2019

DISASTER RISK PROFILE

Flood Drought

Namibia

Building Disaster Resilience in Sub-Saharan Africa

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

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

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UNDRR UN Office for Disaster Risk Reduction

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INTRODUCTION

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

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

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

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

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

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

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

PROBABILISTIC RISK PROFILE: METHODOLOGY

PROBABILISTIC RISK ASSESSMENT

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

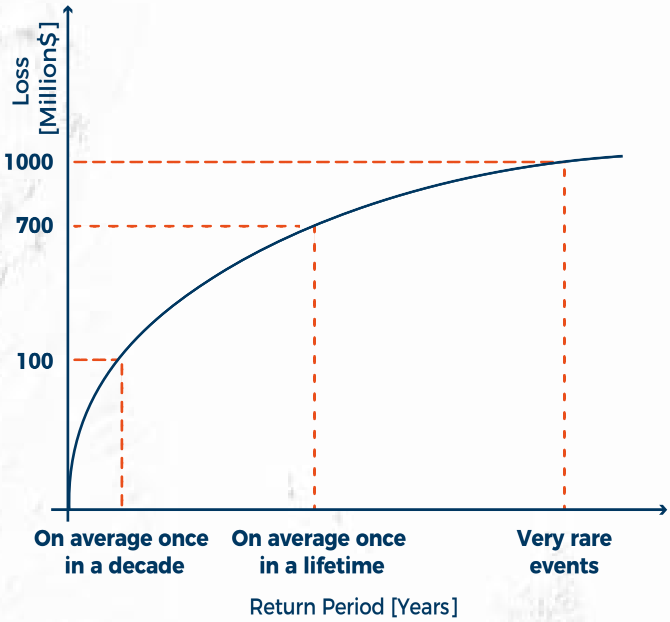
This disaster risk profile for floods and droughts is based on probabilistic risk assessment. Awareness of possible perils that may threaten human lives primarily derives from experience of past events. In theory, series of historical loss data long enough to be representative of all possible disastrous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

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

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

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

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

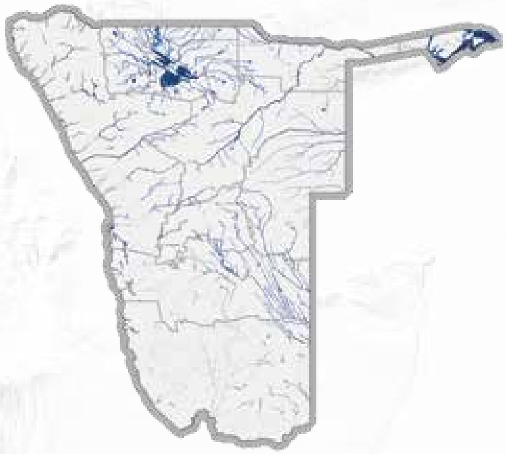


PROBABILISTIC RISK PROFILE: RISK COMPONENTS

HAZARD

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

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



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

VULNERABILITY

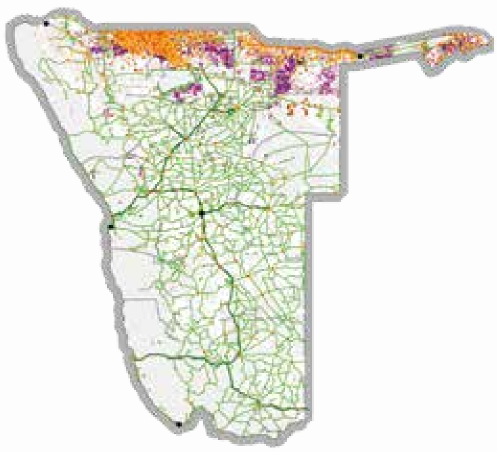
conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of an individual, a community, assets or systems to the impacts of hazards.

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

EXPOSURE

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

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



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

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

A SENDAI ORIENTED RISK PROFILE

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

	INDICATORS			FLOOD			DROUGHT			
				P	F	SEp	P	F	SEp	RISK METRICS
SENDAI INDICATORS	B1		Number of directly affected people	Y	Y	Y	Y	Y	Y	Annual Average
	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					
	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		
	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

Namibia is situated in southwestern Africa and borders South Africa, Botswana and Angola. Largely desert ranchland, much of it's population of 2.5 million people (2016) lives in urban areas (49%) [1,2]. The economic activity declined by about 1% in 2017, registering a contraction for four consecutive quarters. However, the World Bank has estimated that in the medium-term, the economic activity is expected to recover slowly and annual GDP growth is expected to reach 1.5% in 2018, and 3% in 2020, mostly driven by the increase in mining production [1].

Mining accounts for about 12.5% of GDP, but provides more than 50% of foreign exchange earnings. Rich alluvial diamond deposits make the country a primary source for gem-quality diamonds [3]. Namibia normally imports a large quantity of agriculture products, i.e approximately 50% of its cereal requirements. In drought years, food shortages are especially problematic in rural areas [3]. Climate change will likely exacerbate these difficulties.

The flooding and drought risk assessments presented in this report show impacts on various sectors of the economy. Taking these things into account, a thorough understanding of risk is essential to the healthy future development of the country.

SOCIO-ECONOMIC PROJECTIONS

Recently, climate scientists and economists have built 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 development estimations, 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, Namibia's population will increase by 30% between 2016 and 2050 (World Bank Data), whereas GDP is expected to increase more than fivefold.

POPULATION	GDP
2016 Projection	2016 Projection
2.5	11.3
[Million People]	[Billion$]
3.3	61.7
2050 Projection	2050 Projection

NAMIBIA

TOTAL AREA : 824.292 km² *(GOV.NA - 2017)*

POPULATION DENSITY : 3 people/km²

MEDIAN AGE : 21.0 years *(UN DATA - 2017)*

HDI - HUMAN DEVELOPMENT INDEX : 0.65 *(UNDP - 2017)*

LIFE EXPECTANCY AT BIRTH : 64.9 years *(UNDP - 2017)*

MEAN YEARS OF SCHOOLING : 6.8 years *(UNDP - 2017)*

EMPLOYMENT TO POP. RATIO (AGES > 15) : 46.9% *(WB - 2017)*

EMPLOYMENT IN AGRICULTURE : 20.1% *(WB - 2018)*

EMPLOYMENT IN SERVICES : 60.25% *(WB - 2018)*

data from:
http://hdr.undp.org/en/countries/profiles/
https://data.worldbank.org/indicator/
http://data.un.org - http://gov.na/

COUNTRY CLIMATE OUTLOOK

OVERVIEW

Located between the Namib and Kalahari deserts, Namibia has an arid climate. The coastal areas have a smaller temperature variation between day and night, while the range increases in inland areas. Namibia has two rainy seasons, a short one from September to November and a longer one from February through April. The two rainy seasons, partially overlap with the summer months.

Winter in Namibia is the dry season, and runs from June through August [7].

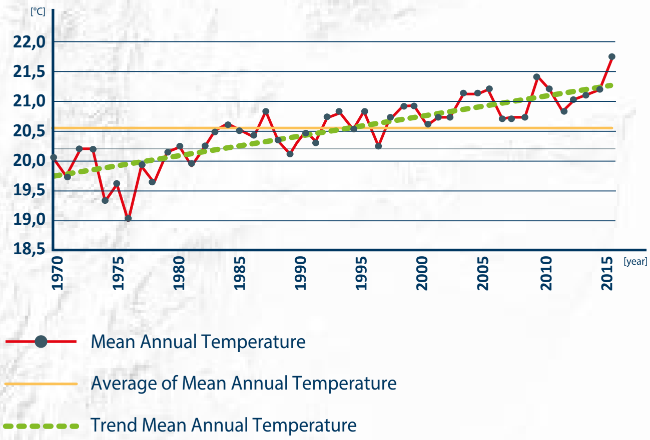
CLIMATE TRENDS

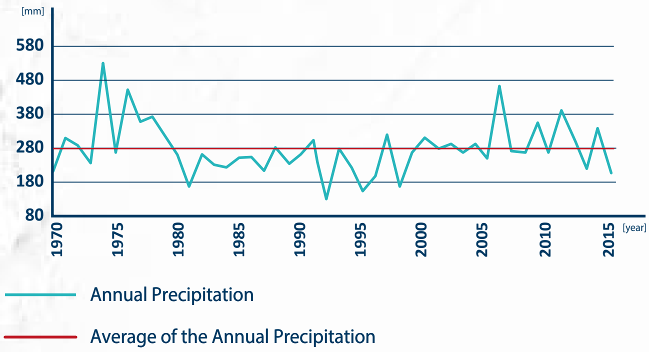
Similarly to other southern african countries, temperature observations indicate that Namibia has experienced a considerable increase in temperature over recent years. An analysis of climate data from 1970 to 2015 [8] (see figures) shows an average rise of circa 1.5°C.

Trends for precipitation are not as clear as those for air temperatures, and are variable in time and space.

Average annual precipitation for Namibia is approximately 276 mm, while the mean number of wet days is very limited, averaging about 44 days.

TEMPERATURE AND PRECIPITATION TRENDS IN CURRENT CLIMATE





RIVERS OF NAMIBIA

Perennial rivers are mostly found in the northern and southern parts of the country, and are transnational. Specifically, the Orange river is on the south at the border with South Africa; in the northern part of the country, Kunene and Okavango border with Angola, Zambezi borders with Zambia and Botswana, while in the northeastern Kwando, Linyanti and Chobe border with Botswana. Many other rivers are ephemeral with significant water flow only after precipations [9]; three main ephemeral water bodies should be mentioned: the Kuiseb River in central-western Namibia that also serves farming and mining activities, the Fish River in southern Namibia and the Cuvelai Basin ephemeral wetlands in central-northern Namibia.

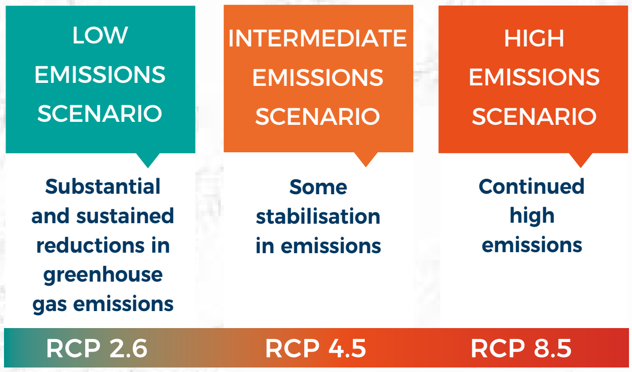
Photo Credits: http://springbok-atlas.blogspot.com/2011/04/swakop-river-windhoek.html

CLIMATE PROJECTIONS FOR NAMIBIA

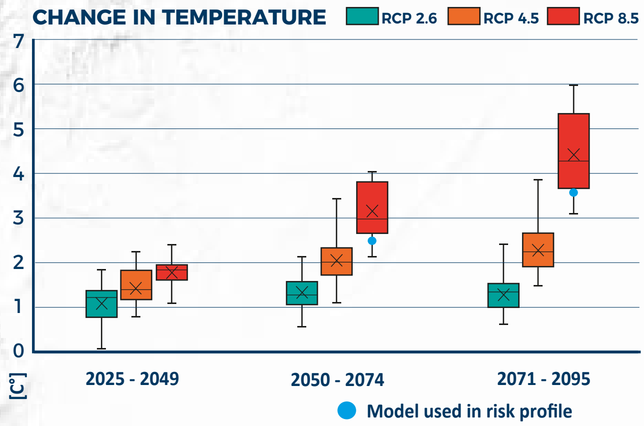
Climate projection studies are abundant for multiple different time spans and with various scales. Climate models are tools that the scientific community uses to assess trends in weather conditions over long periods. In a recent study [10] Alder, et al., compared the observed temperature and precipitations 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).

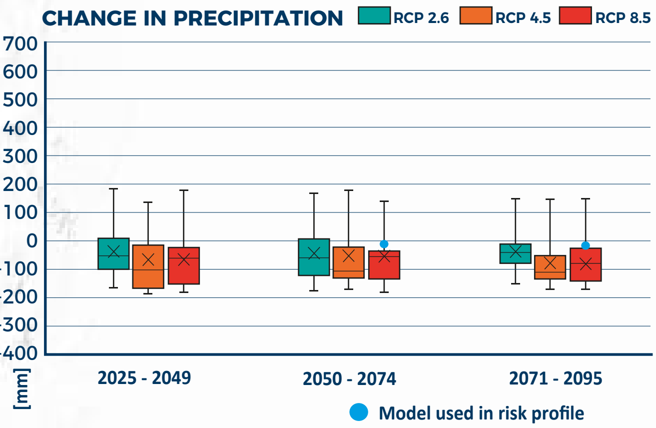
In all periods and in all emission scenarios, models showed an increase in temperature. The increase in temperature was more evident in high emissions scenarios and long term period projections. In high emission scenarios (RCP8.5), model projections showed an increase of between about 2°C and 4°C for the mid term period (2050-2074) and an increase of between about 3°C and 6°C for the long term period (2071-2095). Future changes in precipitation are much more uncertain, but the models predicted a decrease in precipitation in all 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 2°C to 4°C Very likely decrease in precipitation (up to 40%)
Far Future (2071-2095)	Increase in temperature from 3°C to 6°C Very likely decrease in precipitation (up to 40%)



IPCC's Emissions scenarios for Climate Projections



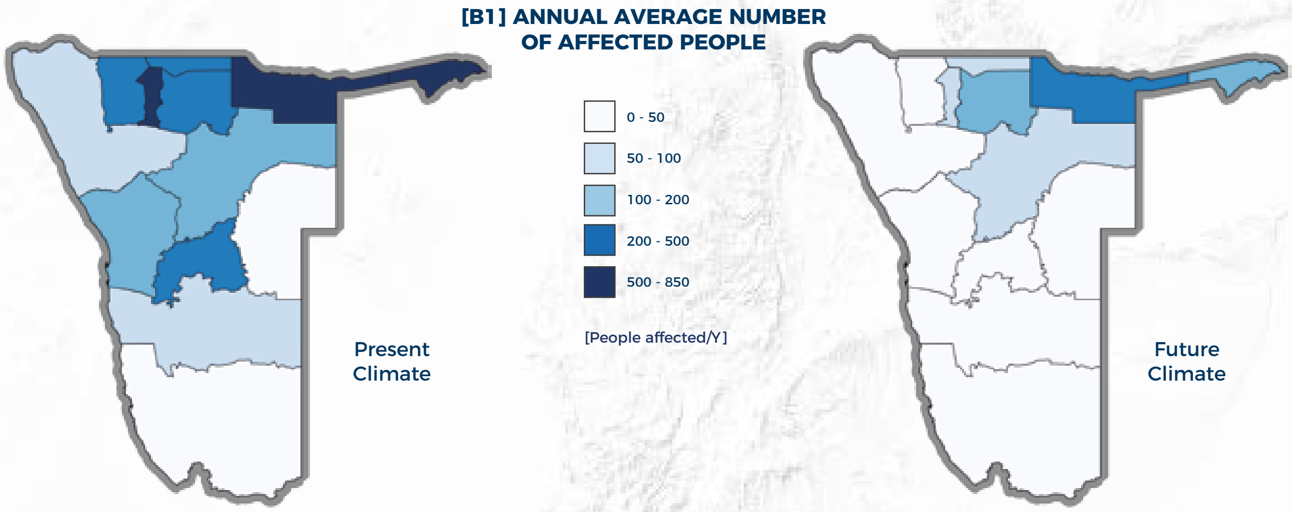


CLIMATE PROJECTIONS USED IN THIS RISK PROFILE

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 the ICHEC-EC-EARTH model, RCP 8.5, 2006-2100).[11,12,13]

This study uses a high-resolution model, accurately calibrated on the African domain, to better capture climate variability, important for assessing extremes. Regional model projections were checked for consistency against the full ensemble of available global models in the area. The model forecasts changes in temperature and annual precipitation by the end of the century, in line with the range of variability of the global models analyzed in the study by Alder and Hostetler [10]; more specifically projected temperatures are a little below the majority of the results of global models and precipitations are a little above. The high emission scenario was maintained as representative of the worst climate change scenario, enabling the analysis of a full range of possible changes. However, in this specific case, the regional model predicts a more moderate, though very significant, increase in temperature (about 3.5°C), which is slightly smaller than the majority of the results of global models. As regards to annual precipitation at the country level, almost no changes are predicted by the regional model in the far future.

RESULTS | FLOODS



KEY MESSAGES

● Floods affect on average about 4 000 people every year, approximately 0.16% of the total population.

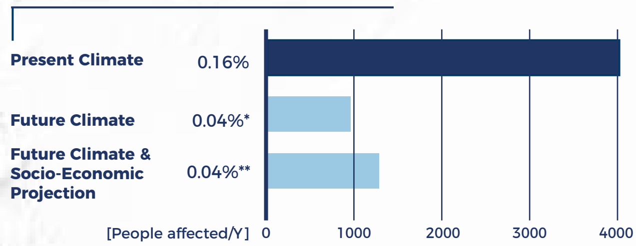
● Most of the affected people are concentrated in the central, northern, and northeastern parts of the country, with hotspots in the Khomas, Kavango (east and west) and Oshama regions.

● The local economy is highly exposed to flooding. On average about 40 million USD $ of GDP per year, which corresponds to about 0.36% of the national GDP, is concentrated in areas potentially affected by floods.

● As climate models predict a very likely decrease in precipitation, the affected population estimated when considering future climate conditions will likely decrease when compared to the value evaluated under current climate conditions. However, as shown in the climate session, climate projections are inherently uncertain and this should be considered when using these estimations in policy planning. Similar behavior is expected for the affected GDP.

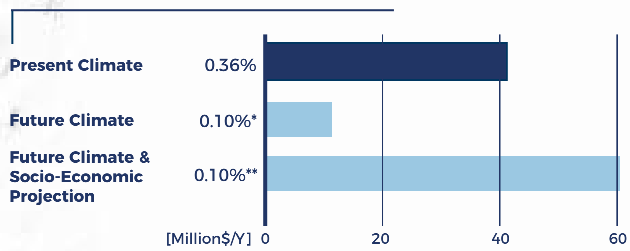
● When population and GDP affected for current climate conditions are compared with estimates under future climate conditions paired with the projected socio-economic situation (*), they show an opposite trend. Specifically, affected population decreases in future conditions while GDP increases, as a result of the disproportional projection growth between population and GDP (population increase of about 30% and GDP by 5-fold)**. These predictions are highly uncertain.

ANNUAL AVERAGE NUMBER OF POTENTIALLY AFFECTED PEOPLE [B1]



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

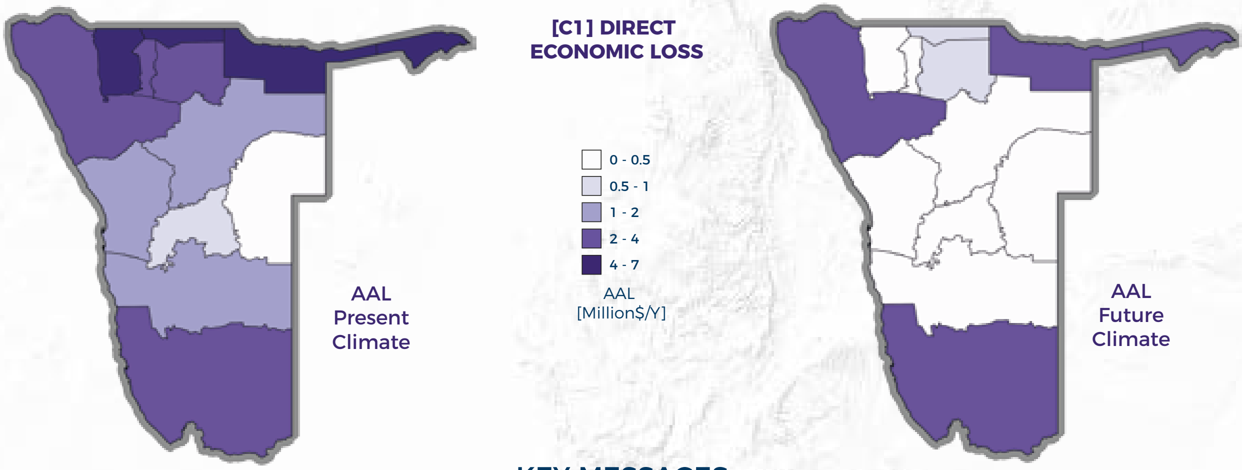
ANNUAL AVERAGE POTENTIALLY AFFECTED GDP



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

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

RESULTS | FLOODS



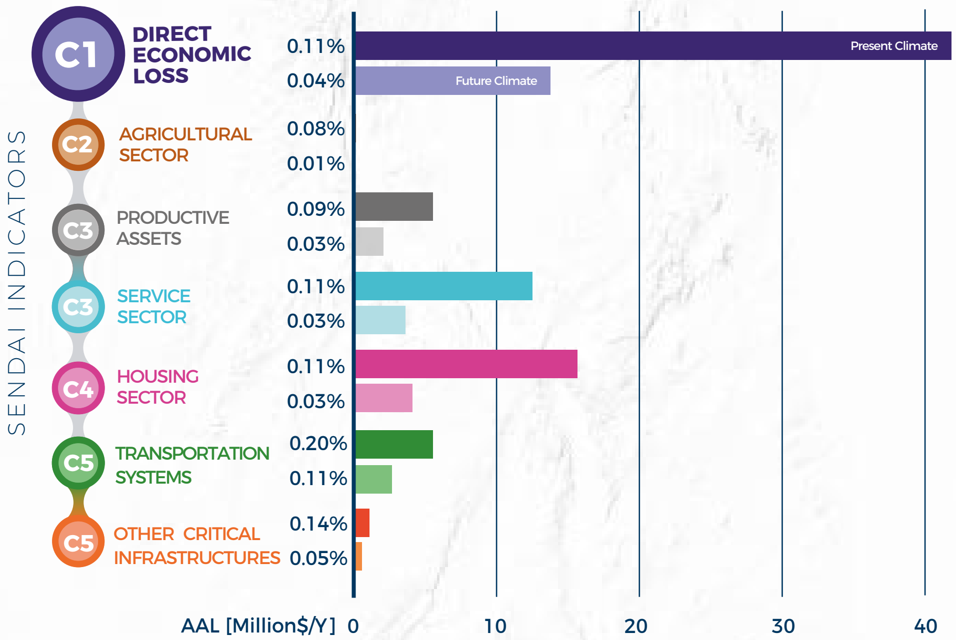
KEY MESSAGES

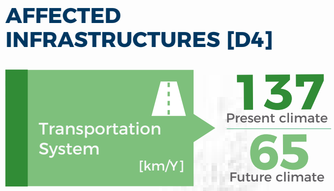
● The direct economic losses in Namibia are roughly in line with the geographical distribution of exposed values. The northern regions and Karas in the south show the biggest losses. The pattern is slightly modified under future climate conditions where there will be a likely decrease in the hazard severity in the north, while the loss level in the south is confirmed.

● The yearly average value of direct economic losses in the present climate exceeds 40 million USD that roughly accounts for 0.11 percent of the total stock value in the country. The largest portion of losses are attributed to the housing and service sectors followed by the transportation and industrial sectors.

● Considering the presently exposed assets, it is likely that average annual losses will decrease under future climate conditions, for all sectors. However, this estimation does not consider socio-economic projections that can eventually invert the future projections.

● The proportion of the different sectors to the overall loss changes under future climate conditions: the reduction for housing and service sectors are more marked. As highlighted before, climate projections are inherently uncertain and this should be considered when using these estimations in policy planning.





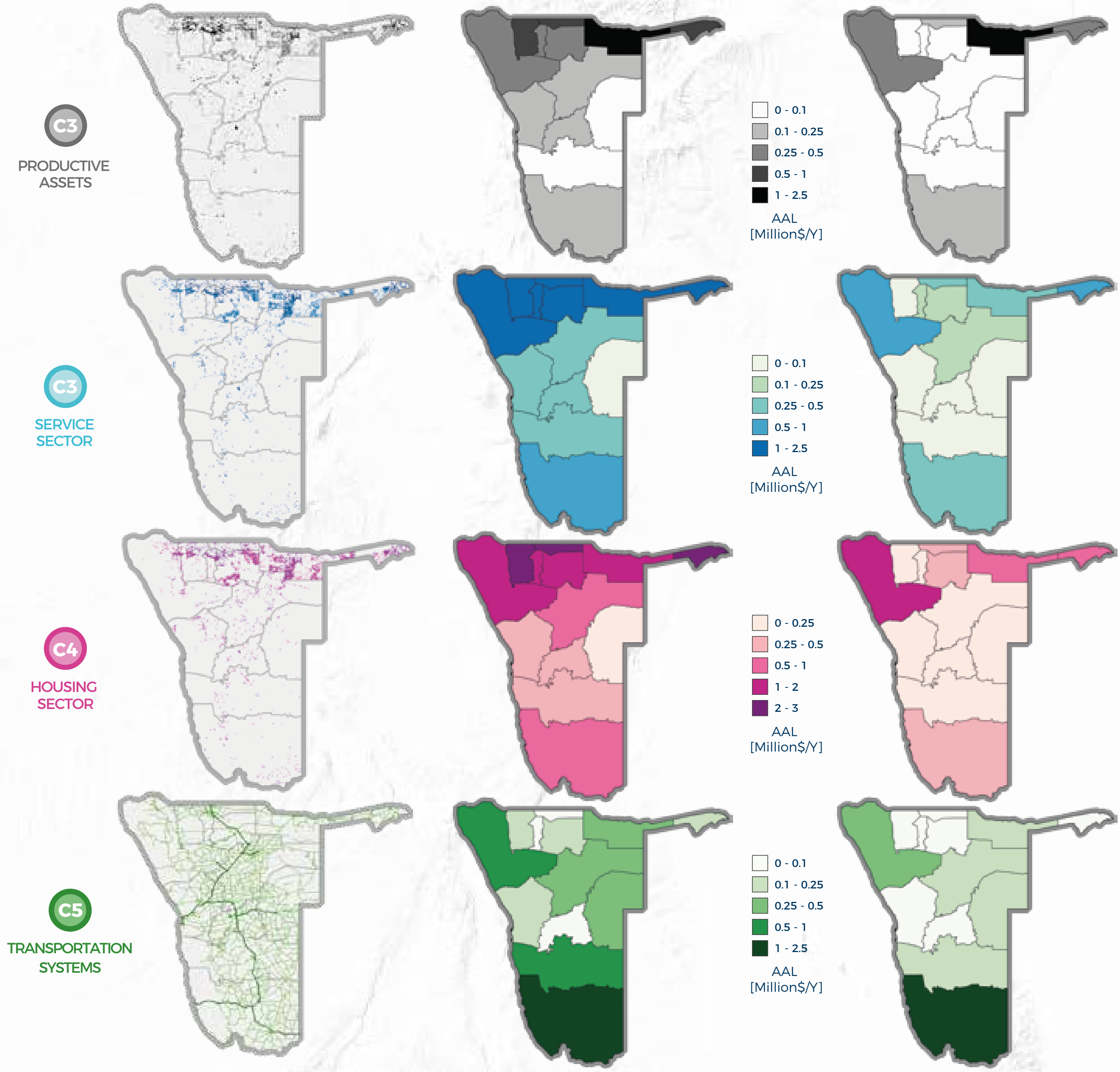
RESULTS | FLOODS

KEY MESSAGES

- The AAL distribution for productive assets clearly resembles the exposure distribution with hotspots in the northern and northeastern regions, as well as in Karas. Direct economic losses in services and housing have similar geo-spatial distribution. The most affected region for the transportation system is Karas, where rail and road infrastructures connect Namibia with South Africa. Kawango is a hotspot for the industrial sector.

- Comparison between present and future climate AALs for all sectors shows that a decrease in economic losses is to be expected. The likely reduction of the losses for future climate conditions is less evident for transportation systems, remarking the high vulnerability of the specific sector.

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



RESULTS | FLOODS

KEY MESSAGES

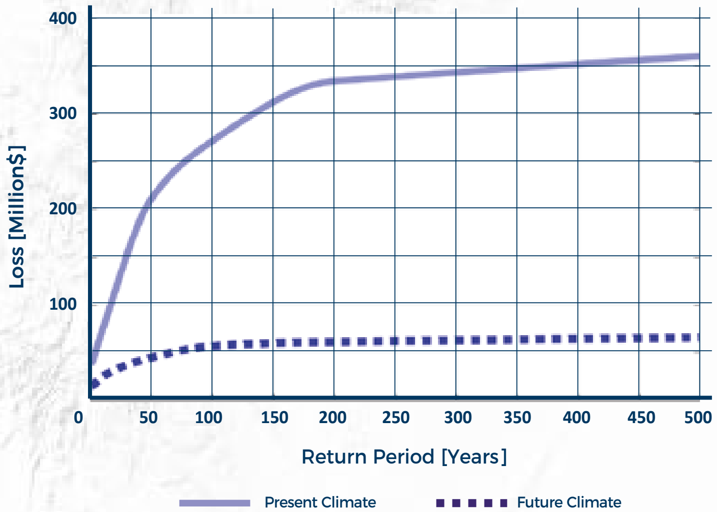
● Though the Average Annual Losses are of about 40 million USD per year, the likelihood of a 100 million dollar loss caused by floods is on average of once per decade, meaning that considerable losses may be experienced frequently. The likelihood of disaster losses of about 250 million USD are on average of once per 80 years. Extreme losses might reach 350 million USD.

● The sectors that are mostly affected by both frequent, very frequent and extreme losses are housing and services. Transport and productive assets invert their proportion from very frequent to rare events.

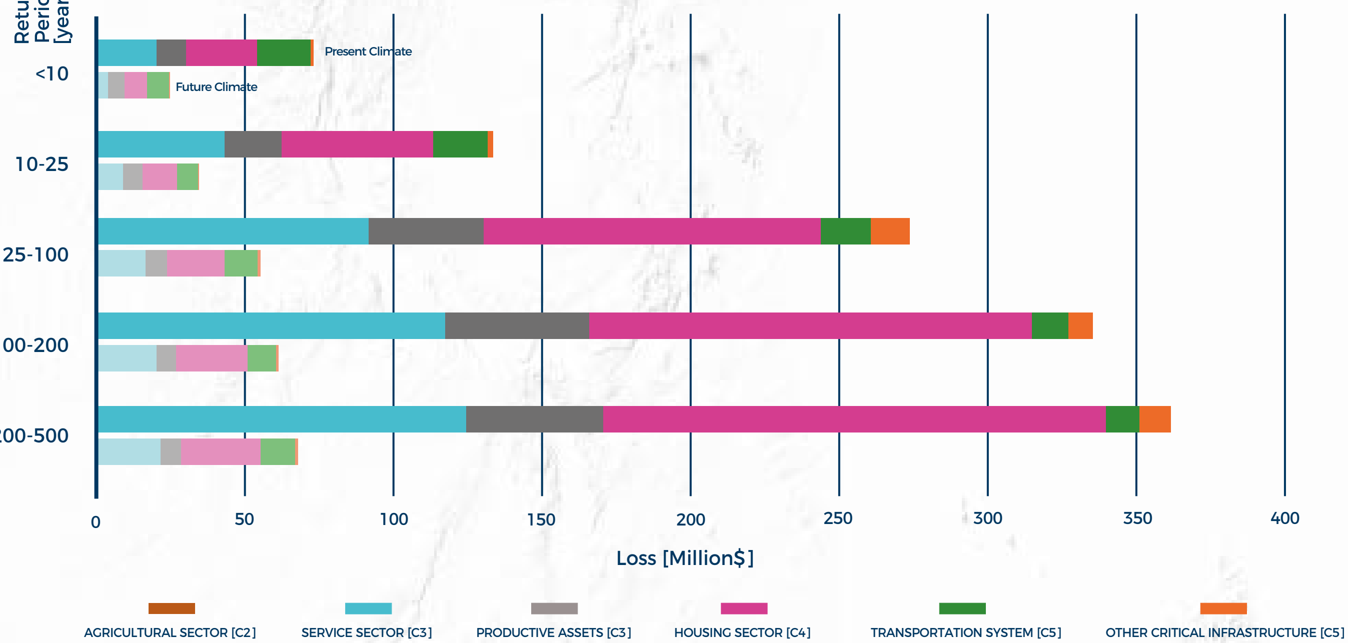
● It is likely that both frequent and extreme losses will be reduced under future climate conditions, however losses bigger than 50 million USD are estimated for frequent disasters (return period larger than 50 years). Given the high level of uncertainty in future climate predictions, worse scenarios may also still be possible (compare climate section at p.8).

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

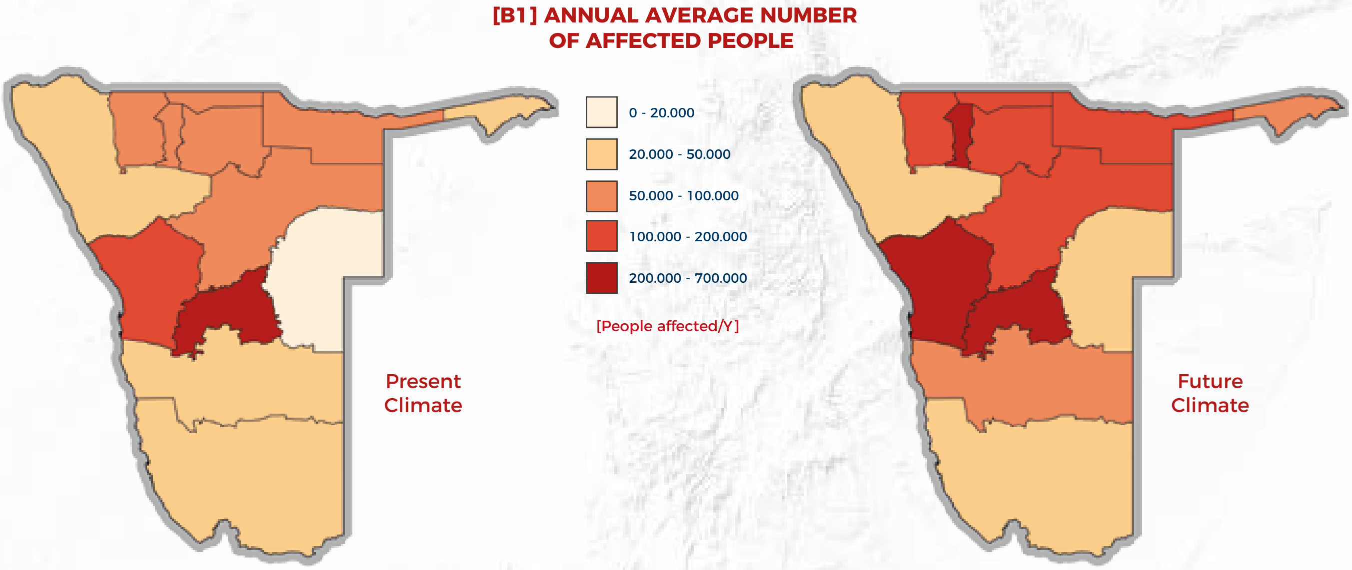
PROBABLE MAXIMUM LOSS CURVE (PML)
C1 - DIRECT ECONOMIC LOSS



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

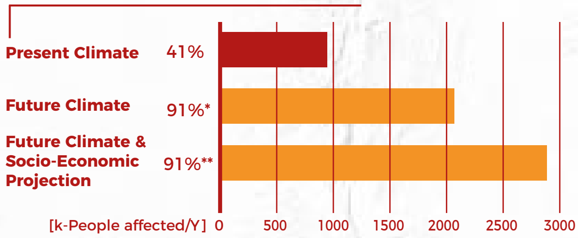


RESULTS | DROUGHTS



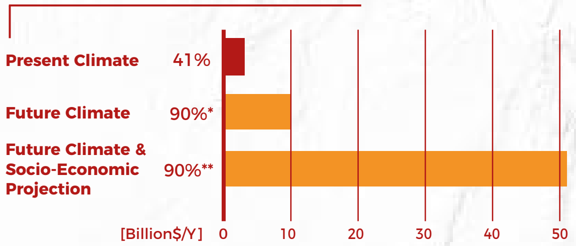
Annual average of population potentially affected by at least three months of drought conditions, as calculated using the standardized precipitation-evapotranspiration index (SPEI) and using a 3-month accumulation period.

ANNUAL AVERAGE NUMBER OF POTENTIALLY AFFECTED PEOPLE [B1]



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

ANNUAL AVERAGE POTENTIALLY AFFECTED GDP



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

KEY MESSAGES

- With respect to present conditions (1951-2000 climate), the probability of occurrence of severe effective precipitation deficiency (precipitation – evapotranspiration) will increase in the future (2050-2100 climate). It is likely that a larger share of Namibia will experience frequent droughts.

- Under current climate conditions, on average 1 million people (41% of the total 2016 Population) are potentially annually affected by droughts. In the future climate, this number is likely going to increase to up to 91% of the population (amounting to on average 3 million people if population growth is accounted for).

- The percentage of GDP potentially affected (produced in areas hit by droughts) is on average about 41%, equivalent to 4 billion USD per year. Under future climate and socio-economic conditions, it is likely that 90% of the GDP will be affected (almost 10 billion USD).

RESULTS | DROUGHTS

KEY MESSAGES

● Most of the affected livestock is in the central northern part of the country. Under future climate conditions, about 100% more livestock is expected to be annually affected by droughts. The affected livestock under current climate conditions is about 883.000 units (43%), while under future climate conditions, considering current livestock units, the projection is likely to increase to 1.8 million units (90% of the total).

● Agricultural losses are dominated by roots. In relative terms, all selected crop productions are strongly affected under future conditions with increases between two (maize) and seven (roots) times, compared to present conditions. Under future conditions, most production losses will be about 10% of their average crop productions, except for grapes (18%).

● Crop production is concentrated in the northern provinces of Namibia. Under future climate conditions, increases in losses have been estimated for the whole northern part of Namibia.

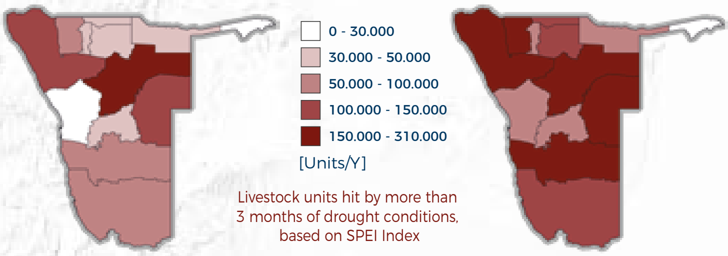
● Approximately a three-fold increase in lost working days is expected under future climate conditions. The loss of working days is estimated at 1 - 2 % of the average amount of working days. However, the number of working days lost, expressed as a percentage of the average amount of days required for harvesting, is approximately six times higher.

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

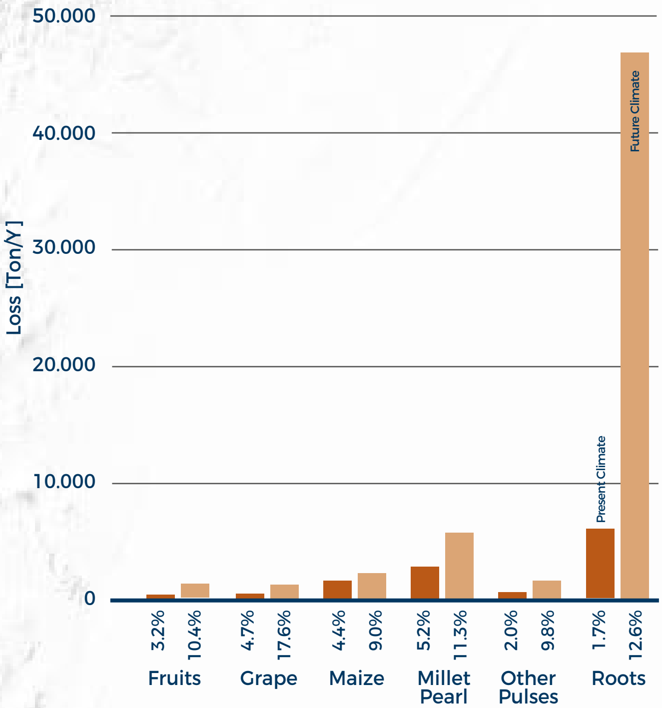
883 | **43%** Present climate

1836 | **90%** Future climate

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



AGRICULTURAL PRODUCTION LOSS

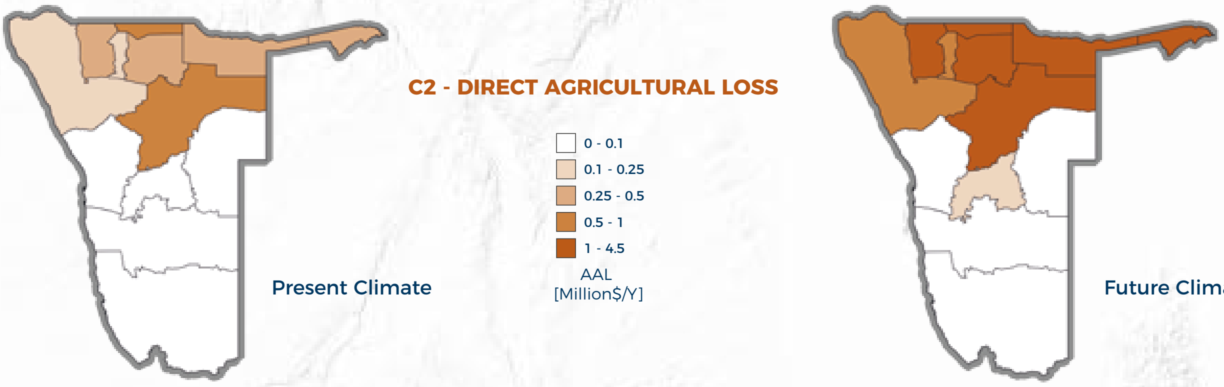


ANNUAL AVERAGE NUMBER OF WORKING DAYS LOST [k-Days]

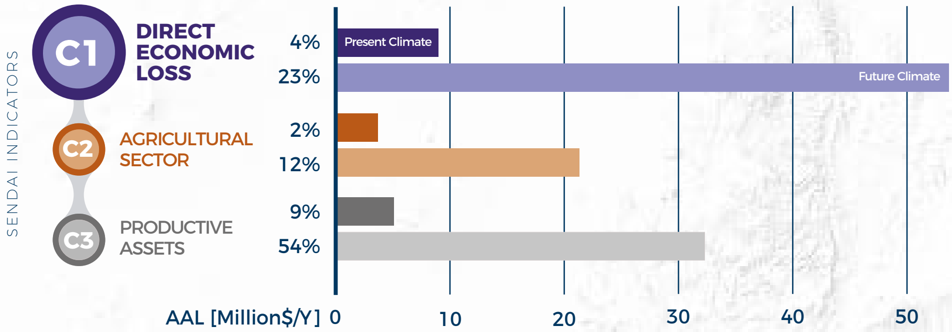
140 | **0.70%** Present climate

460 | **2.20%** Future climate

C2 - DIRECT AGRICULTURAL LOSS



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

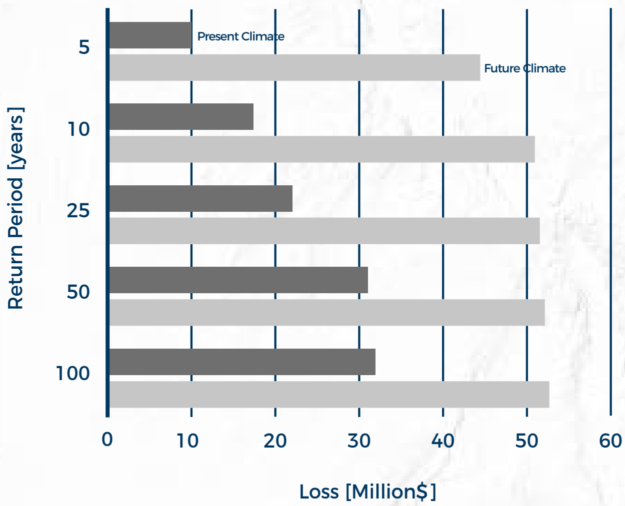
- Total direct economic losses (C1) due to drought are attributable to both losses from crops (C2) and hydropower (C3). C3 losses are estimated a little higher than those for C2.

- Losses in agricultural (crop) production (C2) are projected to increase substantially (almost six times), and may increase to more than 10% of the average income from crops.

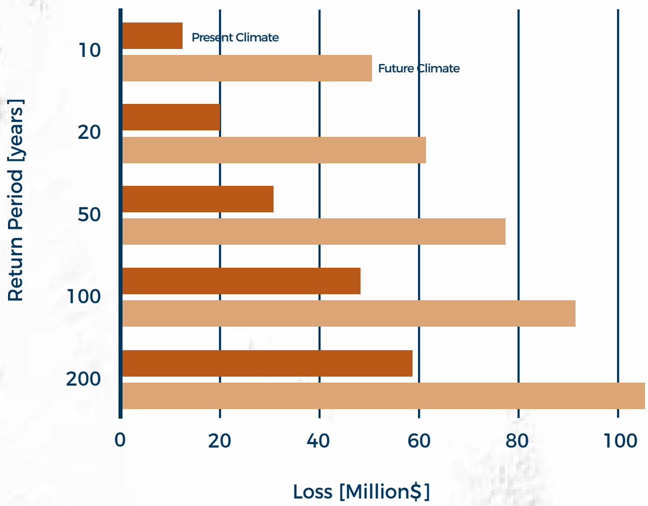
- Under current climate conditions, a gradual increase in agricultural (crop) income losses is expected when return periods go up from 10 to 200 years. Under future climate conditions, agricultural income losses increase significantly when compared to present climate conditions. At the lower return periods, the relative increase is large (e.g. more than 3 times for a return period of 10 years).

- Annual losses in hydropower (defined as production below production under average reservoir conditions) are expected to increase considerably, from 9% to 54%. This increase in annual loss is mainly caused by a sharp increase of high frequent losses (i.e. 1-in-5 year losses), which increase more than four times. This is linked to more frequent low flow conditions in the Kunene river (see SSFI). Losses are based on estimates for the Ruacana hydropower station.

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

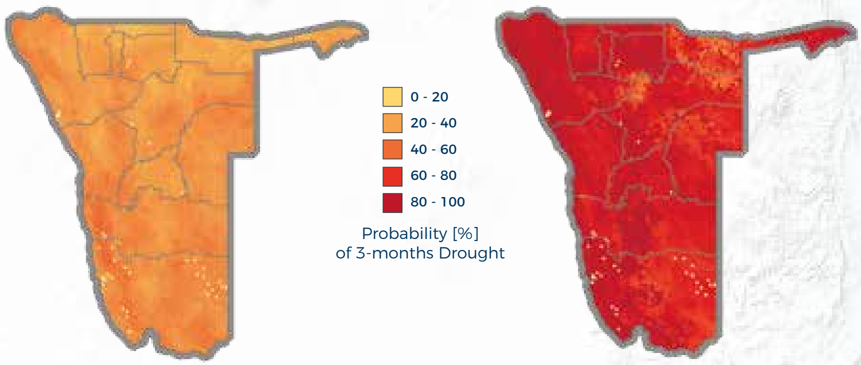


PROBABLE MAXIMUM LOSS (PML)
C2 - AGRICULTURAL LOSS



RESULTS | DROUGHTS

Present Climate | Future Climate

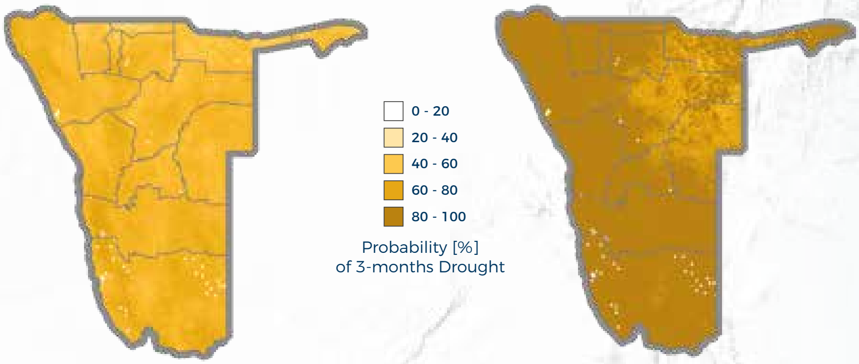


SPEI

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).

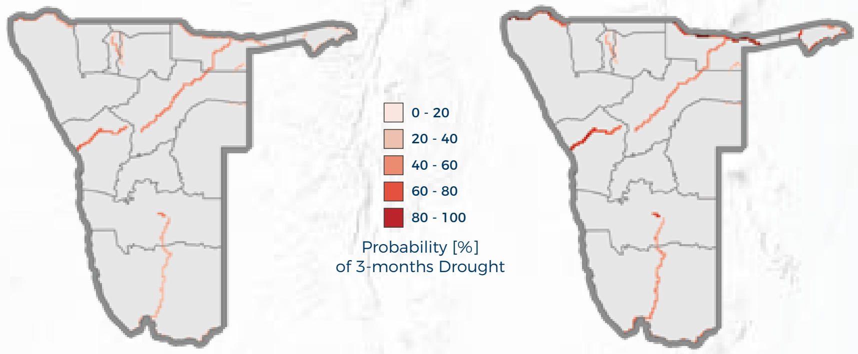
It can be noted that the probability of droughts will increase in the whole country in a changing climate. This is particularly important for areas dependent on rainfall for their water resources.



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).

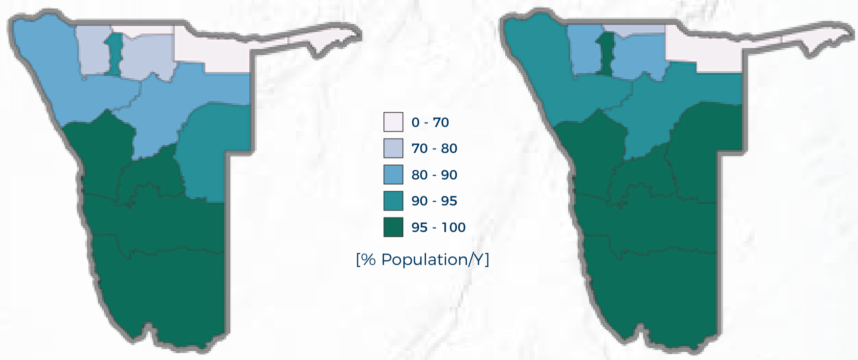
The desertic and arid parts of the country will experience a 100% chance of drought, indicating an almost-permanent state of dryness which now has only a 60-80% chance of occuring. This is particularly important for agricultural and natural areas.



SSFI - Standardised Streamflow Index

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

This is particularly important for areas dependent on rivers for their water supply, navigation and electricity generation.



WCI - Water Crowding Index

These maps show the percentage of the population per region experiencing water scarcity, based on the water available (precipitation minus evapotranspiration) per person per year (<1000 m^3/person/year). Specifically, areas with high concentrations of people (e.g. Oshana) and arid areas (the south) are dependent on water resources from outside their immediate region (~85 km^2).

PROBABILISTIC RISK ASSESSMENT FOR RISK MANAGEMENT

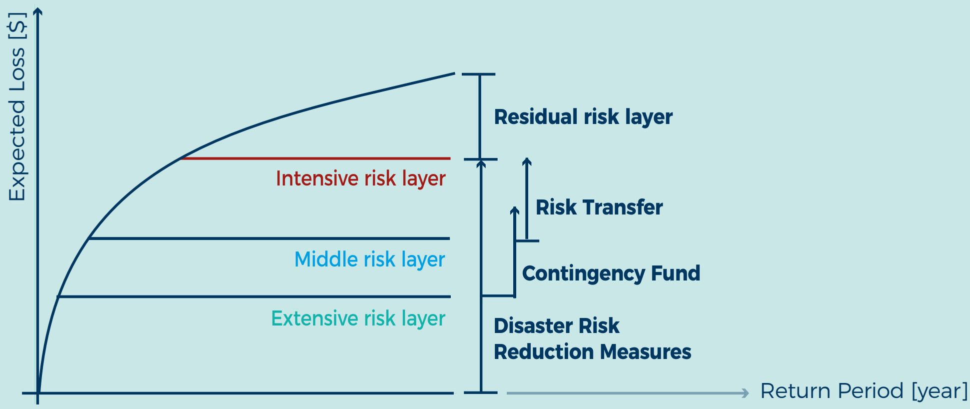
METRICS FOR RISK MANAGEMENT

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

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

PML CURVE

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



GLOSSARY & REFERENCES

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

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

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

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

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

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

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

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

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

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

GLOSSARY & REFERENCES

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

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

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

[1] Namibia overview, WorldBank, http://www.worldbank.org/en/country/namibia/overview

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

[3] https://www.cia.gov/library/publications/the-world-factbook/geos/wa.html

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

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

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

[7] Future Climate for Africa | Africa's climate: Helping decision-makers make sense of climate information, November 2016.

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

[9] Mary Seely and Carole Roberts, Desert Research Foundation of Namibia, Namibia's 'dry' rivers attract international attention on water management, 2008/9 edition of Conservation and the Environment in Namibia, to download free article:
http://www.travelnewsnamibia.com/news/integrated-water-resources-management-namibias-dry-rivers-attract-international-attention/

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

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

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

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

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

www.preventionweb.net/resilient-africa

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