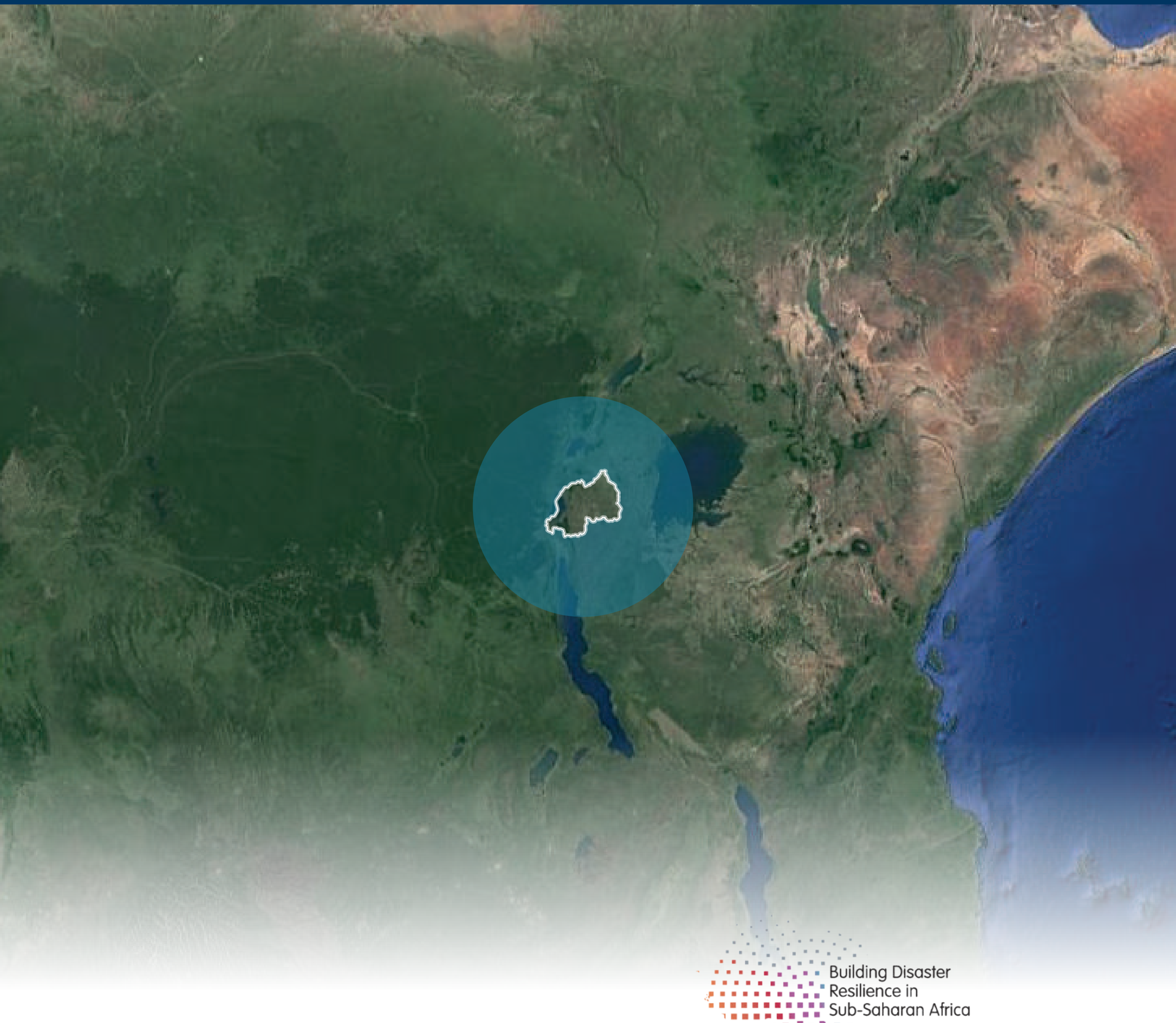
2019

DISASTER RISK PROFILE

Flood Drought

Rwanda



Building Disaster Resilience in Sub-Saharan Africa

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

An initiative of the African, Caribbean and Pacific Group of States funded by the European Union

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UNDRR
UN Office for Disaster Risk Reduction

cima RESEARCH FOUNDATION

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2019 - Review

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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).

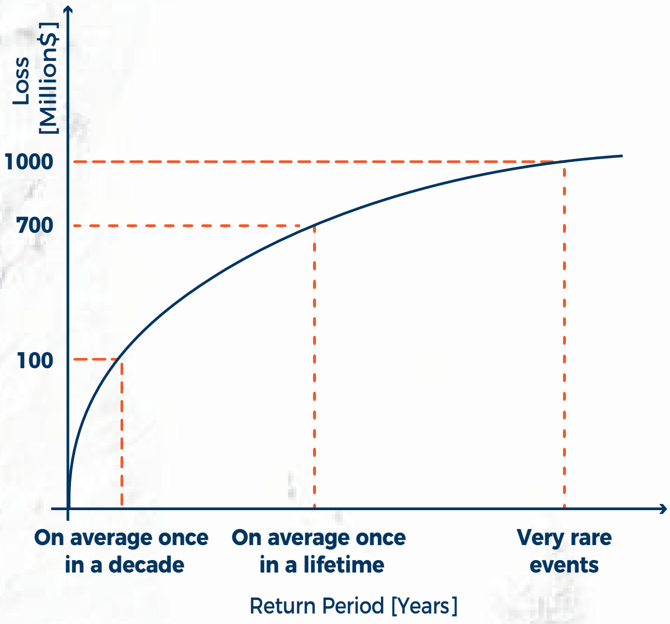
In computing the final metrics (PML, AAL), the uncertainties that permeate the different steps of the computations have been explicitly quantified and taken into account: uncertainties in hazard forcing, uncertainties in exposure values and their vulnerabilities.

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

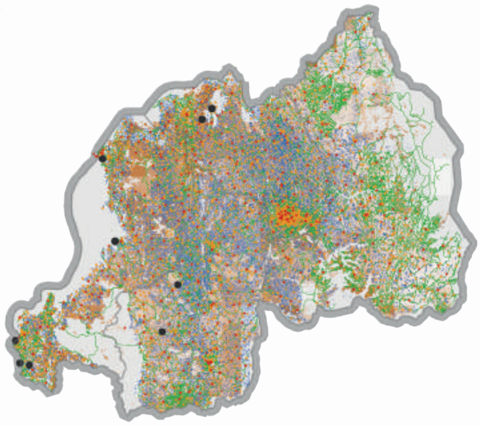
conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of an individual, a community, assets or systems to the impacts of hazards.

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.

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		
		SPI	Standardised Precipitation Index*				Y	Y		
		WCI	Water Crowding Index*				Y	Y		

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

COUNTRY SOCIO-ECONOMIC OUTLOOK

OVERVIEW

A small and landlocked country in the Great Lakes region of central Africa, Rwanda is hilly and fertile with a dense population. [1] About 35% of the country's population labours in subsistence agriculture, as well as some mineral and agro-processing [2]. Tourism, minerals, coffee, and tea are the country's main sources of foreign exchange. Despite Rwanda's fertile ecosystem, food production often does not keep up to pace with demand, creating the necessity for importing food. Energy shortages, instability in neighboring states, and lack of adequate transportation linkages are the main hindrances to private sector growth, but a number of positive indicators, have been observed in recent years. [2] Between 2008 and 2014, poverty dropped from 56.7 % to 39.1% and GDP per capita increased from $479 to $720. Growth consistently averaged 7.8% in the same period, with evidence of economic diversification as the share of agriculture's contribution diminished from 39% to 31%. [3] Climate change and its impacts risk thwarting developments achieved by Rwanda in recent years. This report argues that risk mitigation must be used as an essential tool to ensure continued economic development and political stability as the climate changes. The risk assessments it presents shed some light on to specifically what economic sectors and populations are most at risk now as well as in the projected future.

SOCIO-ECONOMIC PROJECTIONS

Climate scientists and economists have formulated a range of new "pathways" that examine how national and global societies, demographics and economics might lead to different plausible future development scenarios over the next hundred years [4,5]. The scenarios range from relatively optimistic trends for human development, with "substantial investments in education and health, rapid economic growth and well-functioning institutions" [6], to more pessimistic economic and social stagnation, with little investment in education or health in poorer countries, coupled with a fast-growing population and increasing inequalities.

PROJECTIONS USED IN THE RISK PROFILE

The "middle of the road" scenario envisages that historic development patterns will persist throughout the 21st century. According to this prediction, Rwanda's population should double between 2016 and 2050 (World Bank Data), while GDP should increase by a factor of sixteen.

POPULATION	GDP
2016 Projection	2016 Projection
11.9	**8.5**
[Million People]	[Billion$]
22.9	**133.0**
2050 Projection	2050 Projection

RWANDA

AREA : 26.338 km²

MEDIAN AGE : 20 years *(2019)*

HUMAN DEVELOPMENT INDEX : 0.536 *(2018)*

LIFE EXPECTANCY AT BIRTH : 67 years *(2018)*

MEAN YEARS OF SCHOOLING : 4.4 years *(2018)*

EMPLOYMENT TO POP. RATIO (AGES > 15) : 58.1% *(2019)*

EMPLOYMENT IN AGRICULTURE FEMALE : 27.5% *(2019)*
EMPLOYMENT IN AGRICULTURE MALE : 28.5% *(2019)*

EMPLOYMENT IN SERVICES FEMALE : 55.8% *(2019)*
EMPLOYMENT IN SERVICES MALE: 44.7% *(2019)*

data from:
https://www.statistics.gov.rw/
https://www.rw.undp.org/content/rwanda/en/home/countryinfo.html -
http://hdr.undp.org/sites/all/themes/hdr_theme/country-notes/RWA.pdf -
https://data.worldbank.org/indicator/

COUNTRY CLIMATE OUTLOOK

OVERVIEW

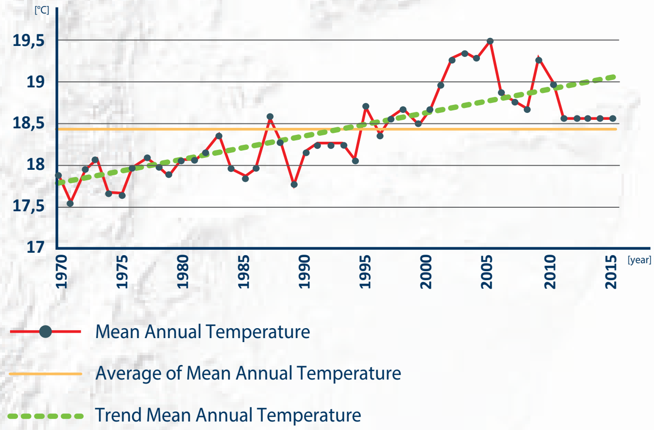
Rwanda is a country located in central-eastern Africa in a dry climate region, an anomaly in the otherwise wet equatorial belt. It is a transition region between the monsoon domains of West Africa and the Indian Ocean. The inter-annual and inter-decadal climate fluctuations, as well as the spatial variability in East Africa, are attributed to complex topography, latitudinal location and the oscillations of the sea surface temperature of the Pacific and Indian oceans [7].

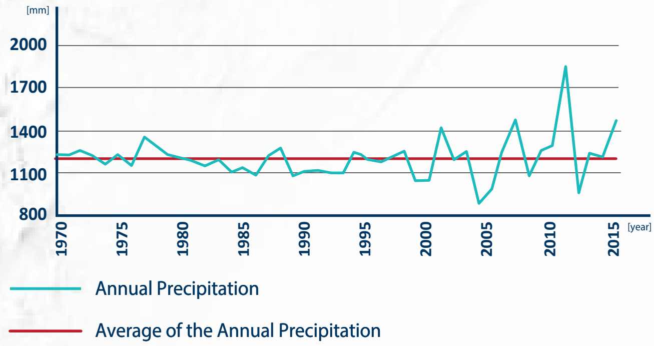
CLIMATE TRENDS

Similarly to other eastern African countries, temperature observations indicate that Rwanda has experienced a considerable increase in temperature in recent years.

The analysis of climate data from 1970 to 2015 [8] shows an increase of around 1˚C, particularly from the 1990s onward. Precipitation levels do not have as clear a trend as air temperatures, and are variable in time and space. The average annual precipitation in Rwanda hovers around 1210 mm while the mean number of wet days is 192. The low variability shown in precipitation at the end of the last century seems to move towards higher variability in the new century. From the 2000s onwards, an increase of both extremely dry (i.e. 2004) and extremely wet years (i.e. 2011) has been observed.

TEMPERATURE AND PRECIPITATION TRENDS IN CURRENT CLIMATE





RIVERS OF THE REPUBLIC OF RWANDA

Rwanda is divided into two major drainage basins: the Nile to the east which covers 67% of the country's territory and delivers 90% of the national waters and the Congo to the west which covers the remaining 33% [9]. The main rivers are the Mwogo, Rukarara, Mukungwa, Base, Nyabarongo and the Akanyaru. The Nyabarongo is called the Akagera after receiving the waters of Rweru Lake. The country's hydrological network also includes several lakes and wetlands. A recent inventory of marshlands in Rwanda (2008) identified 860 marshlands, covering 10.6% of the country, 101 lakes covering 6%, and 861 rivers totaling 6462 km in length [10]. Rwanda's major rivers have 333 proven potential sites for micro-hydropower. Opportunities exist in micro and small Hydropower projects, as well as shared regional hydropower projects with East Africa (EAC) Partners [11]. So far the country has installed 190 MW of generation capacity, with hydropower representing 51% of the electricity production [12].

Photo Credits: A.E Hatangimana, Evode Mugunga/ Umuseke

CLIMATE PROJECTIONS FOR RWANDA

Climate models are tools that the scientific community uses to assess trends in weather conditions over long periods of time. In a recent study Alder, et al. [13], compared the observed temperature and precipitations of the 1980-2004 period with the estimations of a set of global climate models provide by the Coupled Model Intercomparison Project Phase 5 (CMIP5). Three future periods (2025-2049, 2050-2074 and 2071-2095) were then been analyzed for different greenhouse emission scenarios (see IPCC's Emissions Scenarios).

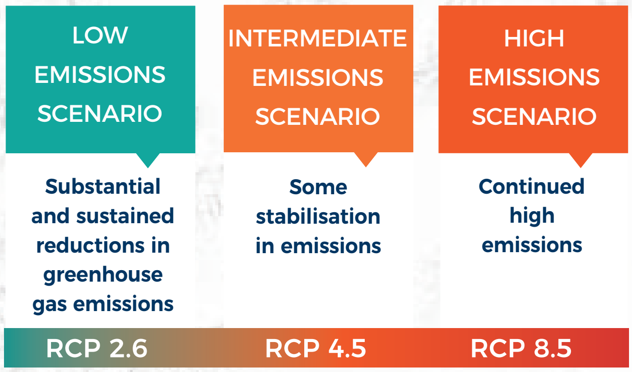
In all periods and emission scenarios, models showed an increase in temperature. The increase of temperature were more evident in high emissions scenarios and long-term period projections. In the high emission scenarios (RCP8.5), model projections showed an increase of between about 2˚C and 4˚C for the mid-term period (2050-2074) and an increase of between about 2.5˚C and 5.5˚C for the long-term period (2071-2095). Future changes in precipitation are much more uncertain, however the models predicted a likely increase in precipitation for all time periods 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 possible 15% increase in precipitation (large spread)
Far Future (2071-2095)	Increase in temperature from 2.5˚C to 5.5˚C possible 15% increase in precipitation (large spread)

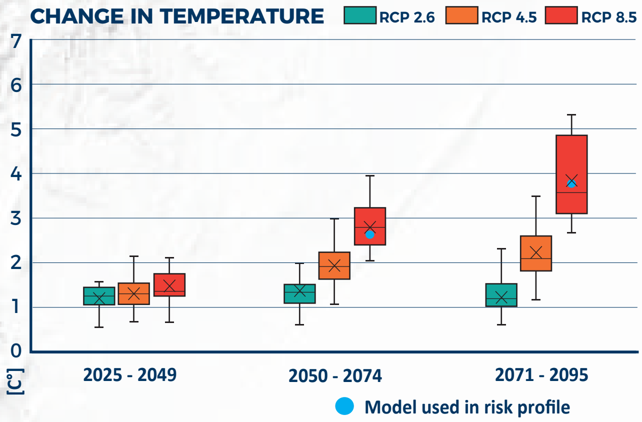
CLIMATE PROJECTIONS USED IN THIS RISK PROFILE

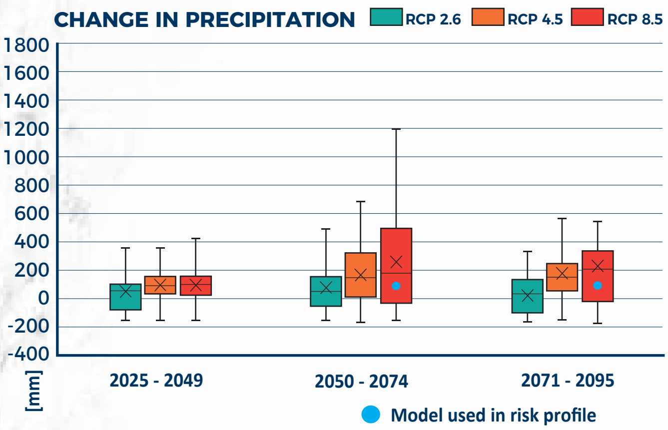
Results presented in the risk profile which refer to climate change have been obtained using a climate projection model based on a high emission scenario (SMHI-RCA4 model, grid spacing 0.44˚ about 50 km- driven by the ICHEC-EC-EARTH model, RCP 8.5, 2006-2100) [14,15,16].

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.[13].



IPCC's Emissions scenarios for Climate Projections

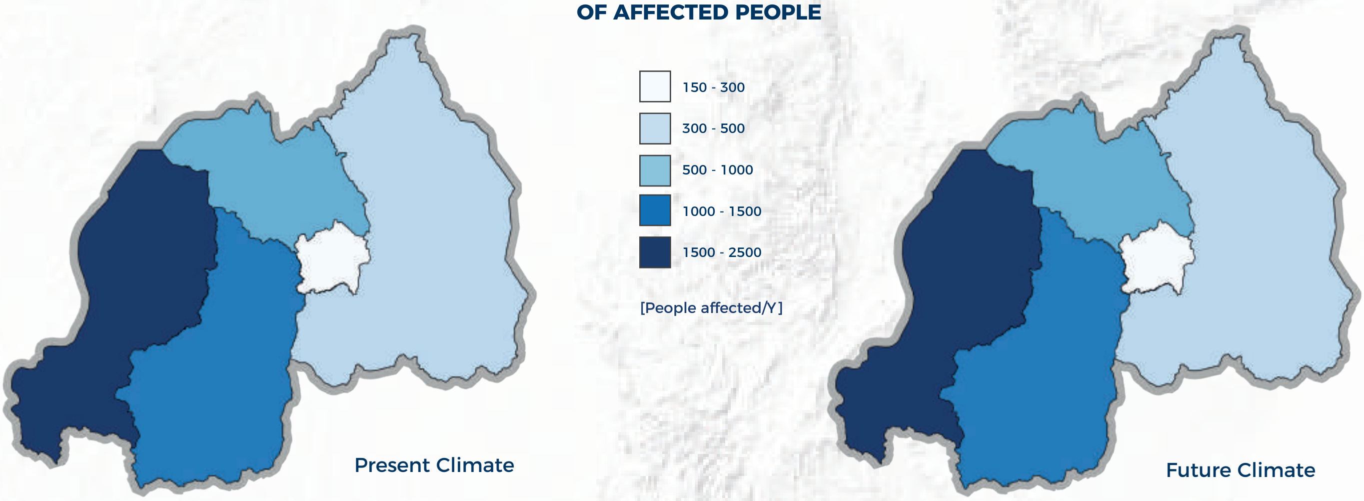




In the specific case of a high emission scenario, the regional model predicted an increase of the annual precipitation (less than 10%), below the ensemble mean. This behaviour is frequently observed in hi-resolution models with respect to global ones. The high emission scenario case was retained as representative of the worst climate change scenario, allowing the analysis of a full range of possible changes.

RESULTS | FLOODS

[B1] ANNUAL AVERAGE NUMBER OF AFFECTED PEOPLE



KEY MESSAGES

● Floods have a considerable impact on Rwanda's population, affecting on average about 5000 people every year, more than 0.04% of the total population of the country.*

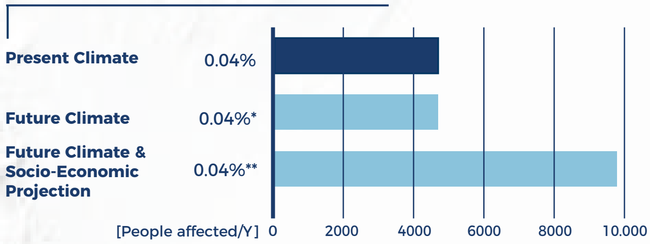
● The affected population is geographically concentrated in the western provinces of the country.

● The area affected by floods contains, in terms of economic activity, 0.22% of the yearly national GDP.*

● Future climate projections do not predict substantial changes in terms of losses, despite the fact that changes in precipitation are important in the last part of the century: almost the same risk figures are computed using weather forcing that considers climate change. However, when the future climate conditions are paired with the projection of future growth in population and GDP** the risk grows: affected people is expected to double while affected GDP is expected to increase by a factor of ten (or more).

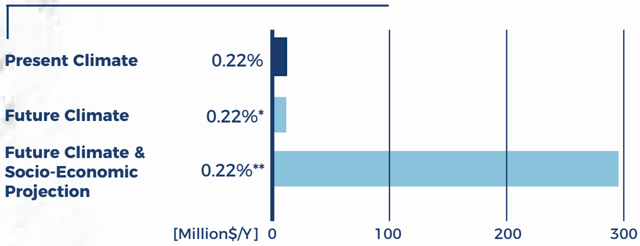
● Taking into consideration the above statements, the importance of a risk informed development in the future is undeniable, notably because of the paired impacts of socio-economic development changes and climate change.

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

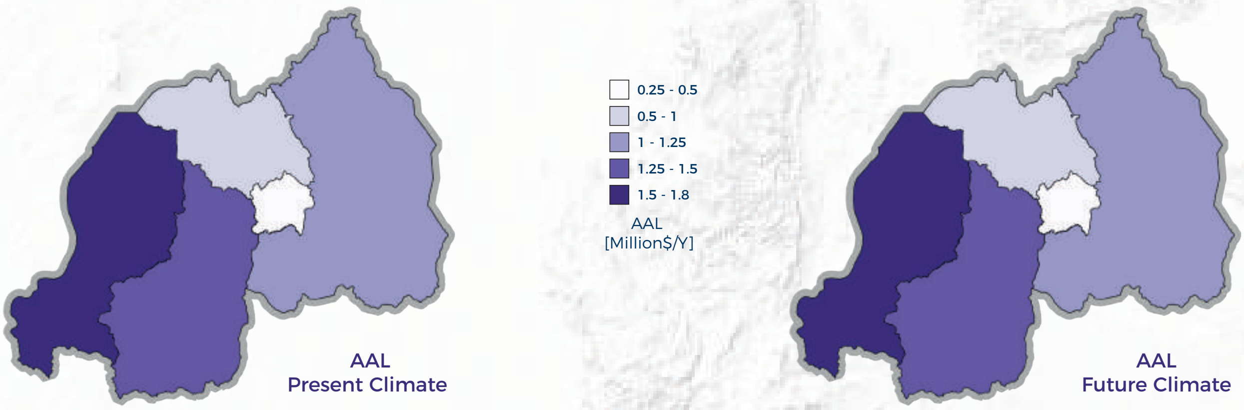


* % computed with reference to the total 2016 GDP
** % computed with reference to the total 2050 GDP

*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

[C1] DIRECT ECONOMIC LOSS



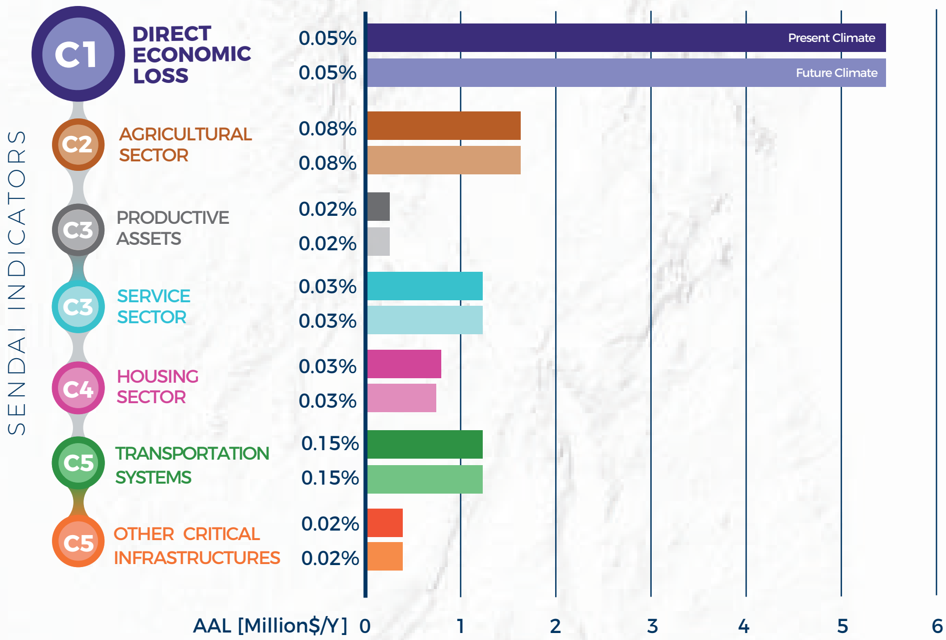
KEY MESSAGES

● The West and South provinces have the largest direct economic loss in Rwanda. The pattern does not change in the future climate, where there are no sensible differences in the hazard conditions.

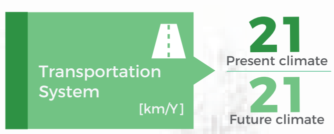
● The value of direct economic losses in terms of AAL in the present climate is of approximately 5.5 million USD, that amounts to 0.05 % of the total exposure value. The various sectors contribute evenly to the total direct economic loss with a predominant importance of the agricultural sector, followed by the transportation sector (i.e. rails and roads), service and housing sectors.

● The proportion of the different sectors to the overall loss is not predicted to change in the future in relative values. A very limited absolute increase of losses in each sector is predicted under future conditions.

● The annual average number of kilometers of roads and railways affected by floods do not significantly change in the projected future. This result is obtained under the assumption that the road and railway network will not change significantly. However, as already discussed for GDP and population levels, the increases in the risk figures are dominated by future changes in exposure. This calls for specific attention in planning future investments in infrastructure so that the risk figures will not increase significantly.



AFFECTED INFRASTRUCTURES [D4]



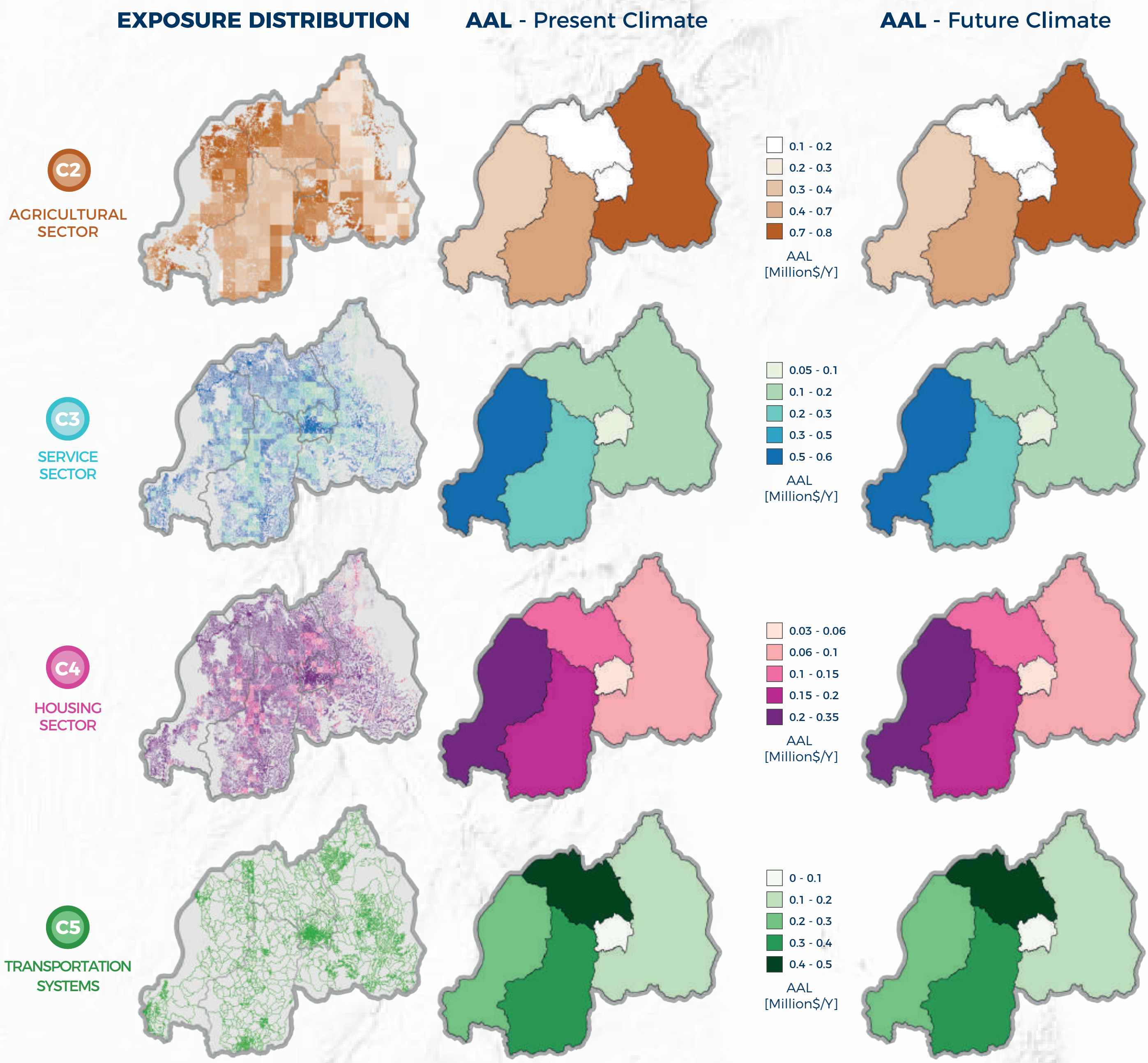
RESULTS | FLOODS

KEY MESSAGES

- The AAL distribution for Housing and Services identifies hotspots in the West Province and in Kigali province. Despite an evident concentration of assets, the North and South provinces show smaller losses in absolute terms.

- The pattern changes when agriculture and transport are analysed: the East province shows the largest losses in the agricultural sector, while the North Province is the hotspot when transportation is considered.

- Comparison between present and future climate AALs does not highlight changes in the geographical risk distribution across all sectors.



RESULTS | FLOODS

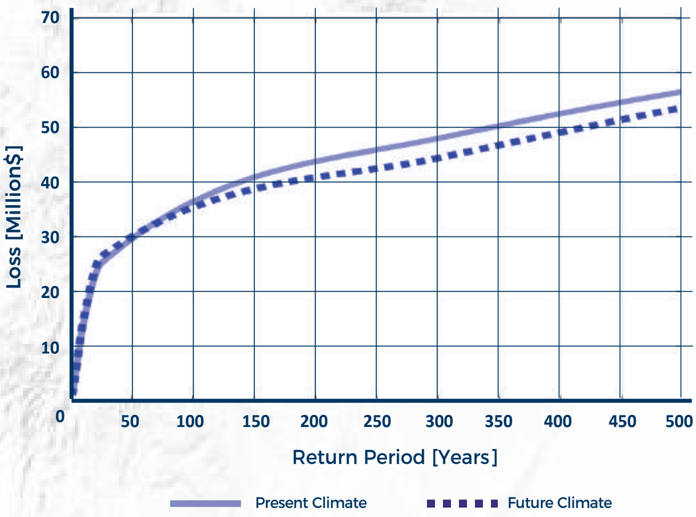
KEY MESSAGES

● The PML curve rises steeply in the first part, the part characterised by high frequency events. The curves for present and future conditions do not differ significantly in the case of frequent events.

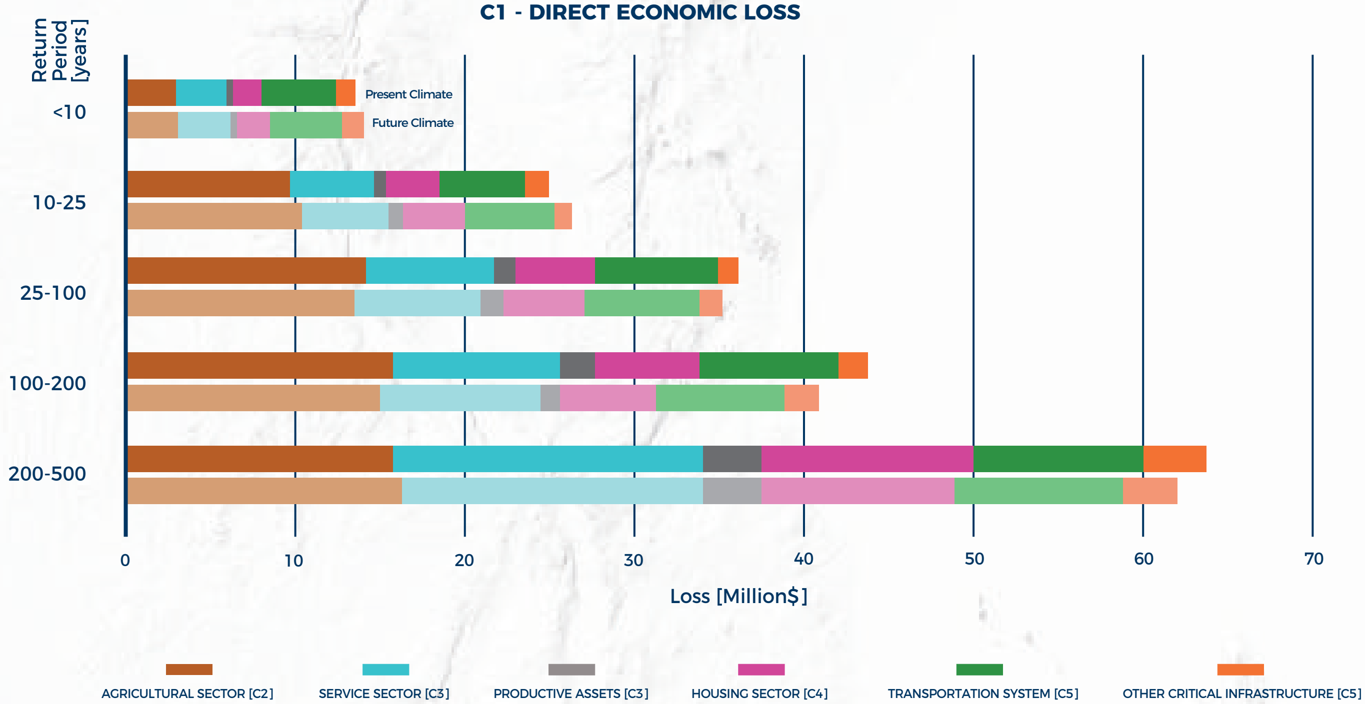
● The share of losses between the sectors for the different return periods does not change significantly, even though it is possible to notice a stronger contribution to the losses from the service sector as we move to more infrequent and damaging events.

● The PML curve rises steeply until the 25-year loss. This sets an unfavourable condition for risk transfer contracts. The first part of the curve should be strategically modified with risk reduction measures before designing a risk transfer option.

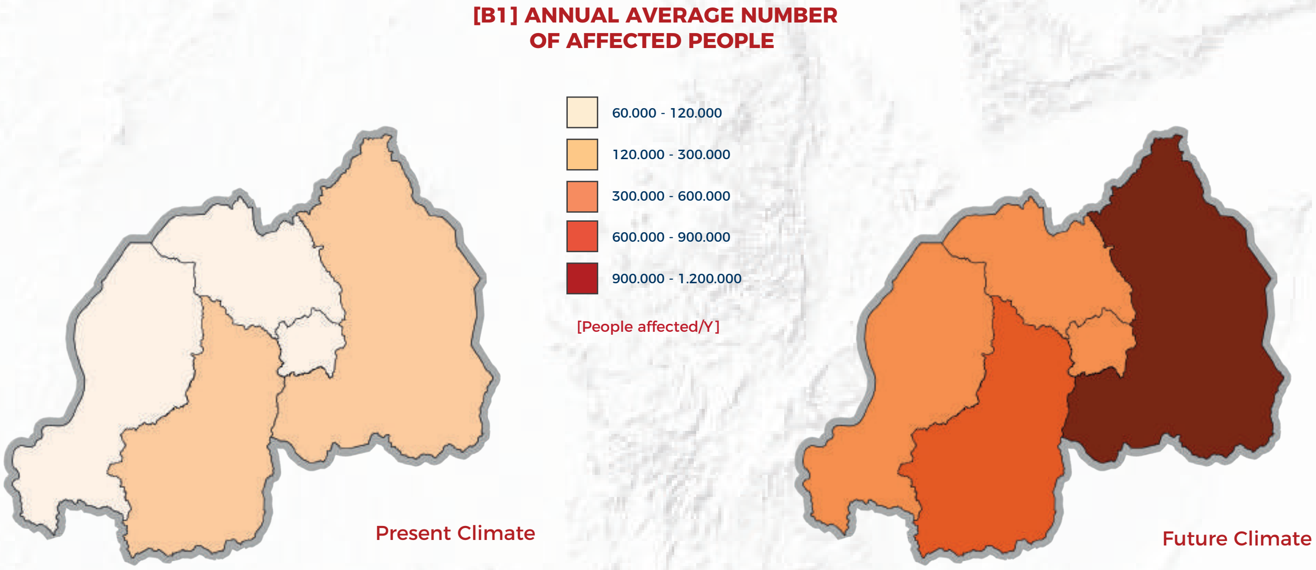
PROBABLE MAXIMUM LOSS CURVE (PML)
C1 - DIRECT ECONOMIC LOSS



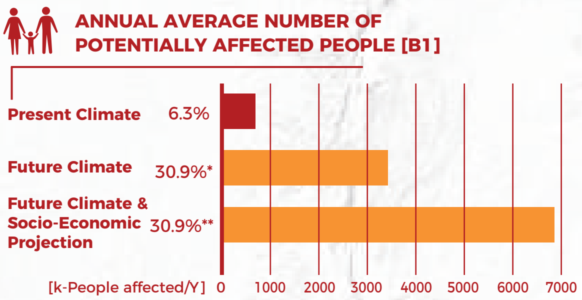
PROBABLE MAXIMUM LOSS CURVE (PML) ACROSS ALL SECTORS
C1 - DIRECT ECONOMIC LOSS



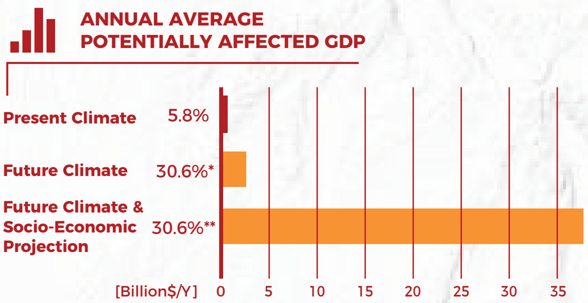
RESULTS | DROUGHTS



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.



* % 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

KEY MESSAGES

- With respect to present climate conditions (1951-2000 climate), precipitation is expected to moderately increase, while a strong increase in temperature is foreseen in the future (2050-2100 climate), causing an increase in the frequency of droughts.

- Currently, on average about 700.000 people (6.3% of the total country population) are exposed to droughts per year. Under future climate conditions, this number is expected to increase to 30.9% (about 7 million people if population growth is accounted for).

- The GDP exposed to droughts is expected to increase by a factor of five. While presently, on average 5.8% of the yearly GDP is exposed to droughts, this is expected to rise to 30.6%.

RESULTS | DROUGHTS

KEY MESSAGES

● In the future, five times more livestock is expected to be annually exposed to droughts. Currently, on average 6% of the country's livestock is annually exposed to drought conditions. Under future climate conditions, this is expected to rise to almost 30%.

● Losses in agricultural production (C2) are projected to almost double under future climate conditions, but still remain low compared to the total income from crops (< 4%). Losses in hydropower generation (C3) due to drought are expected to change by a factor of 2.5 when comparing present and future climate conditions (for Ruzizi dam).

● Total direct economic losses (C1) due to drought are completely dominated by the agricultural sector (C2) with a negligible contribution from the loss in hydropower (C3). Bananas , beans, potatoes, and sweet potatoes are dominant crops in determining the losses due to agricultural production under present and future climate conditions. For future climate conditions, largest increases in absolute losses are projected for sweet potatoes and beans. The relative production loss under future climate conditions is highest for beans, maize and potatoes (> 9%).

● The loss in the number of working days is projected to more than double under future climate conditions. The loss of working days still remains lower than 1% of the total amount of working days under both present and future climate conditions. However, the number of lost working days, expressed as a percentage of the average amount of days required for harvesting, is predicted to increase by approximately five times.

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

450 | 0.28%
Present climate

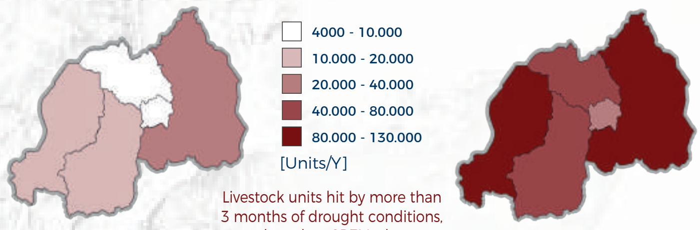
1100 | 0.66%
Future climate

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

77 | 6.0%
Present climate

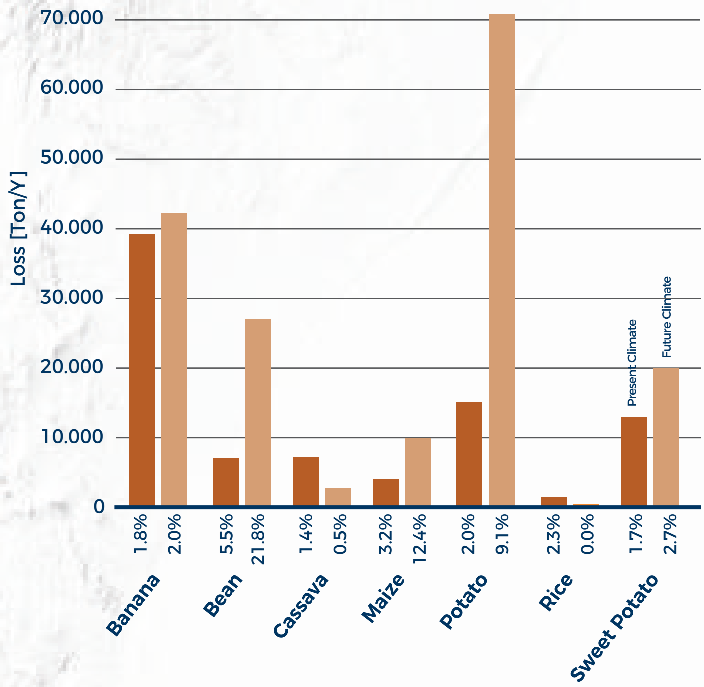
360 | 28%
Future climate

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

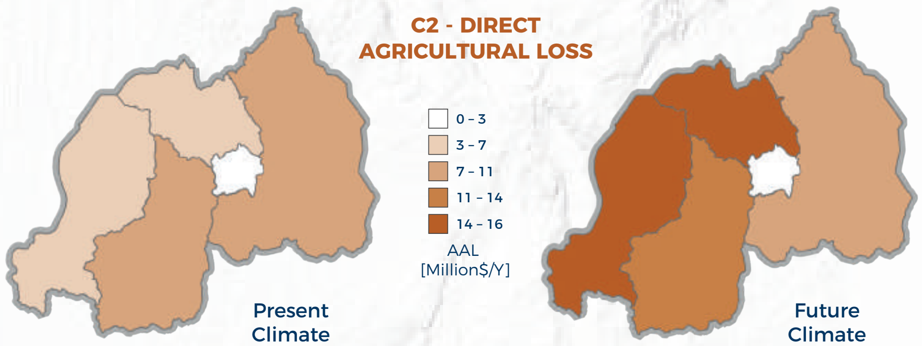


Livestock units hit by more than 3 months of drought conditions, based on SPEI Index

AGRICULTURAL PRODUCTION LOSS

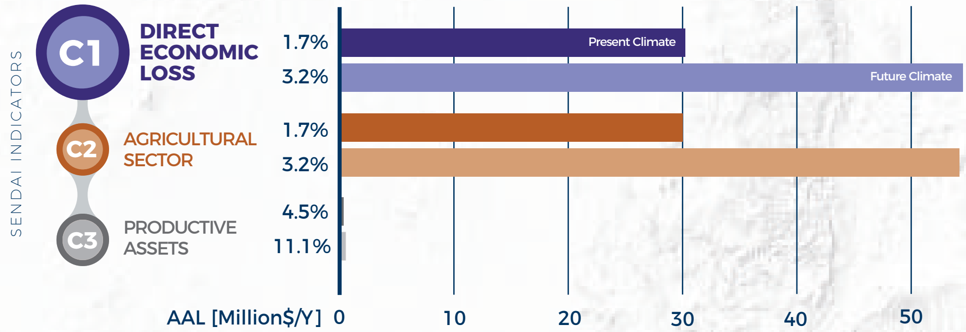


C2 - DIRECT AGRICULTURAL LOSS



● Under present climate conditions, agricultural (crop) losses are a bit higher in the eastern and southern part of Rwanda compared to the northern and western part. However, under future climate conditions, a strong increase in the western and northern part of the country is projected, shifting the highest losses from the east and south towards these parts of the country.

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.

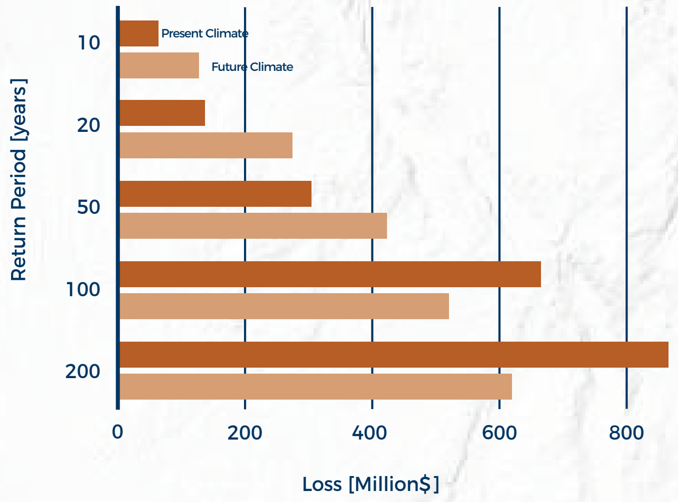
KEY MESSAGES

- In the case of agricultural income losses from crop production, present climate conditions show an important increase in expected losses when return periods go up from 10 to 200 years, especially for rare events with a return period of 100 or 200 years. It is worth noting that these results become more and more uncertain as the rarity of the loss events increase.

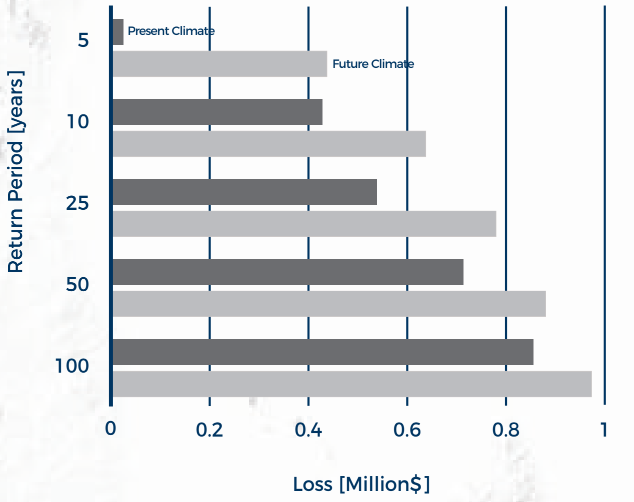
- Agricultural income losses under future climate conditions are projected to increase for the more frequent events (to once in 50 years), but are projected to decline for the more rare events to once in 100 and 200 years.

- For hydropower losses (defined as the production below production with average reservoir conditions under the present climate), losses increase particularly for high frequency events (e.g. 1 in 5 years return period). Losses associated with very rare drought events also increase, but only by a small amount in relative terms.

PROBABLE MAXIMUM LOSS (PML) C2 - AGRICULTURAL LOSS



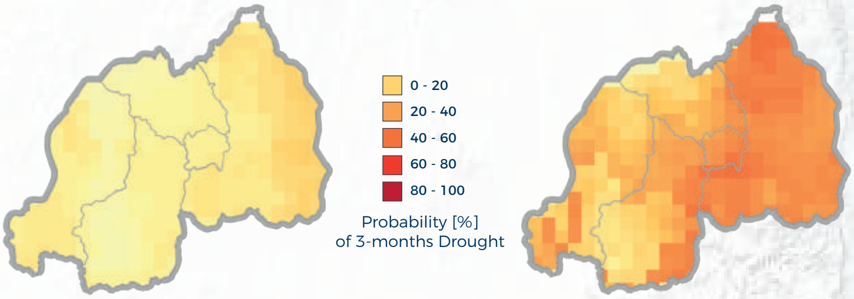
PROBABLE MAXIMUM LOSS (PML) C3 - PRODUCTIVE ASSETS (HYDROPOWER LOSS)



RESULTS | DROUGHTS

Present Climate

Future Climate

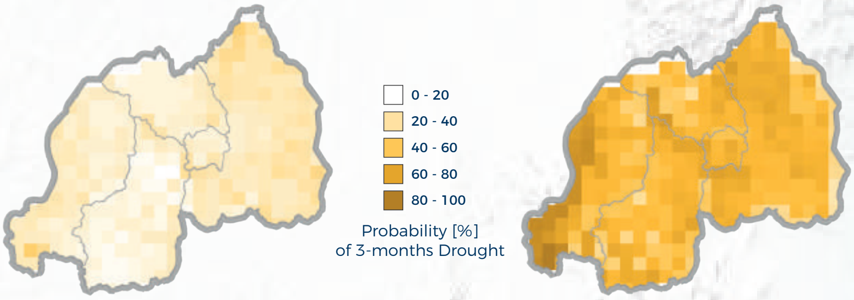


SPEI

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).

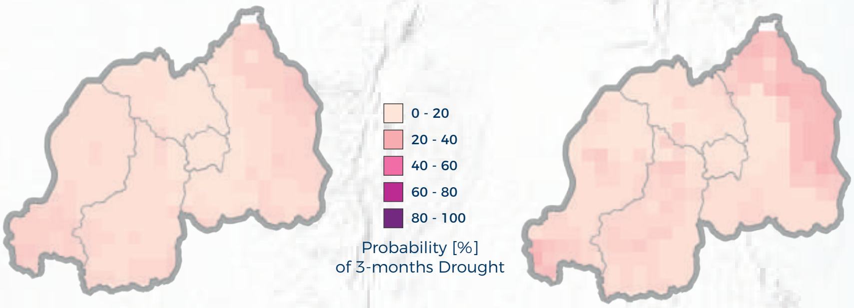
Under future climate conditions, the probability of meteorological droughts will increase in the whole country, and more significantly in the eastern part of the country. This is particularly important for areas dependent on rainfall for their water resources.



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).

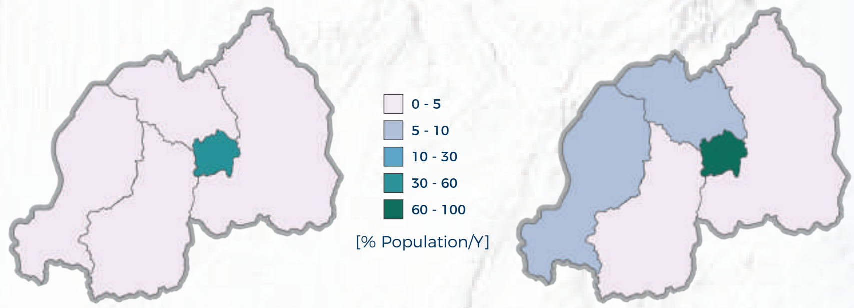
Under future climate conditions, dry soil moisture conditions could be drastically aggravated, as the whole country is projected to experience longer dry periods. This is particularly important for agricultural areas and natural ecosystems.



SPI - Standardised Precipitation Index

These maps denote the average annual chance of a meteorological drought occurring (%). Droughts are defined precipitation levels considerably below normal conditions, calculated through the Standardized Precipitation Index (SPI; see 'Drought' in Glossary).

The probability of experiencing 3 months of precipitation levels considerably below normal conditions increases under future conditions, especially in the eastern part of the country.



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). In Rwanda, areas with high concentrations of people tend to be dependent on outside water resources (primarily Kigali). Under future climate conditions this situation becomes substantially worse for Kigali. A small portion (< 10%) of the population in Amajyaruguru (North) and Iburengerazuba (West) may also become more dependent on water from elsewhere as water availability per person drops below the threshold in some parts.

PROBABILISTIC RISK ASSESSMENT FOR RISK MANAGEMENT

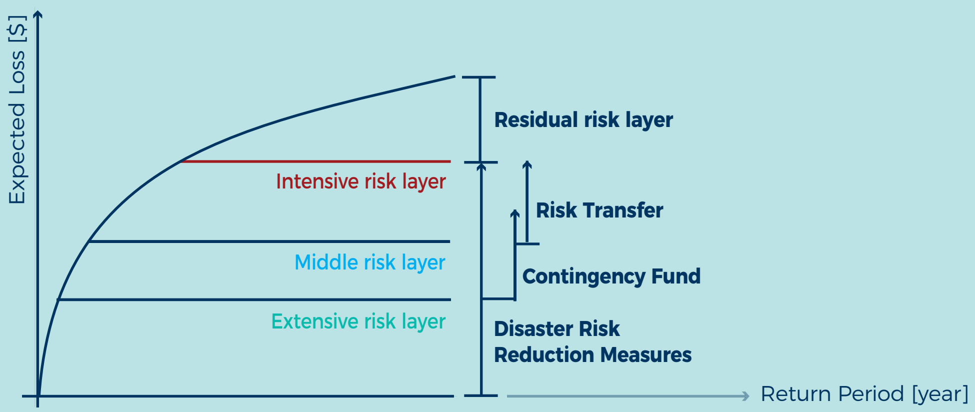
METRICS FOR RISK MANAGEMENT

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*

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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

RISK PROFILES ARE AVAILABLE AT:

riskprofilesundrr.org

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