired with the projected socio-economic situation (*), estimates of the affected people and GDP due to floods show a likely increase, which becomes significant for GDP. Namely, the flood-affected population increases to more than 50.000 persons under future conditions and flood-affected GDP increases by a factor of ten. This is the result of a disproportionate growth projected for the population and for the GDP (population increase of about 30% and GDP by 10-fold)**. Nevertheless, future predictions remain highly uncertain.



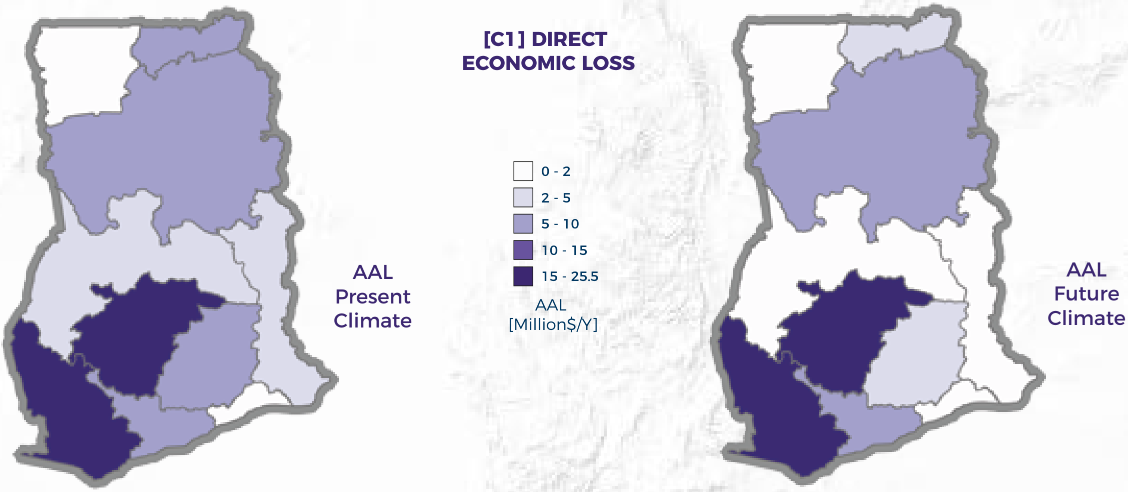
* % computed with reference to the total 2016 Population
** % computed with reference to the total 2050 Population



* % computed with reference to the total 2016 GDP
** % computed with reference to the total 2050 GDP

*2016 was taken as a reference year both for GDP and population.
**the Shared Socioeconomic Pathway (SSP) - "mid of the road" (Medium challenges to mitigation and adaptation) has been used to project population and GDP distributions.

RESULTS | FLOODS



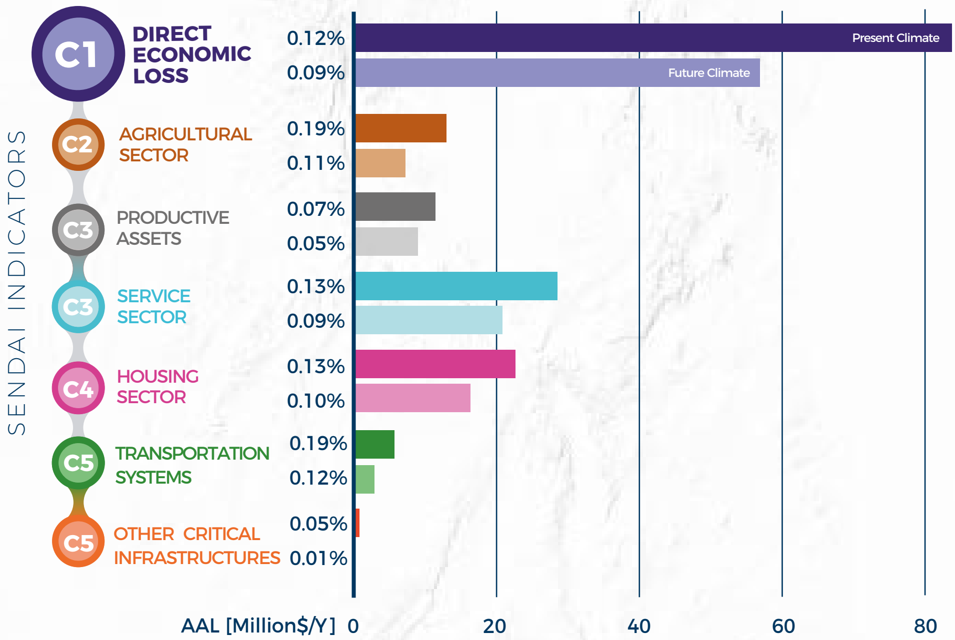
KEY MESSAGES

● Direct economic losses in Ghana show a similar pattern as the flood-affected population. Ashanti and the western regions show the highest losses. This pattern is confirmed in the future climate, although values are reduced in the eastern part of the country.

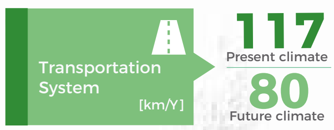
● Direct annual economic losses exceed 80 million USD, which amounts to roughly 0.12% of the total stock value under the present climate. The losses are evenly distributed among the different sectors.

● Considering the presently exposed assets for all sectors, it is likely that average annual losses will decrease under future climate conditions. However, when socio-economic projections are taken into account, such projections could be overturned.

● The proportion of different sectors in the overall loss does not change under future climate conditions. As highlighted above, climate projections are inherently uncertain and this should be taken into account when using these estimations in policy development.



AFFECTED INFRASTRUCTURES [D4]



RESULTS | FLOODS

KEY MESSAGES

● The AAL distribution shows differences across each of the sectors considered. The south-western part of Ghana and the coastal areas remain the most impacted, but the value distribution depends on distinct sectors.

● The comparison of AALs for all sectors between present and future climate conditions shows that a likely reduction of economic losses is expected. The pattern indicating a reduction in economic losses is confirmed in all of the sectors considered.

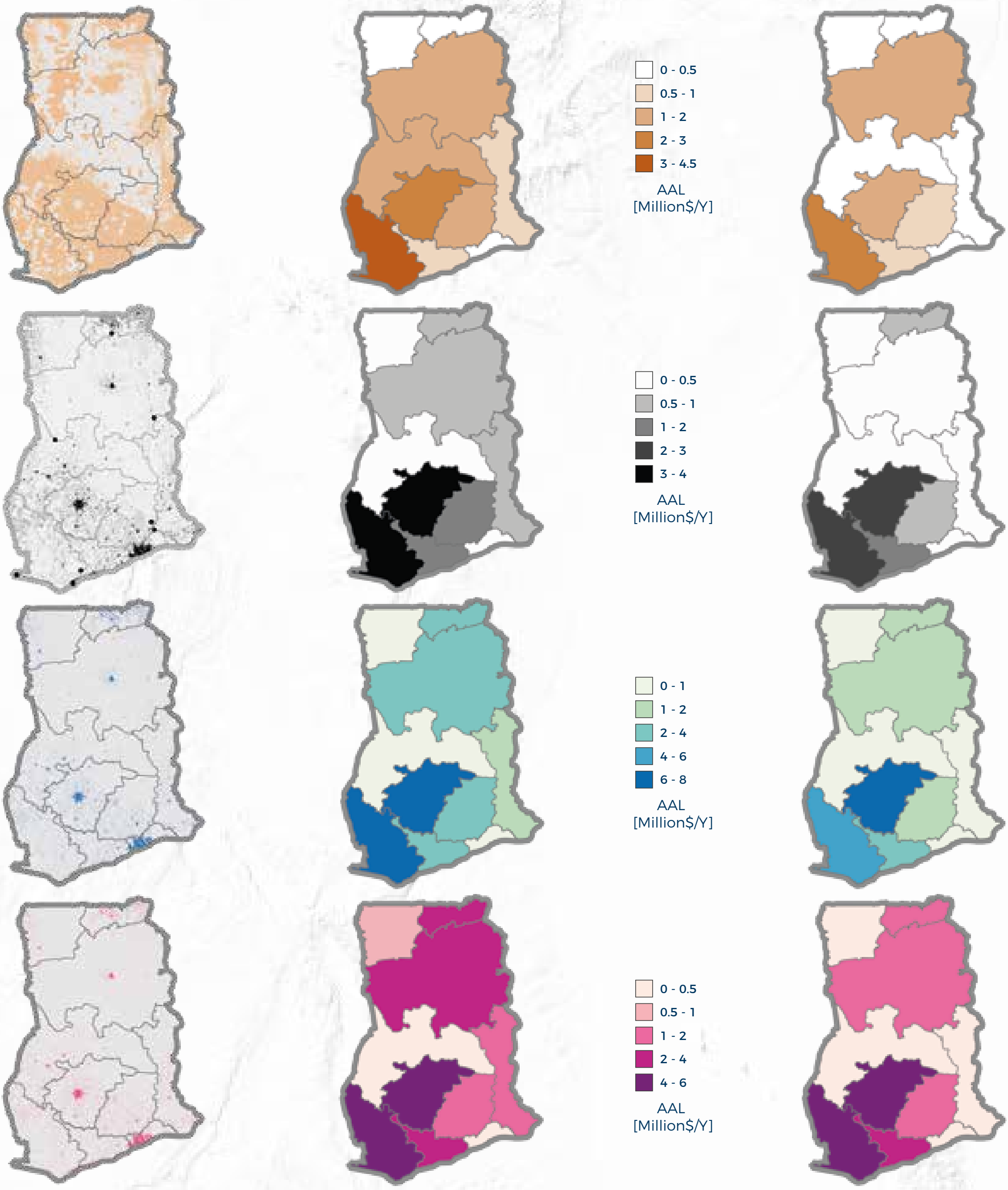
EXPOSURE DISTRIBUTION | **AAL - Present Climate** | **AAL - Future Climate**

C2 AGRICULTURAL SECTOR

C3 PRODUCTIVE ASSETS

C3 SERVICE SECTOR

C4 HOUSING SECTOR



RESULTS | FLOODS

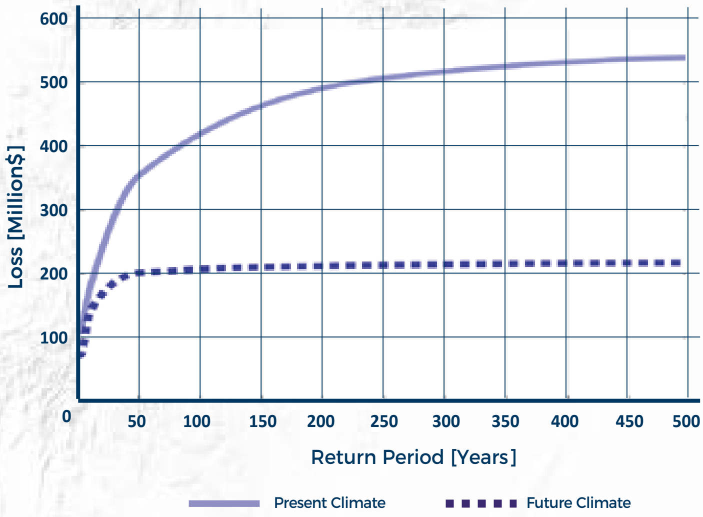
KEY MESSAGES

- Although the Average Annual Loss under future climate conditions is about 80 million USD, the likelihood of a 300 million loss from floods is on average of once every 25 years. This means that considerable losses may be experienced frequently. The likelihood of disaster losses of about 500 million USD is on average once in 200 years. Extremes losses might exceed 500 million USD.

- With the exception of the health, education and transport sectors, which take a smaller share of the total losses, all of the remaining sectors contribute evenly to the cumulative losses across all return periods.

- It is likely that both frequent and extreme flood-related losses will decrease under future climate conditions and greater differences are observed for rare and very rare events. Given the high level of uncertainty in future climate prediction, worse scenarios may also be possible (compare climate section on p.8).

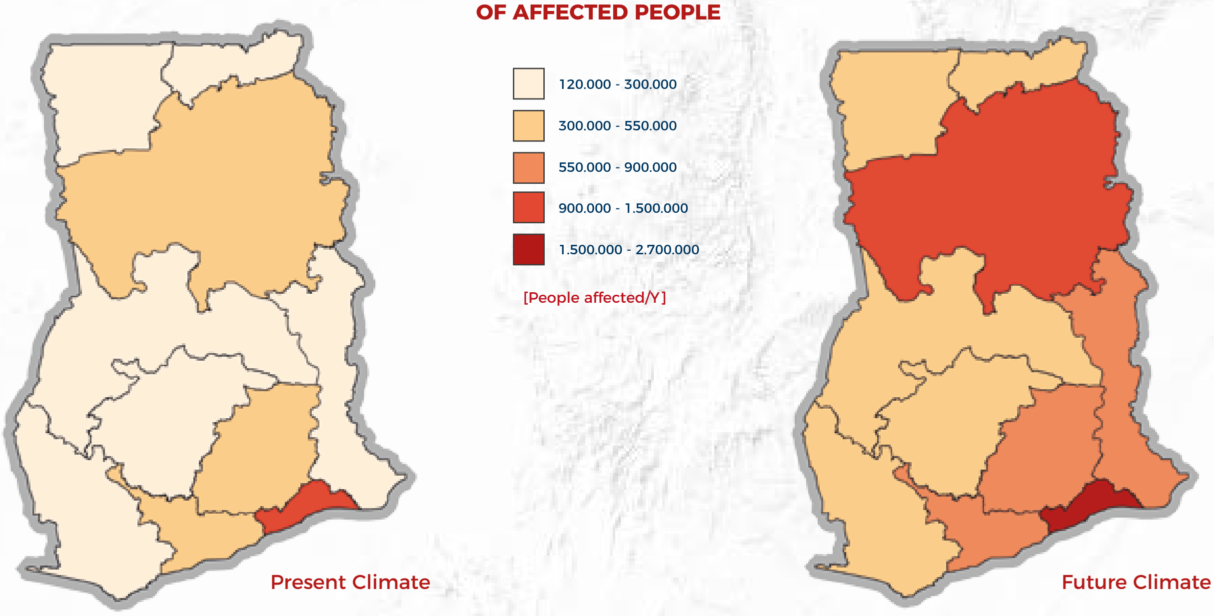
- The specific shape of the PML curve shows that flood risk can be considerably reduced by strategically minimizing the impact of very frequent and frequent disaster events, hence by investing in disaster risk reduction.



PROBABLE MAXIMUM LOSS CURVE (PML) ACROSS ALL SECTORS
C1 - DIRECT ECONOMIC LOSS

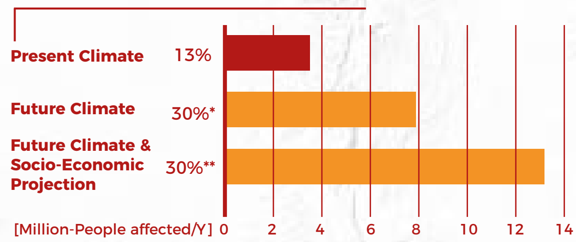
RESULTS | DROUGHTS

[B1] ANNUAL AVERAGE NUMBER OF AFFECTED PEOPLE



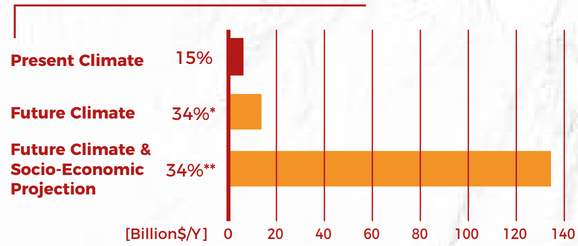
Annual average of population potentially affected by at least three months of drought conditions, as calculated using the standardized precipitation-evapotranspiration index (SPEI) and using a 3-month accumulation period.

ANNUAL AVERAGE NUMBER OF POTENTIALLY AFFECTED PEOPLE [B1]



* % computed with reference to the total 2016 Population
** % computed with reference to the total 2050 Population

ANNUAL AVERAGE POTENTIALLY AFFECTED GDP



* % computed with reference to the total 2016 GDP
** % computed with reference to the total 2050 GDP

KEY MESSAGES

- With respect to present conditions (1951-2000 climate), the probability of occurrence of severe drought (precipitation – evapotranspiration deficiency) will increase (+19%) under future climate conditions (2050-2100 climate). This increased drought hazard will mainly occur in areas which are currently already hard hit.

- Under present climate conditions, on average some 3.5 million people (13% of the total 2016 Population) are annually affected by droughts. In the future, this number is expected to increase to 30% (on average 13 million people if population growth is accounted for).

- Under present climate conditions, the average annual percentage of drought-affected GDP (i.e. the economic value produced in areas hit by droughts) is about 15% of the total GDP. This is equivalent to 6.2 billion USD per year which could be impacted by droughts. In the future, drought-related losses may rise to 34% of the GDP, amounting to 134 billion USD per year, if socio-economic projections are included.

RESULTS | DROUGHTS

KEY MESSAGES

- Under present climate conditions, affected livestock (i.e. animals living in areas hit by droughts) amount to some 295.000 livestock units (13% of the total country livestock). Under future climate conditions (assuming that there is no increase in livestock), the number of affected livestock is projected to increase up to 899.000 units (39% of the total). Presently, most of the livestock in areas affected by drought is situated in the Upper West region of Ghana, whereas under future climate conditions, the Upper East and Northern regions are also likely to see large numbers of livestock affected by drought.

- Under present climate conditions, agricultural crop losses are dominated by five crops - cassava, maize, plantain, taro and yam. Under future climate conditions, most physical losses will come from four crops - cassava, maize, taro and yam. Compared to the present climate, losses will decrease for three of the crops (cassava, cocoa and plantain), whereas for the other five crops (groundnut, maize, taro, tomato and yam) losses will increase. The highest relative losses relate to maize production and amount to 4% of the average crop production under future climate conditions.

- Under present climate conditions, the economic crop production losses are concentrated in the central part of Ghana (Ashanti and Brong-Ahafo provinces) . Under future climate conditions, losses will increase in the Northern, Eastern Ghana and Volta regions, but decrease in the Ashanti, Central and Western Ghana regions.

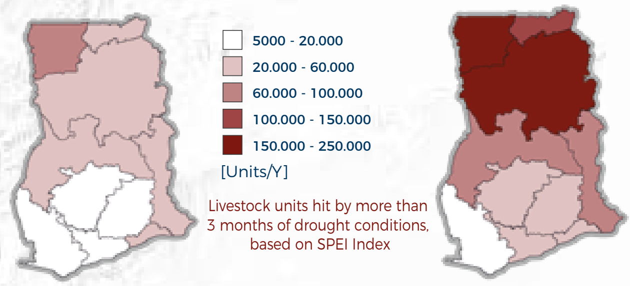
- There is almost no difference in the amount of lost working days between present and future climates. This is because results show that some crop production will increase while others will decrease. In total some 1300 thousand working days are lost, which is less than 0.25% of the average number of working days. This percentage is four times higher when focusing only on the harvesting phase.

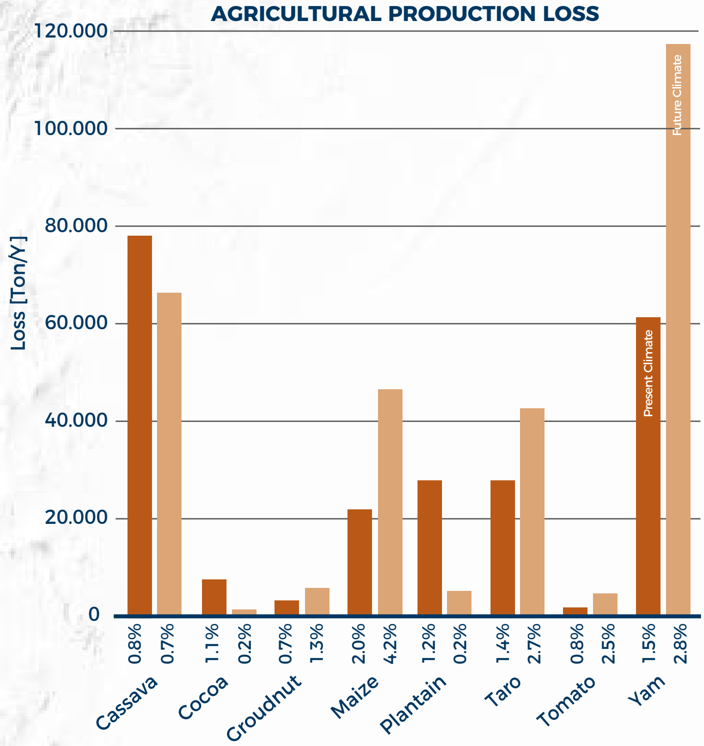
ANNUAL AVERAGE NUMBER OF POTENTIALLY AFFECTED LIVESTOCK UNITS* [k-Livestock units]

295 | **13%** Present climate

899 | **39%** Future climate

*Livestock is a summation of all livestock animals (referred to as livestock units) using FAO conversion factors

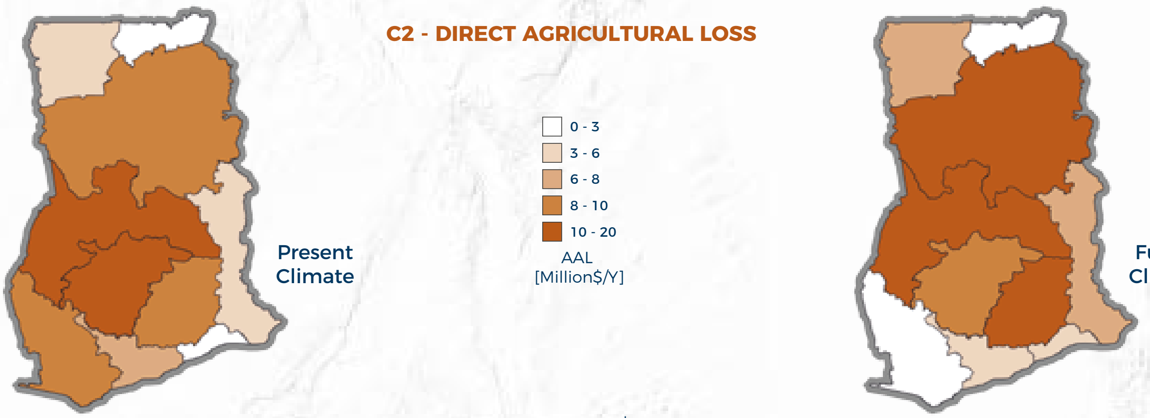




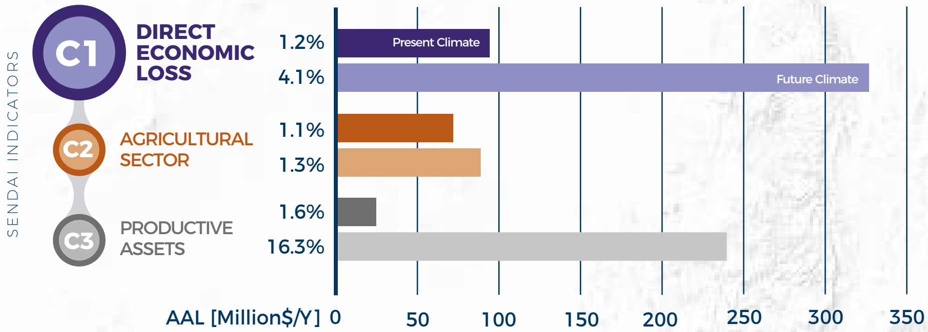
ANNUAL AVERAGE NUMBER OF WORKING DAYS LOST [k-Days]

1290 | **0.23%** Present climate

1340 | **0.24%**



RESULTS | DROUGHTS



C2 is computed considering only direct loss associated with reference agricultural (crop) production. Reference crops considered in the analysis are the ones which contribute to at least 85% of the total country-level gross crop production value. It might therefore happen that crops which have an important role in local commercial or subsistance agriculture can be neglected in the overall analysis.
C3 is computed considering exclusively losses in hydropower production. These are defined as production below levels with average reservoir conditions.

KEY MESSAGES

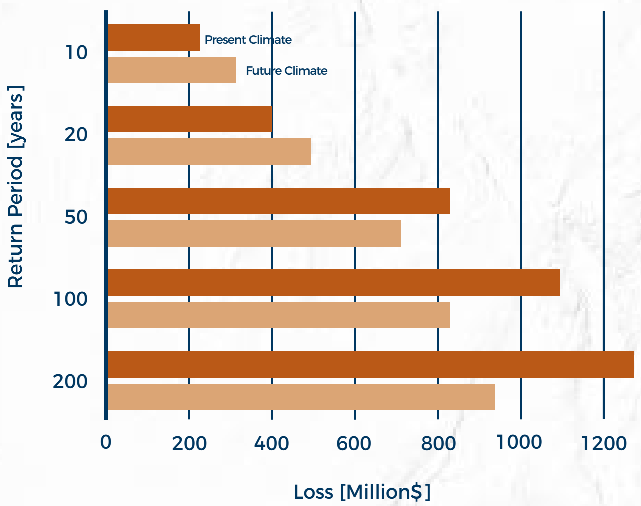
- Under future climate conditions, annual economic loss due to changes in crop production (C2) will only increase slightly from some 72 to 89 million USD. Under both climates, it represents close to 1.2% of the average economic value of crop production.

- Average annual hydropower losses (C3) from the Akosombo and Kpong dams are projected to increase considerably, approximately by a factor of eight overall.

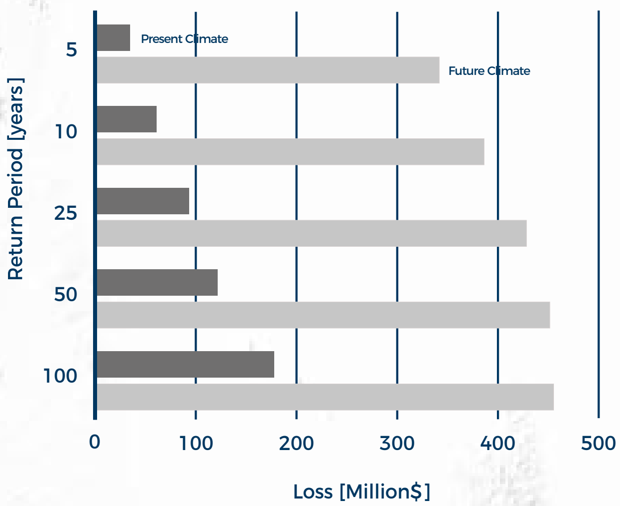
- Under current climate conditions, a gradual increase in agricultural (crop) income loss is expected when return periods go up from 10 to 200 years. Under future climate conditions, losses increase for lower return periods which occur more frequently (10 – 20 years) whereas they decrease for higher return periods (50 – 200 years). This indicates that rarer events will have a lower impact on agricultural (crop) income.

- A strong increase in hydropower losses is expected under future climate conditions. Losses will significantly increase for frequent return periods. In the future, frequent probable maximum losses (5 year return period) will exceed the probable maximum losses currently experienced once every 100 years.

PROBABLE MAXIMUM LOSS (PML)
C2 - AGRICULTURAL LOSS

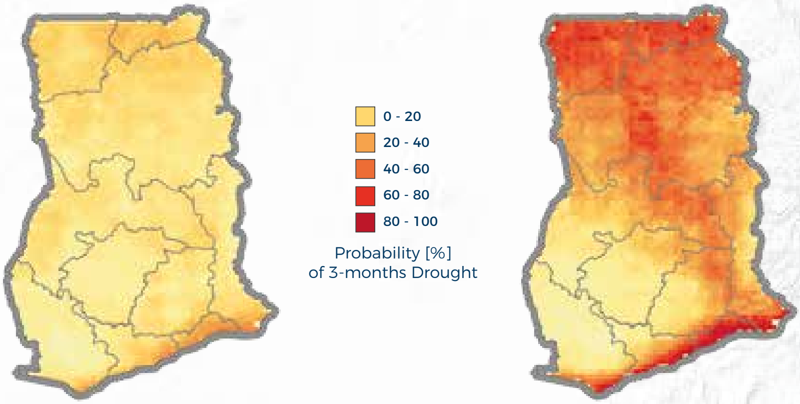


PROBABLE MAXIMUM LOSS (PML)
C3 - PRODUCTIVE ASSETS (HYDROPOWER LOSS)



RESULTS | DROUGHTS

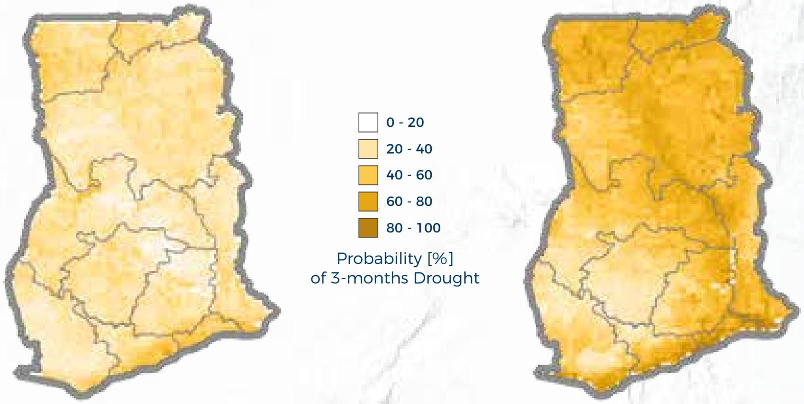
Present Climate | Future Climate



SPEI

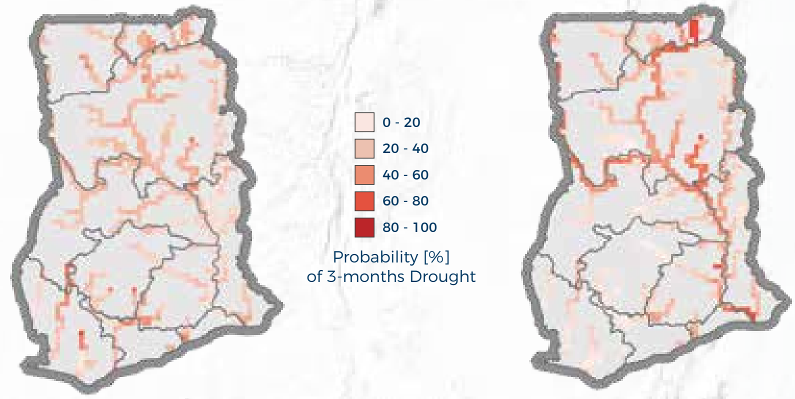
Standardised Precipitation-Evapotranspiration Index

These maps denote the average annual chance of a meteorological drought occurring (%). Droughts are defined as 3 months of precipitation minus evapotranspiration values considerably below normal conditions; calculated through the Standardized Precipitation - Evapotranspiration Index (SPEI; see 'Drought' in Glossary).
It can be noted that an increase in droughts under future climate conditions will be most pronounced in the north and along the coast of the country. This is particularly important for areas dependent on rainfall for their water resources.



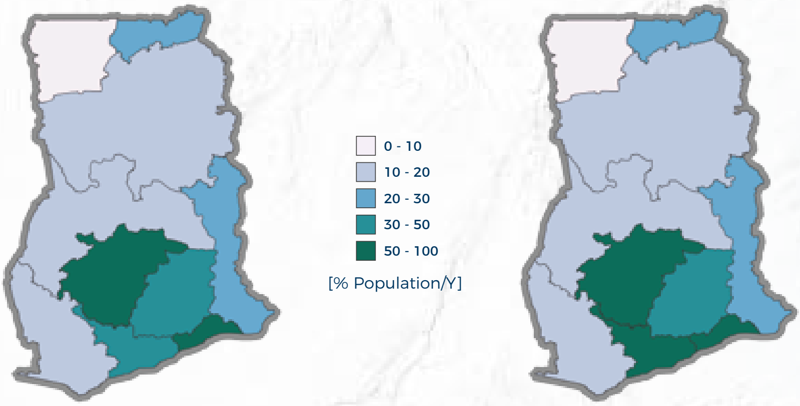
SSMI - Standardised Soil Moisture Index

These maps denote the average annual chance of a subsurface drought occurring (%). Droughts are defined as 3 months of soil moisture conditions considerably below normal conditions; calculated through the Standardized Soil Moisture Index (SSMI; see 'Drought' in Glossary).
Under future climate conditions, Ghana will experience more soil moisture droughts in almost all of its provinces. This is particularly important for agricultural and natural areas.



SSFI - Standardised Streamflow Index

These maps denote the average annual chance of a hydrological drought occurring (%). Droughts are defined as 3 months of stream flow levels considerably below normal conditions; calculated through the Standardized StreamFlow Index (SSFI; see 'Drought' in Glossary).
In Ghana, an increase in drought frequency is expected under future climate conditions, which is mainly felt in the downstream parts of rivers flowing to lake Volta. This is particularly important for areas dependent on rivers for their water supply, navigation and electricity generation.



WCI - Water Crowding Index

These maps show the percentage of the population per region experiencing water scarcity, based on the water available (precipitation minus evapotranspiration) per person per year (<1000 m^3/person/year). Water scarcity indicates that a population depends on water resources from outside their immediate region (~85 km^2). Water scarcity is closely related to population density. Currently, the highest percentage of population experiencing water scarcity is in the Ashanti region (with 1.5+ million people - city Kumasi) and in the Greater Accra metropolitan area that has about 4 million inhabitants. In the future, the Central region with the city of Cape Coast will have more than 50% of its population unable to be self-sufficient in water resources.

PROBABILISTIC RISK ASSESSMENT FOR RISK MANAGEMENT

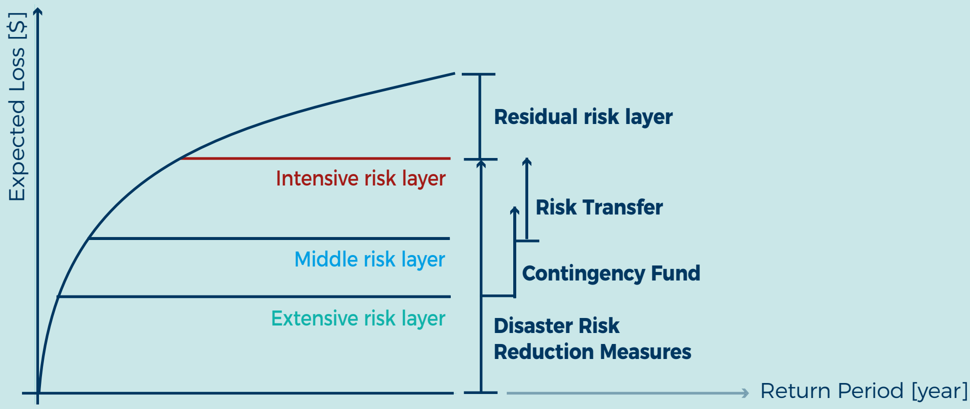
METRICS FOR RISK MANAGEMENT

Risk information may be used to put in place a broad range of activities to reduce risk. Such measures range from improving building codes and designing risk reduction measures, to undertaking macro-level risk assessments used to prioritise investments. Risk metrics help discern the risk contribution of different external factors (such as demographic growth, climate change, urbanization expansion, etc.). They also provide a net measure of progress in the implementation of disaster risk reduction policies. Average Annual Loss (AAL) can be interpreted as an opportunity cost. This is because resources set aside to cover disaster losses could be used for development. Monitoring AAL in relation to other country economic indicators – such as the GDP, capital stock, capital investment, reserves, and social expenditure – provides an indication of a country's fiscal resilience, broadly defined as holding internal and external savings to buffer against disaster shocks. Economies can be severely disrupted if there is a high ratio of AAL to the value of capital stock. Similarly, future economic growth can be compromised if there is a high ratio of AAL to capital investment and reserves. Social development will be challenged if there is a high ratio of AAL to social expenditure. Moreover, limited ability to recover quickly may significantly increase indirect disaster losses. Countries that already have compensatory mechanisms such as effective insurance in place and that can rapidly compensate for losses will recover far more quickly than those that do not. Such mechanisms may include insurance and reinsurance, catastrophe funds, contingency financing arrangements with multilateral finance institutions, and market-based solutions such as catastrophe bonds (UNDRR, 2011 and 2013).

The PML curve is particularly useful in order to articulate a full DRR strategy. It describes the loss that can be experienced for a given return period. Knowing the different level of losses expected on a certain frequency can help to understand how to organise a strategy combining different risk reduction, mitigation, or avoidance actions.

PML CURVE

The PML curve can be subdivided into three main layers. The Extensive Risk Layer is typically associated with risk reduction measures (e.g. flood defences, local vulnerability reduction interventions). The Mid Risk Layer captures cumulative losses from higher impact events. Losses within this layer are commonly mitigated using financial funds which are managed at the country level, such as the contingency fund. Losses which constitute the Intensive Risk Layer (severe and infrequent hazard events) are difficult to finance at the country level. Mechanisms of risk transfer are therefore required to address losses associated with this Intensive Risk layer (e.g. insurance and reinsurance measures). The remaining layer of the curve is Residual Risk (catastrophic events). It is the risk that is considered acceptable/tolerable due to the extreme rarity of such events and associated loss levels. Given its rarity, there are no concrete actions to reduce risk beyond preparedness (e.g. civil protection actions, humanitarian aid coordination).



GLOSSARY & REFERENCES

AFFECTED PEOPLE and GDP
Affected people are the ones that may experience short-term or long-term consequences to their lives, livelihoods or health and in the economic, physical, social, cultural and environmental assets. In the case of this report "affected people from Floods" are the people living in areas experiencing a flood intensity (i.e. a flood water level) above a certain threshold. Analogously, in this report "affected people from Droughts" are the people living in areas experiencing a drought intensity (i.e. a SPEI value) below a certain threshold. The GDP affected has been methodologically defined using the same thresholds both for floods and droughts.

CLIMATE MODEL*
A numerical representation of the climate system based on the physical, chemical and biological properties of its components, their interactions and feedback processes, and accounting for some of its known properties. Climate models are applied as a research tool to study and simulate the climate, and for operational purposes, including monthly, seasonal, and interannual climate predictions.

DISASTER RISK*
The potential loss of life, injury, or destroyed, or damaged assets which could occur to a system, society, or a community in a specific period of time, determined probabilistically as a function of hazard, exposure, vulnerability, and capacity.

DROUGHT
Droughts, defined as unusual and temporary deficits in water supply, are a persistent hazard, potentially impacting human and environment systems. Droughts, which can occur everywhere, should not be confused with aridity, a permanent climate condition. in this profile drought hazard is denoted by various indices, covering a range of drought types (meteorological, hydrological and soil moisture droughts) and standardised using seasonal data (i.e. values accumulated over 90 days). A drought is defined as at least three consecutive months with standardised index values below a certain drought threshold, indicating conditions that are significantly dryer than normal given the reference period 1951-2000.
This drought threshold varies between -0.5 and -2, according to the aridity index of that area: the dryer the area, the less extreme the water deficit needs to be be in order to be considered 'a drought'. droughts are analysed in terms of hazard, exposed population, livestock, and GDP. drought induced losses are explicitly estimated for crop production and hydropower generation.

FLOOD*
Flood hazard in the risk assessment includes river (fluvial) flooding and flash flooding. This risk profile document considers mainly fluvial flooding and flash floods in the main urban centres. Fluvial flooding is estimated at a resolution of 90 m using global meteorological datasets, a global hydrological model, a global flood-routing model, and an inundation downscaling routine. Flash flooding is estimated by deriving susceptibility indicators based on topographic and land use maps. Flood loss curves are developed to define the potential damage to the various assets based on the modelled inundation depth at each specific location.

LOSS DUE TO DROUGHT (CROPS)
Economic losses from selected crops result from multiplying gross production in physical terms by output prices at farm gate. Losses in working days have been estimated as function of crop-specific labour requirements for the cultivation of selected crops. Annual losses have been computed at Admin 1 level as the difference relative to a threshold, when an annual value is below this threshold. The threshold equals the 20% lowest value from the period 1951-2000 and has also been applied for the future climate. Losses at national level have been estimated as the sum of all Admin 1 losses.

RESIDUAL RISK*
The disaster risk that remains in unmanaged form, even when effective disaster risk reduction measures are in place, and for which emergency response and recovery capacities must be maintained.

RESILIENCE*
The ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform, and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management.

RETURN PERIOD*
Average frequency with which a particular event is expected to occur. It is usually expressed in years, such as 1 in X number of years. This does not mean that an event will occur once every X numbers of years, but is another way of expressing the exceedance probability: a 1 in 200 years event has 0.5% chance to occur or be exceeded every year.

**UNDRR terminology on Disaster Risk Reduction: https://www.unisdr.org/we/inform/publications/7817*

GLOSSARY & REFERENCES

RISK*
The combination of the probability of an event and its negative consequences. While in popular usage the emphasis is usually placed on the concept of chance or possibility, in technical terms the emphasis is on consequences, calculated in terms of "potential losses" for some particular cause, place, and period. It can be noted that people do not necessarily share the same perception of the significance and underlying causes of different risks.

RISK TRANSFER*
The process of formally or informally shifting the financial consequences of particular risks from one party to another, whereby a household, community, enterprise, or State authority will obtain resources from the other party after a disaster occurs, in exchange for ongoing or compensatory social or financial benefits provided to that other party.

**UNDRR terminology on Disaster Risk Reduction: https://www.unisdr.org/we/inform/publications/7817*

[1] Ghana CIA Factbook https://www.cia.gov/library/publications/the-world-factbook/geos/gh.html

[2] http://www.worldometers.info/world-population/ghana-population/

[3] WorldBank, Ghana Overview, https://www.worldbank.org/en/country/ghana/overview

[4] Keywan Riahi et al., The Shared Socioeconomic Pathways and their energy, land use, and greenhouse gas emissions implications: An overview, Global Environmental Change, Volume 42, January 2017, Pages 153-168

[5] Richard H. Moss et al., The next generation of scenarios for climate change research and assessment, Nature volume 463, pages 747–756 (11 February 2010)

[6] Brian C. O'Neill et al., The Scenario Model Intercomparison Project (ScenarioMIP) for CMIP6, Geosci. Model Dev., 9, 3461–3482, 2016, doi:10.5194/gmd-9-3461-2016

[7] McSweeney, C., New, M. & Lizcano, G. 2010. UNDP Climate Change Country Profiles: Ghana, Available: https://www.geog.ox.ac.uk/research/climate/projects/undp-cp/UNDP_reports/Ghana/Ghana.lowres.report.pdf

[8] McSweeney, C., New, M., Lizcano, G. & Lu, X. 2010. The UNDP Climate Change Country Profiles Improving the Accessibility of Observed and Projected Climate Information for Studies of Climate Change in Developing Countries. Bulletin of the American Meteorological Society, 91, 157-166.

[9] Harris, I. P. D. J., Jones, P. D., Osborn, T. J., & Lister, D. H. (2014). Updated high-resolution grids of monthly climatic observations-the CRU TS3. 10 Dataset. International Journal of Climatology, 34(3), 623-642.

[10] FAO (2005). Aquastat, Ghana. http://www.fao.org/nr/water/aquastat/countries_regions/GHA/

[11] Alder, J. R., & Hostetler, S. W. (2015). Web based visualization of large climate data sets. Environmental Modelling & Software, 68, 175-180.

[12] Abba Omar, S. & Abiodun, B.J., How well do CORDEX models simulate extreme rainfall events over the East Coast of South Africa? Theor Appl Climatol (2017) 128: 453. https://doi.org/10.1007/s00704-015-1714-5

[13] Nikulin, G., Jones, C., Giorgi, F., Asrar, G., Büchner, M., Cerezo-Mota, R., ... & Sushama, L. (2012). Precipitation climatology in an ensemble of CORDEX-Africa regional climate simulations. Journal of Climate, 25(18), 6057-6078.

[14] Nikulin G, Lennard C, Dosio A, Kjellström E, Chen Y, Hänsler A, Kupiainen M, Laprise R, Mariotti L, Fox Maule C, van Meijgaard E, Panitz H-J, Scinocca J F and Somot S (2018) The effects of 1.5 and 2 degrees of global warming on Africa in the CORDEX ensemble, Environ. Res. Lett., doi:10.1088/1748-9326/aab2b4

The results presented in this report have been elaborated to the best of our ability, optimising the publicly data and information available. All geographic information has limitations due to scale, resolution, data and interpretation of the original sources.

www.preventionweb.net/resilient-africa

www.undrr.org

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riskprofilesundrr.org

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