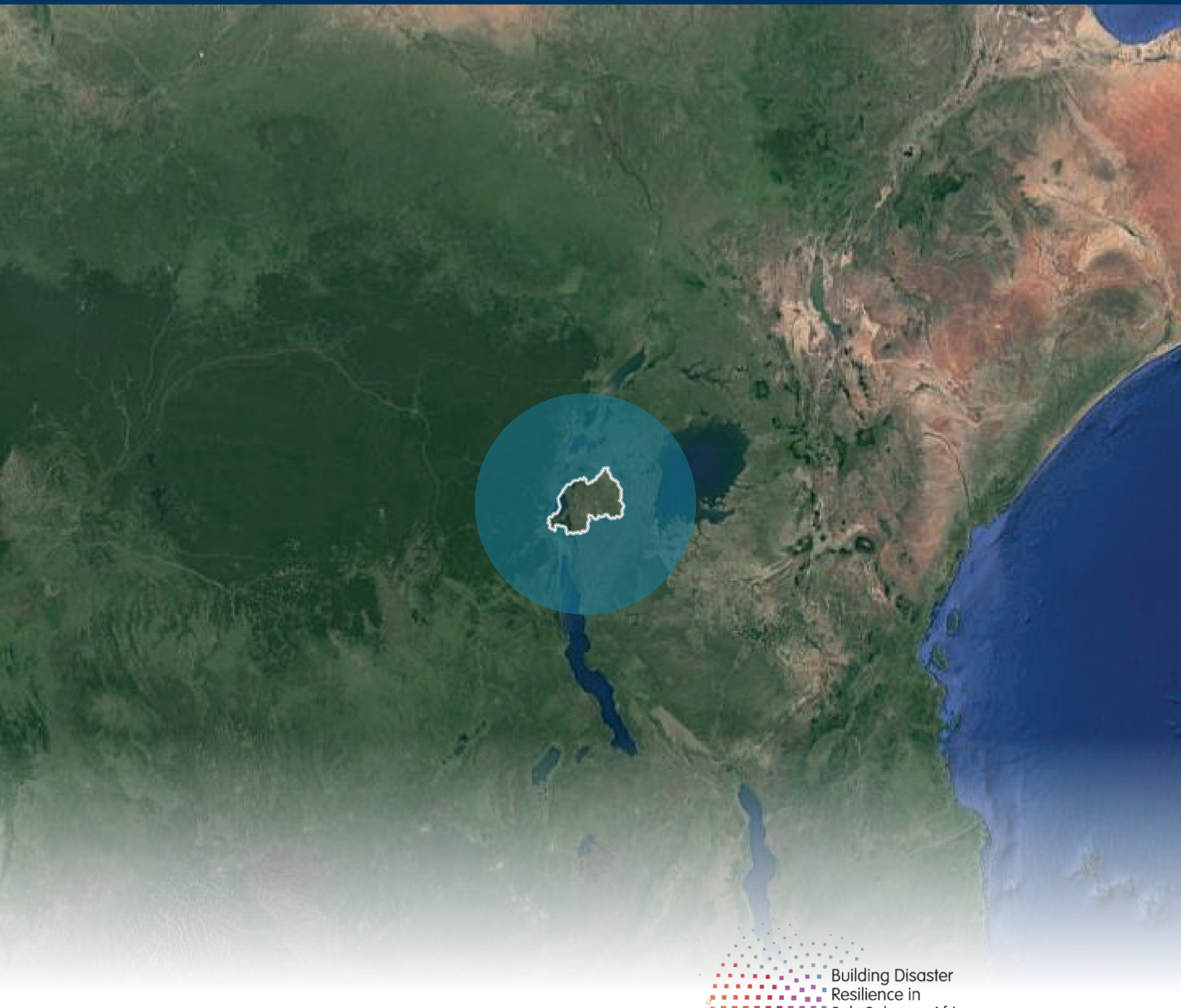
DISASTER RISK PROFILE

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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cima RESEARCH FOUNDATION

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International Centre on Environmental Monitoring
Via Magliotto 2. 17100 Savona. Italy
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Via Armando Magliotto, 2 - 17100 Savona - Italy;
Phone: +39 019230271 - Fax: +39 01923027240
E-mail: info@cimafoundation.org
www.cimafoundation.org

Design and layout: CIMA Research Foundation
Video Production: Don't Movie, Italy

In collaboration with:

PROJECT TEAM

Authors
Roberto Rudari [1]
Sjaak Conijn [3]
Silvia De Angeli [1]
Hans de Moel [2]
Luca Ferraris [1;4]
Elisabetta Fiori [1]
Tatiana Ghizzoni [1]
Isabel Gomes [1]
Marco Massabò [1]
Lauro Rossi [1]
Eva Trasforini [1]

Scientific Team
Nazan An [6]
Chiara Arrighi [1;5]
Valerio Basso [1]
Guido Biondi [1]
Alessandro Burastero [1]
Lorenzo Campo [1]
Fabio Castelli [1;5]
Mirko D'Andrea [1]
Fabio Delogu [1]
Giulia Ercolani [1;5]
Simone Gabellani [1]
Alessandro Masoero [1]
Ben Rutgers [3]
Franco Siccardi [1]
Francesco Silvestro [1]
Andrea Tessore [1]
Tufan Turp [6]
Marthe Wens [2]

Editing and Graphics
Silvia De Stefano [1]
Andrew Eddy, Canada
Rita Visigalli [1]

Supporting Team
Simona Pozzati [1]
Luisa Colla [1]
Monica Corvarola [1]
Iain Logan [7]
Rich Parker [8]
Elisa Poggi [1]
Martino Prestini [1]

With the support of the UNISDR Regional Office for Africa

CIMA Research Foundation [1]
Vrije Universiteit Amsterdam [2]
Wageningen University & Research [3]
Università di Genova [4]
Università di Firenze [5]
Bogazici University [6]
GEG [7]
Training in Aid [8]

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INTRODUCTION

Disasters are on the rise, both in terms of frequency and magnitude.
From 2005-2015, more than 700 thousand people worldwide have lost their lives due to disasters that have affected over 1.5 billion people, with women, children and people in vulnerable situations disproportionately affected. The total economic loss was 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 strong political leadership, commitment, and involvement of all stakeholders at all levels from local to national and international, with a view 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 programme "Building Disaster Resilience to Natural Hazards in Sub-Saharan African Regions, Countries and Communities", UNISDR engaged 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, Ghana, Guinea Bissau, Kenya, Kingdom of Eswatini, Ivory Coast, Namibia, Rwanda, São Tomé and Príncipe, Tanzania, 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 programme *"Building Disaster Resilience to Natural Hazards in Sub-Saharan African Regions, Countries and Communities"*. The programme is being implemented in Africa by four partners: the African Union Commission, the United Nations Office for Disaster Risk Reduction (UNISDR), 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

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.

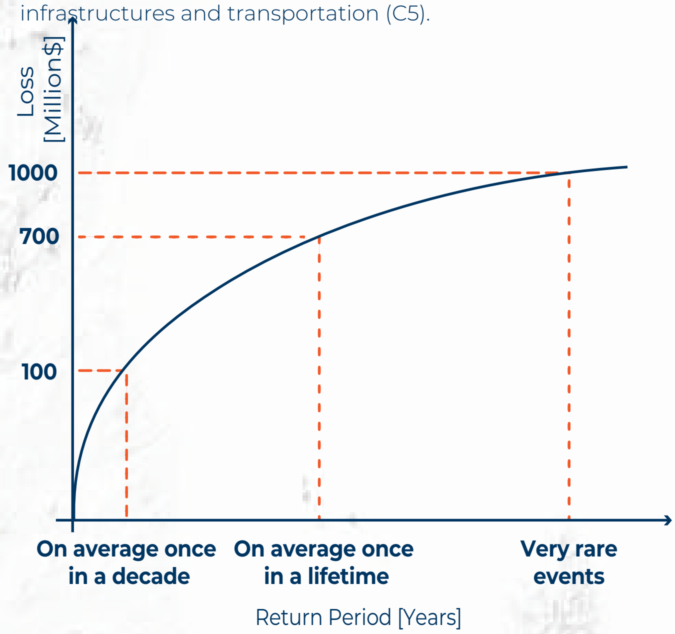
This disaster risk profile for floods and droughts is based on probabilistic risk assessment. Awareness of possible perils that may threaten human lives primarily derives from experience of past events. In theory, series of historical loss data long enough to be representative of all possible disastrous events that occurred in a portion of territory would provide all 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.

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. A realistic set of all possible hazardous events (scenarios) that may occur in a given region, including very rare, catastrophic events, is simulated. For each event, potential impacts are computed in terms of economic losses or number of people and assets affected, considering publicly available information on Hazard, Exposure, and Vulnerability. Finally, statistics of losses are computed and summarised through proper quantitative economic risk metrics, such as: 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 are explicitly quantified and taken into account: uncertainties in the hazard forcing, uncertainties in the 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, the AAL also accounts for much larger losses that occur less frequently. As such, AAL represents the funds that would be required annually in order to cumulatively cover the average disaster loss over time.

Probable Maximum Loss (PML) describes the maximum loss that could be expected corresponding to a given likelihood, expressed in terms of annual probability of exceedance or its reciprocal, the return period. For example, 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 that, for instance, 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 same 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.

A modelling chain composed of climate, hydrological, and hydraulic models using all the available information, in terms of rainfall, temperature, humidity, wind, and solar radiation, to best predict possible flood and drought scenarios. 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 at different locations.

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

VULNERABILITY

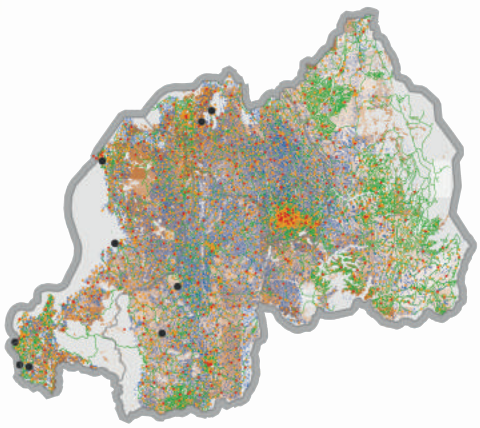
conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of an individual, a community, assets or systems to the impacts of hazards.

The direct losses on the different elements at risk are evaluated applying vulnerability functions, which link the hazard intensity to the expected loss (economic loss or number of affected people), considering also the associated uncertainty. Vulnerability functions are differentiated for each typology of exposed element and take into account local factors, such as typical constructive typologies for infrastructures or the crop seasonality for the agricultural production. For flood, vulnerability is a function of the water depth. The only exception is represented by agricultural production, for which it is a function of the season in which the flood is occurring. In the case of agricultural drought, the 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, when the loss of hydropower production is evaluated.

EXPOSURE

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

The losses caused by floods and droughts are evaluated on population, GDP and a series of critical sectors (education, health, transport, housing, and productive and agricultural sectors). The critical sectors are created clustering all 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.

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

RWANDA DISASTER RISK PROFILE

COUNTRY CLIMATE OUTLOOK

OVERVIEW

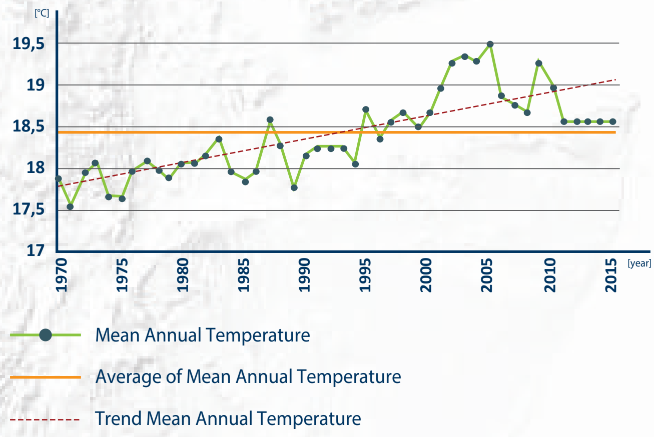
Rwanda is a country located in Central - Eastern Africa. This zone is traditionally presented as a major dry climate region, an anomaly in the otherwise wet equatorial belt. It is a transition region between the monsoon domains of West Africa and the Indian Ocean. The inter-annual and inter-decadal climate 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 [1].

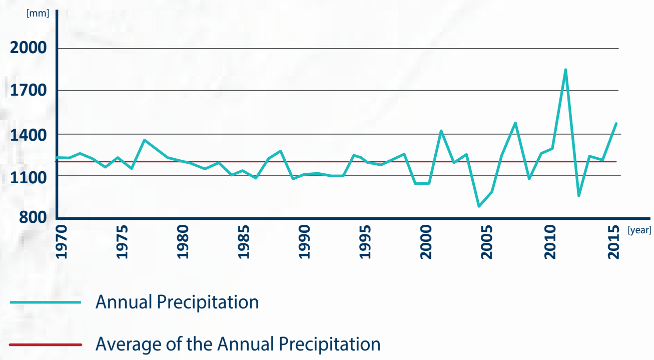
CLIMATE TRENDS

Similarly to other Eastern Africa 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 [2] shows an increase of temperature of around 1°C. This increase is particularly noticeable from the 1990s onward.

Precipitation do not have as clear a trend as air temperatures, and is variable in time and space. The average annual precipitation for Rwanda is about 1210 mm while the mean number of wet days is around 192. The low variability shown in precipitation at the end of the last century seems to move towards higher variability in the new century. Starting from the 2000s, an increase of extreme dry (i.e. 2004) and wet years (i.e. 2011) has been observed.

TEMPERATURE AND PRECIPITATION TRENDS IN CURRENT CLIMATE





RIVERS OF RWANDA

Rwanda is divided into two major drainage basins: the Nile to the east covering 67% of the Country's territory and delivering 90% of the national waters and the Congo to the west which covers the remaining 33% [3]. The main rivers are 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 includes also several lakes and wetlands. A recent inventory of marshlands in Rwanda (2008) identified 860 marshlands, covering a total surface which corresponds to 10.6% of the country surface, 101 lakes covering almost 6% of the country surface, and 861 rivers totalling 6462 km in length [4]. Rwanda's major Rivers have proven 333 potential sites for Micro-hydropower countrywide. Opportunities exist in Micro and Small Hydropower projects and shared regional hydropower projects with East Africa (EAC) Partners [5]. So far the country has installed about 190 MW of generation capacity with hydropower representing 51% of the electricity production [6].

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

CLIMATE PROJECTIONS FOR RWANDA

There is a wealth of climate projection studies over multiple time spans and multiple scales. Climate models are tools that the scientific community uses to assess the trends of weather conditions over long periods. In a recent study [7], temperature and precipitation change from global climate models of the Coupled Model Intercomparison Project Phase 5 (CMIP5), for different greenhouse emission scenarios (see IPPC's Emissions Scenarios) were reported. Three future periods (2025-2049, 2050-2074 and 2071-2095) were compared against the reference period 1980-2004.

For the far future (2071-2095), models projections show an increase between 2.5°C and 5.5°C when the high emission scenario is considered.

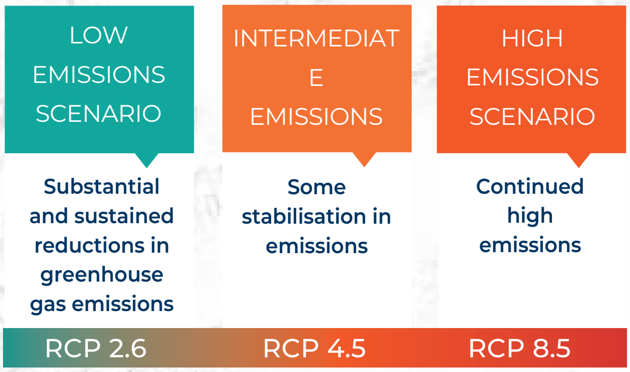
Precipitation projections are more uncertain. By the end of the century (2071-2095) the models show a strong disagreement especially when the high emission scenario is considered predicting both large increase as well as a decrease in the annual precipitation. On average an increase of 15% is predicted as an ensemble mean.

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)

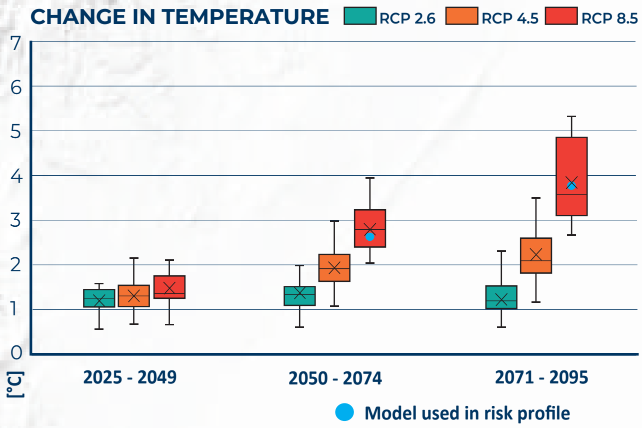
CLIMATE PROJECTIONS USED IN THIS RISK PROFILE

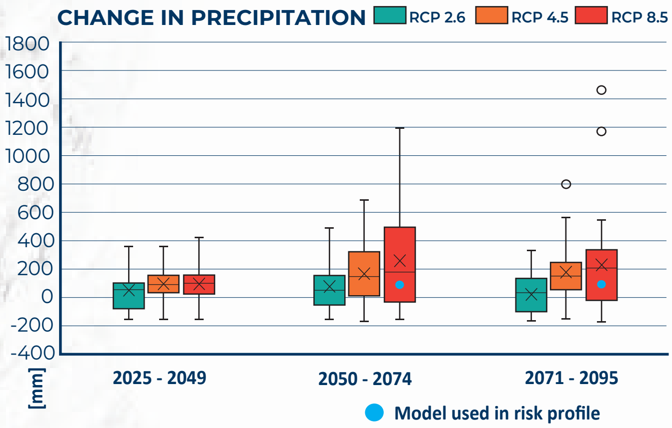
The results of the Risk Profile referring to climate change have been obtained using a climate projection model based on a high emission scenario (SMHI-RCA4 model, grid spacing 0.44°-about 50 km- driven by ICHEC-EC-EARTH model, RCP 8.5, 2006-2100) [8,9,10].

In this study, it was decided to use a high-resolution model properly calibrated on the African domain to better capture the climate variability that is important for assessing extremes. The regional model projections were checked for consistency against the full ensemble of available global models in the area. The model forecasted changes in temperature and annual precipitation by the end of the century are in line with the range of variability of the global models analyzed in the study from Alder and Hostetler [7]. 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.



IPCC's Emissions scenarios for Climate Projections





COUNTRY SOCIO-ECONOMIC OUTLOOK

OVERVIEW

Small and landlocked in the Great Lakes region of central Africa, Rwanda is a hilly and fertile country with a densely packed population [11]. About 34% of its people lives in urban areas and the median age is 19.6 years.
Rwanda's economy is agrarian with about 35% of the population engaged in subsistence agriculture, and with some mineral and agro-processing [12]. Tourism, minerals, coffee, and tea are main sources of foreign exchange. Despite Rwanda's fertile ecosystem, food production often does not keep pace with demand, requiring food imports. Although several factors still constrain the economic growth of the Country[12], a number of positive indicators have been observed in recent years. Between 2008 and 2014, poverty dropped from 56.7% to 39.1%. GDP per capita increased from $479 to $720, and growth has consistently averaged 7.8%, with evidence of economic diversification as the share of agriculture's contribution reduced from 39% to 31% and those of other sectors increased [13].

PROJECTIONS

Over the past few years climate scientist and economist have built a range of new "pathways" that examine how national and global societies, demographics and economics might modify over the next century under different plausible future development scenarios [14,15]. The scenarios go from the relatively optimistic trends for human development, with "substantial investments in education and health, rapid economic growth, and well-functioning institutions"[16], to more pessimistic economic and social development, with little investment in education or health in poorer countries coupled with a fast-growing population and increasing inequalities.

SOCIO-ECONOMIC PROJECTIONS USED IN THE RISK PROFILE

The "middle of the road" scenario envisages that the historical patterns of development are continued throughout the 21st century. The results shown in this report are referred to this scenario. Using these boundary conditions, the population of Rwanda in 2050 will be double the level of 2016 (World Bank Data), while GDP will be almost 16 times higher.

POPULATION	GDP
2016 Projection	2016 Projection
11.918	**8.476**
[Million People]	[Billion$]
22.953	**133.066**
2050 Projection	2050 Projection

RWANDA

AREA : 26.338 km²

MEDIAN AGE : 19.6 years

HUMAN DEVELOPMENT INDEX : 0.498

LIFE EXPECTANCY AT BIRTH : 64.7 years

MEAN YEARS OF SCHOOLING : 3.8 years

EMPLOYMENT TO POP. RATIO (AGES > 15) : 82.9%

EMPLOYMENT IN AGRICULTURE : 66.9%

EMPLOYMENT IN SERVICES : 24.9%

data from:
http://hdr.undp.org/en/countries/profiles/RWA
https://data.worldbank.org/country/rwanda
http://www.worldometers.info

A “SENDAI DRIVEN” PRESENTATION

The Sendai Framework guides the organisation of the risk profile results.

The **first page** of results refers to Sendai Framework Target B: “*Substantially reduce the number of affected people globally by 2030*” and specifically to Sendai indicator B1: “*Number of directly affected people attributed to disasters*“.

The **second page** presents indicators that contribute to increasing knowledge of the country on Sendai Framework Target C: “*Reduce direct disaster economic loss in relation to global gross domestic product (GDP) by 2030*”.
The indicator C1 “*Direct economic loss attributed to disasters*” is computed as a compound index of several indicators computed in a fully probabilistic manner in this study that can be reconciled to the Sendai indicators.

In the case of floods, the indicators used are:
·C2 Direct agricultural loss attributed to disasters (based on the main crops).
·C3 Direct economic loss to all other damaged or destroyed productive assets attributed to disasters. In this risk profile, C3 is split into two components: productive assets (industrial buildings and energy facilities) and service sector (governmental and service buildings).
·C4 Direct economic loss in the housing sector attributed to disasters.
·C5 Direct economic loss resulting from damaged or destroyed critical infrastructure attributed to disasters. In this risk profile C5 is split into two components: transportation systems (roads and railways) and other critical infrastructures (health and education facilities).

Sendai Framework **Target D**: “*Substantially reduce disaster damage to critical infrastructure and disruption of basic services, among them health and educational facilities, including through developing their resilience by 2030*” is also addressed. The count of affected critical infrastructures (e.g. health and education facilities and kilometres of transportation network) is provided.

In the case of droughts, the indicators computed are:
·C2 Direct agricultural loss attributed to disasters (based on the main crops).
·C3 Direct economic loss to all other damaged or destroyed productive assets attributed to disasters. In these calculations, only hydropower losses are assessed in the context of drought.

In the **third page** of results for floods, the most relevant sectors for the country are selected and their AAL distribution is presented in present and future climate conditions in relation to the exposure distribution considered in the study. In the case of droughts, the spatial distribution of the main hazard indexes is presented as they represent the main driver for risk computations. An explanation box for each drought hazard index is given in the page to help their interpretation.

For floods, the results are broken down on the **fourth and final page** according to different return periods and presented in terms of PML curve of the total damage across all sectors. The contribution of the different sectors is highlighted in each range of return periods of the total damage.
In the case of droughts, the result derived in economic terms for income losses due to lack of agricultural production and loss of hydropower production are broken down according to different return periods.

RESULTS | FLOODS

KEY MESSAGES

- Floods have a considerable impact on population in Rwanda affecting on average about 12000 people every year, more than 0.1% of the total population of the Country[a].

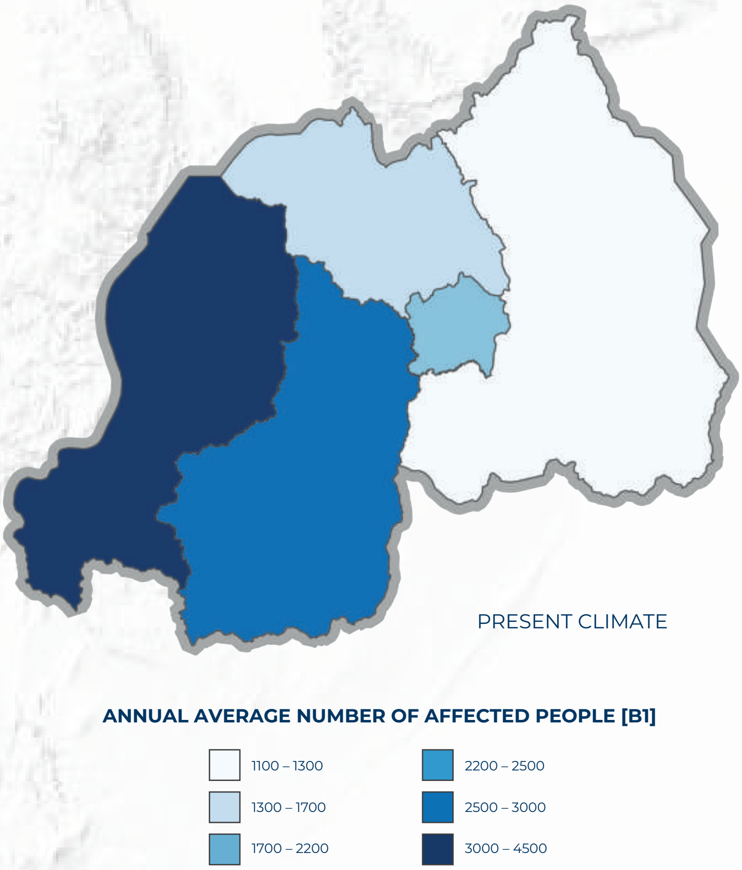
- The affected people are mostly concentrated in West and South provinces.

- The GDP percentage in areas affected by floods cumulates on average almost 0.5% of the total GDP[a] every year at country level.

- In Rwanda future climate projections do not predict substantial changes in terms of losses despite the fact that changes in precipitation are sensible in the last part of the century: almost the same risk figures are computed using weather forcing that considers climate change.

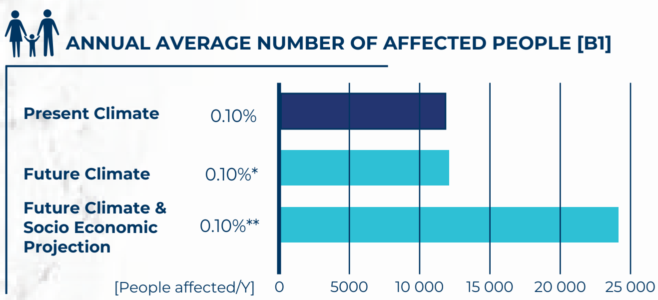
- Pairing the future climatic conditions with the projection of future growth in population and GDP[b], the risk grows in future: affected people is expected to double while affected GDP is expected to increase by a factor of fifteen.

- Taking into consideration the above statements the importance of a risk informed development in future becomes undeniable especially here where computations highlight the importance of the future developments of the Country with respect to the climate change forcing.



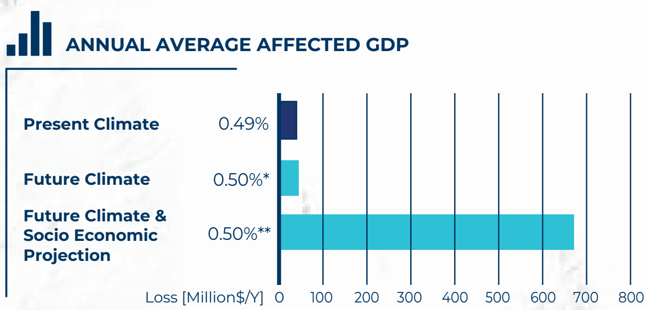
ANNUAL AVERAGE NUMBER OF AFFECTED PEOPLE [B1]

ANNUAL AVERAGE NUMBER OF AFFECTED PEOPLE [B1]



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

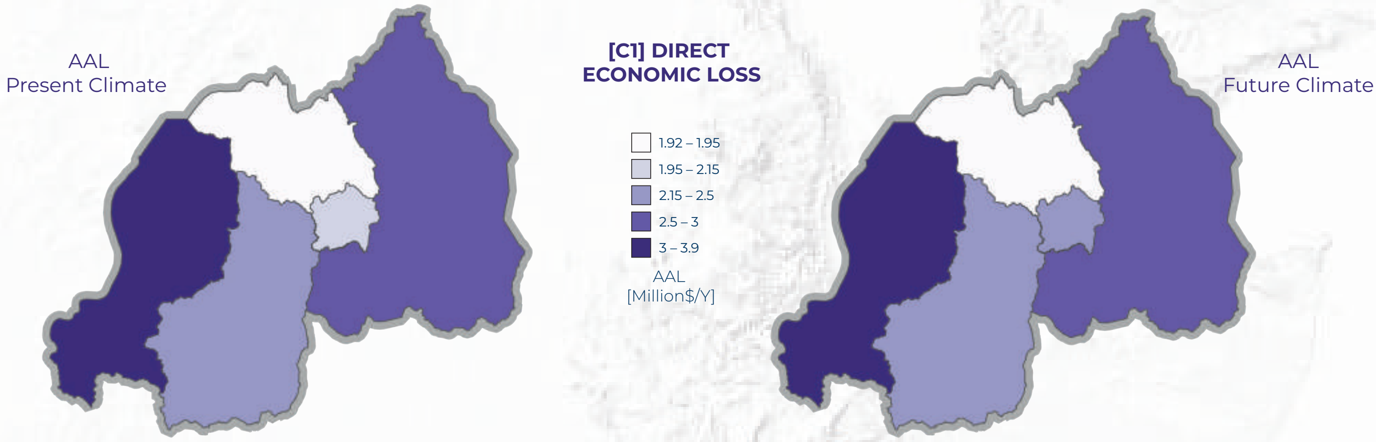
ANNUAL AVERAGE AFFECTED GDP



[a] 2016 was taken as a reference year both for GDP and population.

[b] the Shared Socioeconomic Pathway (SSP) - 2 "middle of the road" (Medium challenges to mitigation and adaptation) has been used to project population and GDP distributions.

RESULTS | FLOODS



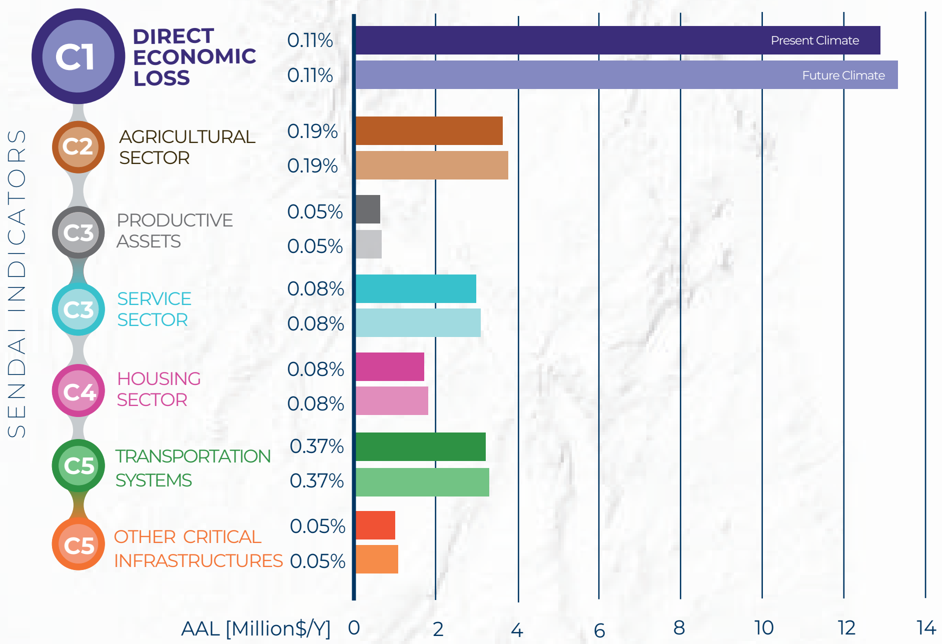
KEY MESSAGES

- West and East provinces have the largest direct economic loss in Rwanda. The pattern does not change in future climate since there are no sensible differences in the hazard conditions.

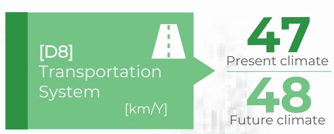
- The value of direct economic losses in terms of AAL in present climate sums up to about 13 millions of USD that accounts for 0.11 percent of the total exposure value. The various sectors contribute evenly to the total direct economic loss with a predominant importance of the agricultural sector followed by the transportation sector (i.e. rails and roads), service and housing sectors.

- The proportion of the different sectors to the overall loss does not change in future. A very limited increase of losses in each sector is predicted in future conditions.

- The annual average number of kilometers of roads and railways affected by floods does not significantly change in future. This result is obtained under the assumption that the road and railway networks will not change in future. However, as already discussed for GDP and Population the increase in the risk figures is dominated by future changes in exposure. This calls for specific attention in planning future investments in infrastructures so that their risk figures will not increase significantly.



AFFECTED INFRASTRUCTURES [D]



RESULTS | FLOODS

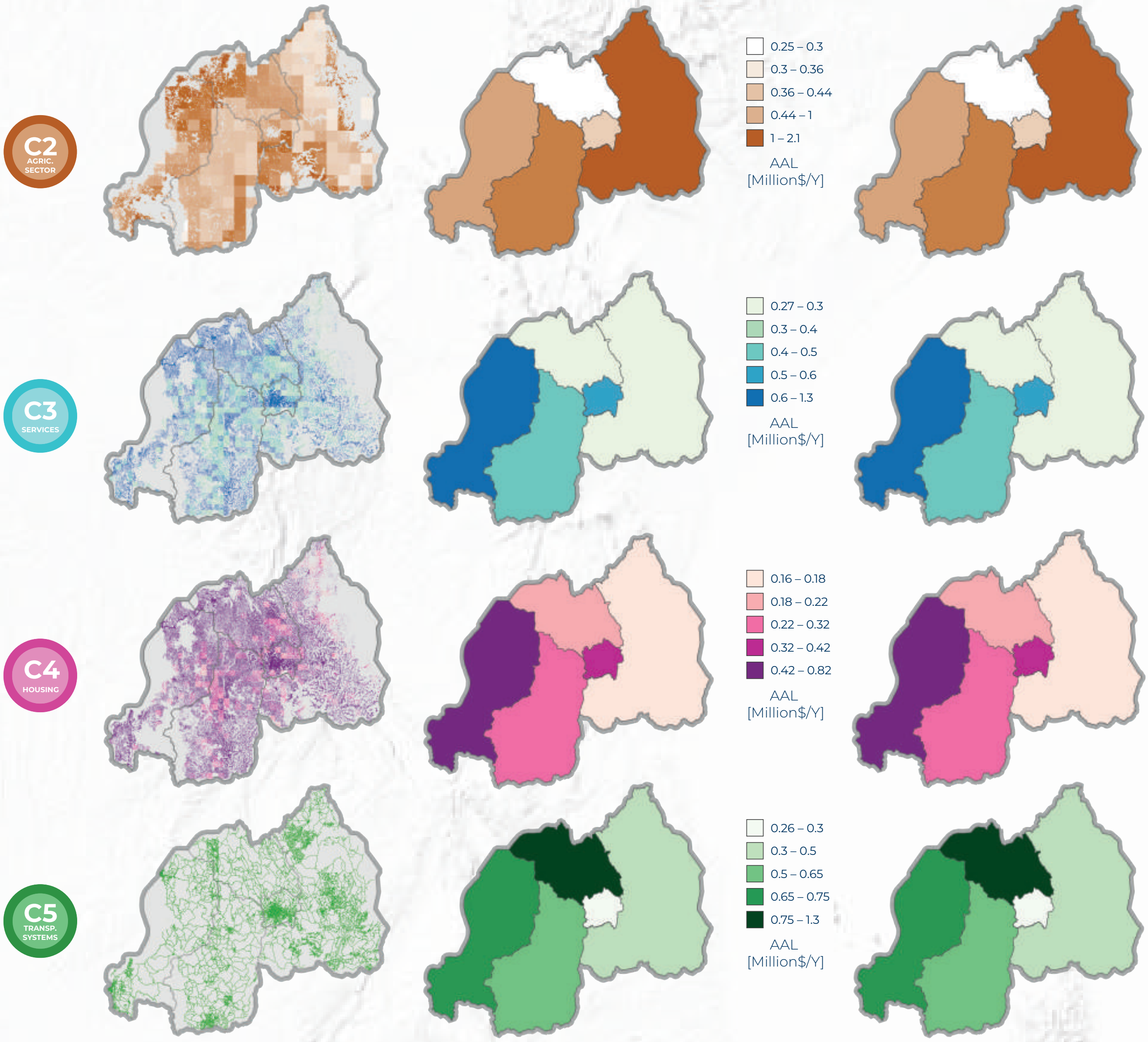
KEY MESSAGES

- The AAL distribution for Housing and Services identifies hotspots in 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 is the one showing 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.

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



RESULTS | FLOODS

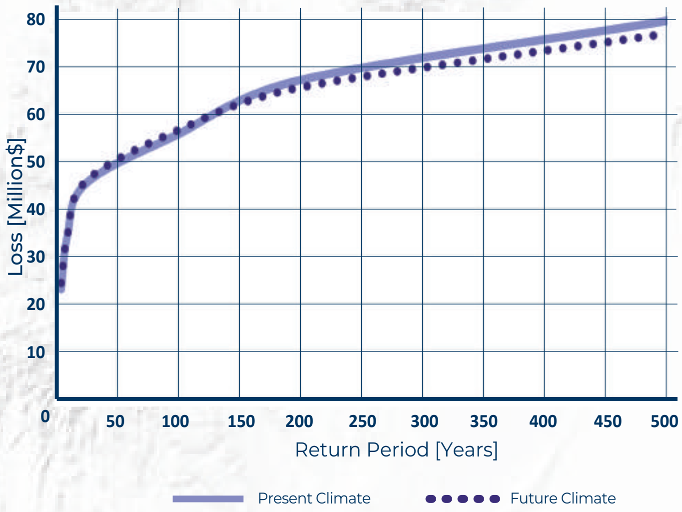
KEY MESSAGES

- The PML curve rises steep in the first part, the one characterised by the high frequency events. The curves for present and future conditions do not differ significantly.

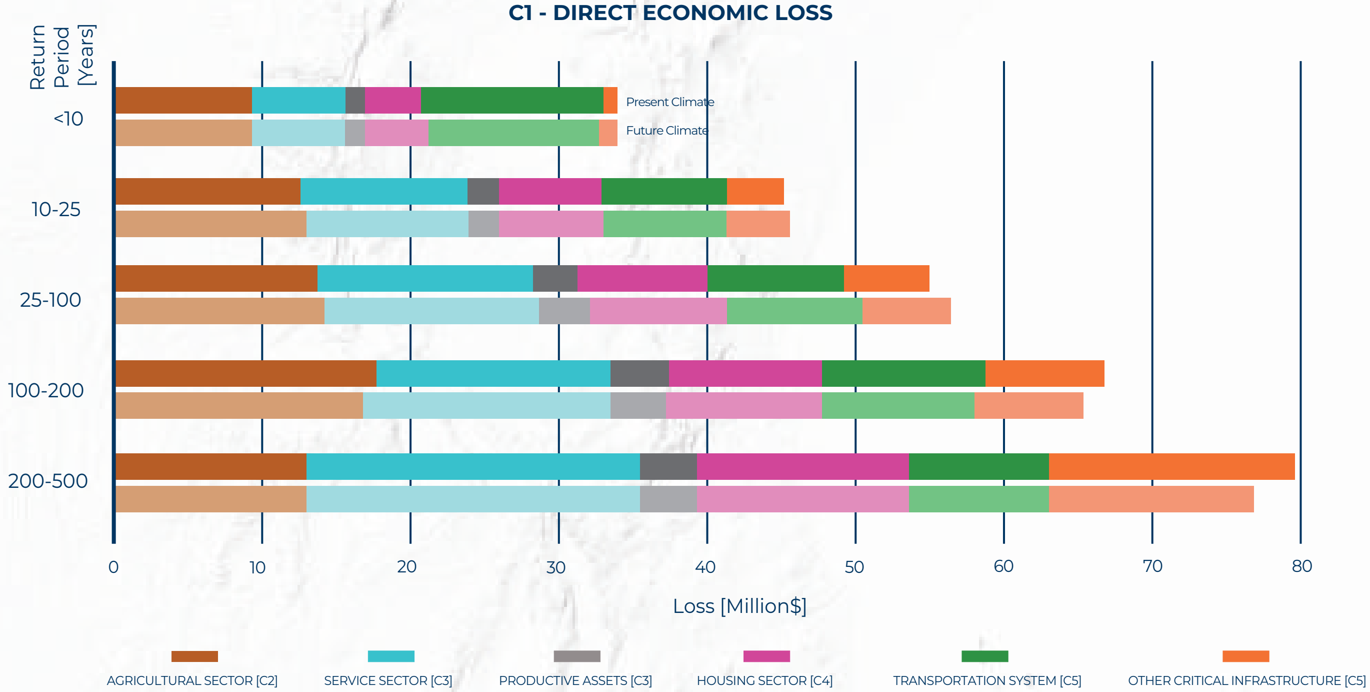
- The share of losses between the sectors for the different return periods does not change significantly, even though it is possible to notice a stronger contribution to the losses from the service sector and the critical infrastructures as we move to more infrequent and damaging events.

- The PML curve rises steep till the 25 year loss and flattens after that. 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

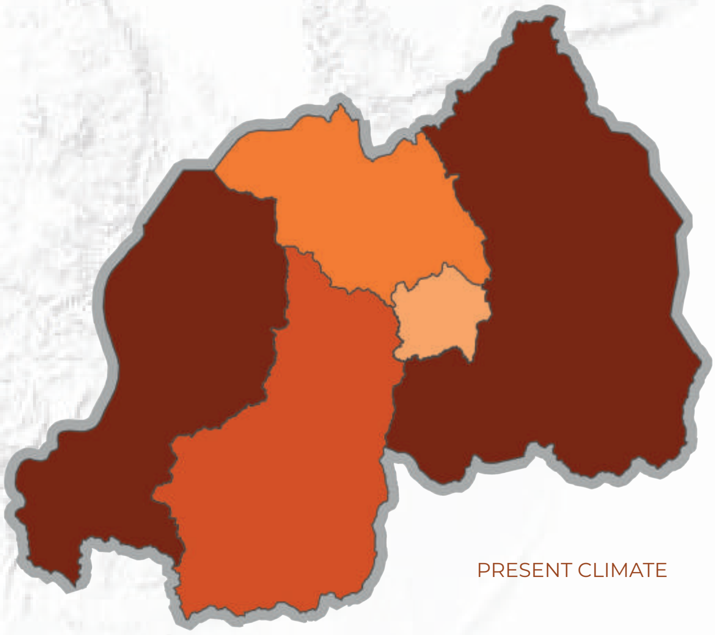


RESULTS | DROUGHTS

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.

KEY MESSAGES

- With respect to present 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.
- The GDP affected by droughts is expected to increase by a factor 7. While presently, annually on average 1.9% of the GDP is affected by droughts, this is expected to rise to 13.7%.
- In the future conditions 6 times more livestock is expected to be annually affected by droughts. Currently, on average 2.8% of the livestock are annually affected by drought conditions. In the future conditions this is expected to be 17%.
- Currently, on average about 300,000 people (2.5%) per year are affected by droughts. In the future conditions, this number is expected to increase to 15% (over 3 million people if population growth is accounted for).

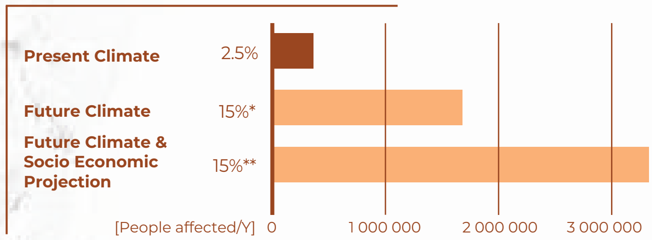


ANNUAL AVERAGE NUMBER OF AFFECTED PEOPLE [B1]

- 0 – 1000
- 1000 – 5000
- 5000 – 10.000
- 10.000 – 40.000
- 40.000 – 70.000
- 70.000 – 100.000

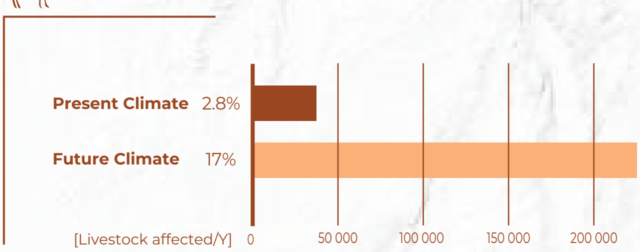
This map shows the average annually affected people by drought conditions. Drought conditions are calculated using the Standardized Precipitation-Evapotranspiration Index. Drought conditions are defined as at least three months of dry conditions (see glossary).

ANNUAL AVERAGE NUMBER OF AFFECTED PEOPLE [B1]

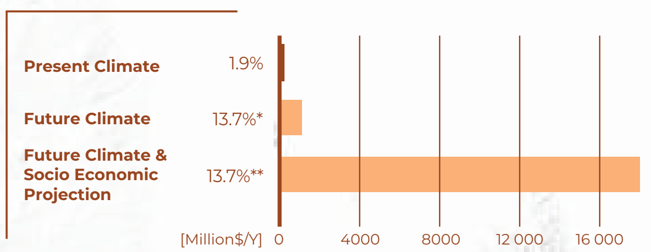


* % computed with reference to the total 2016 Population / GDP
** % computed with reference to the total 2050 Population / GDP

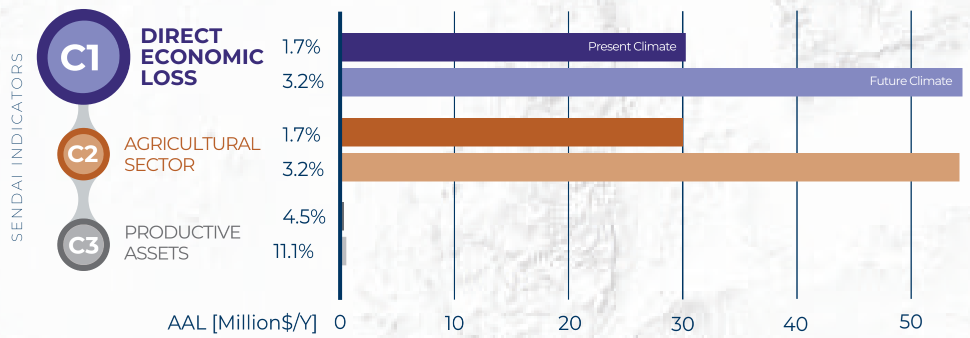
ANNUAL AVERAGE NUMBER OF AFFECTED LIVESTOCK



ANNUAL AVERAGE AFFECTED GDP



RESULTS | DROUGHTS



C2 is computed considering only the direct loss suffered because of a loss of agricultural (crop) production with respect to a reference production in the present climate. The crops considered in the analysis are the ones that contribute at country level to at least 85% of the total gross crop production value. It might therefore happen that crops that have an important role in the local agriculture (commercial or for subsistence) might be neglected in the overall analysis. C3 is computed considering only the loss in hydropower production as compared to a nominal production in present climate.

KEY MESSAGES

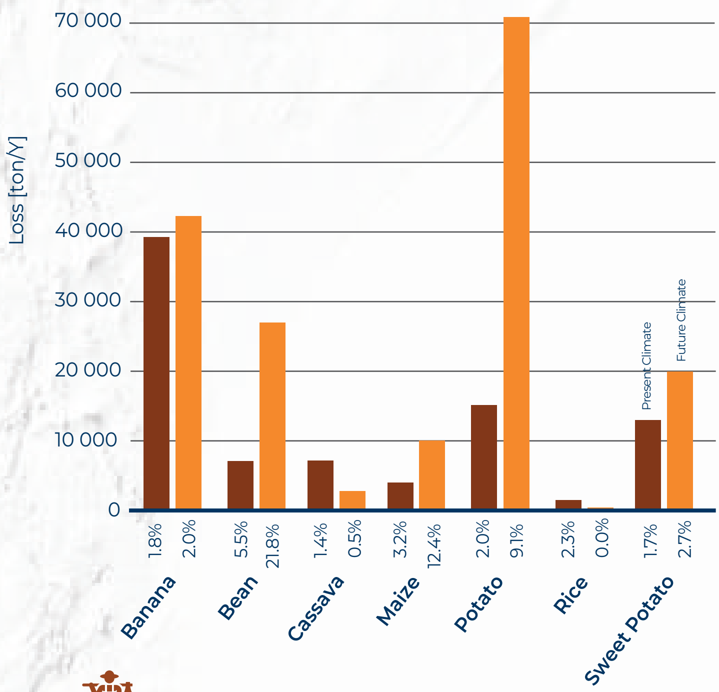
- Losses in agricultural production (C2) are projected to almost double under future climate conditions, but still remain low compared to the total income from crops (< 4%). Losses in hydropower generation (C3) due to drought are expected to change with a factor of 2.5, when comparing present and future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

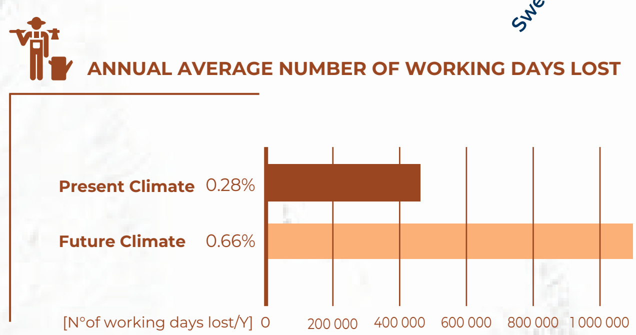
- Banana, bean and (sweet) potato are dominant crops in determining the losses due to agricultural production under present and future climate conditions. For future conditions, large increases in losses are projected for potato and bean. The production loss for bean, maize and potato is relatively high under future climate conditions (> 9%).

- The loss in number of working days is projected to more than double under future conditions. The loss of working days still remains less than 1% of total working days for both present and future situations. However, the number of lost working days, expressed as a percentage of the average amount of days required for harvesting, is circa 5 times higher.

AGRICULTURAL PRODUCTION LOSS



ANNUAL AVERAGE NUMBER OF WORKING DAYS LOST



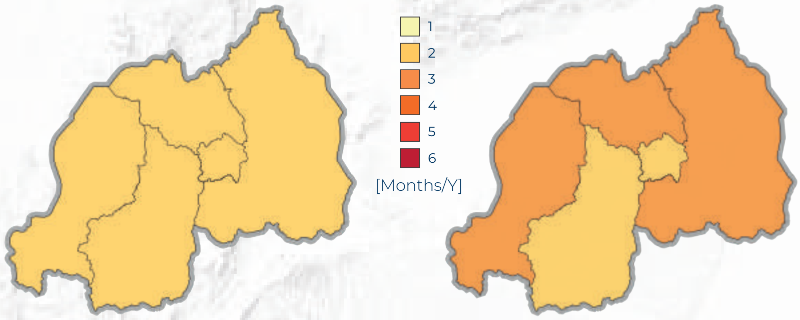
RESULTS | DROUGHTS

Present Climate | Future Climate

SPEI

Standardised Precipitation-Evapotranspiration Index

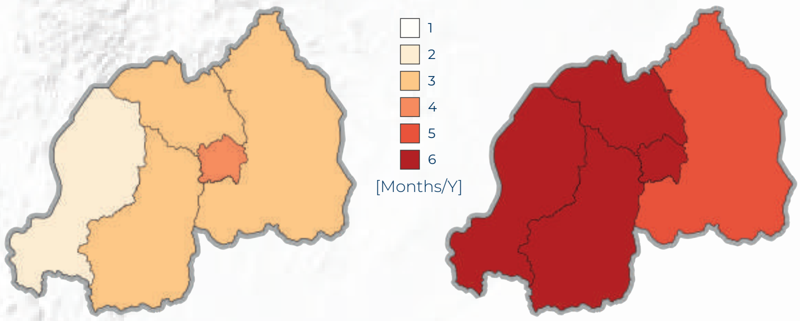
This map denotes the average amount of dry months in a year for a return period of 1 in 10 years. Dry months are defined using the Standardized Precipitation minus Evapotranspiration Index (SPEI; see 'Drought' in Glossary). This is particularly important for areas dependent on rainfall for their water resources. In future climate conditions particularly the north may see an increase in droughts, with more than 3 months of dry conditions per year for a once in 10 years event



SSMI

Standardized Soil Moisture Index

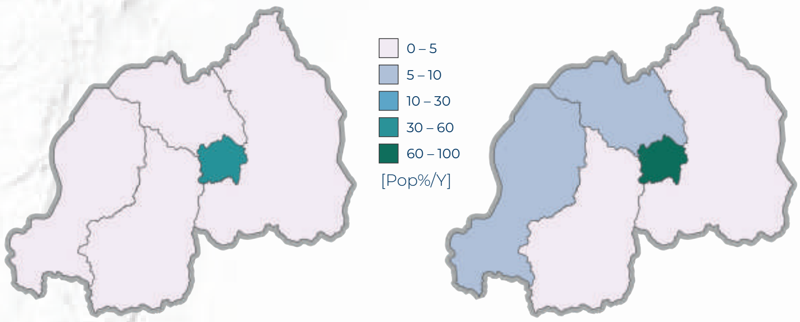
This map denotes the average amount of months per year with low soil moisture conditions for a return period of 1 in 10 years. Soil moisture is calculated using the Standardized Soil Moisture Index (SSMI) using the same threshold as SPEI (see 'Drought' in Glossary). Under future climate conditions dry soil moisture condition will drastically aggravate, as the whole country will experience longer dry periods. Particularly the west of Rwanda sees a large increase in dry soil moisture conditions.



WCI

Water Crowding Index

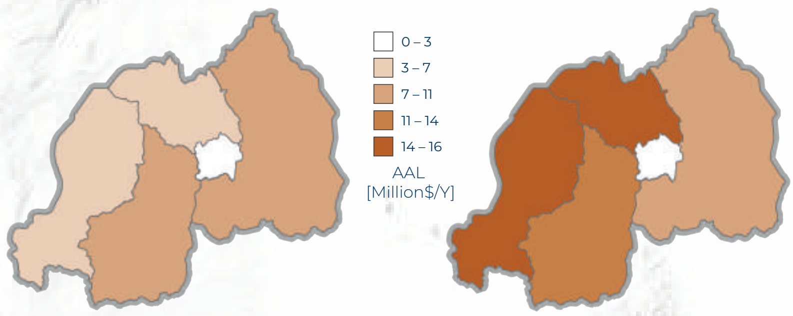
These maps show the percentage of the population per province experiencing water scarcity, based on the water available per person per year (<1000 m³/person/y). Water scarcity basically indicates that a population is dependent on water resources from outside their immediate region (~85 km²). Specifically, areas with high concentrations of people are dependent on outside water resources (primarily Kigali). Under future climate conditions this aggrevates for Kigali substantially, but also a small portion (<10%) of the population in Amajyaruguru (North) and Iburengerazuba (West) may become more dependent on water from elsewhere as water availability per person drops below the threshold in



C2

Agricultural Sector

Under present climate conditions, agricultural (crop) losses are slightly 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 Rwanda is projected, shifting the highest losses from the east and south towards these parts of the country.

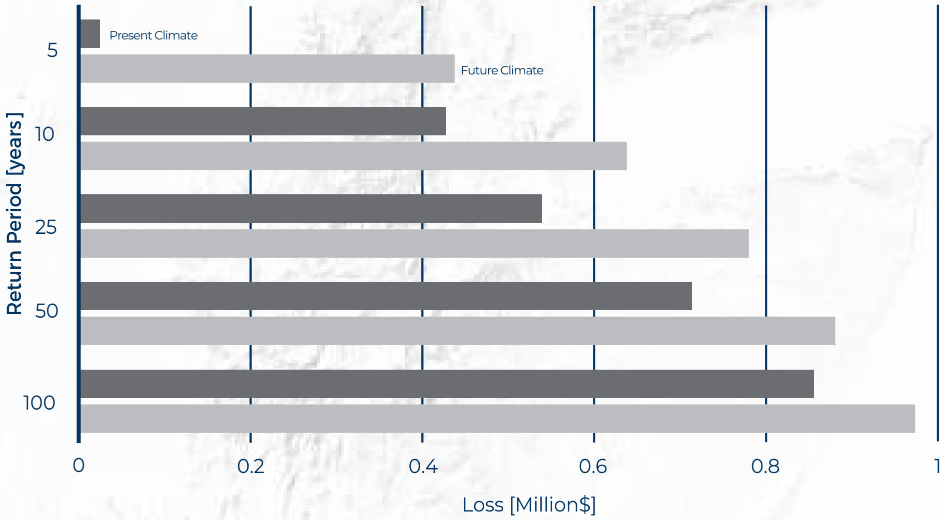


RESULTS | DROUGHTS

KEY MESSAGE

● For hydropower losses (defined as production below production, evaluated with average reservoir conditions in present climate), losses increase particularly for high frequent events (e.g. 1 in 5 years return period). Losses associated with very rare drought events also increase, but only slightly relatively.

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

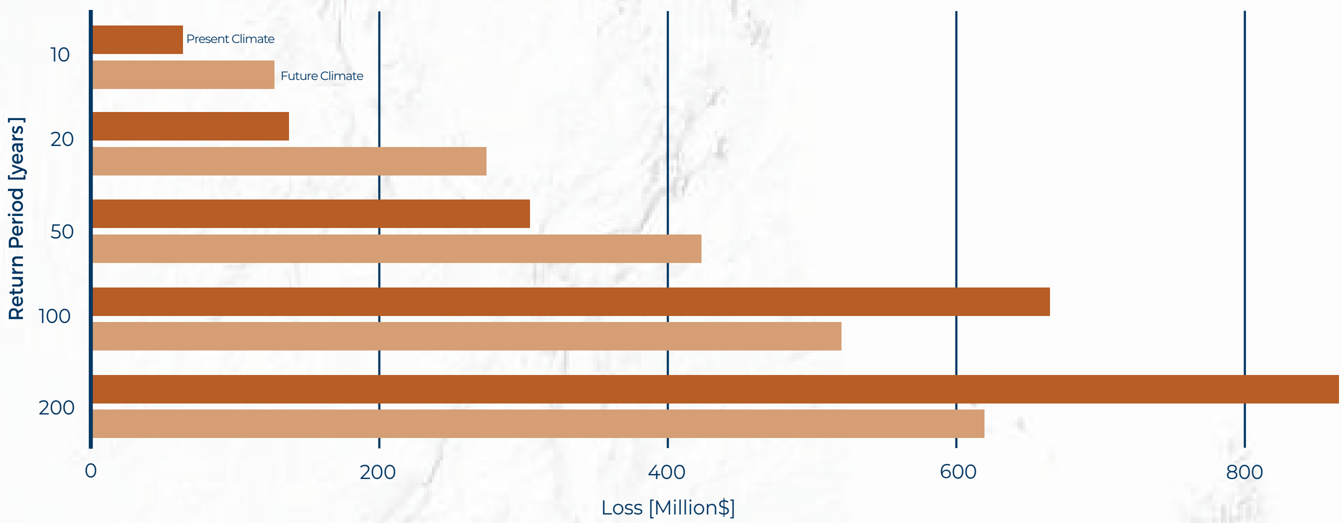


KEY MESSAGES

● In the case of agricultural income losses from crop production, the present climate conditions present a strong increase in expected losses when return periods go up from 10 to 200 years, especially for the rare events with a return period of 100 and 200 years. It is worth noting that these results might be affected by a high level of uncertainty as we move into the very rare losses domain.

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

PROBABLE MAXIMUM LOSS (PML)
C2 - AGRICULTURAL LOSS



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, from improving building codes and designing risk reduction measures, to carrying out macro-level assessments of the risks to prioritise investments. Risk metrics can help discern the contributions of different external factors (such as demographic growth, climate change, urbanization expansion, etc.) and provide a net measure of progress of disaster risk reduction policies implementation.

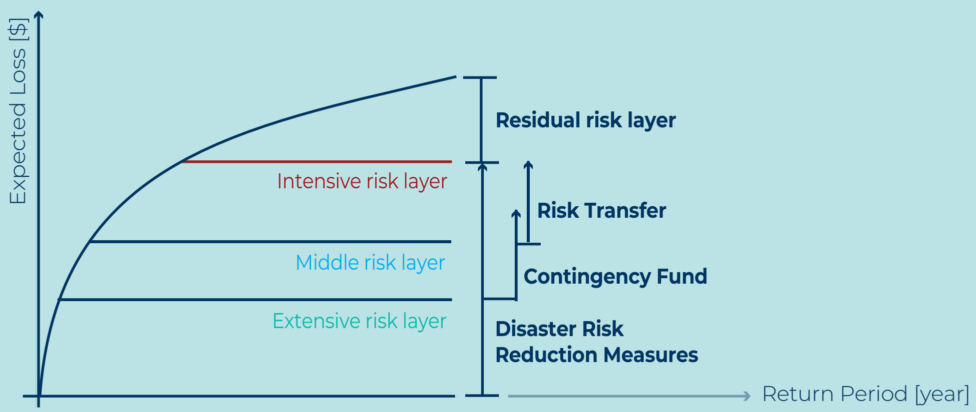
AAL can be interpreted as an opportunity cost, given that resources set aside to cover disaster losses could be used for development. Monitoring AAL in relation to other country economic indicators, such as GDP, capital stock, capital investment, reserves, and social expenditure, would provide indications of country fiscal resilience, broadly defined as comprising 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 (UNISDR, 2011 and 2013).

The PML curve is particularly useful in order to articulate a full DRR strategy. The PML curve 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 layers. Extensive Risk Layer: this layer is typically the one associated with risk reduction measures (e.g. flood defences, local vulnerability reduction interventions). Immediately after this extensive layer is the Mid Risk Layer, which builds up cumulative losses from higher impact events. The losses of this layer are normally mitigated using financial funds, like a contingency fund, that are normally put in place and managed by the country itself.

The losses that compose the Intensive Risk Layer (severe, infrequent hazard events) are difficult to finance on the country level, and a mechanism of risk transfer has to be put in place (e.g. insurance and reinsurance measures). The remaining layer of the curve determines the Residual Risk (catastrophic events), which is the risk that is considered acceptable/tolerable due to the extreme rarity of the events able to determine such loss levels. Due to this rarity, there are no concrete actions to reduce risk beyond preparedness actions that tend to ease the conditions determined by the event (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.

AVERAGE ANNUAL LOSS (AAL)*
Average Annual Loss (also Average Damage per year) is the estimated impact (in monetary terms or number of people) that a specific hazard is likely to cause, on average, in any given year. It is calculated based on losses (including zero losses) produced by all hazard occurrences over many years.

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
Drought refers to dryer than normal conditions of a specific area (i.e. variability). Not to be confused with aridity, which refers to a lack of water resources in absolute terms. In this profile, drought hazard is denoted by various indicators, covering a range of the drought types. Both hydrological and agricultural droughts are explicitly addressed, both in terms of hazard, exposed population and GDP, and corresponding losses related to crop production and hydropower generation. Drought hazard and risk are modelled based on distributed rainfall and a hydrological model solving the water balance (same one as used for the flood risk assessment). Dry conditions are defined as months with standardised SPEI values below -1.5, which correspond with the driest 6% of months as found in the period 1951-2000 (assessed for January, February, March, etc. separately).

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.

PROBABLE MAXIMUM LOSS (PML)*
PML is the value of the largest loss that could result from a disaster in a defined return period such as 1 in 100 years. The term PML is always accompanied by the return period associated with the loss.

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.

**UNISDR 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.

**UNISDR 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.unisdr.org

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africa.cimafoundation.org

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