

2019

DISASTER RISK PROFILE



Flood



Drought

Botswana (Republic of)



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



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



This project is funded by
the European Union



UNDRR
UN Office for Disaster Risk Reduction



© CIMA Research Foundation
International Centre on Environmental Monitoring
Via Magliotto 2. 17100 Savona. Italy
2019 - Review

Africa Disaster Risk Profiles are co-financed by the EU-funded ACP-EU Natural Disaster Risk Reduction Program and the ACP-EU Africa Disaster Risk Financing Program, managed by UNDRR.

DISCLAIMER

This document is the product of work performed by CIMA Research Foundation staff.

The views expressed in this publication do not necessarily reflect the views of the UNDRR or the EU. The designations employed and the presentation of the material do not imply the expression of any opinion whatsoever on the part of the UNDRR or the EU concerning the legal status of any country, territory, city or area, or of its authorities, or concerning the delineation of its frontiers or boundaries.

RIGHTS AND PERMISSIONS

The material in this work is subject to copyright. Because UNDRR and CIMA Research Foundation encourage dissemination of its knowledge, this work may be reproduced, in whole or in part, for non-commercial purposes as long as full attribution to this work is given.

Citation: UNDRR and CIMA (2019). *Botswana Disaster Risk Profile*.

Nairobi: United Nations Office for Disaster Risk Reduction and CIMA Research Foundation.

Any queries on rights and licenses, including subsidiary rights, should be addressed to CIMA Research Foundation:

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

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

In collaboration with:



PROJECT TEAM

Authors

Roberto Rudari ^[1]
Amjad Abbashar ^[2]
Sjaak Conijn ^[4]
Silvia De Angeli ^[1]
Hans de Moel ^[5]
Auriane Denis-Loupot ^[2]
Luca Ferraris ^[1,5]
Tatiana Ghizzoni ^[1]
Isabel Gomes ^[1]
Diana Mosquera Calle ^[2]
Katarina Mouakkid Soltesova ^[2]
Marco Massabò ^[1]
Julius Njoroge Kabubi ^[2]
Lauro Rossi ^[1]
Luca Rossi ^[2]
Roberto Schiano Lomoriello ^[2]
Eva Trasforini ^[1]

Scientific Team

Nazan An ^[7]
Chiara Arrighi ^[1,6]
Valerio Basso ^[1]
Guido Biondi ^[1]
Alessandro Burastero ^[1]
Lorenzo Campo ^[1]
Fabio Castelli ^[1,6]
Mirko D'Andrea ^[1]
Fabio Delogu ^[1]
Giulia Ercolani ^[1,6]
Elisabetta Fiori ^[1]
Simone Gabellani ^[1]
Alessandro Masoero ^[1]
Enrico Ponte ^[1]
Ben Rutgers ^[4]
Franco Siccardi ^[1]
Francesco Silvestro ^[1]
Andrea Tessore ^[1]
Tufan Turp ^[7]
Marthe Wens ^[5]

Editing and Graphics

Adrien Cignac-Eddy ^[1]
Rita Visigalli ^[1]

Supporting Team

Simona Pozzati ^[1]
Luisa Colla ^[1]
Monica Corvarola ^[1]
Anduela Kaja ^[1]
Iain Logan ^[8]
Rich Parker ^[9]
Tatiana Perrone ^[1]
Elisa Poggi ^[1]
Martino Prestini ^[1]
Maria Ravera ^[1]

With the support of the UNDRR Regional Office for Africa

CIMA Research Foundation ^[1] UNDRR ^[2]
Vrije Universiteit Amsterdam ^[5] Wageningen University & Research ^[4]
Università di Genova ^[5] Università di Firenze ^[6]
Bogazici University ^[7] GEG ^[8] Training in Aid ^[9]

INDEX

Introduction.....	P.4
Probabilistic Risk Profile: Methodology.....	P.5
Probabilistic Risk Profile: Components.....	P.6
A Sendai Oriented Risk Profile.....	P.7
Country Socio-Economic Outlook.....	P.8
Country Climate Outlook.....	P.9
Results Floods.....	P.11
Results Droughts.....	P.15
Probabilistic Risk Assessment for Risk Management.....	P.19
Glossary & References.....	P.20

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.

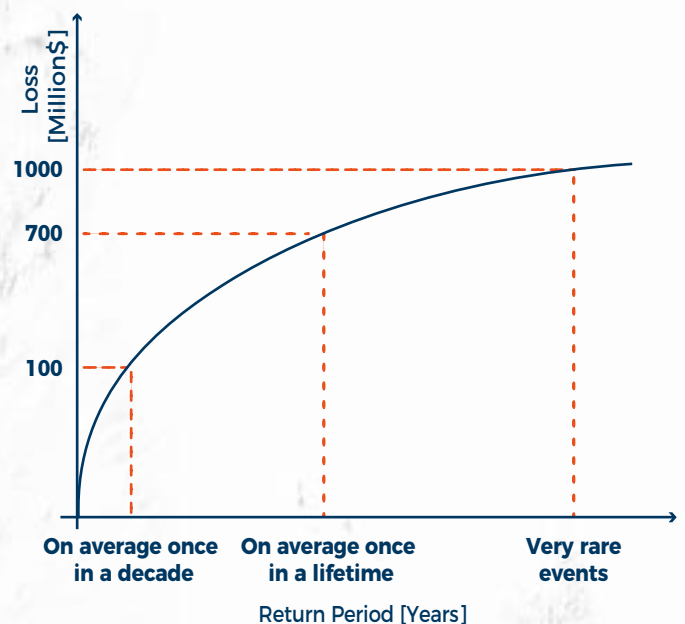
In the absence of extensive historical data, a modelling approach is needed to best predict possible present and future scenarios, taking into consideration the spatial and temporal uncertainties involved in the analysed process. This profile simulates a realistic set of all possible hazardous events (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>

BOTSWANA DISASTER RISK PROFILE

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			RISK METRICS
			P	F	SEp	P	F	SEp	
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					
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

Landlocked in the centre of southern Africa, Botswana borders Zambia, Zimbabwe, Namibia, and South Africa. Mostly made up of tableland, it has a population of about 2.2 million^[1]. The Republic of Botswana has developed rapidly in the last half-century and is now an upper middle-income country. The country's GDP increased on average by about 5% per annum over the past decade with growth peaking between 2008 and 2011. Economic activity is expected to intensify in the future, driven mostly by mining, construction, the service sector and increased public investments^[2]. Despite Botswana's impressive economic performance however, the country faces high levels of poverty, and unemployment hovering around a staggering 18%. This, coupled with the country's extremely high income inequality makes Botswana particularly vulnerable to disasters^[3]. As shown in the flood and drought risk assessments presented in this report, climate change will have important impacts on Botswana's social and economic fabric. It argues that a thorough understanding of risk is therefore essential to the future social and economic development of the country.

SOCIO-ECONOMIC PROJECTIONS

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

PROJECTIONS USED IN THE RISK PROFILE

The "middle of the road" scenario used in this risk profile envisages that the historical patterns of development are continued throughout the 21st century. Following this projection Botswana's population will increase by roughly 20% between 2016 and 2050 (World Bank Data), while GDP is expected to increase more than fivefold.

POPULATION



2016 Projection

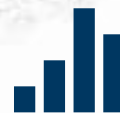
2.2

[Million People]

2.7

2050 Projection

GDP



2016 Projection

15.6

[Billion\$]

88.3

2050 Projection



BOTSWANA

AREA : 581.730 km² (FAO)POPULATION DENSITY : 4 people/km²

MEDIAN AGE : 24.7 years

HDI - HUMAN DEVELOPMENT INDEX : 0.717 (UNDP - 2017)

LIFE EXPECTANCY AT BIRTH : 67.6 years (UNDP - 2017)

MEAN YEARS OF SCHOOLING : 9.3 years (UNDP - 2017)

EMPLOYMENT TO POP. RATIO (AGES > 15) : 58.9% (WB - 2017)

EMPLOYMENT IN AGRICULTURE : 26.2% (WB - 2017)

EMPLOYMENT IN SERVICES : 60.3% (WB - 2017)

data from:

<http://hdr.undp.org/en/countries/profiles/><https://data.worldbank.org/indicator/><http://www.fao.org/countryprofiles/index/en/?iso3=bwa>

COUNTRY CLIMATE OUTLOOK

OVERVIEW

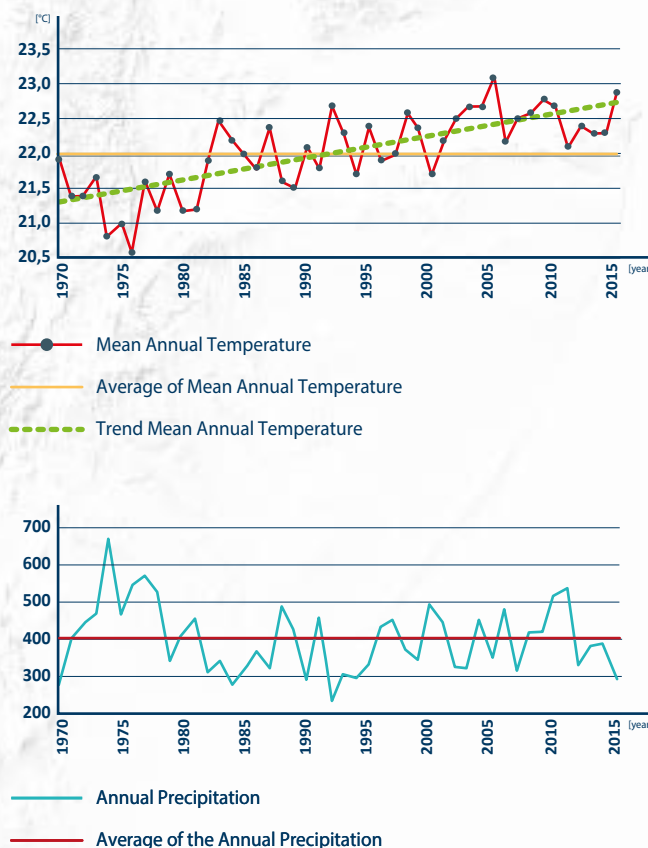
Botswana has a semi-arid climate with hot and dry conditions most of the year. The dry season is exacerbated in the winter from May to August. Precipitations are concentrated during the summer rainy season from November to March ^[7]. There are three distinct agro-ecological zones in the country ^[8]:

- Centre and West: the Kalahari Desert covers over two-thirds of the total national area. Although it has low rainfall, the predominant landscape is not desert, but savannah grasslands interspersed with woodland. The sandy soils are not well suited for cultivation, but support considerable numbers of cattle, goats, other livestock and wildlife.
- East: The predominant landscape is savannah grasslands and woodlands, with a small amount of forest. The climate is less harsh than the Kalahari and the soil is more fertile. Annual rainfall generally exceeds 400 mm.
- North-west: the area is predominantly covered by the Okavango Delta and Makgadikgadi pans. Okavango delta presents vast areas of open water and lush wetlands with an abundance of wildlife. Makgadikgadi Pans have vast, flat and salty depressions.

CLIMATE TRENDS

Similarly to other southern African countries, temperature observations indicate that Botswana has experienced a considerable increase in temperature over recent years. An analysis of climate data from 1970 to 2015 ^[9] shows an average rise of around 1.5 °C. Trends for precipitation are not as clear as those for air temperatures and they vary in time and space. The average annual precipitation for Botswana is approximately 400 mm, while the mean number of wet days is around 53.

TEMPERATURE AND PRECIPITATION TRENDS IN CURRENT CLIMATE



RIVERS OF THE REPUBLIC OF BOTSWANA

Botswana is drained by a complex system of multiple trans-boundary rivers which originate either in South Africa or in Angola. The Molopo, Limpopo and Nossop are in the south and mark the country's border with South Africa. Most of these rivers dry up in the summer, but during the monsoon season they frequently flood their banks ^[10,11].





During the rainy season, the Limpopo river becomes navigable.

The northern part of the country has some unique rivers: the Chobe, a tributary of the great Zambezi River, the Linyanti at the border with Zambia and the Okavango. The Okavango delta is the world's largest inland delta. The Makgadikgadi Pan is a salt pan situated in the middle of the dry savanna of north-eastern Botswana and it counts among the largest salt flats in the world.

<http://www.botswanaturism.co.bw/explore/okavango-delta>

CLIMATE PROJECTIONS FOR BOTSWANA

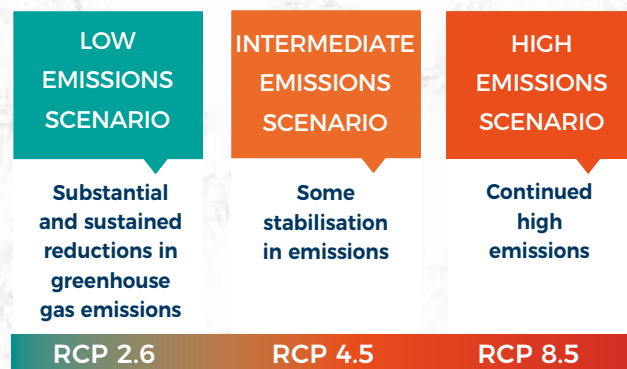
Climate projection studies are abundant for multiple different time spans and with various scales. Climate models are tools that the scientific community uses to assess trends in weather conditions over long periods. In a recent study ^[12] Alder, et al., compared the observed temperature and precipitations 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). For all periods and emission scenarios, models showed an increase in temperature. Temperature increase was more evident in high emissions scenarios and long-term period projections. In high emission scenarios (RCP8.5) for the mid-term period (2050-2074), model projections showed a temperature increase of between 2°C and 4.5°C and an increase of between about 3.5°C and 6°C for the long term period (2071-2095). Future changes in precipitation are much more uncertain; however the models predicted a decrease in precipitation for both the medium and long-term periods and for all different emission scenarios.

Time Frame	Climate Projections (RCP 8.5 - High emission scenario)	
Mid-term Future (2050-2074)		Increase in temperature from 2°C to 4.5°C
		Very likely decrease in precipitation (up to 25%)
Far Future (2071-2095)		Increase in temperature from 3.5°C to 6°C
		Very likely decrease in precipitation (up to 25%)

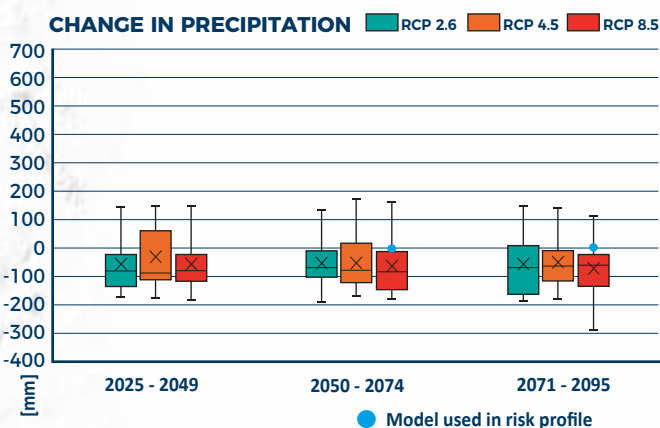
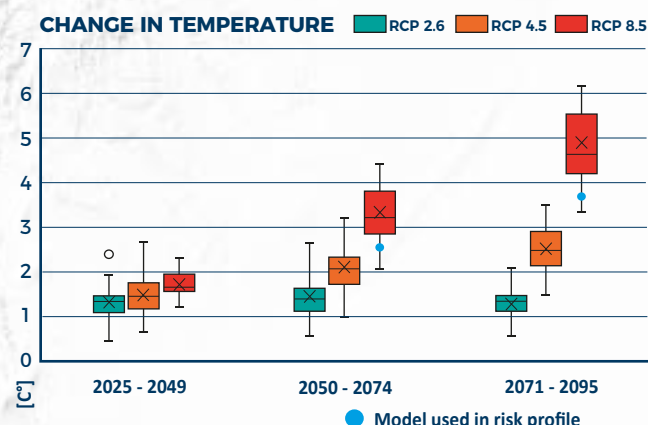
CLIMATE PROJECTIONS USED IN THIS RISK PROFILE

Results referring to climate change presented in this Risk Profile were obtained using a climate projection model based on a high emission scenario (SMHI-RCA4 model, grid spacing 0.44° about 50 km- driven by the ICHEC-EC-EARTH model, RCP 8.5, 2006-2100) ^[13,14,15].

This study uses a high-resolution model which has been accurately calibrated for the African domain. This allows for a better capture of climate variability which is key in assessing extremes. Regional model projections were checked for consistency against a full ensemble of global models available for the area. The Regional model forecasts changes in temperature and annual precipitation. These are in line with the range of variability of global models analyzed in the study by Alder et al. ^[12].

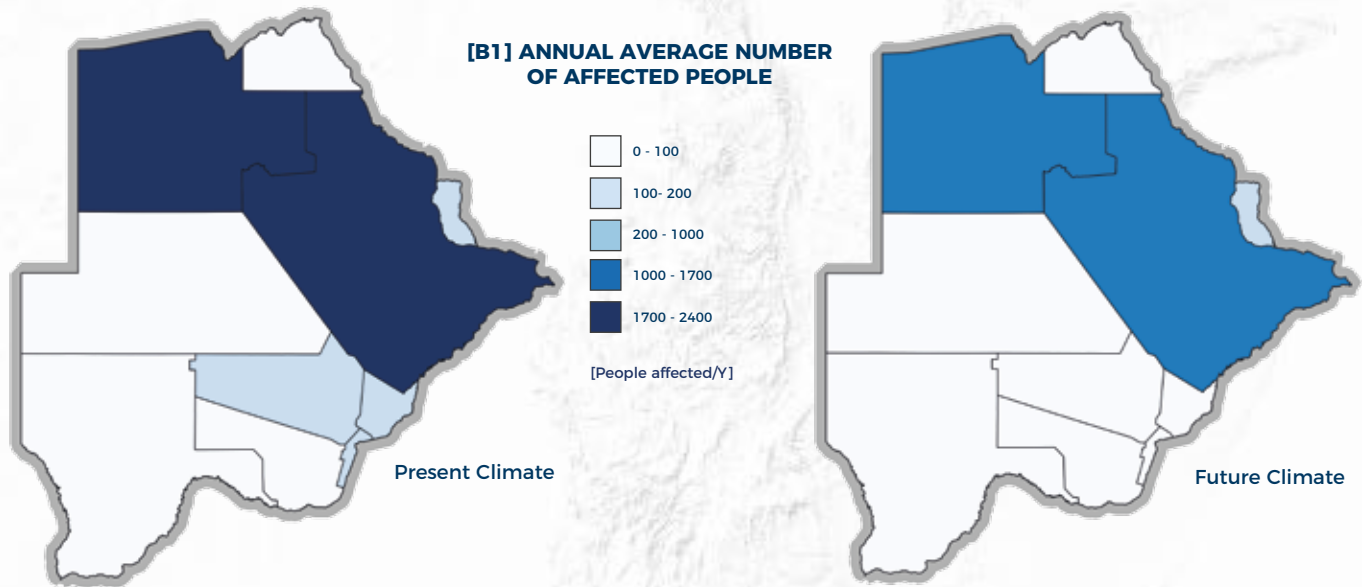


IPCC's Emissions scenarios for Climate Projections



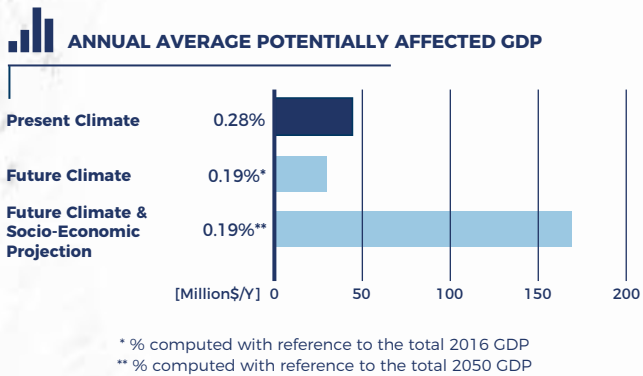
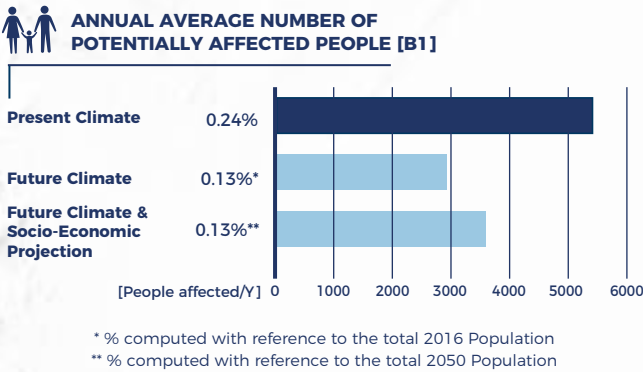
For the specific case of the high emission scenario, the Regional model predicts a more moderate increase in temperature (almost 3.5°C in the long term period) when compared to the global ensemble. With regard to annual precipitation at the country level, changes are predicted by the Regional model in the long-term period.

RESULTS | FLOODS



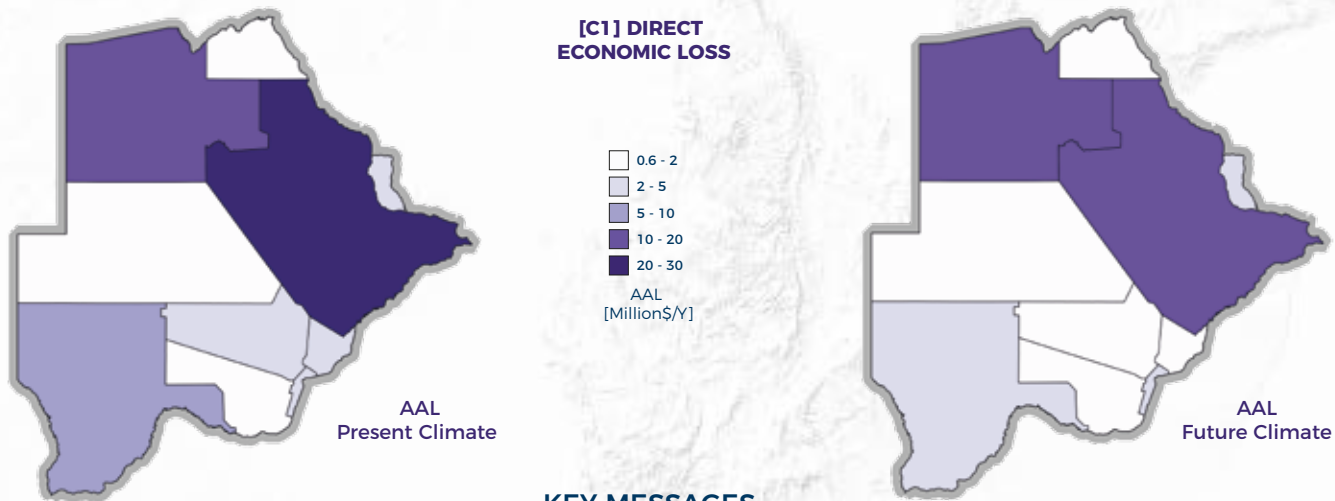
KEY MESSAGES

- Flooding affects on average more than 5,000 people, approximately 0.24% of the total population of the country.
- A majority of the affected people are concentrated in the Central district, which is the most populous district, and in Ngamiland, where the delta of the Okavango river is located.
- The local economy is significantly exposed to floods. On average, almost 50 million USD of GDP per year is potentially affected by floods. This correspond to about 0.28% of the total national GDP.
- As climate models predict significant increase in temperature and a stable precipitation, the flood affected population as well as potentially affected GDP are likely to decrease under future climate conditions when compared to the values evaluated under current climate conditions. However, as shown in the climate session, climate projections are inherently uncertain. This uncertainty must be considered when the above estimations are used in policy development.
- Under future climate conditions, both current and projected socio-economic situations improve. Namely, the flood affected population decreases and the national GDP increases. This is a result of the disproportional growth projected for the population and the GDP (population increase of about 30% and GDP by 5-fold)**. The future prediction is highly uncertain.



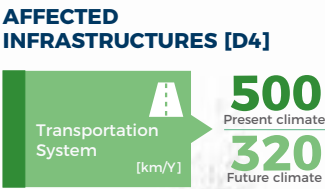
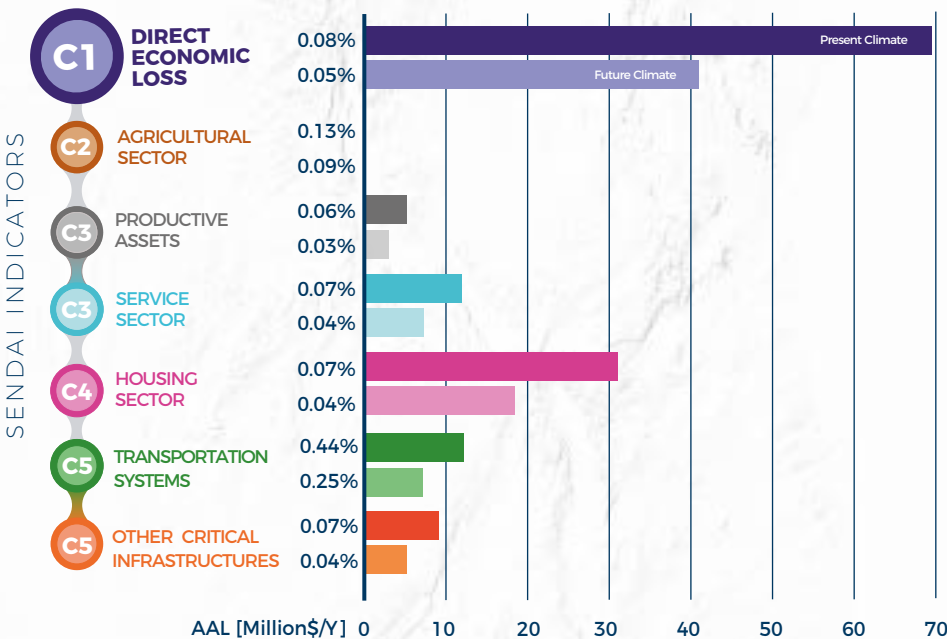
*2016 was taken as a reference year both for GDP and population.
**the Shared Socioeconomic Pathway (SSP) - "mid of the road" (Medium challenges to mitigation and adaptation) has been used to project population and GDP distributions.

RESULTS | FLOODS



KEY MESSAGES

- Direct economic losses in Botswana are concentrated in the central district and in the Ngamiland district. The pattern, although with reduced values, is confirmed in the future climate.
- Direct annual economic losses amount to 70 million USD, which corresponds to roughly 0.08 percent of the total stock value under present climate conditions. The larger portion of losses is incurred in three sectors - housing, service and transportation, followed by the health and education sectors.
- Considering the presently exposed assets for all sectors, it is likely that average annual losses will decrease under future climate conditions. However, this estimation does not consider socio-economic projections which could overturn the future projections.
- The proportion of different sectors in the overall loss does not change under future climate conditions. As highlighted above, climate projections are inherently uncertain and this should be considered when using these estimations in policy development.



RESULTS | FLOODS

KEY MESSAGES

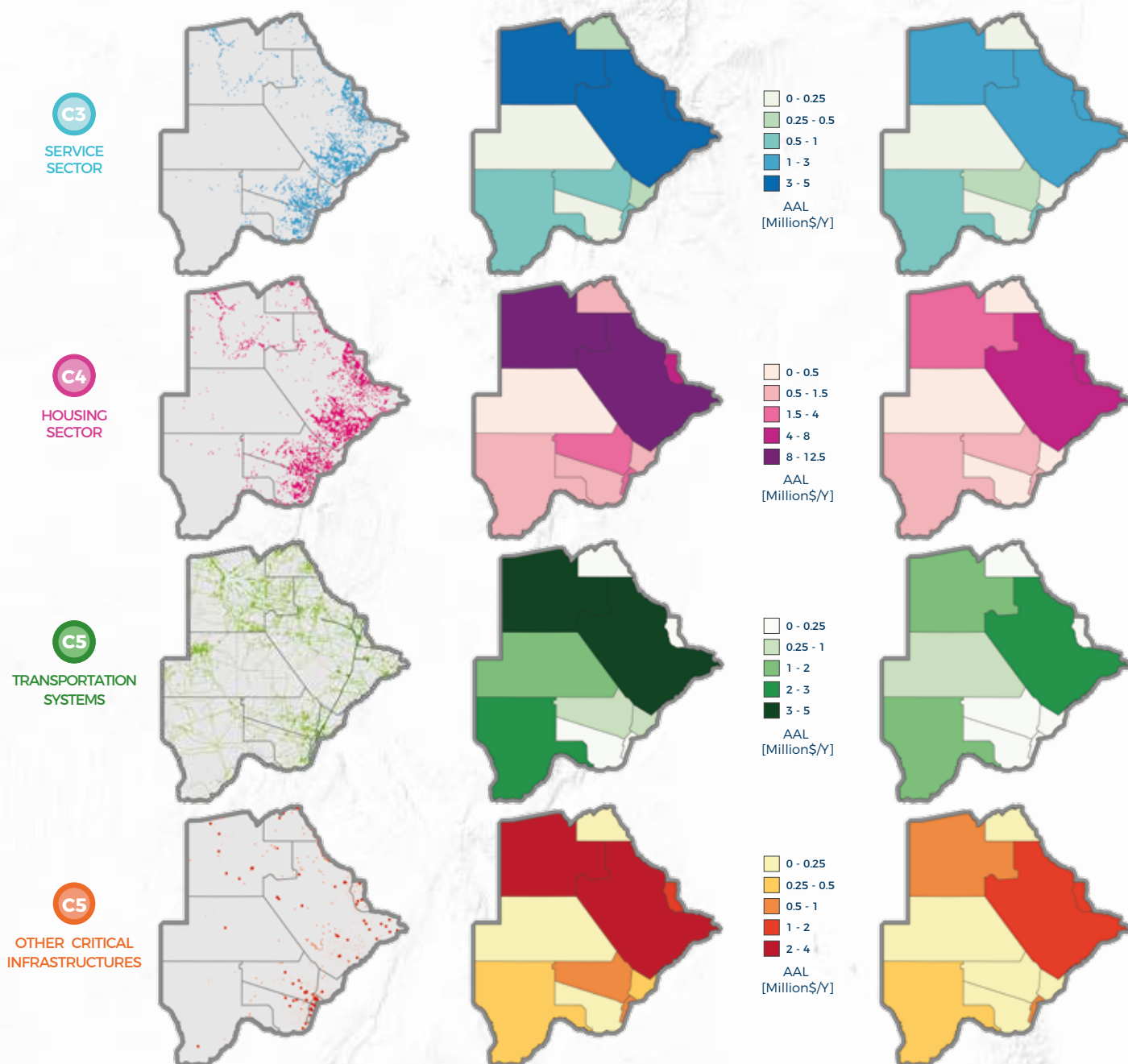
● The AAL distribution for the different sectors confirms the exposure distribution with hotspots in central and Ngamiland districts. the north-eastern and south-eastern districts show remarkable losses despite their limited area.

● The comparison of AALs, for all sectors, between present and future climates, shows that a decrease in economic losses is likely. The pattern indicating a reduction in economic losses is confirmed in all sectors considered.

EXPOSURE DISTRIBUTION

AAL - Present Climate

AAL - Future Climate

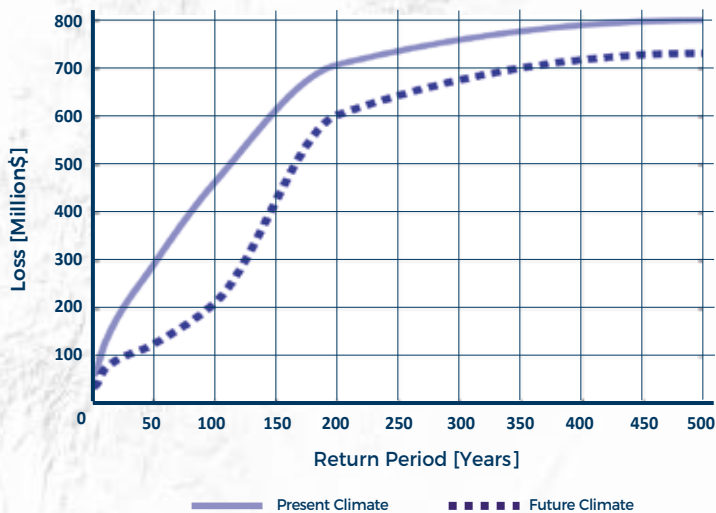


RESULTS | FLOODS

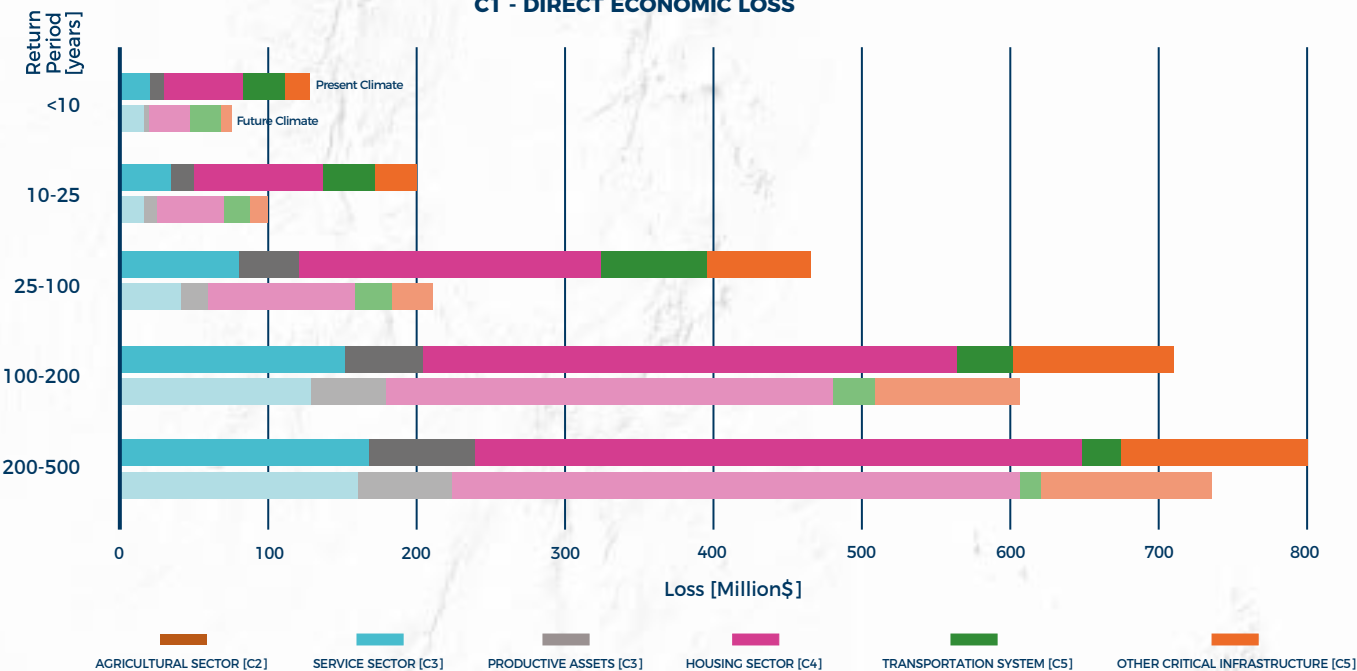
KEY MESSAGES

- Although under future climate conditions Average Annual Loss is about 70 million USD/y, the likelihood of a 200 million loss from floods is on average of once every 20 years. This means that considerable losses may be experienced frequently. The likelihood of disaster loss of about 500 million USD is on average once in 100 years. Extremes losses might reach 800 millions USD.
- Sectors that are most affected by very frequent and frequent loss events are housing, services and transport; the losses distribution among sectors slightly changes moving from rare to very rare loss events and the share of the transport sector decreases in favor of the other critical infrastructures.
- It is likely that both frequent and extreme losses will decrease under future climate conditions and greater differences are observed for rare events. Given the high level of uncertainty in future climate prediction, worse scenarios may also be possible (compare climate section on p.8).
- The specific shape of the PML curve, shows that flood risk can be considerably reduced by strategically minimizing the impact of very frequent disaster events, hence by investing in disaster risk reduction.

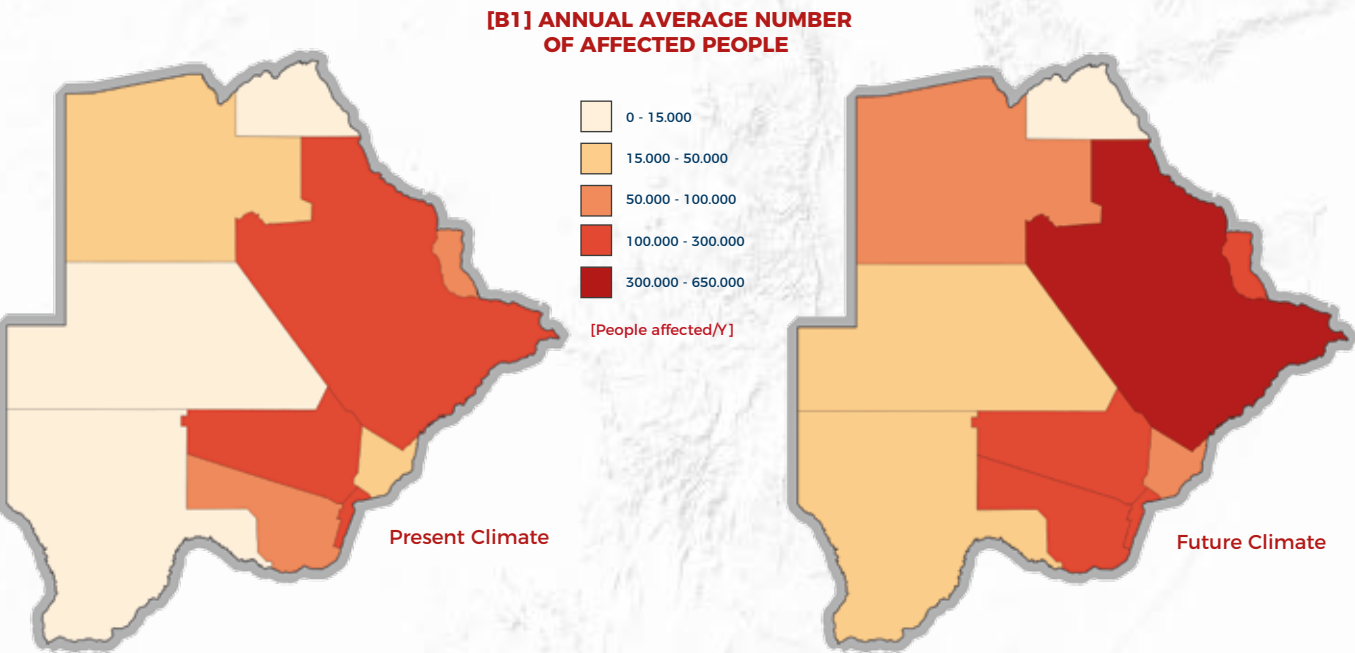
PROBABLE MAXIMUM LOSS CURVE (PML)
C1 - DIRECT ECONOMIC LOSS



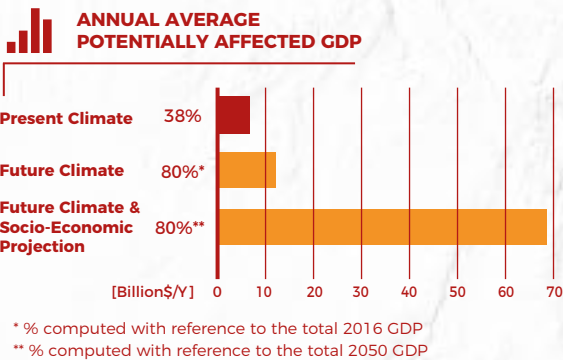
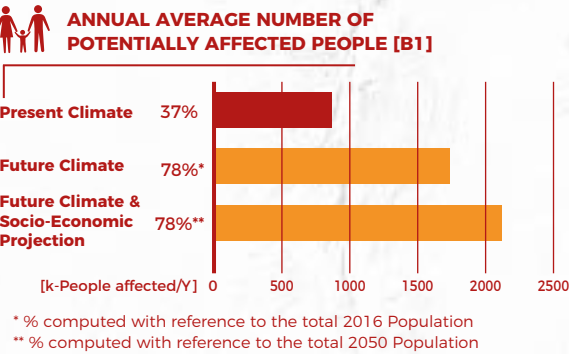
PROBABLE MAXIMUM LOSS CURVE (PML) ACROSS ALL SECTORS
C1 - DIRECT ECONOMIC LOSS



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.



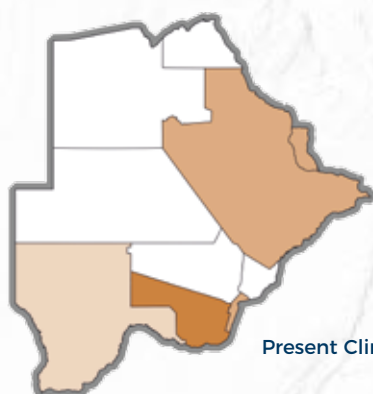
KEY MESSAGES

- With respect to present conditions (1951-2000 climate), the probability of occurrence of severe effective precipitation deficiency (precipitation – evapotranspiration) will increase by 45% in the future (2050-2100 climate). It is likely that a larger share of Botswana will experience frequent droughts.
- In a present climate, on average about 845.000 people (37% of the total 2016 population) are annually affected by droughts. Under future climate conditions, this number is expected to increase to 78% (on average 2.1 million people if population growth is accounted for).
- The average annual percentage of GDP affected by droughts (i.e. the economic value produced in areas hit by droughts) is about 38% of the total GDP. This is equivalent to 5.8 billion USD of GDP per year that could be impacted by droughts. Under future climate conditions, this may rise to 80% of the GDP (12 billion USD), which could amount to 68 billion USD if socio-economic projections are accounted for.

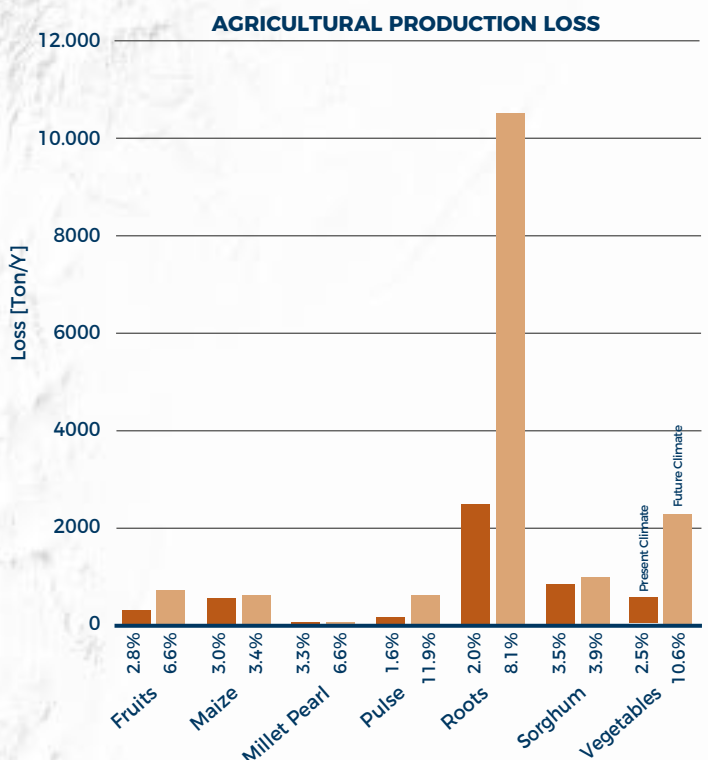
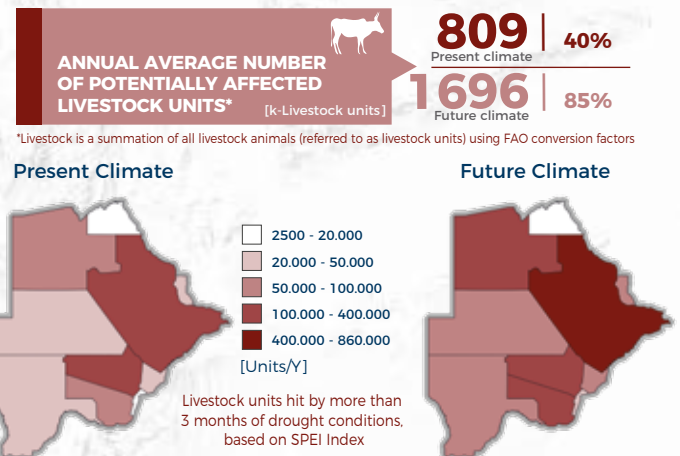
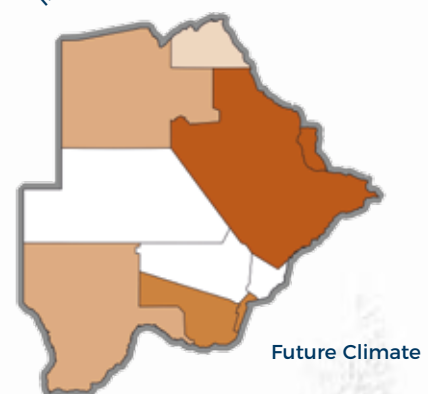
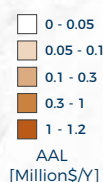
RESULTS | DROUGHTS

KEY MESSAGES

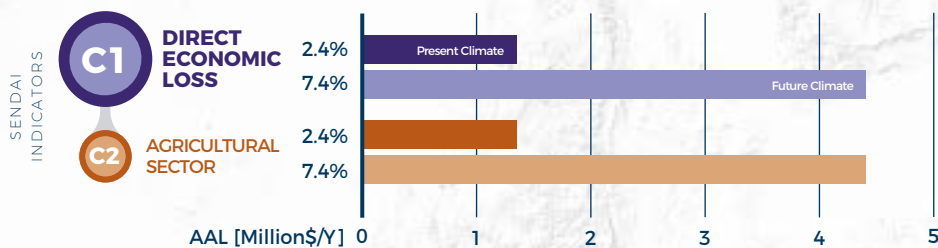
- Under current climate conditions, about 0.8 million livestock units (40% of the total country livestock) are affected by drought. Under future climate conditions (but keeping the current amount of livestock), the number of affected livestock is projected to increase up to 1.7 million units (85% of the total). Currently, most of the livestock affected by droughts is situated in the central district of Botswana, whereas under future climate conditions, Ngamiland, Kweneng and the southern districts are likely to see large numbers of livestock affected by drought.
- Agricultural crop losses are dominated by roots. In relative terms, all selected crop productions, except for maize and sorghum, are strongly affected under future conditions (with increases between two and sevenfold compared to present climate conditions). Under future conditions, the highest relative production losses are about 10% of their average crop productions for pulses and vegetables.
- Under present climate conditions, crop production losses are concentrated in the southern and eastern parts of Botswana. Under future climate conditions, losses increase in most provinces of Botswana except in the central part of the country.
- The amount of lost working days is expected to increase by more than two times under future climate conditions, while remaining below 1% 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 twelve times higher.



C2 - DIRECT AGRICULTURAL LOSS



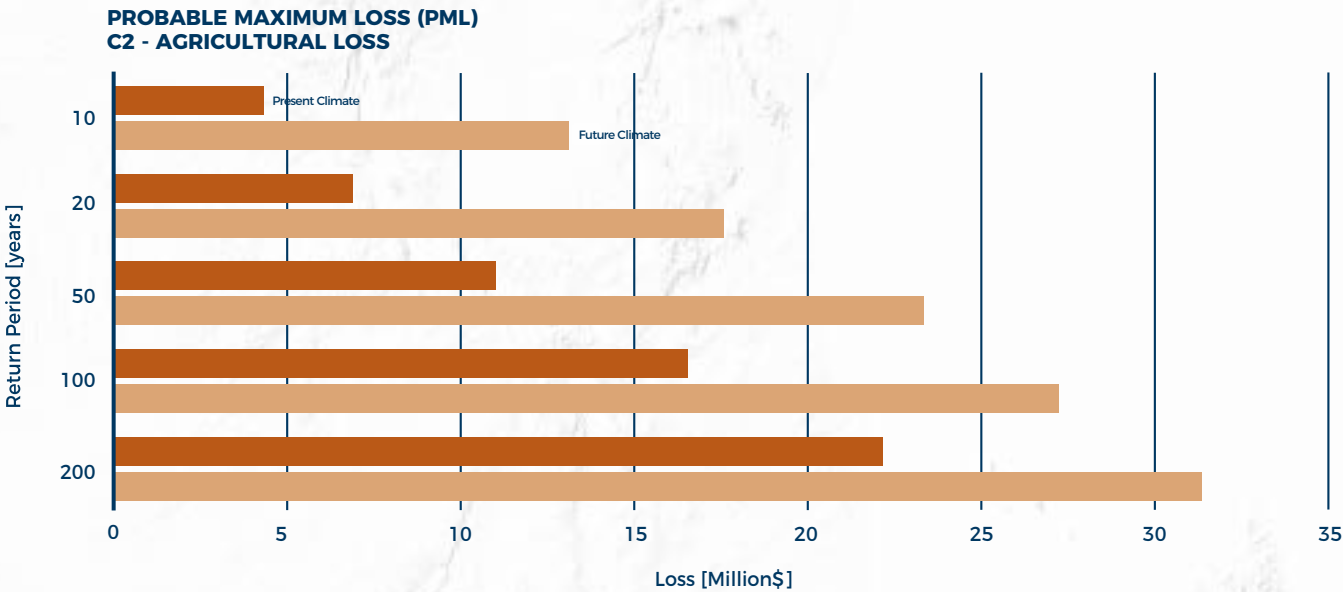
RESULTS | DROUGHTS



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 subsistence agriculture can be neglected in the overall analysis.

KEY MESSAGES

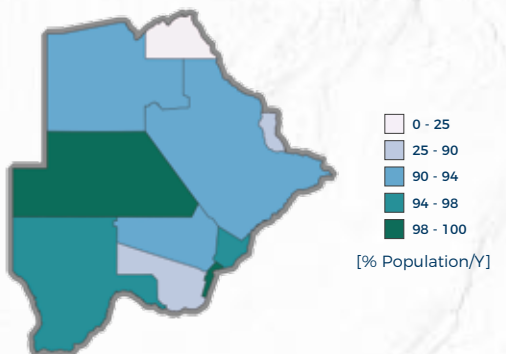
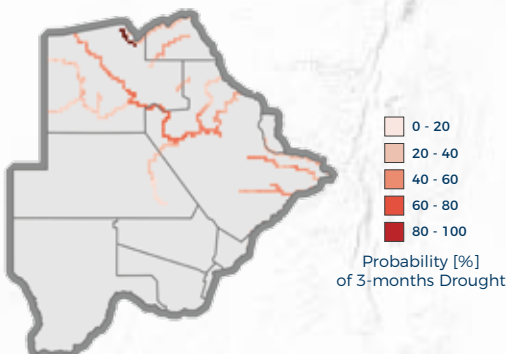
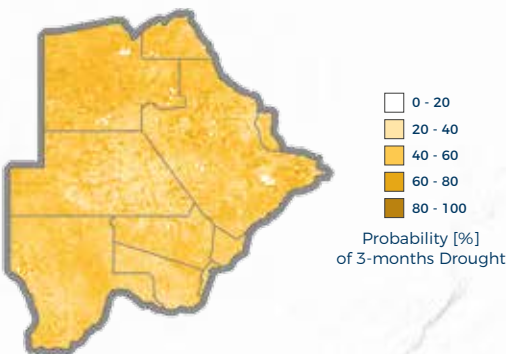
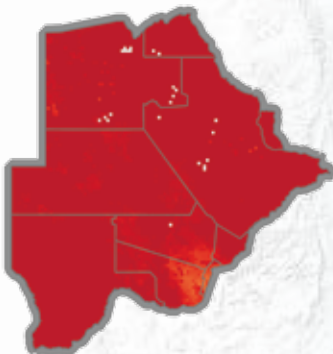
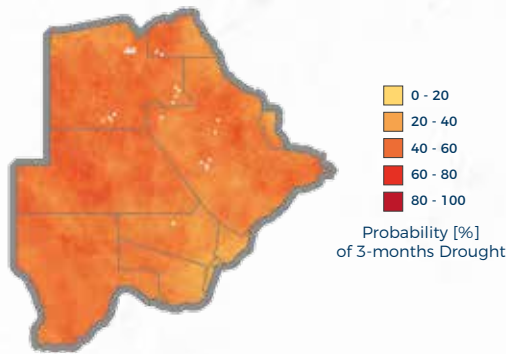
- Average annual crop production loss (C2) increases substantially (three times) and reaches more than 4 million USD per year under future climate conditions which equals to roughly 7% of the total income from crops.
- Under current climate conditions, a gradual increase in agricultural (crop) income losses is expected when return periods go up from 10 to 200 years. Under future climate conditions, and when compared to present climate conditions, agricultural income losses increase significantly. At lower return periods, the relative increase is large (e.g. approximately 3 times for a return period of 10 years).



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, due to climate change, the probability of meteorological droughts will increase in the whole country. This is particularly important for areas dependent on rainfall for their water resources.

SSMI - Standardised Soil Moisture Index

These maps denote the average annual chance of a subsurface drought occurring (%). Droughts are defined as 3 months of soil moisture conditions considerably below normal conditions; calculated through the Standardized Soil Moisture Index (SSMI; see 'Drought' in Glossary). It can be noted that, in the future, the probability of soil moisture droughts will increase the most in the north and east of the country. 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). Mainly the Boteti and Limpopo rivers will face a higher chance of droughts in future climate conditions. 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 m³/person/year). Water scarcity indicates that a population depends on water resources from outside their immediate region (~85 km²). While the majority of the population lives in the east of Botswana, the highest percentage of people suffering from water scarcity is in the warm, semi-arid to arid Ghanzi district.

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

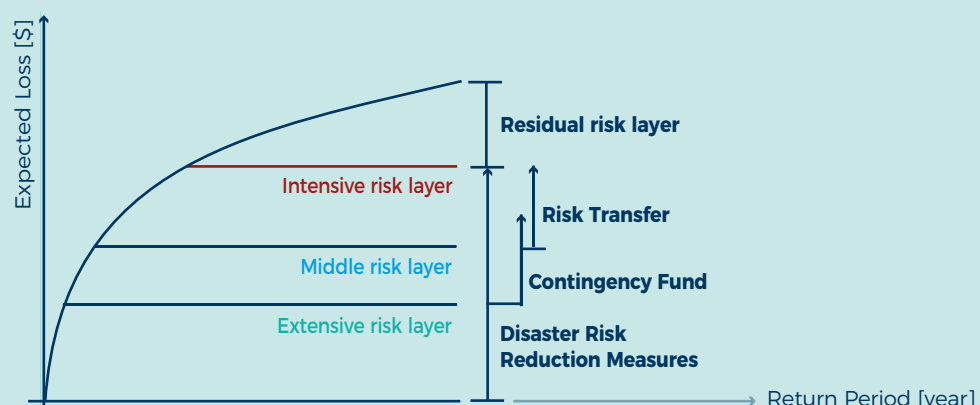
compromised if there is a high ratio of AAL to capital investment and reserves. Social development will be challenged if there is a high ratio of AAL to social expenditure. Moreover, limited ability to recover quickly may significantly increase indirect disaster losses. Countries that already have compensatory 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 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] <http://www.worldometers.info/world-population/botswana-population/>

[2] Republic of Botswana CIA Factbook. <https://www.cia.gov/library/publications/the-world-factbook/geos/bc.html>

[3] WorldBank. <http://www.worldbank.org/en/country/botswana/overview>

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

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

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

[7] <https://www.climate-zone.com/climate/botswana/>

[8] FAO Aquastat, Botswana, http://www.fao.org/nr/water/aquastat/countries_regions/BWA/

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

[10] <https://www.mapsofworld.com/botswana/botswana-river-map.html>

[11] <https://www.worldatlas.com/webimage/countrys/africa/botswana/bwland.htm>

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

[13] 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>

[14] 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.

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

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

www.preventionweb.net/resilient-africa
www.undrr.org

RISK PROFILES ARE AVAILABLE AT:

riskprofilesundrr.org



This publication has been produced with the assistance of the European Union.
The contents of this publication are the sole responsibility of CIMA Research Foundation
and can in no way be taken to reflect the views of the European Union.