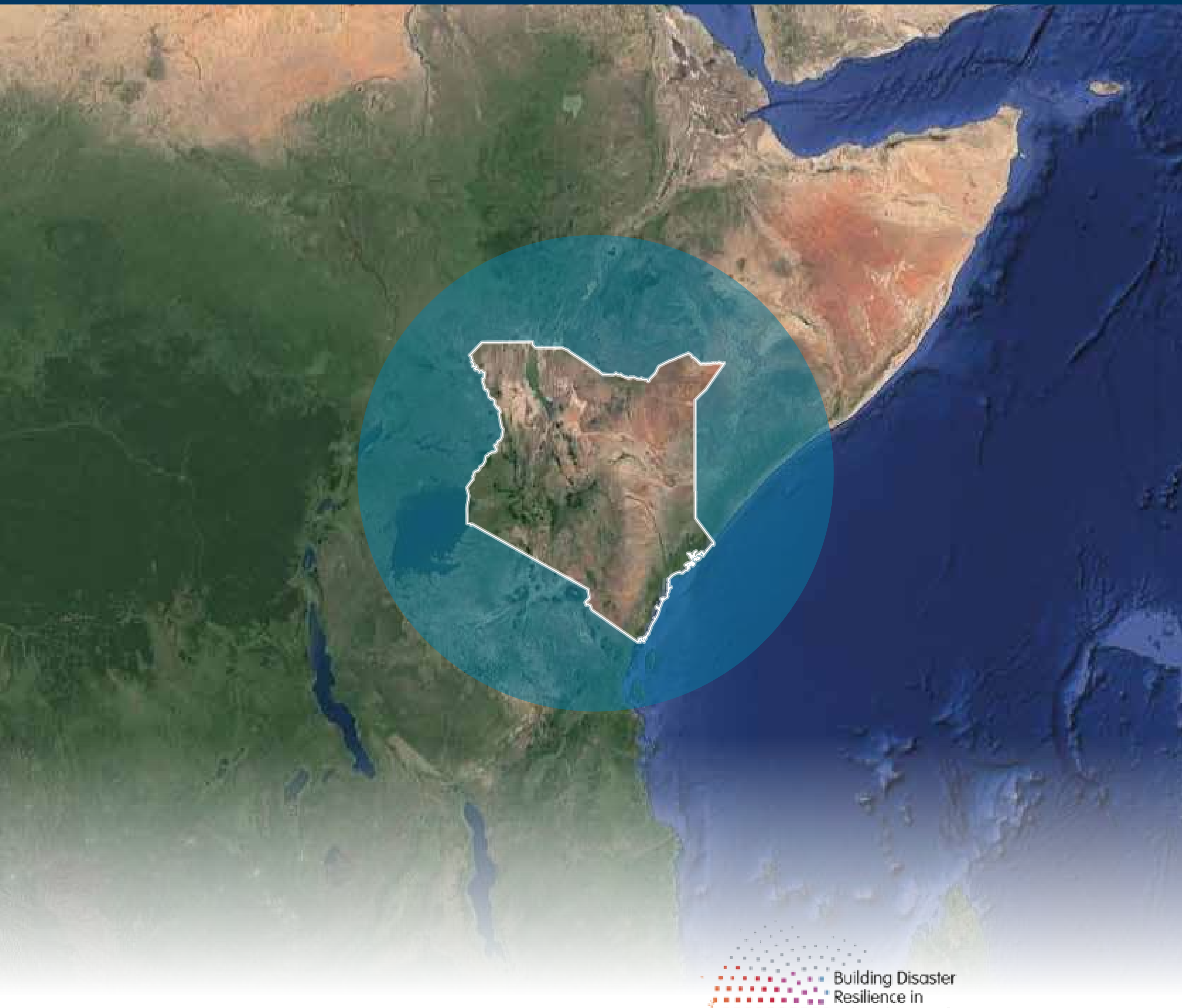
2019

DISASTER RISK PROFILE

Flood Drought

Kenya



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

Building Disaster Resilience in Sub-Saharan Africa

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

This project is funded by the European Union

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.

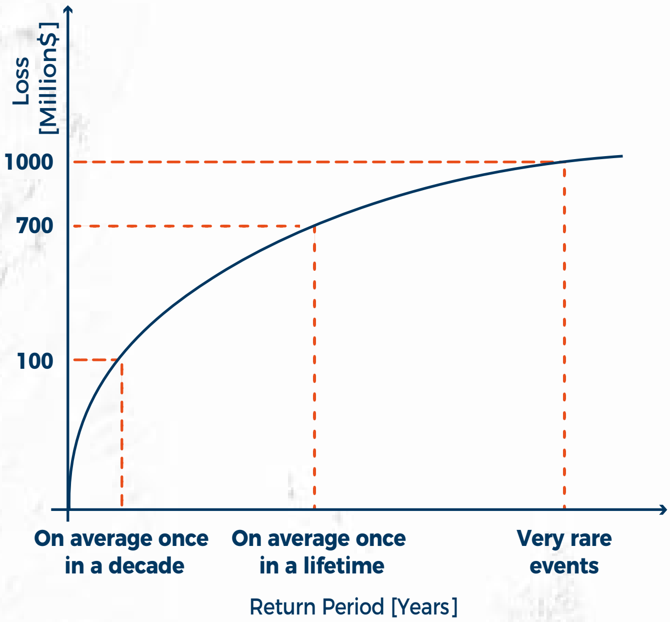
This disaster risk profile for floods and droughts is based on probabilistic risk assessment. Awareness of possible perils that may threaten human lives primarily derives from experience of past events. In theory, series of historical loss data long enough to be representative of all possible disastrous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

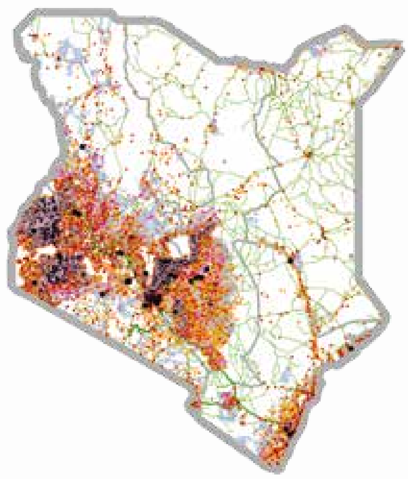
conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of an individual, a community, assets or systems to the impacts of hazards.

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.

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

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

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

A SENDAI ORIENTED RISK PROFILE

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

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

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

COUNTRY SOCIO-ECONOMIC OUTLOOK

OVERVIEW

Situated on the equator, in Eastern Africa, the republic of Kenya has made significant political, structural and economic reforms that have driven sustained economic growth, social development and political gains over the past decade. Its entrepreneurship and human capital give it huge potential for further growth, job creation and poverty reduction.

Kenya's population is young, with a median age of only 19 years, and mainly rural. Currently, only 27% of the population lives in urban areas, but this is changing, as the country continues to urbanize at a rapid rate of 4.23% [1].

While economic activity faltered following the 2008 global economic recession, growth resumed subsequently, reaching 5.8% in 2016, and placing Kenya as one of the fastest growing economies in Sub-Saharan Africa [2]. In that year, the major sources of GDP growth were in agriculture, forestry and fishing (15.2%), manufacturing (6.3%), transport and storage (9.7%), information and communication (6.1%), construction (8.2%), real estate (12.3%) and financial services (7.3%) [3]. Continued sustained growth and development are at risk of being thwarted by climate change. The flooding and drought risk assessments presented in this report show impacts on various sectors of the economy, most notably in the agricultural, housing, service and transport sectors. They also emphasize the vulnerability of urban areas, a problem which will only be exacerbated by increased urbanization. Thus, a thorough understanding of risk is essential to the healthy future development of the country.

SOCIO-ECONOMIC PROJECTIONS

Recently, 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 used in this risk profile envisages that the historical patterns of development are continued throughout the 21st century. Following this projection, Kenya's population will increase by 45% between 2016 and 2050 (World Bank Data), while GDP will increase sevenfold.

POPULATION	GDP
2016 Projection	2016 Projection
48.5	70.9
[Million People]	[Billion$]
77.9	509.9
2050 Projection	2050 Projection

KENYA

AREA : 581.309 km² *(KNBS.OR.KE)*

POPULATION DENSITY : 83.4 people/km²

MEDIAN AGE : 19.0 years *(UNDP - 2017)*

HDI - HUMAN DEVELOPMENT INDEX : 0.59 *(UNDP - 2017)*

LIFE EXPECTANCY AT BIRTH : 67.3 years *(UNDP - 2017)*

MEAN YEARS OF SCHOOLING : 6.5 years *(UNDP - 2017)*

EMPLOYMENT TO POP. RATIO (AGES > 15) : 57.9% *(WB - 2017)*

EMPLOYMENT IN AGRICULTURE : 38.0% *(WB - 2017)*

EMPLOYMENT IN SERVICES : 47.8% *(WB - 2017)*

data from:
www.knbs.or.ke
http://hdr.undp.org/
https://data.worldbank.org/indicator/

COUNTRY CLIMATE OUTLOOK

OVERVIEW

Kenya is located in Eastern Africa, which is generally seen as a major dry climate anomaly region in an 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].

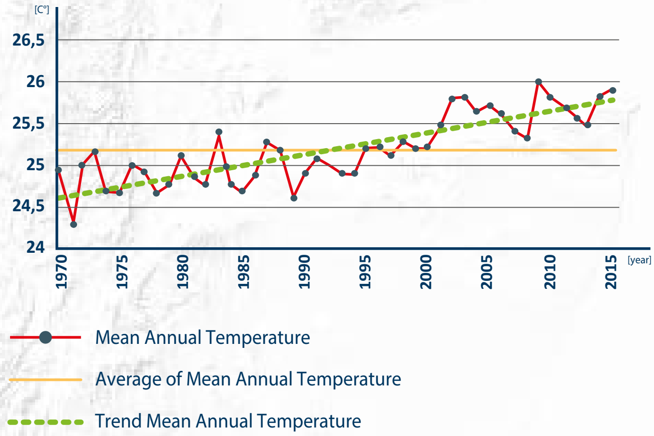
CLIMATE TRENDS

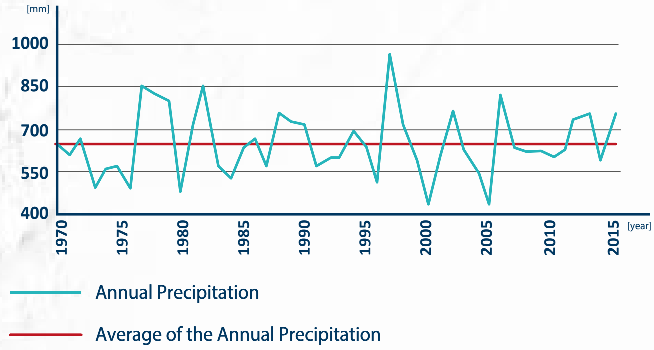
Similarly to other East African countries, Kenya has experienced a considerable increase in temperature in recent years. Climate data from 1970 to 2015 [8] shows warming of around 1°C, particularly noticeable from the 1990s onward.

Precipitation does not have as clear of a trend as air temperature, and is variable in time and space. Over the last 40 years, rainfalls have marginally increased in Kenya.

The average annual precipitation for Kenya is about 650 mm while the mean number of wet days is around 100, with a very large difference between wet and dry years.

TEMPERATURE AND PRECIPITATION TRENDS IN CURRENT CLIMATE





RIVERS OF KENYA

The Mau Forest Complex is the largest drainage basin in Kenya and acts as a natural water tower. Numerous rivers originate from the forest, including the Southern Ewaso Ng'iro, and the Mara River. Approximately 1 million people directly, with a further 10 million people indirectly, depend on these rivers that feed Lake Victoria, Lake Nakuru and Lake Natron. A secondary important drainage system is formed by the Tana and Galana rivers in the southern part of Kenya. Tana turns around the massif of Mount Kenya and then forms the large Masinga Reservoir. With a sequence of reservoirs located downstream of Masinga, the Tana River feeds a system of hydroelectric plants, which together produce up to a third of the country's electricity needs. The two largest rivers of the western Kenya Highlands are the Nzoia and the Yala. Yala Falls and Selby Falls (on a tributary of the Nzoia) have considerable potential for generating hydroelectric power. [9]

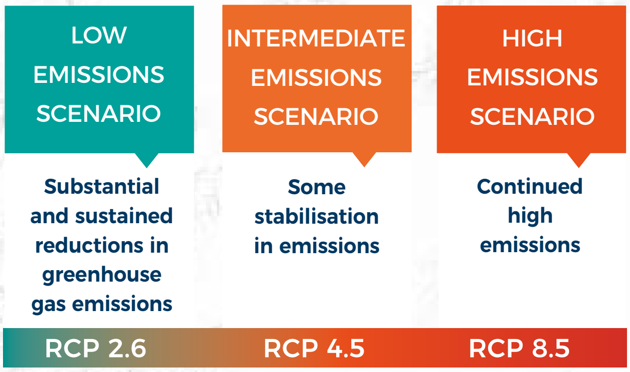
Photo Credit: Ryan Harve - https://commons.wikimedia.org/wiki/File:Masai_Mara_River_aerial.jpg

CLIMATE PROJECTIONS FOR KENYA

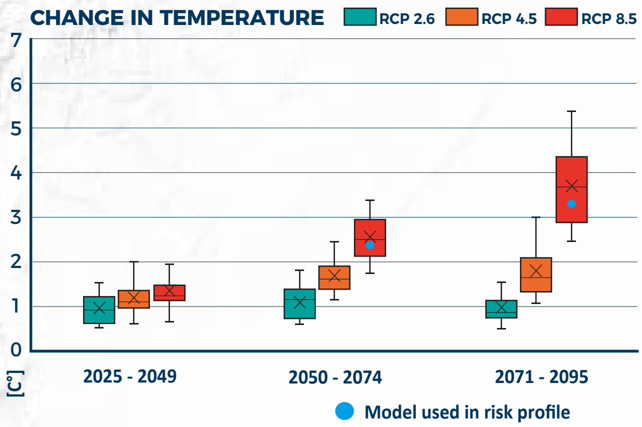
Climate projection studies are abundant for multiple different time spans and with various scales. Climate models are tools that the scientific community uses to assess trends in weather conditions over long periods. In a recent study [10] Alder, et al., compared the observed temperature and precipitations of the 1980-2004 period with the estimations of a set of global climate models provided by the Coupled Model Intercomparison Project Phase 5 (CMIP5). Three future periods (2025-2049, 2050-2074 and 2071-2095) were then analyzed for different greenhouse emission scenarios (see IPCC's Emissions Scenarios).

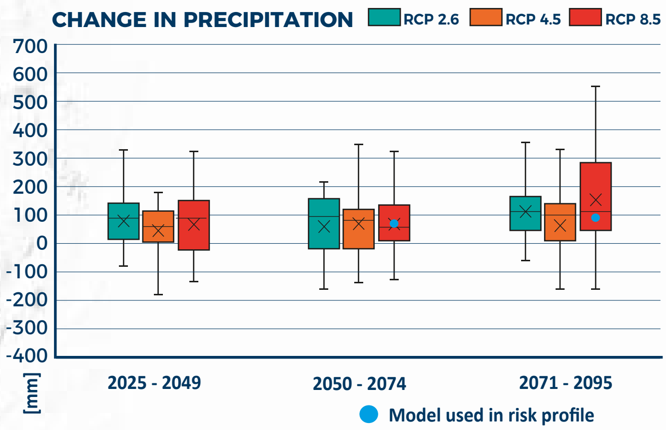
In all periods and in all emission scenarios, models showed an increase in temperature. The increase in temperature was more evident in high emissions scenarios and long term period projections. In high emission scenarios (RCP8.5), model projections showed an increase of between about 1.5˚C and 3.5˚C 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, but the models predicted a likely increase in precipitation for all time periods and for all emission scenarios.

Time Frame	Climate Projections (RCP 8.5 - High emission scenario)
Mid-term Future (2050-2074)	Increase in temperature from 1.5˚C to 3.5˚C uncertain variations in precipitation, with possible increase
Far Future (2071-2095)	Increase in temperature from 2.5˚C to 5.5˚C uncertain variations in precipitation, with possible increase



IPCC's Emissions scenarios for Climate Projections



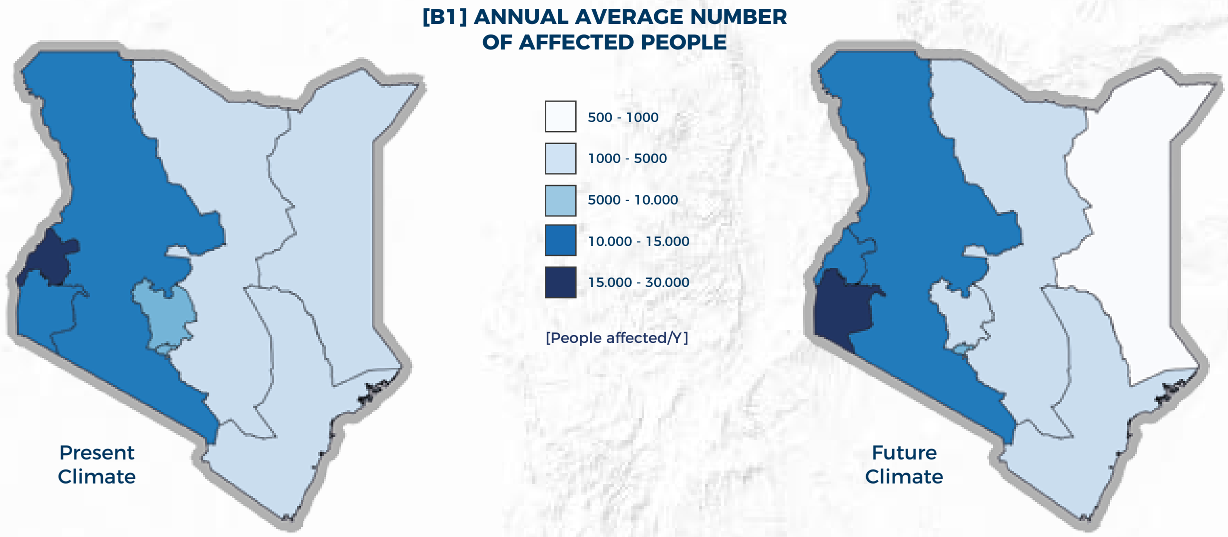


CLIMATE PROJECTIONS USED IN THIS RISK PROFILE

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) [11, 12, 13]

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 model forecasted changes in temperature and annual precipitation by the end of the century, in line with the range of variability of the 26 global models analyzed in the study from Alder and Hostetler [10], even though the regional model tends to predict smaller increases in temperature and precipitation with respect to the ensemble average. 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



KEY MESSAGES

● Floods affect on average about 75.000 people every year, more or less 0.15% of the total population of the country.

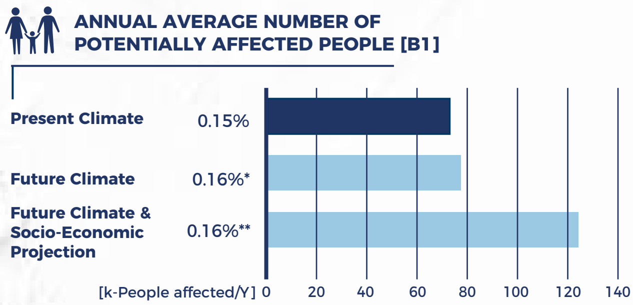
● The affected people are geographically concentrated in the most urbanised provinces, as to be expected: the Nyanza, Western and Rift Valley provinces. Nairobi, despite the limited size of the province, is significantly impacted.

● The GDP produced in areas affected by floods is also proportionally high, cumulating on average 0.16% of the total national GDP.

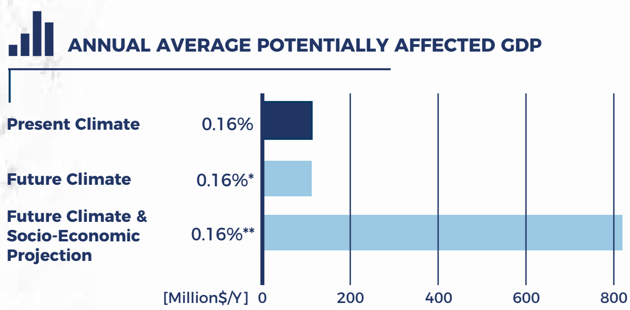
● Future climate projections do not seem to drastically change the risk-scape and its geographical pattern: a slight increase is visible at the national level when future climatic conditions are taken as a forcing on the present population and GDP distribution. This variation is however small if one takes into account the uncertainty of these types of predictions.

● The increase in risk becomes evident when the future climatic conditions are paired with the projection of future growth in population and GDP**: affected population almost doubles and affected GDP increases by one order of magnitude.

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



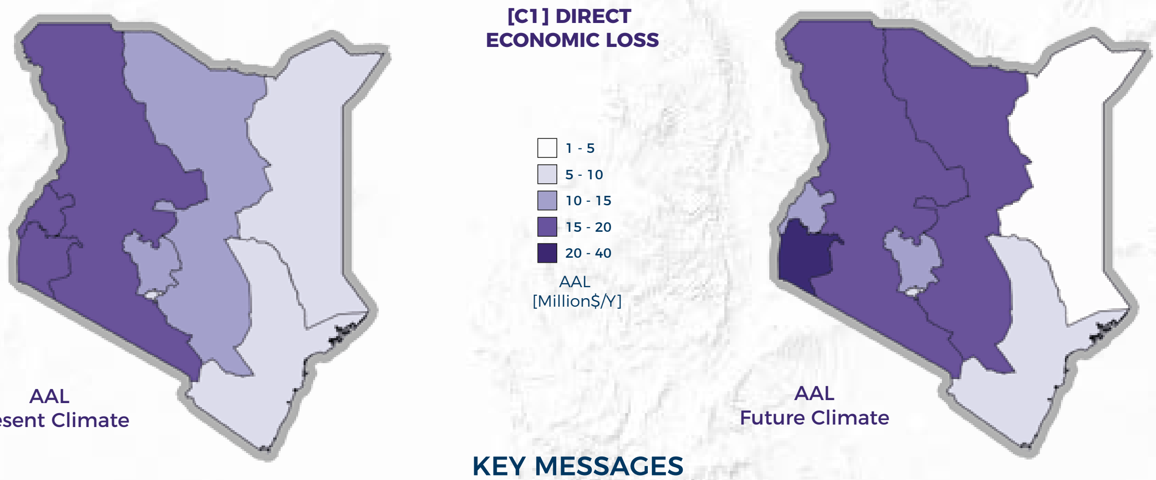
* % computed with reference to the total 2016 Population
** % computed with reference to the total 2050 Population



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

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

RESULTS | FLOODS

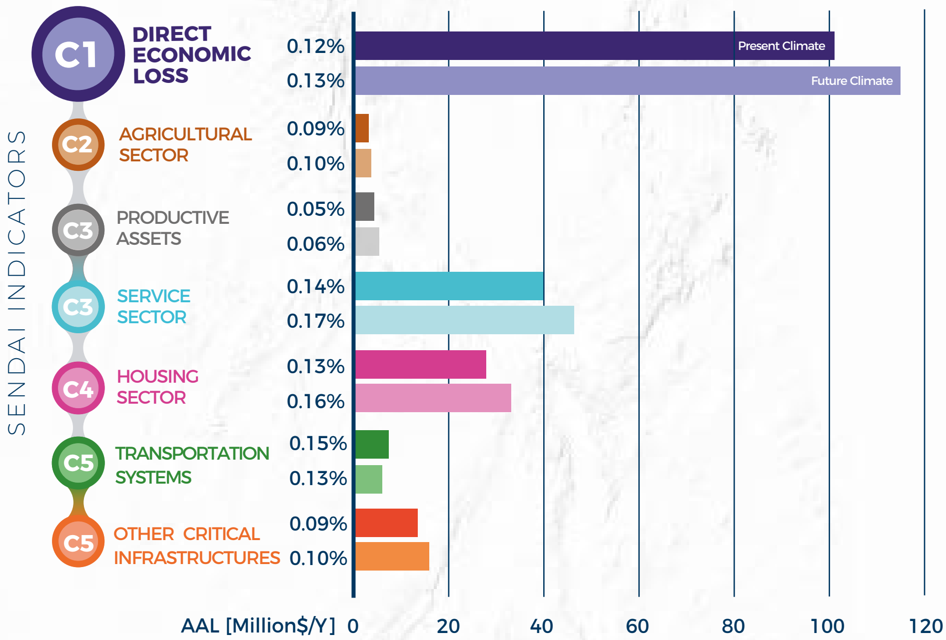


KEY MESSAGES

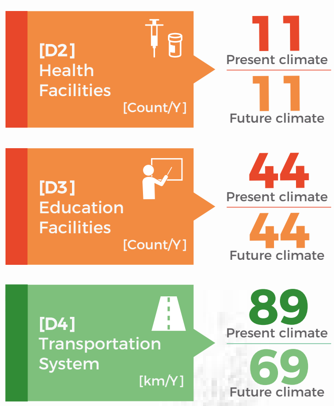
● The direct economic loss in Kenya is geographically distributed in line with the exposed values but provinces around Lake Victoria are the ones that show the biggest losses in this case. The pattern is confirmed in future climate predictions, where a significant increase of the losses (around 25%) is visible.

● The value of the average direct economic losses every year is 100 million USD. That accounts for roughly 0.12 percent of the total stock value in the present climate. The larger portion of losses is due to the housing, service, health sectors and education facilities, that together account for about 70% of the overall loss, while the productive and agricultural sectors account together for less than 10%.

● The proportion of the different sectors to the overall loss does not change significantly in the future and losses tend to increase with the exception of the transportation sector. This is due to the pattern of future flood hazards that show an increase in the south western region of Kenya, but a decrease in the eastern part. As a consequence, the sector in which losses are least affected by climate change is transportation due to the uniform distribution of the transport network in all provinces.



AFFECTED INFRASTRUCTURES [D1]



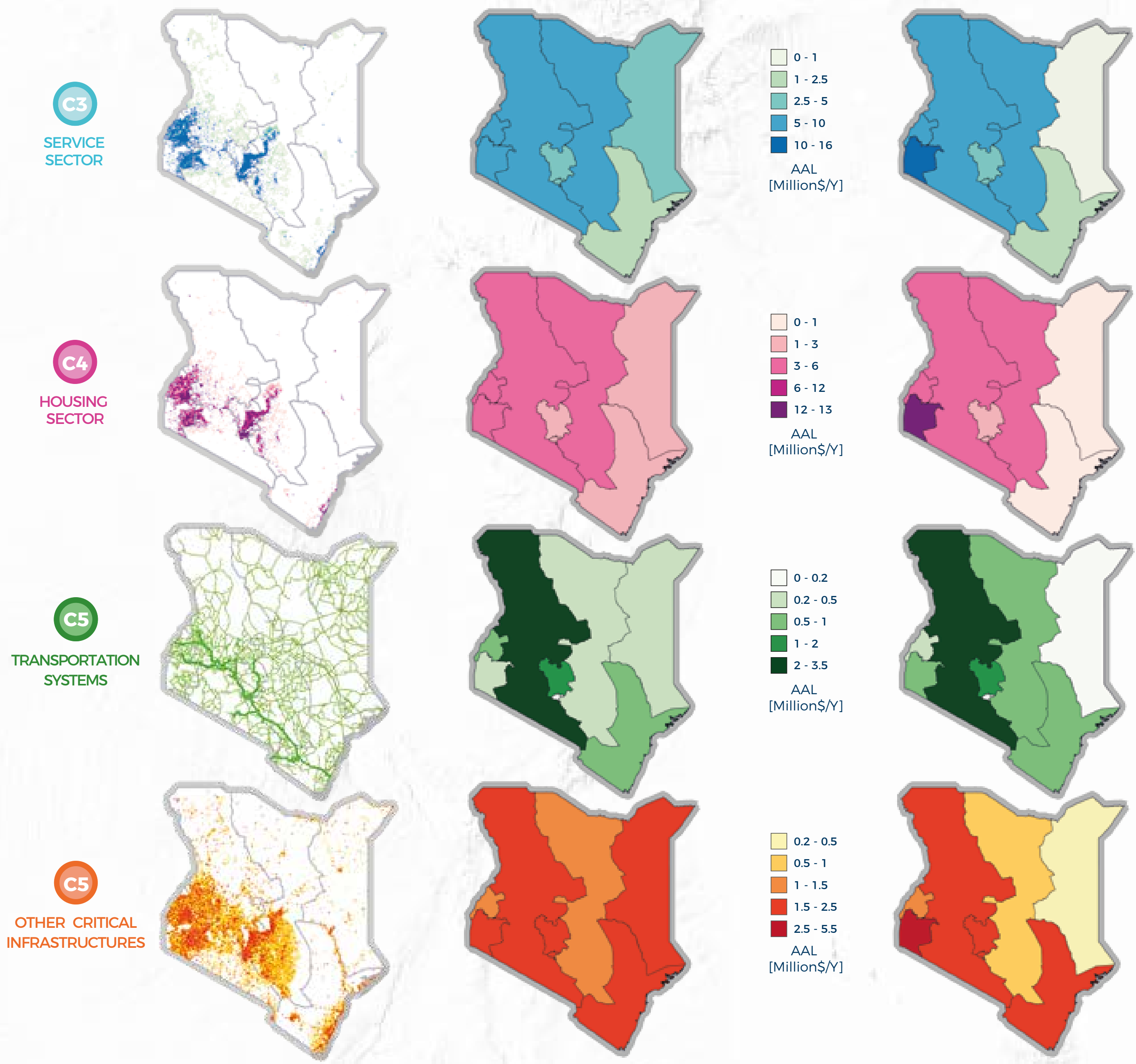
RESULTS | FLOODS

KEY MESSAGES

- The AAL distribution for the housing and service sectors clearly resembles the exposure distribution, identifying hotspots in the Nyanza, Western,Rift Valley and Eastern provinces.

- Comparisons between present and future climate AALs for all sectors show an increase of losses in the western and central parts of the country with one hotspot in Nyanza, while a decrease is visible in the north eastern part of the country.

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



RESULTS | FLOODS

KEY MESSAGES

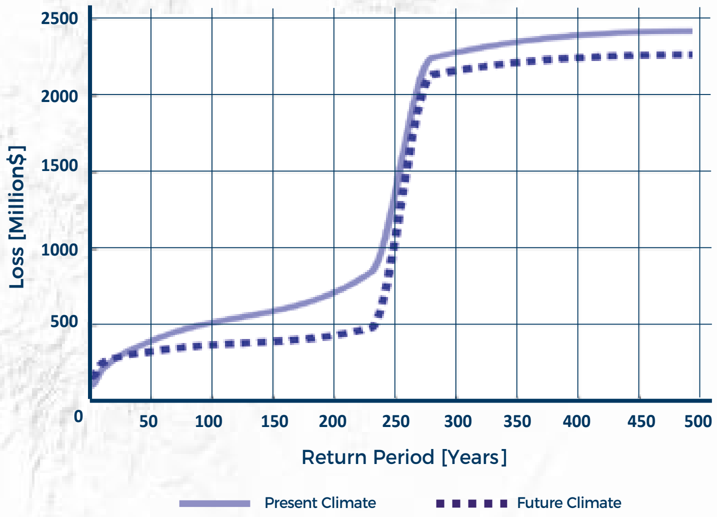
- The PML curve comparison highlights that in future climate conditions the frequency of small losses will be higher, but this tendency will revert when losses are higher than a 50 year return period.

- In this future scenario, DRR investments will produce even more benefits than they would in present climate conditions. They can be seen as "no regret" measures of climate adaptation.

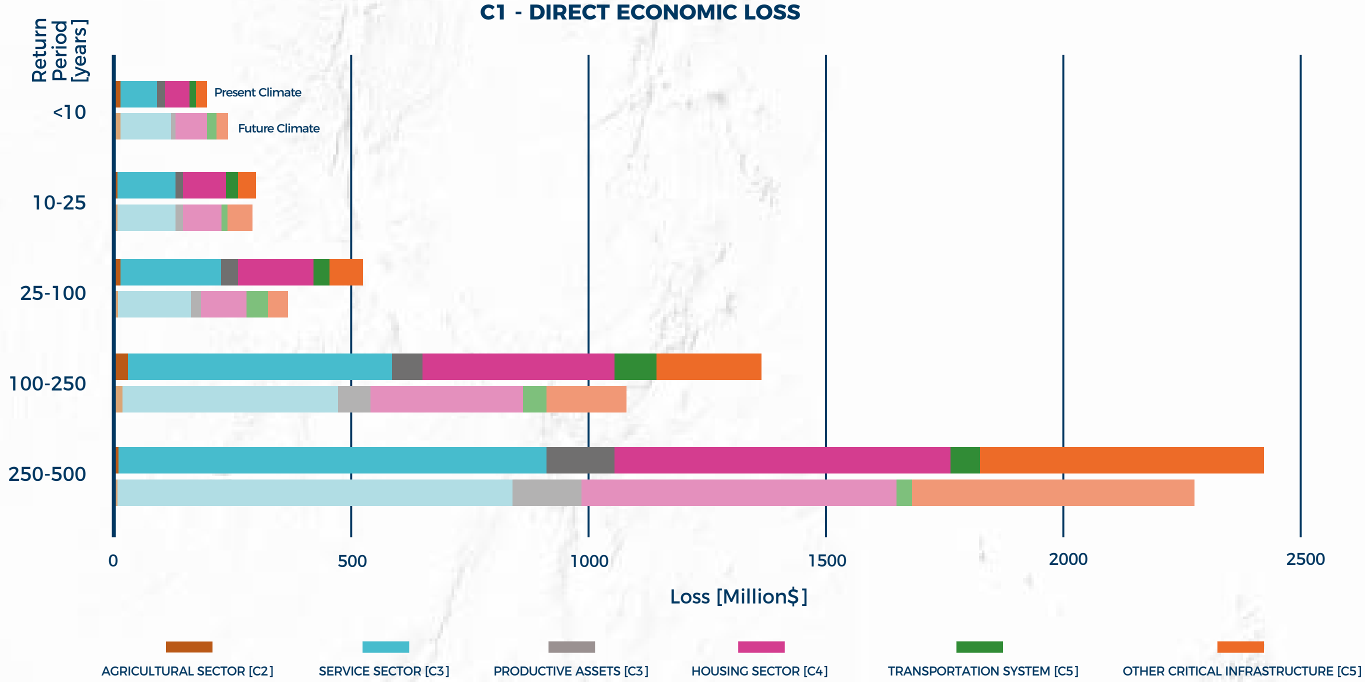
- The share of losses of the critical infrastructure sector tends to increase drastically when less frequent losses are considered but for all return periods the PML values are strongly determined by the combined losses of the housing, service and critical facilities sectors.

- The PML curve rises steeply until the 30 year loss and shows a second change in slope after the 200 year loss. This second rise is due to the sudden exposure of the Nairobi urban area, when floods reach more major levels. The first rapid rise 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

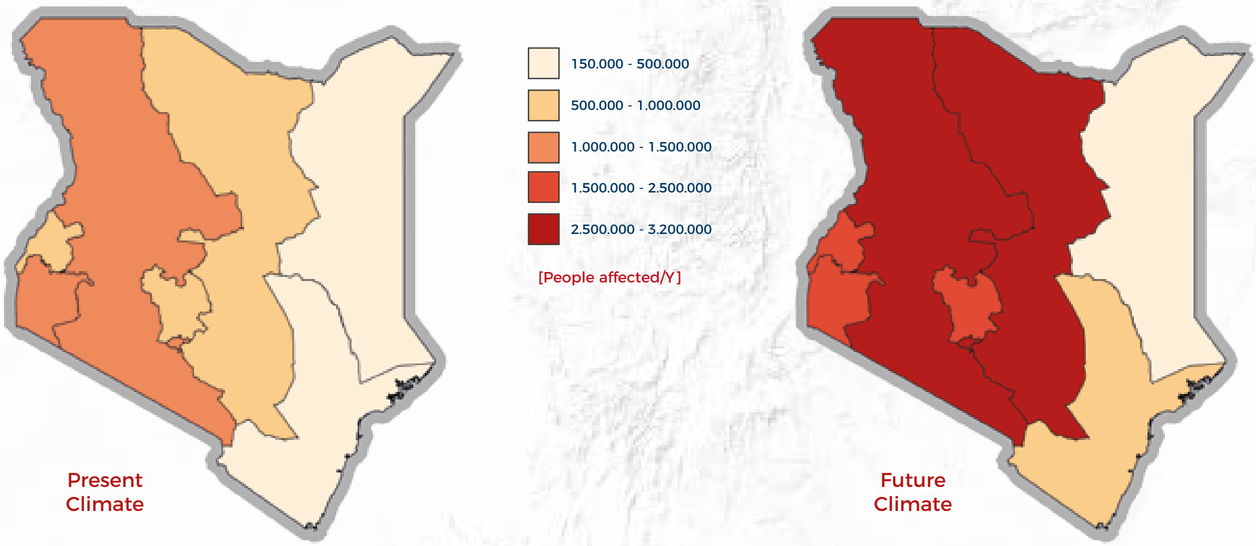


PROBABLE MAXIMUM LOSS CURVE (PML) ACROSS ALL SECTORS
C1 - DIRECT ECONOMIC LOSS



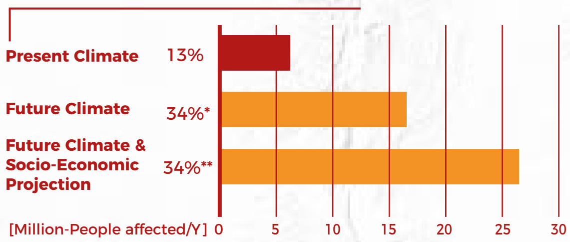
RESULTS | DROUGHTS

[B1] ANNUAL AVERAGE NUMBER OF AFFECTED PEOPLE



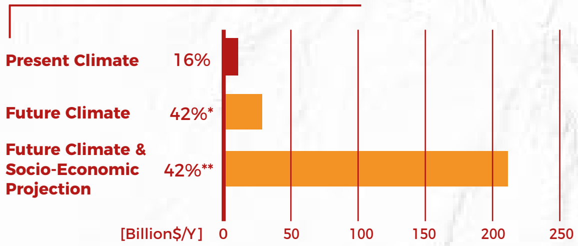
Annual average of population potentially affected by at least three months of drought conditions, as calculated using the standardized precipitation-evapotranspiration index (SPEI) and using a 3-month accumulation period.

ANNUAL AVERAGE NUMBER OF POTENTIALLY AFFECTED PEOPLE [B1]



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

ANNUAL AVERAGE POTENTIALLY AFFECTED GDP



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

KEY MESSAGES

- With respect to present conditions (1951-2000 climate), precipitation is expected to increase slightly, but a strong increase in temperature is also foreseen in the future (2050-2100 climate), causing an increase in the frequency of droughts.
- Currently, on average 6.5 million people (13%) per year are exposed to droughts. In the future, this number is expected to increase to 34% (more than 25 million people if population growth is accounted for).
- The GDP exposed to droughts is expected to triple. While presently on average 16% of the GDP is exposed to droughts, this is expected to rise to 42%.

RESULTS | DROUGHTS

KEY MESSAGES

- In the future two times more livestock is expected to be annually exposed to droughts. The current average of 21% is expected to rise to 48%.

- Maize, sugarcane and potato are dominant crops in determining losses due to the extent of their production losses under present and future climate conditions. In future climate conditions large increases in losses are projected for cabbage, cassava, potato, sweet potato and wheat. There will, however, be a remarkable decrease in production loss for sugarcane.

- For the loss in number of working days, an increase is projected under future conditions of circa 33%. The loss of working days is estimated to be less than 0.5% of total working days for both present and future situations. However, the number of working days lost, expressed as a percentage of the average amount of days required for harvesting, is circa five times higher.

- The pattern of agricultural losses shows a concentration of losses in the western part of the country. Under future climate conditions, there will be an increase throughout the whole country. The distribution map for labour days is comparable to the one for agricultural losses.

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

1310 | 0.33% Present climate

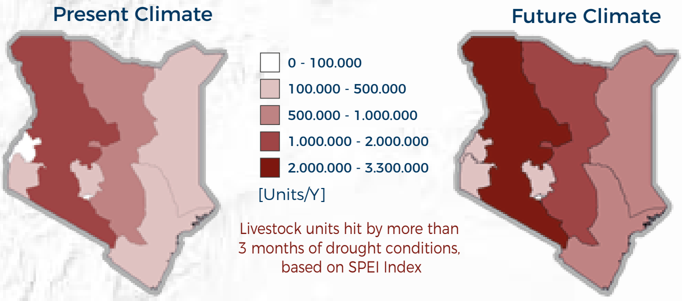
1971 | 0.49% Future climate

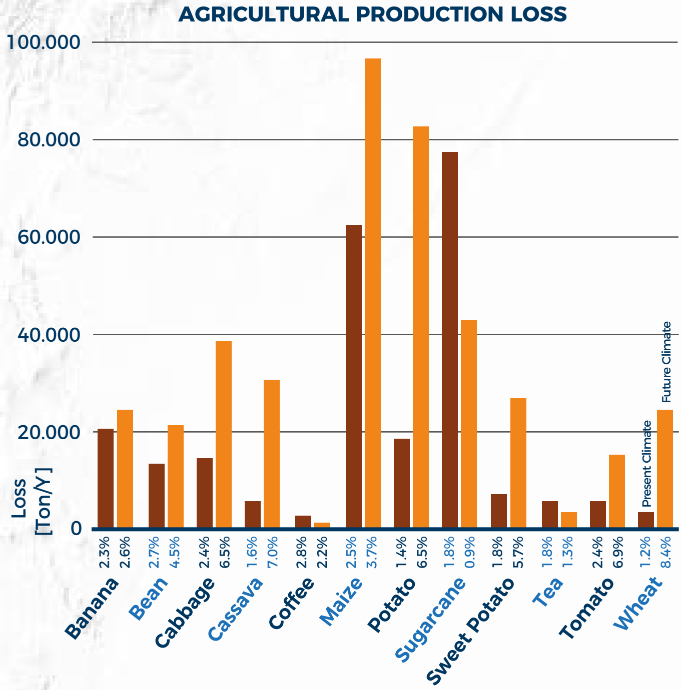
ANNUAL AVERAGE NUMBER OF POTENTIALLY AFFECTED LIVESTOCK UNITS* [k-Livestock units]

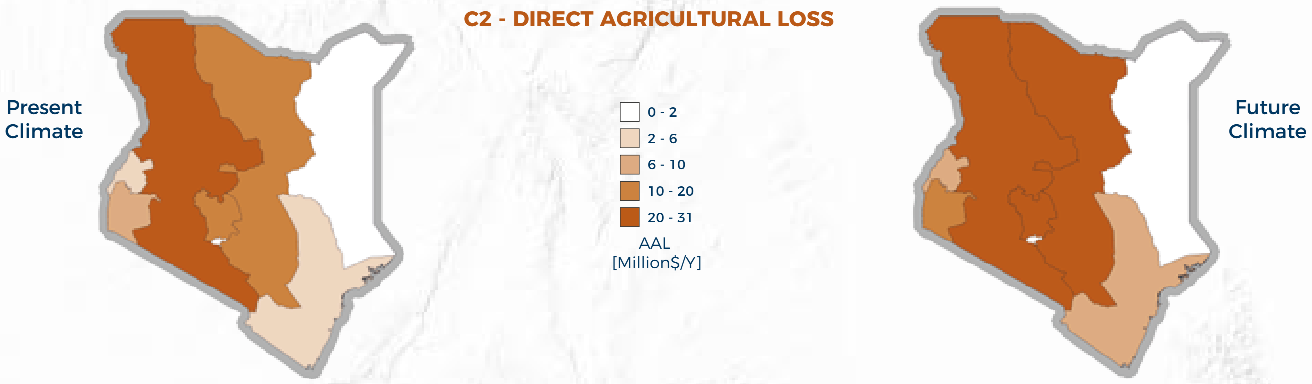
3300 | 21% Present climate

7360 | 48% Future climate

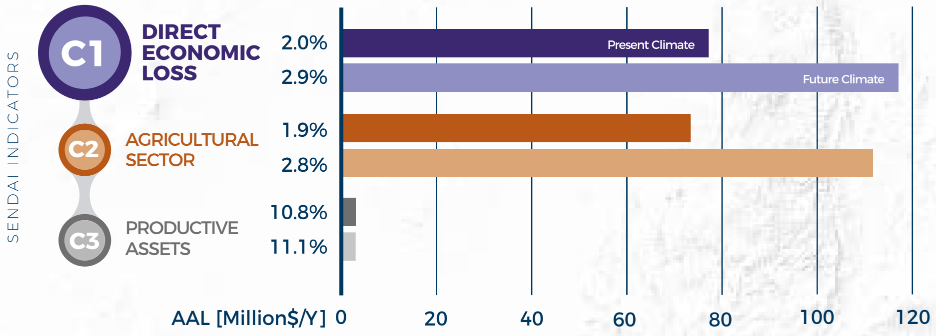
*Livestock is a summation of all livestock animals (referred to as livestock units) using FAO conversion factors







RESULTS | DROUGHTS



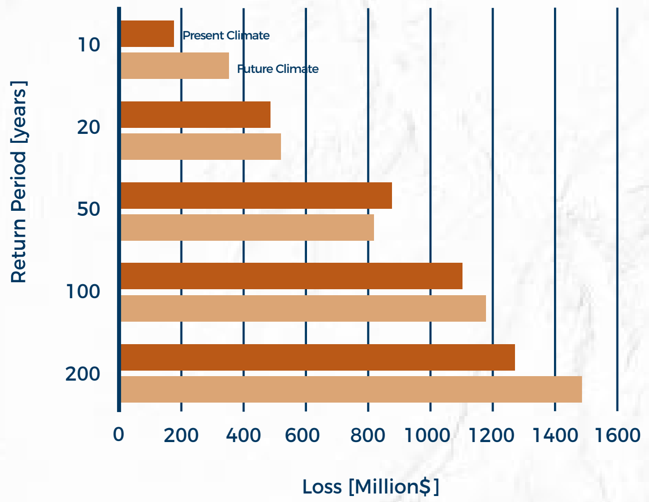
C2 is computed considering only direct loss associated with reference agricultural (crop) production. Reference crops considered in the analysis are the ones which contribute to at least 85% of the total country-level gross crop production value. It might therefore happen that crops which have an important 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

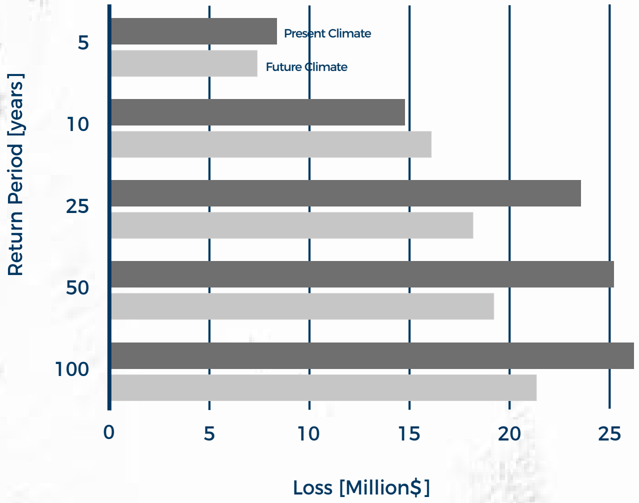
- Losses in agricultural production (C2) are projected to increase by more than 50%, but still remain low compared to total income from crops (< 3%). Losses in hydropower generation (C3) due to drought are not expected to change when comparing present and future climate conditions.This is a net result of losses from Turkwel increasing substantially, and losses slightly decreasing in the Tana basin.
- Total direct economic losses (C1) due to drought is completely dominated by the agricultural sector (C2) with a negligible contribution from the loss of hydropower (C3).

- In the case of agricultural income losses (defined as the production below a threshold, which is calculated as the lowest 20% production under present climate conditions), the present climate conditions present a gradual increase in expected losses when return periods go up from 10 to 200 years. It is worth noting that these might be affected by a high level of uncertainty as we move into the very rare losses domain.
- Agricultural income losses in future climate conditions are comparable with those in present climate conditions for the medium return periods, but increase more strongly for the lowest return period (10 years). The relative increase is highest for most frequent losses, i.e. almost doubling for the 10 year return period.
- For hydropower losses, losses decrease a bit for most of the return periods (losses only increase slightly for a return period of ten years).

PROBABLE MAXIMUM LOSS (PML)
C2 - AGRICULTURAL LOSS

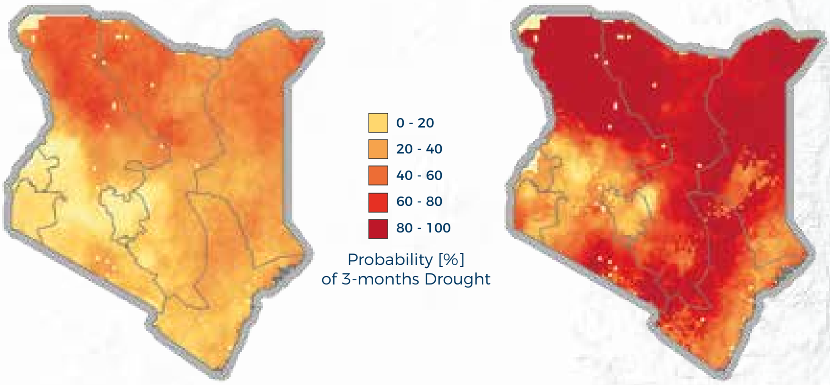


PROBABLE MAXIMUM LOSS (PML)
C3 - PRODUCTIVE ASSETS (HYDROPOWER LOSS)



RESULTS | DROUGHTS

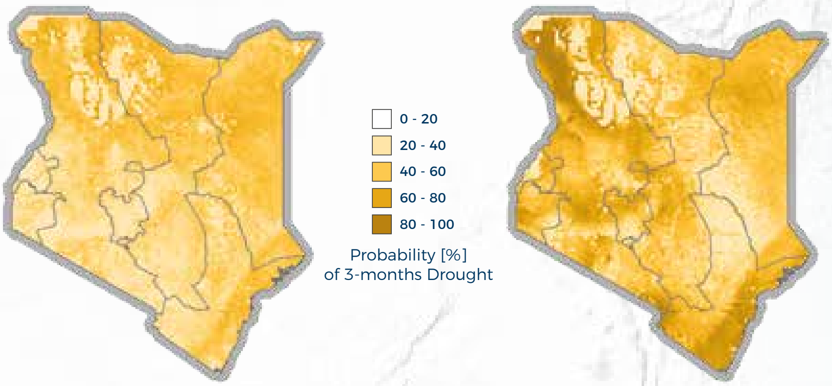
Present Climate   Future Climate



SPEI

Standardised Precipitation-Evapotranspiration Index

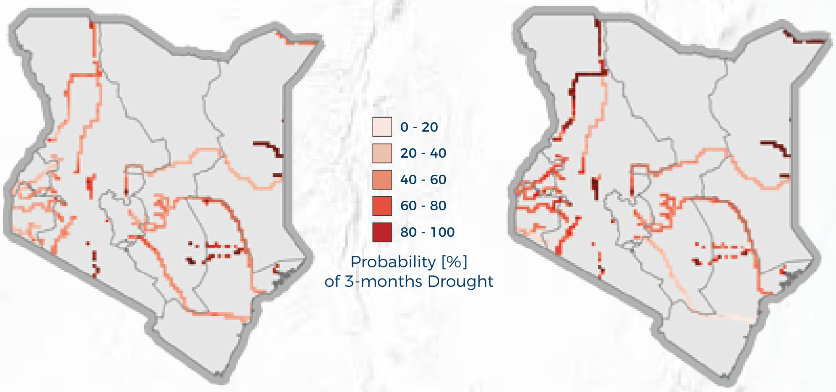
These maps denote the average annual chance of a meteorological drought occurring (%). Droughts are defined as 3 months of precipitation minus evapotranspiration values considerably below normal conditions; calculated through the Standardized Precipitation - Evapotranspiration Index (SPEI; see 'Drought' in Glossary). It can be noted that currently, the probability of droughts is the highest in the north of the country and in the Rift Valley. These places will also see the highest increase in droughts in a future climate. 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).

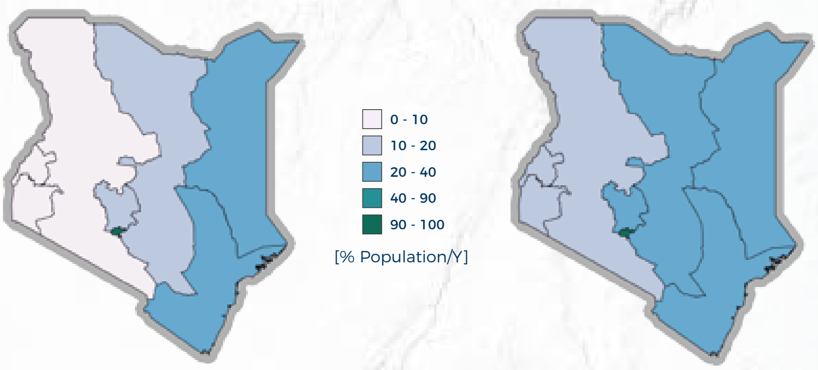
In the north of the country, the probability of droughts will increase the most. In Turkana and the south-east of Kenya, soil moisture droughts will become more frequent. This is particularly important for agricultural areas and nature.



SSFI - Standardised Streamflow Index

These maps denote the average annual chance of a hydrological drought occurring (%). Droughts are defined as 3 months of stream flow levels considerably below normal conditions; calculated through the Standardized StreamFlow Index (SSFI; see 'Drought' in Glossary).

The probability of droughts in the upstream reaches of rivers is quite high in Kenya. This is particularly important for areas dependent on rivers for their water resources.



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). Specifically, areas with high concentrations of people are dependent on outside water resources (primarily Nairobi, but also in the arid eastern part). With climate change, the proportion of the population dependent on water from elsewhere will increase throughout the entire country.

PROBABILISTIC RISK ASSESSMENT FOR RISK MANAGEMENT

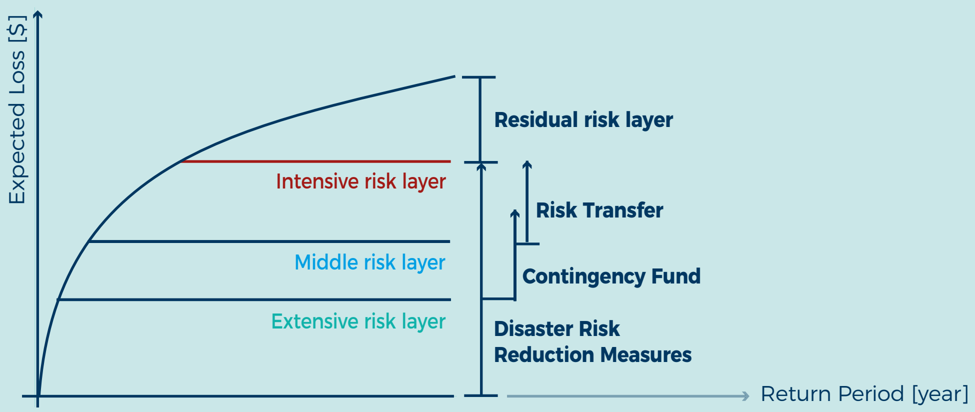
METRICS FOR RISK MANAGEMENT

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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[2] Kenya overview, WorldBank, https://www.worldbank.org/en/country/kenya/overview#1

[3] Kenya Economic Report 2017, Kenya Institute for Public Policy Research and Analysis (KIPPRA)

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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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