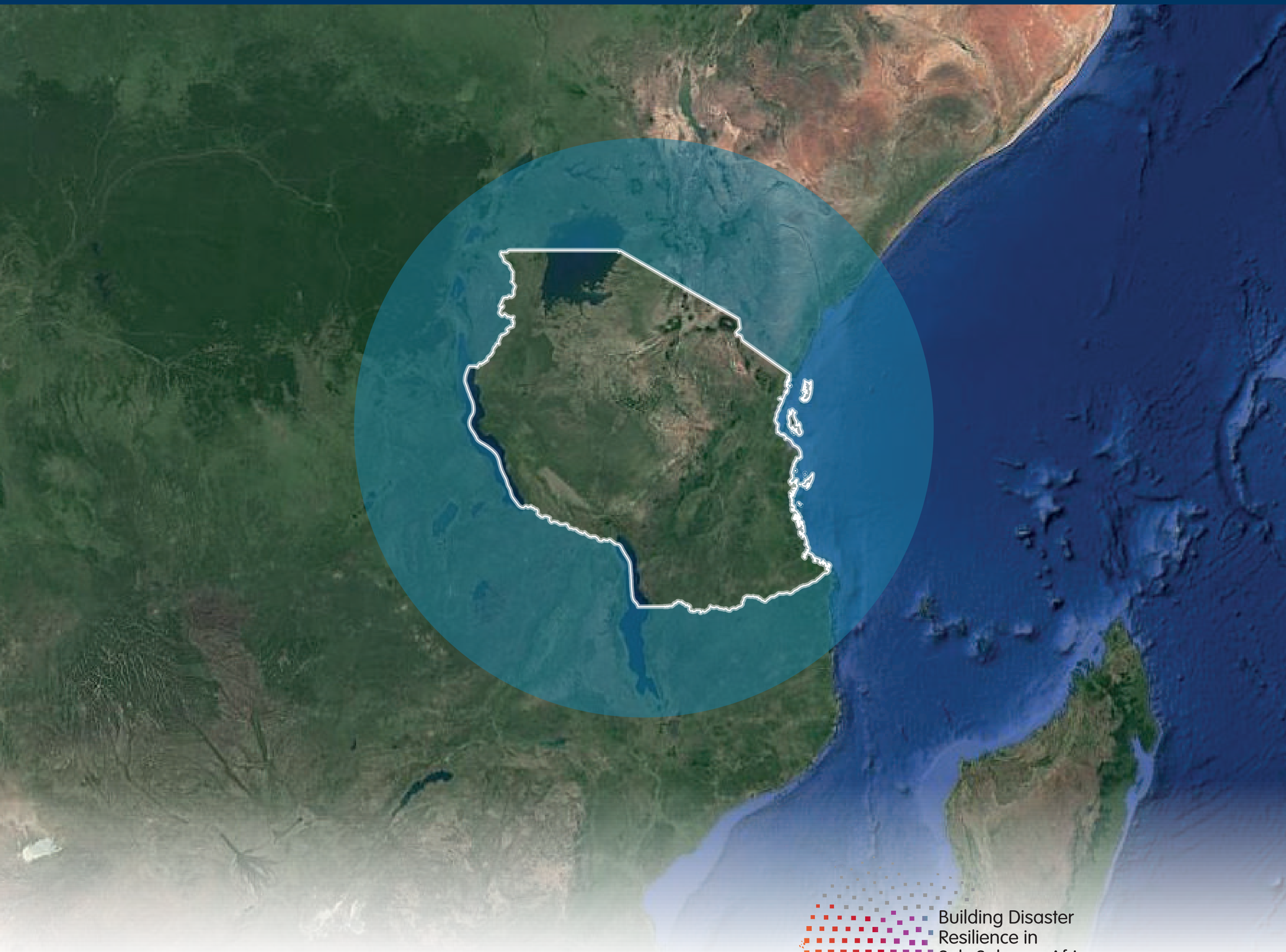
2019

DISASTER RISK PROFILE

Flood Drought

UR Tanzania



Building Disaster Resilience in Sub-Saharan Africa

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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Via A. Magliotto, 2 - 17100 Savona - Italy • Phone: +39 019230271 - Fax: +39 01923027240
info@cimafoundation.org • www.cimafoundation.org

Design and layout: CIMA Research Foundation

In collaboration with: VU University Amsterdam; Wageningen University & Research

Project Team

Authors
Roberto Rudari [1]
Amjad Abbashar [2]
Sjaak Conijn [4]
Hans de Moel [3]
Auriane Denis-Loupot [2]
Luca Ferraris [1;5]
Tatiana Ghizzoni [1]
Adrien Gignac-Eddy [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]
Marthe Wens [3]

Scientific Team
Nazan An [7]
Chiara Arrighi [1;6]
Valerio Basso [1]
Guido Biondi [1]
Gulia Bruno [1]
Alessandro Burastero [1]
Lorenzo Campo [1]
Fabio Castelli [1;6]
Mirko D'Andrea [1]
Fabio Delogu [1]
Giulia Ercolani [1;6]
Giacomo Fagugli [1]
Elisabetta Fiori [1]
Simone Gabellani [1]
Alessandro Masoero [1]
Alessia Matanò [1]
Enrico Ponte [1]
Ben Rutgers [4]
Franco Siccardi [1]
Francesco Silvestro [1]
Andrea Tessore [1]
Tufan Turp [7]

Editing
Isabel Gomes [1]
Adrien Gignac-Eddy [1]

Graphics
Rita Visigalli [1]

Supporting Team
Simona Pozzati [1]
Luisa Colla [1]
Monica Corvarola [1]
Anduela Kaja [1]
Daniela Perata [1]
Tatiana Perrone [1]
Elisa Poggi [1]
Martino Prestini [1]
Maria Ravera [1]

Country Team
Matamwe Jimmy Said [8]
Guido Uhinda [11]
Jane Alfred [8]
Charles Elikunda Msangi [8]
Samueli Mbuya [9]
Elibariki Mwanga [10]
John Kiriwai [8]
Ewald Bonifasi [8]
Ally Mwatima [8]

With the support of the UNDRR Regional Office for Africa

CIMA Research Foundation [1] UNDRR [2]
Vrije Universiteit Amsterdam [3] Wageningen University & Research [4]
Università di Genova [5] Università di Firenze [6] Bogazici University [7]
Disaster Management Department, Prime Minister's Office [8]
Central Forecasting Office, Tanzania Meteorological Authority [9]
Water Resources Development Department, Ministry of Water [10]
Ardhi University [11]

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During the past two years, as the scientific team collected data and conducted the risk assessment process, the vital contributions and continuous feedback provided by the Tanzanian institutions once again revealed the importance of collaborative, fruitful relationships for knowledge sharing and horizontal learning.

The consortium would like to express its gratitude and acknowledge the valuable support it received from all of its Tanzanian partners, namely: the Prime Minister's Office for Disaster Management Department, the Vice President's Office, the National Bureau of Statistics, the Ministry of Finance and Planning, the Ministry of Agriculture, the Ministry of Water, the Ministry of Energy, the Dar es Salaam Regional Commissioner's Office, the Tanzania Commission for Science and Technology, the Tanzania Meteorological Agency and the National Emergency Coordination Group.

The present disaster risk profile is not only the synthesis of insights gained during several months collecting data and conducting risk modelling in UR Tanzania, but also the result of having mobilized more than six hundred risk managers from fifteen other African countries during strategic national workshops, consultative meetings and individual interviews. This opportunity, made possible through the implementation of the ACP-EU funded programme "*Building Disaster Resilience to Natural Hazards in Sub-Saharan African Regions, Countries and Communities*", allowed us to listen to the real challenges, perceptions and priorities on risk governance and societal needs. As a result, we believe that we have moved towards a common understanding of risk in each of the countries we have had the privilege to work with.

Aligned to the Sendai Framework for Disaster Risk Reduction, and as representatives of the scientific community, the consortium will always encourage countries to increase research on disaster risk causes and scenarios, supporting local authorities in understanding the value of a systematic interface between policy and science for decision-making. Under this lens, three main groups of stakeholders were identified as key beneficiaries of this report:

• **Policy makers, risk managers and local academia**, who wish to develop their risk knowledge and to apply and promote evidence-informed policy making for good public risk governance.
• **Civil society leaders**, who wish to explore the evolving roles that they may play, through advocacy and awareness, given the foreseen economic, environmental and social changes.
• **International Donors and NGOs** who wish to identify priority sectors and regions for risk mitigation funding and actions.

As science is first and foremost at the service of humankind, we hope that this report facilitates the translation of knowledge into solutions to reduce disaster losses, increase societal resilience and the capacity to create development models able to provide a better future for all of Earth's inhabitants.

The Consortium

Foreword

The Disaster Risk Profile for Tanzania provides a comprehensive view of hazard, risk and related uncertainties for floods and droughts. The study considered possible changes in climate and socio-economic situation, projected over the next 50 years. Major floods and drought not only cause huge negative impacts on human life, but also can result in enormous economic losses, hence inhibit achievement of sustainable development. These events carry critical policy implications and trigger new questions on vulnerability, risk and uncertainty.

Disaster loss from extensive disaster risk associated to floods and drought is on the rise in Tanzania with grave consequences to livelihood of individuals, as a result of increasing vulnerabilities related to changing climate, weather variability, technological and socio-economic conditions. These disasters are undeniably increasing due to factors such as unplanned urbanization taking place within high-risk zones, economic development in hazard-prone areas, environmental degradation and population growth. These factors indicate a future where disasters could increasingly threaten the national economy, its population and sustainable development.

The adoption of the comprehensive Disaster Risk Profile for flood and drought underscores the commitment of the Government of Tanzania towards disaster risk reduction for resilience building at all levels and the development and maintenance of sound response and recovery mechanisms.
The developed risk profile will guide different users in various fields to take disaster risk informed action. I commend this profile will prove useful to the policy makers, risk managers, academia, researchers, development partners, NGO's, civil society, media and private sectors in the hopes that it will inspire all to redouble our collective efforts to create and maintain resilient communities and nations.

Ms. Dorothy A. Mwaluko
Permanent Secretary
Prime Minister's Office

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Acronyms & Abbreviations

AAL	Annual Average Loss
ACP	African, Caribbean, and Pacific group of states
CCA	Climate Change Adaptation
CIMA	International Centre on Environmental Monitoring
DRM	Disaster Risk Management
DRR	Disaster Risk Reduction
EU	European Union
GDP	Gross Domestic Product
IIASA	International Institute for Applied Systems Analysis
IPCC	Intergovernmental Panel on Climate Change
NGO	Non-Governmental Organization
PML	Probable Maximum Loss
PRA	Probabilistic Risk Assessment
RCP	Representative Concentration Pathway
SDGs	Sustainable Development Goals
SSPs	Shared Socio-economic Pathways
STAG	Scientific and Technical Advisory Group (UNDRR)
UN	United Nations
UNDRR	United Nations for Disaster Risk Reduction
USD	United States Dollars


Rita Visigalli

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Risk information for sustainable development

Over the last few decades, disasters resulting from natural hazards have often derailed hard-earned development plans and progress. Disasters damage infrastructure, lifelines and critical facilities and often result in severe human, financial, cultural and environmental losses. While disasters have direct consequences on development efforts, inversely, "bad development" can itself be a driver of risk. Non-planned urbanization and the building of non risk-resilient infrastructure are some examples of unsustainable development. These approaches to development increase the vulnerability of populations and of existing economic systems, while depleting the natural ecosystems, in a vicious cycle.

Over the last four decades, Sub-Saharan Africa has experienced more than 1000 disasters (*World Bank, 2017*), affecting approximately 320 million people (*Preventionweb*). The majority of disasters in Africa are hydro-meteorological in origin, with droughts affecting the largest number of people and floods occurring frequently along major river systems and in many urban areas. Cyclones, geological events, sea level increase, coastal erosion and storm surges also deeply affect the continent. Sub-Saharan Africa's disaster risk profiles relate information on natural hazards to each countries' population and economic exposures and vulnerabilities. These exposures and vulnerabilities are exacerbated by countries' limited coping capacities and resources for investing in disaster risk reduction and recovery measures. In this context, post-disaster rehabilitation often implies the intervention of international aid or the diversion of national funds originally planned for development interventions, resulting in a tremendous setback for societal development as a whole.

Disasters, however, can be significantly minimised with rigorous scientific risk modelling and through effective institutional and community preparedness. Considering that natural hazard events will likely change in frequency and magnitude due to climate change in the near future, it is necessary to ensure that risk assessments be conducted systematically, so as to provide a quantitative basis for disaster risk reduction and climate adaptation measures. Risk reduction processes must also be based on the effective communication and application of **risk information** through the strengthening of institutional and human **capacities**. Risk assessments and the risk information they provide should support risk-informed **decision-making** towards resilience building across all levels and within all socio-economic development sectors.

Risk reduction and resilience building are embedded in the various global frameworks adopted in 2015 and 2016, such as the Addis Ababa Action Agenda, the Paris Agreement, the Agenda for Humanity, the New Urban Agenda, the Sendai Framework for Disaster Risk Reduction and the 2030 Agenda for Sustainable Development. These international frameworks are the result of a long-term process developed by different communities, often from different cultural and scientific backgrounds, but their final aim points towards the same sustainable future. As such, the frameworks are closely intertwined and should be coherently implemented. Challenges such as poverty eradication, economic growth, reduction of inequalities and the creation of sustainable cities and settlements are some examples that require a massive, joint effort to design and apply coherent policies and strategies.

These need to be based on scientific risk information that assesses vulnerability, hazard and exposure to estimate disaster impacts - quantifying population and economic losses across different regions and sectors.

SENDAI / SDG'S INDICATORS

	INDICATORS			FLOOD			DROUGHT			SDG	SDG INDIC.
				C	P	SEP	C	P	SEP		
SENDAI INDICATORS	B1		Number of directly affected people	•	•	•	•	•	•	1 11 13	1.5.1 11.5.2 13.1.1
SENDAI INDICATORS	C1 Direct economic loss attributed to disasters	C2	Direct agricultural loss (Crops)	•	•		•	•		2	-
SENDAI INDICATORS	C1 Direct economic loss attributed to disasters	C3	Direct economic losses to productive asset (Industrial Buildings + Energy Facilities)	•	•		•	•		1	1.5.2
SENDAI INDICATORS	C1 Direct economic loss attributed to disasters	C3	Direct economic losses in service sector	•	•					1	1.5.2
SENDAI INDICATORS	C1 Direct economic loss attributed to disasters	C4	Direct economic losses in housing sector	•	•					1	1.5.2
SENDAI INDICATORS	C1 Direct economic loss attributed to disasters	C5	Direct economic losses to transportation systems (Roads + Railways)	•	•					1	1.5.2
SENDAI INDICATORS	C1 Direct economic loss attributed to disasters	C5	Direct economic losses to other critical infrastructures (Health + Education Facilities)	•	•					1	1.5.2
SENDAI INDICATORS	D1 Damage to critical infrastructure attributed to disasters	D2	Number of destroyed or damaged health facilities	•	•					11	-
SENDAI INDICATORS	D1 Damage to critical infrastructure attributed to disasters	D3	Number of destroyed or damaged educational facilities	•	•					11	-
SENDAI INDICATORS	D1 Damage to critical infrastructure attributed to disasters	D4	Number of other destroyed or damaged critical infrastructure units and facilities (Transportation systems)	•	•					11	-
* No official Sendai indicators	Agricultural & Economic Indicators		GDP of affected areas*	•	•	•	•	•	•	1	1.5.2
* No official Sendai indicators	Agricultural & Economic Indicators		Number of potentially affected livestock units*				•	•		2	-
* No official Sendai indicators	Agricultural & Economic Indicators		Number of working days lost*				•	•		2	-
* No official Sendai indicators	Agricultural & Economic Indicators		Food Energy Loss				•	•		2	-
* No official Sendai indicators	Agricultural & Economic Indicators		Crop Drought Tolerance				•	•		2	-
* No official Sendai indicators	Hazard Index	SPEI	Standardised Precipitation-Evapotranspiration Index*				•	•			
* No official Sendai indicators	Hazard Index	SSMI	Standardised Soil Moisture Index*				•	•			
* No official Sendai indicators	Hazard Index	SSFI	Standardised StreamFlow Index*				•	•			
* No official Sendai indicators	Hazard Index	SPI	Standardised Precipitation Index*				•	•			
* No official Sendai indicators	Hazard Index	WCI	Water Crowding Index*				•	•			

C Current Climate (1979 - 2018)
P Projected Climate (2051-2100)
SEP Socio-Economic Projection (2051-2100)

Why a probabilistic risk assessment?

The added value of a Probabilistic Risk Assessment (PRA) is often misunderstood, as audiences tend to view it as a highly technical method that is difficult to apply or understand. These difficulties represent a challenge for communicating risk results.
A probabilistic disaster risk profile should be seen as a risk diagnosis instrument, as it provides indications on possible hazardous events and their impact. Both past and probable future events are taken into consideration in a comprehensive risk assessment exercise. In this risk profile two different climate scenarios were considered:

- **under current climate conditions**: with disaster risk assessed using the observed climate conditions in the **1979 - 2018** period;
- **under projected climate conditions**: with disaster risk being assessed under projected climate conditions (projected period **2051 - 2100**), considering the IPCC scenario RCP 8.5 which foresees an increase in the global temperature between 1,5°C and 4°C by 2100, and assuming that further risk mitigation measures will not be put in place.

Probabilistic disaster risk profiles consider all possible risk scenarios in a certain geographical area. This means that both low frequency, high loss impact events, as well as high frequency, lower loss impact events are calculated. Included is their probability of occurrence, and all elements of the risk equation (risk = hazard X exposure X vulnerability / capacity), their variability and uncertainty ranges.

$$\underset{\text{Risk}}{R} = \frac{\underset{\text{Hazard}}{H} \times \underset{\text{Exposure}}{E} \times \underset{\text{Vulnerability}}{V}}{\underset{\text{Capacity}}{C}}$$

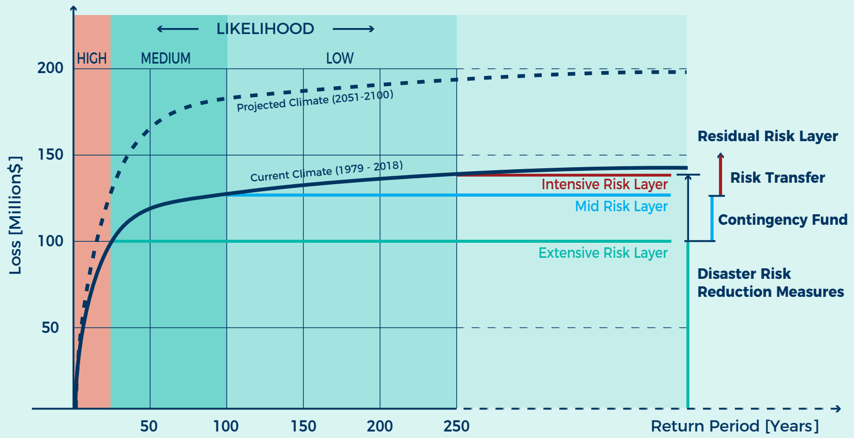
Events which have never been historically recorded but might occur in projected climate conditions are also considered in the risk analysis. This feature is particularly useful in the context of climate change which is dramatically increasing uncertainty about future hazard patterns. Thus, societies need to calculate their "worst" possible impacts in order to be prepared. Under this lens, there is no valid alternative to a probabilistic analysis in order to address this uncertainty in a usable, quantitative way.

By assigning a probability of occurrence to each event magnitude, a probabilistic risk profile quantifies the expected direct impacts of disasters through economic metrics and affected population, both at aggregated and at disaggregated levels (ex. affected children, women and people with disabilities, different regions and development sectors). As this risk information is framed within return periods as a conventional probability measure, a PRA approach provides a clear vision of the risk trends:

This risk information - expressed in an annual average loss curve (AAL) and a probable maximum loss curve (PML) is calculated both at a national scale, as well as by sector and by region, allowing for a geographic and quantitative comparison of disaster losses, as well as within a country and/or between countries. These analyses and comparison exercises are an important step of the risk awareness processes, key in pushing for risk reduction, risk adaptation and risk management mechanisms to be put in place.

PML CURVE INTERPRETATION

Large-scale natural hazards don't necessarily lead to important economic losses. An event that occurs in a desert for example (i.e. no exposure) would not result in any losses. It is therefore important to understand the estimated losses events are likely to produce. The PML curve shows the likelihood of a certain scenario producing an estimated amount of losses. In this example, under current climate conditions, Country X would experience at least one disaster event, leading to losses equal or greater than 50 million dollars, on average every three to five years, and at least one disaster event, leading to losses greater or equal than 130 million dollars, on average every one hundred years. Under projected climate conditions (IPCC RCP 8.5), losses equal or greater than 50 million dollars can be experienced on average every three to five years, while losses equal or greater than 130 million dollars can be experienced on average once every 25 years. In this case, high frequency disasters - within a return period of 10 years and losses of equal or greater than 70 million dollars will keep a constant pattern, both in current and projected climate conditions. Medium and rare frequency loss events (medium and low likelihood) - with a return period ranging from 25 to 250 years are expected to lead to an increase between 30% and 50% in economic losses in future. The PML curve can be subdivided into three main layers: the **Extensive Risk Layer** typically associated with risk reduction measures (e.g. flood defences, vulnerability reduction interventions); the **Mid Risk Layer** that captures higher losses which are commonly mitigated using financial funds at country level, such as the contingency fund; the **Intensive Risk Layer** (severe and infrequent hazard events) that is normally managed trough risk transfer mechanisms such as insurance and reinsurance measures. The remaining Residual Risk (catastrophic events) is the risk that is considered acceptable/tolerable due to the extreme rarity of the events causing such loss levels. Given their rarity, there are no concrete actions to reduce risk beyond preparedness (e.g. civil protection actions, humanitarian aid coordination).



Probabilistic disaster risk profiles are used as the first step in cost-benefit analyses of investments and policies for disaster risk reduction. Cost-benefit analyses show decision-makers the required level of public sector financing and/or insurance mechanisms to support disaster risk management across sectors, an important tool for guiding risk management policies. In the medium and long term, these investments and policies improve social and economic outcomes, as well as institutional coherence and efficiencies. The return on these investments (i.e. from the decrease in disaster losses) will free resources, allowing future budgets to address other development challenges, thus creating a virtuous cycle. The integration of disaster risk profiles developed with a probabilistic approach instils an added value, not only by delivering highly reliable science-based information, but also as a trigger for integrated and resilient development approaches.

Climate Scenarios

Although the international community is consensually aware of the ongoing global warming due to the emission of greenhouse gases and air pollutants in the atmosphere, its main consequences are expected to be observed in the behaviour of projected climate patterns.

Both historical and projected climate patterns cannot be analysed without considering its intrinsic link with socioeconomic development. Factors like population, economic activity, urbanization, social equality and consumption patterns determine the way energy, land and natural resources are used. These in turn determine the emission of greenhouse gases and air pollutants in the atmosphere. Climate change is expected to impact socio-economic activities by, for example, increasing the frequency and severity of extreme weather events with direct impacts in societal well-functioning and development.

The way this climate-social dependency will translate into projected climate patterns is inherently uncertain, as it depends on human decisions, actions and behaviours yet to be made. But the future is not completely unknown: scenarios can be used to explore what could and what should happen in different decision-making contexts, analysing the consequences on the development of the projected climate conditions. With this in mind, in the late 2000s, the international climate community started developing scenarios to explore how the world might change over the next century, looking at possible trajectories of population, economic growth and greenhouse emissions, both through isolated and integrated approaches.

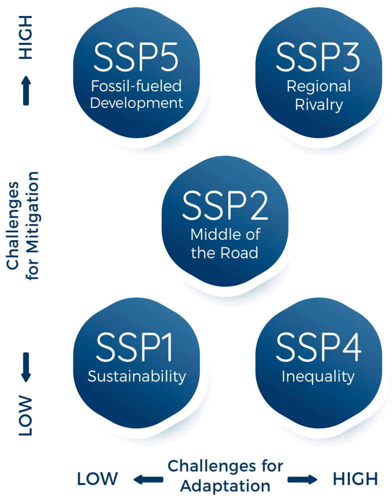
The Representative Concentration Pathways (RCPs) were developed to describe the different levels of greenhouse gases and other radiative forces that might occur by 2100 - not including any socioeconomic narratives - and are represented in four different pathways: 2.6, 4.5, 6.0, 8.5.

SCENARIO NAME	ASSUMES WE REDUCE CO_2 EMISSIONS	PREDICTED TEMPERATURE INCREASE BY 2100	PREDICTED SEA LEVEL RISE BY 2100
RCP 2.6	VERY QUICKLY	(1˚C)	0.44 m
RCP 4.5	SOMEWHAT QUICKLY	(1.8˚C)	0.53 m
RCP 6.0	MORE SLOWLY	(2.4˚C)	0.55 m
RCP 8.5	HARDLY AT ALL	(4.1˚C)	0.74 m

Source table: https://www.exploratorium.edu/climate/looking-ahead

Another set of “pathways” were developed in 2016, by modelling the behaviour of socioeconomic factors such as population, economic growth, education, urbanization and the rate of technological development. They are known as the “*Shared Socioeconomic Pathways*” (SSPs) and are based on five different ways in which the world might evolve:

SSP1 - a world of sustainability focused growth and equality
SSP2 - a "middle of the road" world where trends broadly follow their historical patterns
SSP3 - a fragmented world of "resurgent nationalism"
SSP4 - a world of ever-increasing inequality
SSP5 - a world of rapid and unconstrained growth in economic output, energy use



Source image: https://climatescenarios.org/primer/socioeconomic-development

Each of the SSPs socioeconomic conditions can be related to estimates of future energy use characteristics and greenhouse gas emissions, therefore the connection between SSPs and RCPs is crucial for combined modelling.
In our case the SSP2 - middle of the road pathway has been chosen as one of the most probable scenarios for future development. This choice is based on the fact that no specific information or study was gathered in this direction thus, a "central" scenario was thought to be the most adequate choice. In the "*middle of the road*" SSP2, emissions will continue to increase through the end of the century, reaching between 65GtCO2 and 85GtCO2, resulting in a warming of 3.8-4.2°C. As a result, the combination of the RCP8.5 worst case scenario with SSP2 is a consistent choice that highlights the future risk figures in the absence of a strong, global and coordinated commitment towards a climate change mitigation policy.

Both RCP and SSPs were designed to be complementary: while the RCPs set pathways for greenhouse gas concentrations and the amount of warming that could occur by the end of the century, SSPs set the stage on which reductions in emissions will - or will not - be achieved. Moreover, SSPs are now being used as important inputs for the latest climate models and will be integrated in the Sixth Assessment of the Intergovernmental Panel on Climate Change (to be published in 2020-2021) and to explore how the climate goals of the **Paris Agreement** could be met.

SOCIO-ECONOMIC PROJECTIONS FOR UR TANZANIA

This risk profile assumed the SSP2 for its projection analysis: a "*middle of the road*" world where trends broadly follow their historical patterns. According to these conditions, the population of UR Tanzania in 2050 will more than double compared to 2018 Census Projection, whereas GDP is expected to increase by twelve times compared to 2018 local data.

POPULATION [Million People]
54.2* 2018
130.0 2050 Projection

GDP [Billion$]
56.9 2018
702.1 2050 Projection

*Projected figures based on 2012 population and Housing Census

PROJECTING POPULATION GROWTH AND URBANIZATION

Population levels are projected to increase in the future, but population distribution is also projected to change dramatically. Urbanization will be a driving force in many African countries in the coming decades. This will affect the riskscape, especially for localized hazard patterns such as the ones on floods. In this profile a model has been used to mimic population growth and urbanization based on a simplified Cellular Automata similar to the one proposed in the literature (i.e. SLEUTH from Clarke and Gaydos, 1998*). Starting from a grid representation of population distribution over the country, the model simulates the evolution of two simultaneous processes triggered by a myriad of seemingly random events: population growth in each location and population migration from one location to another. The evolving population pattern is conditioned by population density, presence of bodies of water, distance that needs to be covered for internal migration and the ability of certain locations/cities to attract populations. The attractiveness of a certain location increases with its vicinity to transport infrastructure and with increasing urban connectivity, so that urbanization is a spontaneous, dynamic evolution of the model. Parameters of the model are calibrated with data and projections of population growth and urbanization from UN-World Population Prospects**.

Northern part of Dar es Salaam, current population density

Northern part of Dar es Salaam, 2050 projection of population density

** Clarke, K.C., and L. Gaydos., 1998. Loose-coupling a cellular automaton model and GIS: Long-term urban growth prediction for San Francisco and Washington/Baltimore, Int J of Geographic Inf Sci. 12, 699–714.*
*** https://population.un.org/wpp/*

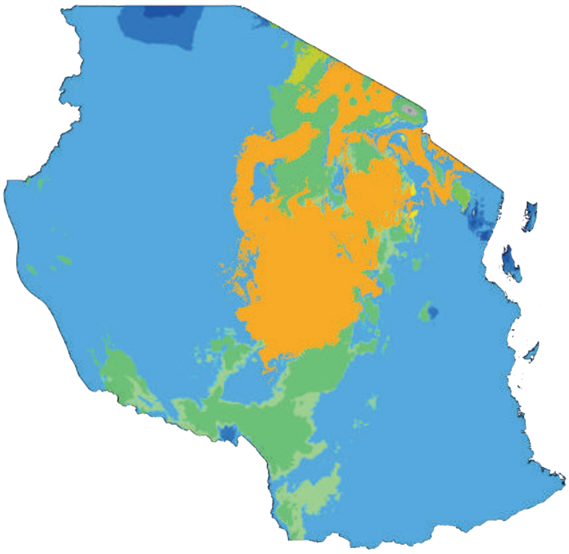
Local data collected

	AREA	DATA TYPE	LEVEL OF DETAILS	SOURCE OF DATA
EXPOSURE	Built-up	Building Blocks or Building footprints (with attributes information)	Built-up Areas (Building footprints of 13 urban area in UR Tanzania including Dar es Salaam, Tanga, Arusha, Mwanza, Mtwara, Lindi, Mbeya, Moshi, Morogoro, Tabora, Shinyanga, Ruvuma, Musoma)	Ministry of Lands Housing and Human Settlements Development (MLHHSD) Dodoma
	Population	Population Census Polygons at Ward level Population Statistics (age distribution, gender, minorities at national or sub-national scale)	Sub-Municipal Scale (Mtaa level)	Tanzania National Bureau of Statistics (NBS) Dodoma
	GDP	Sector-specific gross domestic product (GDP) Local Gross Domestic Product (e.g., Regional)	Sector Specific at District level	Tanzania National Bureau of Statistics (NBS) Dodoma
	AGRICULTURE	Agricultural Areas With Associated Types of Crops, Production Cost and/Or Wholesale Price In $ Per Ton Information on the growing cycle of each crop	Crop Calendar – was based on different types of crops countrywide Crop prices – was based on market places for different types of crops in UR Tanzania	Ministry of Agriculture
	CRITICAL INFRASTRUCTURES	Location of Critical Infrastructure (e.g., health, education, energy production) possibly with attributes information.	Primary and Secondary Schools Countrywide Health Facilities including dispesaries, Healthcentres and Hospitals	President's Office – Regional Administrations and Local Government (PO-RALG) – schools and Health facilities information
			Energy Types and sources	Ministry of Energy
		Linear critical infrastructure (e.g., railways, roads, etc)	Trunks and Primary Roads Countrywide	Ministry of Works, Transport and Communication
HAZARD	HAZARD	Monthly average rainfall dat	Monthly average data for 5 years (2014-2018) from 19 stations	Tanzania Meteorological Agency (TMA)
		min/max and average daily temperature for as many locations as possible	Monthly average data for 5 years (2014-2018) from 19 stations	
		Daily discharges for as many locations as possible (at least 10 years of observations)	Daily dischrge data from all Basins in Tanznaia for 6 years and above	Ministry of Water
		Monthly discharges for as many locations as possible (at least 10 years of observations)	Monthly discharge data for main rivers in the contry for 34 years (1954-1988)	
LOSS	LOSS DATA	Type of event (flash flood, riverine flood, storm event, drought etc...)	Data on flood events and their related impacts countrywide	Disaster Management Department DMD - Prime Minister's Office
		Economic loss characterized by location and date of occurrence	Area-specific and dates of occurrence and impacts	
		Number of people affected/ displaced	Event-specific, aggregated at a district level	
		Physical damages (e.g., number of houses destroyed/damaged/km of roads affected)	Event-specific and aggregated at a district level	

UR TANZANIA CLIMATE TRENDS

UR Tanzania's mainland is composed of a central plateau, highlands along the north and south, and coastal plains. Tanzanian territory also encompasses the coastal islands of Zanzibar, Mafia, and Pemba.
In the Köppen climate classification, most of the country is classified as tropical savanna with a semi-arid central region with some stretches of warm desert climate. South-western areas have a temperate to subtropical oceanic climate. Climate varies across regions influenced by regional heterogeneity and topography, with coastal hot and humid while the north-western highlands are cool and temperate. Temperatures range between 10°C during the cold season (May-August), and 20°C during the hot season (October-March). Other parts of the country have a temperature that is higher than 20°C, with the highest temperatures observed along the coastal regions and western parts of the country.

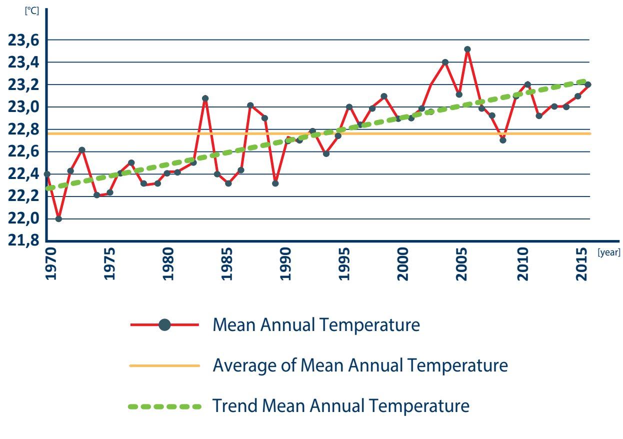
Similarly to other eastern African countries, temperature observations indicate that UR Tanzania has experienced a considerable increase in temperature over recent years. An analysis of climate data from 1970 to 2015 shows an average rise of around 1°C. Seasonal rainfall over UR Tanzania varies significantly in space and time, characterized by two types of rainfall patterns: bimodal and unimodal.
These rainfall patterns are influenced by the movement of the Intertropical Convergence Zone (ITCZ). This movement means regions in the Southwestern, Central, Southern and Western parts of the country to observe a unimodal rainfall pattern (from October to May), while regions in the North, Northern coast, North-eastern highlands, Lake Victoria basin and the Island of Zanzibar receive two distinct seasonal rainfalls: the short rain season - Vuli - from October to December, and the long rain season - Masika - from March to May. The total amount of rainfall in these seasons usually ranges from 50 to 200 mm per month, but varies greatly between regions [1] .
The annual rainfall total also varies from 200 to 1.000 mm over most of the country. The highest amount of total annual rainfall is recorded over Southwestern and North eastern highlands, while central UR Tanzania has a semi-arid climate observing an annual rainfall of less than 400 mm.

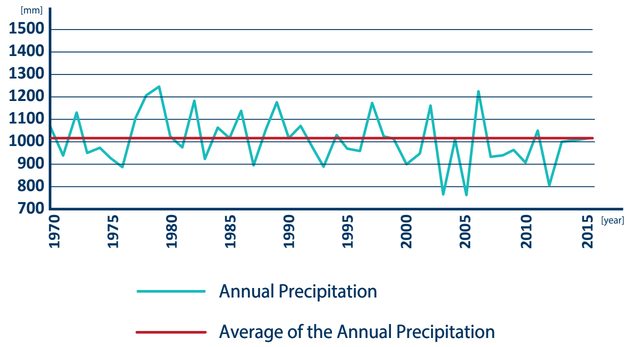


UR Tanzania map of Köppen climate classification

- Tropical, rainforest (Af)
- Tropical, monsoon (Am)
- Tropical savanna (Aw)
- Arid, steppe, hot (BSh)
- Temperate, dry winter, hot summer (Csa)
- Temperate, dry winter, hot summer (Cwa)
- Temperate, dry winter, warm summer (Cwb)
- Temperate, no dry season, hot summer (Cfa)
- Polar, tundra (ET)
- Polar, frost (EF)

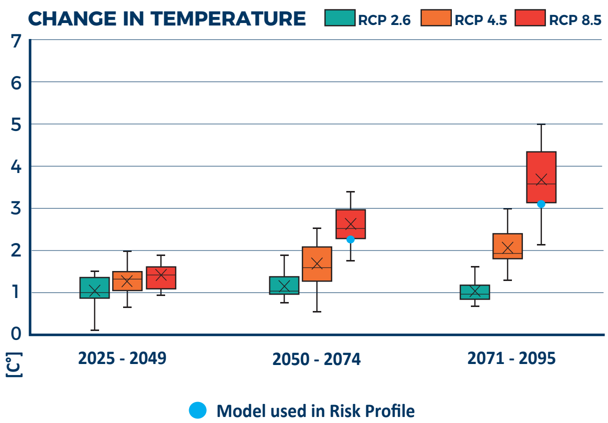
TEMPERATURE AND PRECIPITATION TRENDS (1970 - 2015)

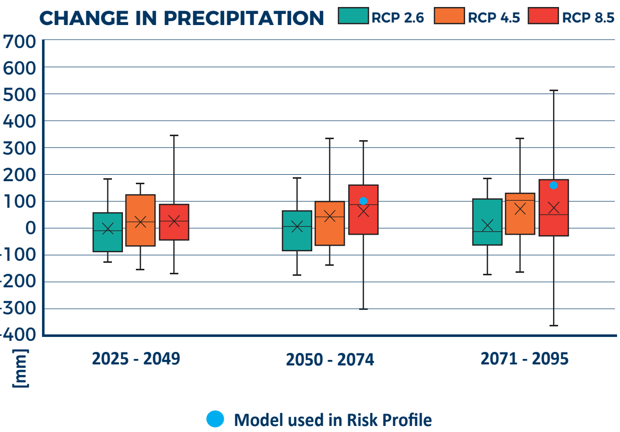




UR TANZANIA CLIMATE PROJECTIONS

In a recent study Alder et al. [2] compared the observed temperature and precipitation values registered in the period 1980-2004 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 analysed considering the different Representative Concentration Pathways (RCPs) used in the IPCC Fifth Assessment Report for greenhouse emission scenarios [3].
In all future projections, both long term and short term, and for all emission scenarios, model simulations showed an increase in temperature. The increase was more substantial in the high emission scenario (RCP8.5) and for long-term periods projections. Projections in the high emission scenario showed, moreover, an increase in temperature between 2.2°C and 4.2°C for the mid-term period (2050-2074) and an increase of up to 4 °C for the long-term period (2071-2095). Future changes in precipitation were more uncertain, however the models predicted a moderate increase - around 10% - in precipitation for the medium term. Projections for the long-term period show a divergent change.





The climate indicators used in this risk profile have been obtained using a climate projection model based on the RCP 8.5 - high emission scenario for the period 2006-2100 (SMHI-RCA4 model, grid spacing 0.44° about 50 km - driven by the ICHEC-EC-EARTH model). This Regional high-resolution model that is part of the CORDEX Africa project [4] was then accurately calibrated for the African domain, allowing for a better capture of the climate variability and its inherent extremes. Projections deriving from the Regional Model were then checked for consistency against the full ensemble of global models available for the area. Results show that the Regional Model forecasted changes in temperature and annual precipitation which are in line with the range of variability presented by Alder et al.
Within the RCP 8.5 scenario, the Regional Model predicts a moderate temperature rise compared to the Global ensemble. On the contrary, regarding the annual precipitation at the country level, the Regional Model predicts a higher increase in the long-term period than the one predicted on average by the Global ensemble.

REFERENCES

1: McSweeney, C., New, M., and Lizcano, G. (2010). UNDP Climate Change Country Profiles, Tanzania. Available online at: https://digital.library.unt.edu/ark:/67531/metadc226754/
2: Alder, J. R., & Hostetler, S. W. (2015). Web based visualization of large climate data sets. Environmental Modelling & Software, 68, 175-180.
3: https://www.ipcc.ch/assessment-report/ar5/
4: https://www.cordex.org/domains/region-5-africa/

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.

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 USD) are considered in both current (2016) and future (2050) scenarios. The critical sectors are characterised in terms of their economic value (in USD), using the most updated information available.

pixabay.com

FLOOD

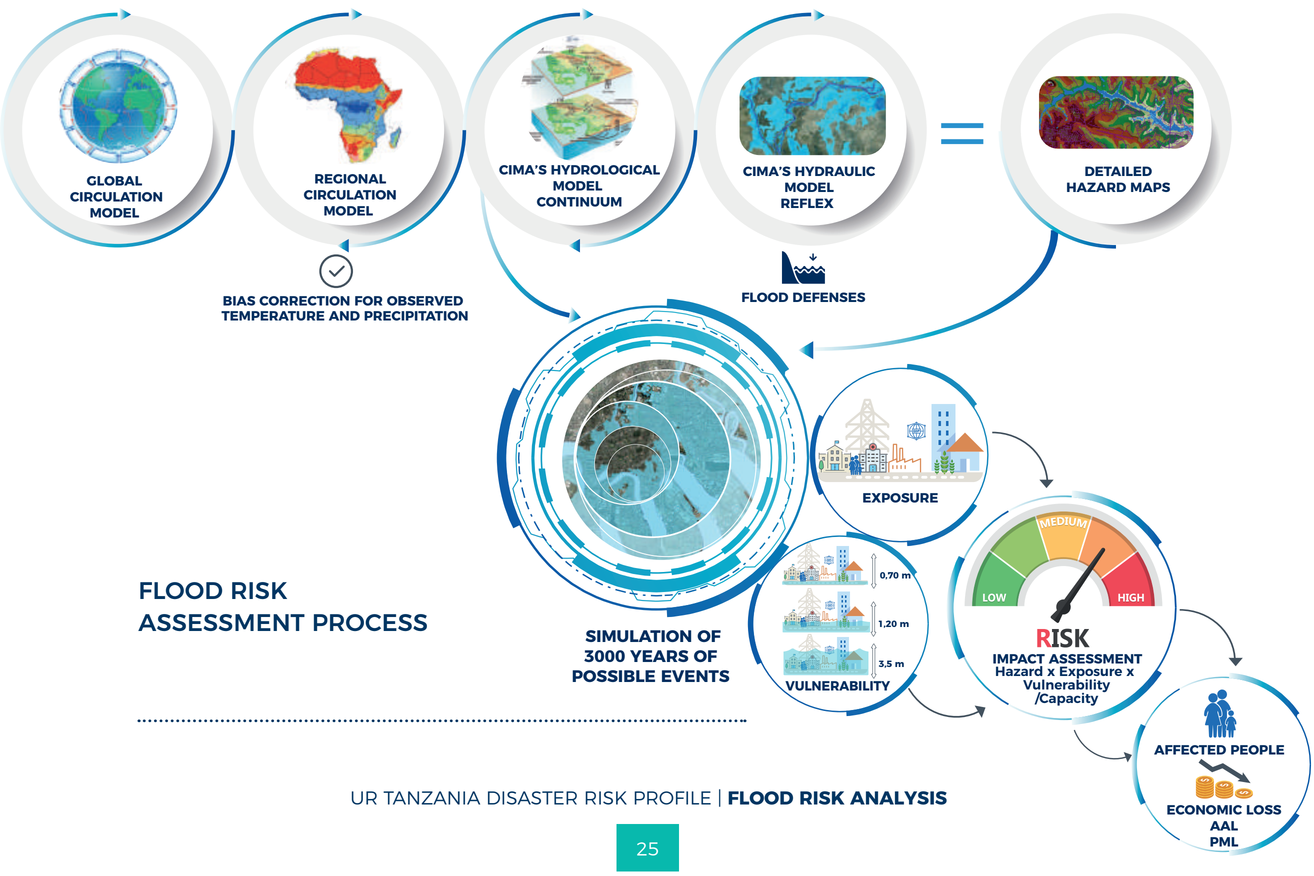
Results (Fig. & Tab.)

Flood Risk Analysis

Flood risk assessment involves four main steps: flood hazard assessment; identification and characterization of exposed elements; vulnerability assessment and capacity / performance of flood protection/structural mitigation measures in lowering flood damaging conditions. From the combination of these four steps into a flood model we are able to determine **risk**.

Different procedures and methodologies to determine risk are used worldwide through a variety of models and approaches. Their common aim is to understand the probability that different magnitudes of damaging flood characteristics - considering flood depth, horizontal flood extent, flood velocity and flood duration - will occur over an extended period of time. These estimates can be calculated both in current and projected climate conditions through a consistent analysis of meteorological, geological, hydrological, hydraulic and topographic properties of the watershed, channels, and floodplains, resulting in detailed hazard maps. Hazard maps are then combined with the reproduction of past events patterns and the modelling of projected future events. Information on the performance capacity of flood protection measures is finally added to the analysis. This workflow allows for the estimation of the "expected" water depth for a certain location and/or individual infrastructures, for a set of reference scenarios. From this step on, it is possible to explore the full frequency distribution of events and the consequent damage to exposed assets, taking into consideration their different levels of vulnerability.

The probability of a given flood magnitude is expressed in terms of the "return period" (or recurrence interval). Return period is the average time interval, in years, separating two consecutive events equal or exceeding the given flood magnitude. The damage assessment is converted into economic metrics through the computation of the average annual loss - the expected loss per year, averaged over many years - and the probable maximum loss - a relationship describing all the potential losses with a certain probability range.



FLOOD RISK
ASSESSMENT PROCESS

Within this articulated process, access to data is of vital importance to achieve an accurate risk evaluation. Not only is it necessary to feed information to the modelling chain for the identification of possible hazards in specific locations, such as historical series of observed temperature, rainfall and discharges volumes, it is also crucial to feed the damage models with detailed data on population and assets' levels of exposure and vulnerability. It is only possible to fully understand the economic, social and environmental impacts of past and future possible events with this data. To this end, the present risk profile considers five categories of potentially exposed values. Information about those values were provided by local institutions whenever available. Regional and global datasets were used both as substitutes, when local data was not available, and as data validators, to cross check the consistency of different data sources.

POPULATION

Population estimates were obtained through official censuses at the maximum level of detail available. In the case of UR Tanzania, this information was obtained at the ward level. Further information on age, gender, schooling and the presence of vulnerable groups were accessed through official datasets at the local or district level. Global datasets on population were only used in this study to retrieve spatial binary information (population/no-population at any point in space) or information on the relative distribution of population inside a given area. This study considered population according to two different levels of detail:

- the density, meaning the spatial distribution of population across the country;
- the statistical composition, according to the population categories used to identify vulnerable segments (e.g. children, women, people with disabilities).

Projections for future population were produced using the Shared Economic Pathway - SSP2 - "*Middle of the Road*" where global population growth is expected to be moderate in the first half of the century and levels off in the second half.

BUILT-UP

Information on the built-up area refers to two main aspects: to the description of the physical exposure of buildings, in terms of their spatial location inside or outside flood-prone areas; the elements which might influence its vulnerability - such as its occupancy characteristics, the existence of basements, and the typology of its constructive materials;

The built-up data prepared for the present risk profile were obtained from the exposure dataset used in the Global Assessment Report 2015 and in the The Atlas of the Human Planet 2017. They have been divided into three sector classes, according to the exposure categories reported in the Sendai Framework Indicators: housing sector distribution, service sector distribution and productive sector distribution (limited to the industrial sector as the energy production is considered separately).

Whenever possible, local data was also included, regarding:

- Number of storeys of residential buildings in urban and rural areas;
- Number of storeys of non-residential buildings (e.g. business, government etc.) in urban areas;
- Construction materials in urban and rural areas;
- Elevation of the ground floor;
- Average construction cost of residential buildings in urban and rural areas per unit surface area;
- Average construction cost of non-residential buildings (e.g. business, government etc.) in urban areas per unit surface area.

GROSS DOMESTIC PRODUCT (GDP)

Present national GDP data was obtained from the World Bank national studies (*https://data.worldbank.org/indicator/NY.GDP.MKTP.CD*). However, in order to improve the accuracy of the risk results in terms of affected GDP, two increased levels of detail were added from official national data:

• Sub-national gross domestic product (regional and, if available, district level)
• Sector-specific gross domestic product (agriculture, industry, services and commerce (either at national or, if available, at sub-national

Projections of the GDP in 2050 were extracted from the SSP Database from IIASA, using the estimates for the Shared Economic Pathway - SSP2 - *'Middle of the Road'* scenario where income inequality persists or improves only slowly and challenges to reducing vulnerability to societal and environmental changes remain.

AGRICULTURAL PRODUCTION

The data on agricultural production refers mainly to the economic value and the vulnerability of the most relevant crop types in the national agricultural production. Estimates of crop distribution, useful to understand production and land use patterns, were obtained through the Spatial Production Allocation Model (MapSpam - September 2019 release) and coupled with national production prices.
The use of local data was useful to identify the most relevant crops and to describe its vegetative/growing cycles, used for vulnerability characterization. Thus, the data analysed included:

• List of crops which account for at least 85% of the Total Gross Production Value of all crops for the country;
• The economic values in terms of production cost and/or wholesale price in USD per ton for each crop;
• Information on the growing cycle of each crop.

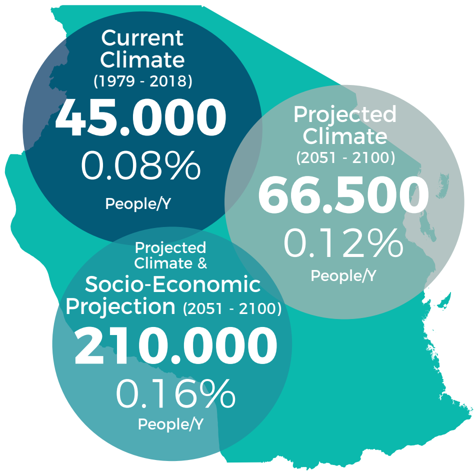
In this risk profile iteration, the selection of crops considered was not only based on their commercial value but also to the role that specific produces play in the average diet of the population. A decrease in the availability of this crops on the national market may result in food insecurity.

CRITICAL INFRASTRUCTURES

Critical infrastructures data refer to the description of the physical exposure in terms of spatial location of school, medical and hospital facilities, energy plants, as well as the transport network combined with their economic values. The main added values of this information rely on knowing the exact location of the infrastructure, the typology of its construction materials, and, in the case of roads, also its elevation and the construction costs per km.
As the available information on critical infrastructures - such as education and health structures was not spatially accurate enough for their direct use in the risk assessment, the scientific team opted to aggregate these data at the ward or district level (depending on the available ancillary information) and then redistribute it in space following the localization of built-up areas. This allowed for the maintenance of the information content of the data on each relevant sector, decreasing potential errors linked to considering a wrong localization of the buildings.

POPULATION

[B1] - ANNUAL AVERAGE NUMBER OF POTENTIALLY AFFECTED PEOPLE



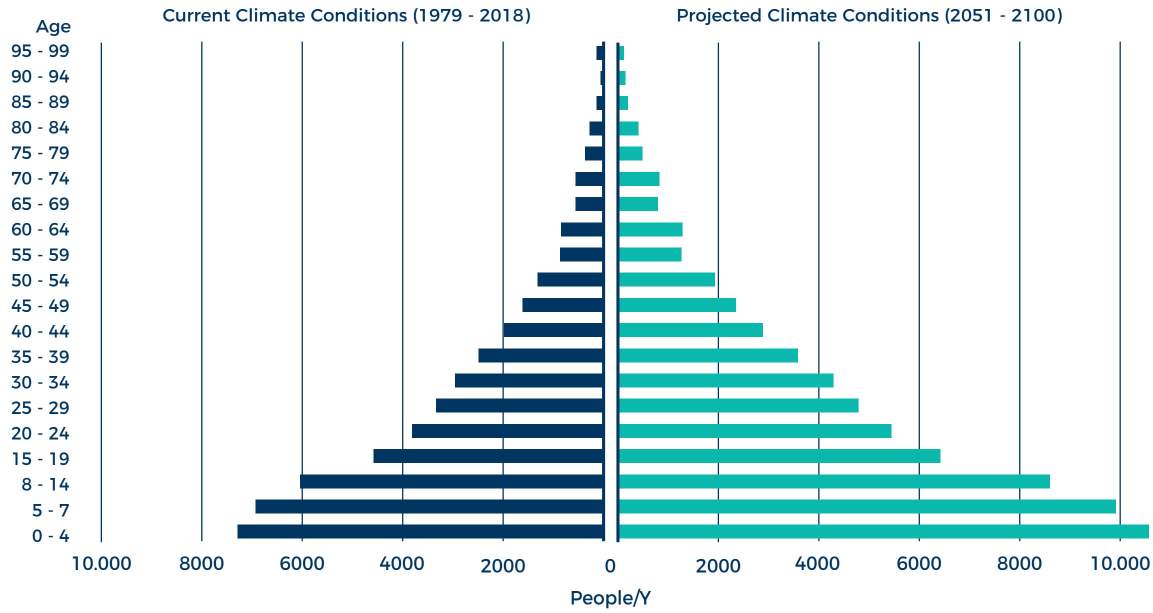
[B1] - Annual Average Number of potentially affected People
Fig. F01

	Current Climate (1979 - 2018)	Projected Climate (2051 - 2100)
POTENTIALLY AFFECTED CHILDREN 0-4	7230	10.650
POTENTIALLY AFFECTED YOUTH 5-14	12.520	18.650
POTENTIALLY AFFECTED ELDERLY >65	2000	3000
	People/Y	People/Y
POTENTIALLY AFFECTED FEMALES	22.900	34.100

[B1] - Annual Average Number of potentially affected People (Special categories) - Tab. F02

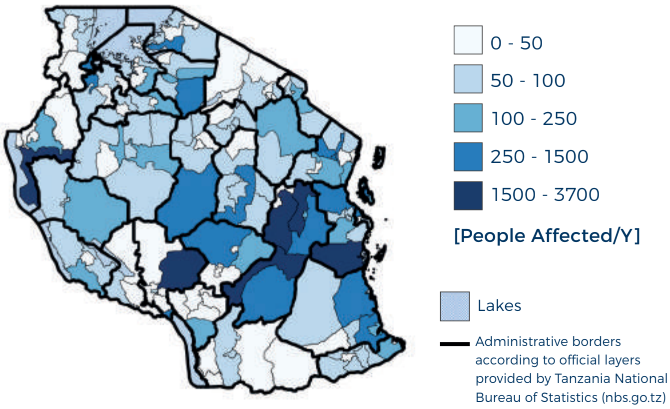
In East Africa, UR Tanzania is one of the countries that is most affected by severe weather and extreme climate events. Floods represent a prominent issue in UR Tanzania, affecting on average more than 45.000 people every year (about 0.08 % of UR Tanzania's total population). These numbers are predicted to change in the future due to two main concurrent factors. On the one hand, climate patterns are expected to shift and cause an increase of the flood hazard level. Considering one possible projected climate scenario (RCP8.5 - worst case scenario), the average number of people affected by floods every year could reach up to 66.500 (0.12% of the current population), causing an overall increase in the average risk. On the other hand, if we consider the socio-economic development and therefore the possible change in values distribution, concentration and vulnerability, this number could increase about fourfold, reaching 210.000 people affected every year on average. This figure, that amounts to 0.16% of the total predicted population, is the result of the combined effect of the expected future hazard patterns and the overall predicted increase in urbanization and population.

Annual Average Number of potentially affected People
Fig. F03

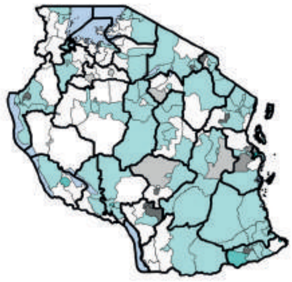


POPULATION

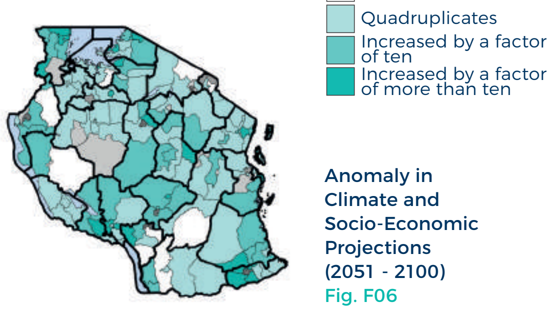
[B1] - ANNUAL AVERAGE NUMBER OF POTENTIALLY AFFECTED PEOPLE



Current Climate Conditions (1979 - 2018) - Fig. F04



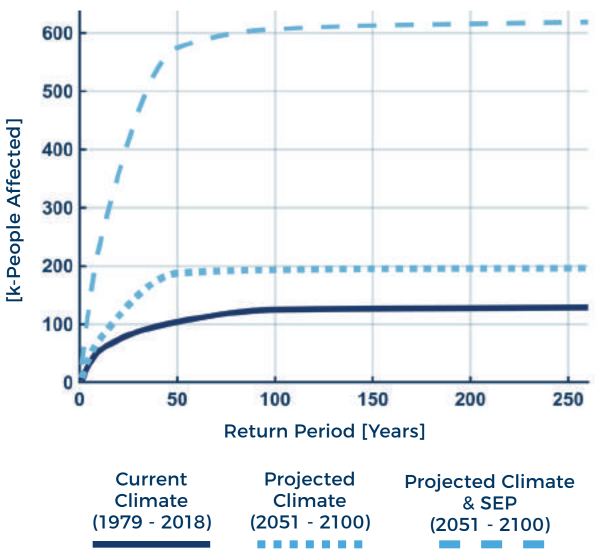
Anomaly in Projected Climate Conditions (2051 - 2100) Fig. F05



Anomaly in Climate and Socio-Economic Projections (2051 - 2100) Fig. F06

In terms of geographical distribution, the majority of the population affected is concentrated in the central part of the country, from west to east, with a particular focus on the coastal areas. In the projected future, this pattern is confirmed with marked increases in the eastern and western ends of the country as well as around the Lake Victoria area as presented in the future anomaly maps. The age and gender structure of the affected people resembles the overall age and gender structure of the country's demography. UR Tanzania is a young population and, as such, the majority of the affected people are below 24 years of age. It is interesting to focus on the most vulnerable categories, such as children in their school age and elderly people, which might suffer more serious consequences from flood events. These vulnerable categories represent about 50% of the affected population both in the present and projected climate conditions. The majority of affected people are women. This is particularly interesting in terms of vulnerability, especially in rural areas where women attend to the majority of the work in agricultural fields and as such are more vulnerable to unexpected flood episodes. Women also play a prominent role in rural society and their enhanced exposure to floods should be better analyzed from the socio-economic standpoint.

Population PML - Fig. F07



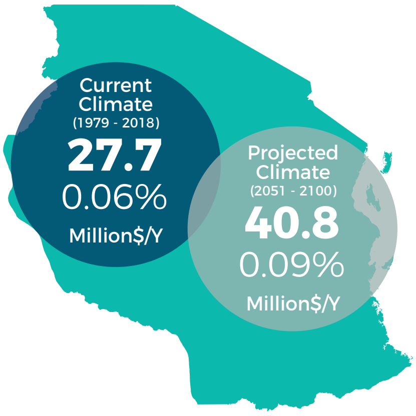
[B1] - PROBABLE MAXIMUM LOSS CURVE OF POTENTIALLY AFFECTED PEOPLE

According to the PML curve, a 50-year return period event (i.e. an event that is on average experienced with equal or greater magnitude twice per century) will affect on average around 100.000 people under current climate conditions, but this figure could increase (considering both climate change and socio-economic development) to almost 600.000 people in future. It is evident that such an event would pose serious civil protection management issues and should be considered when planning future emergency resources.

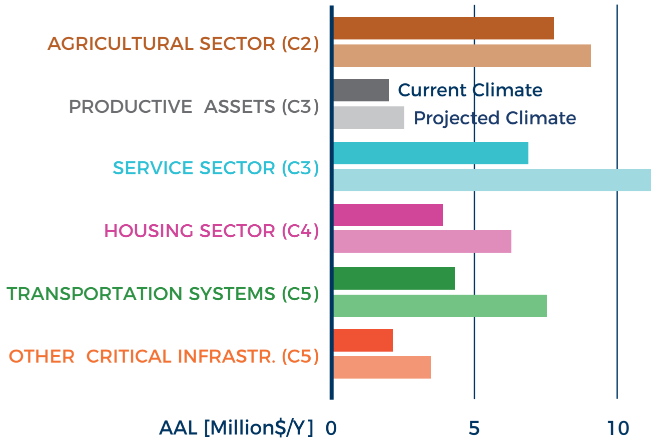
[C1] DIRECT ECONOMIC LOSS

[C1] - AVERAGE ANNUAL LOSS

[C1] - Average Annual Loss - Fig. F08



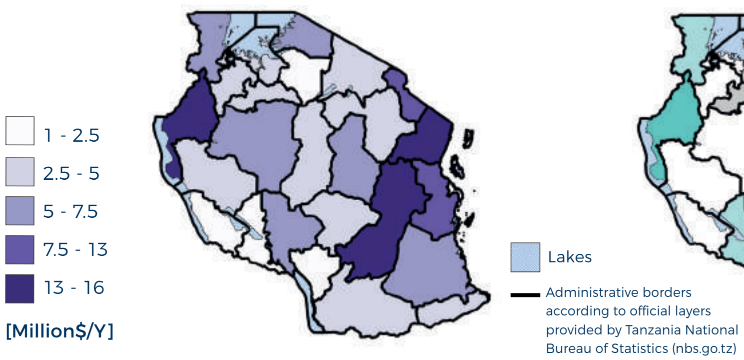
Average Annual Loss per sector - Fig. F09



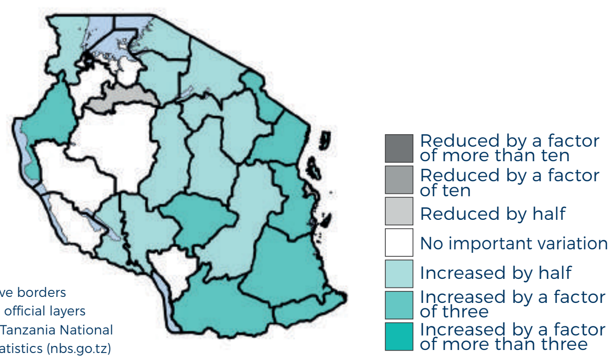
Sendai Target C envisages the substantial reduction of direct economic losses by 2030. The estimated direct economic losses from floods in UR Tanzania is of about 28 million USD per year, which is roughly 0.06% of the total economic value of the assets considered. Loss is more or less evenly distributed among sectors, but the services (commercial) and agricultural sectors are slightly more affected, followed by the housing, transportation, critical facilities and productive sectors. Considering one possible projected climate scenario (RCP8.5 - worst case scenario), the average direct economic losses will reach 41 million USD per year (0.09% of the total value of the present assets), an increase of about 50% with respect to the value estimated under current climate conditions. This is a significant increment that should be taken into account in long-term planning and policies, even considering the uncertainty associated with such types of estimates.

	Current Climate (1979 - 2018)	Projected Climate (2051 - 2100)
D4 - AFFECTED (KM/Y) INFRASTRUCTURES	139	230
D3 - AFFECTED (UNITS/Y) SCHOOLS	27	38
D2 - AFFECTED (UNITS/Y) HOSPITALS	12	16

Damage to critical infrast. - Tab. F10



AAL - Current Climate Conditions (1979 - 2018) - Fig. F11



Anomaly in Projected Climate Conditions (2051 - 2100) - Fig. F12

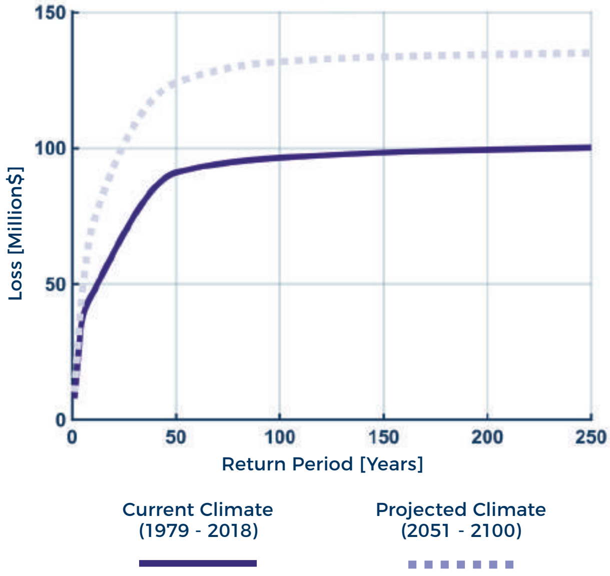
The impact of floods in UR Tanzania has a sparse spatial distribution with the majority of the regions showing potential losses due to floods. The majority of economic losses are expected to occur in Morogoro, Tanga and Pwani in the east and Kigoma in the west. Results for projected climate conditions (RCP8.5 - worst case scenario) do not significantly modify the spatial pattern. However, the strongest increase in risk is expected on the coast, including the regions of Lindi and Mtwara. Uncertainty in climate predictions and ongoing evolution of the socio-economic situation of the country might significantly influence these estimates.

[C1] DIRECT ECONOMIC LOSS

[C1] - PROBABLE MAXIMUM LOSS CURVE

The PML curves provide important information on the frequency of floods and associated economic losses. Despite the fact that the average annual losses are of around 28 million USD per year, floods with losses of at least 50 million USD are expected to occur very frequently, with a return period of about 10 years (i.e. an event with equal or greater magnitude that is on average experienced every decade). Considering projected climate conditions, the frequency of high-impact floods will increase significantly, and it will be very likely (return period of about 25 years) to experience floods with losses of at least 100 million USD.

PML - Fig. F13



GDP

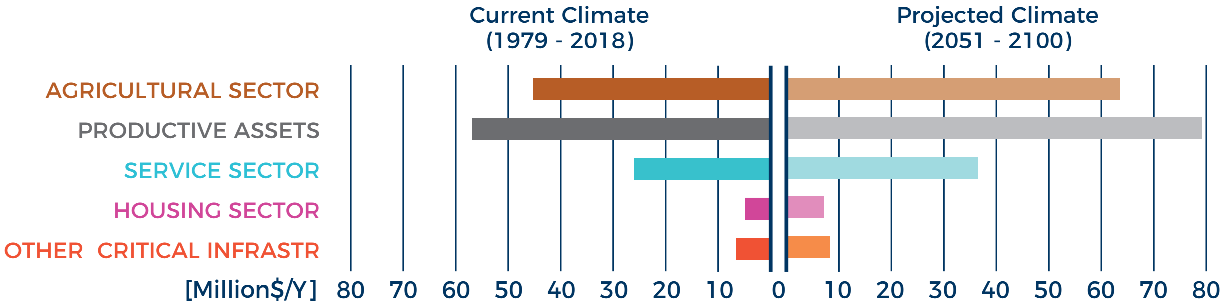
ANNUAL AVERAGE GDP PRODUCED IN POTENTIALLY AFFECTED AREAS

An indication of the risk incidence on the economy can be drawn from the GDP affected (i.e. the GDP produced in areas affected by floods). It is a proxy of direct and indirect potential losses due to floods. Areas subject to flooding over a certain magnitude might suffer indirect losses: assets might be partially or completely damaged and economic activities stopped. In the current climate, the annual GDP produced in areas affected by floods represents on average 0.26% of the total (147 million$/Y). Under projected climate conditions this value is expected to increase to 0.36% (208 million$/Y) and, if socioeconomic projections are taken into consideration, it is expected to reach more than 2 billions USD per year The productive sector is the most affected, followed by the agricultural sector and the service sector. Services related to critical infrastructure and housing suffer the smallest losses in relative terms. This is due to the GDP accounting not only for the asset values, but also of the value created by the activities linked to those assets. In the projected future, the value of the losses of the productive sector still dominates.

	Current Climate (1979 - 2018)	Projected Climate (2051 - 2100)	Projected Climate & SEP (2051 - 2100)
Million$/Y	147	208	2563
%	0.26%	0.36%	0.36%

Annual Average GDP Affected - Tab. F14

Annual Average GDP produced in potentially affected areas - Fig. F15



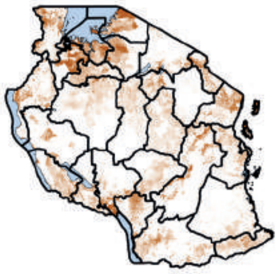
DIRECT ECONOMIC
LOSS PER SECTOR

Lakes

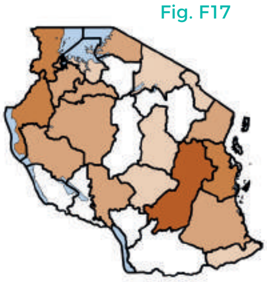
Administrative borders according to official layers provided by Tanzania National Bureau of Statistics (nbs.go.tz)

AGRICULTURAL SECTOR [C2]

Exposure Map - Fig. F16



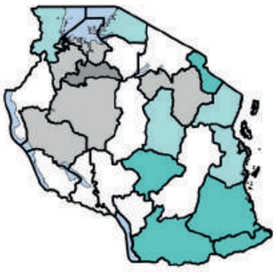
AAL - Current Climate Conditions (1979-2018)
Fig. F17



- 0 - 0.1
- 0.1 - 0.2
- 0.2 - 0.5
- 0.5 - 1
- 1 - 2

[Million$/Y]

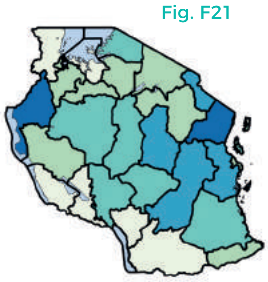
Anomaly in Projected Climate Conditions (2051 - 2100)
Fig. F18



SERVICE SECTOR [C3]

Exposure Map - Fig. F20

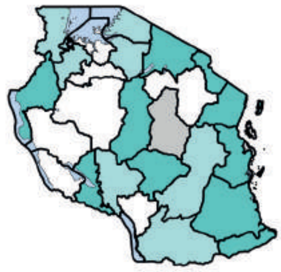
AAL - Current Climate Conditions (1979-2018)
Fig. F21



- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.3
- 0.3 - 0.8
- 0.8 - 1.7

[Million$/Y]

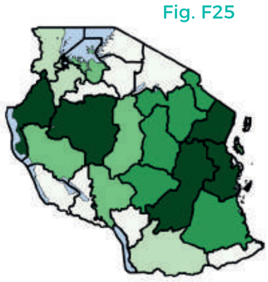
Anomaly in Projected Climate Conditions (2051 - 2100)
Fig. F22



TRANSPORT SECTOR [C5]

Exposure Map - Fig. F24

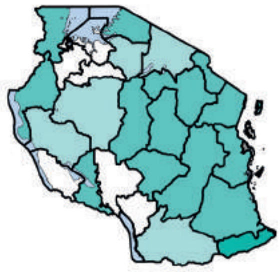
AAL - Current Climate Conditions (1979-2018)
Fig. F25



- 0 - 0.03
- 0.03 - 0.08
- 0.08 - 0.15
- 0.15 - 0.3
- 0.3 - 0.8

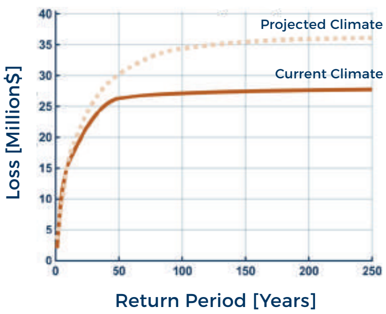
[Million$/Y]

Anomaly in Projected Climate Conditions (2051 - 2100)
Fig. F26

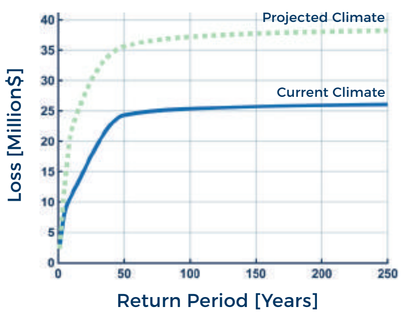


- Reduced by a factor of more than ten
- Reduced by a factor of ten
- Reduced by half
- No important variation
- Increased by half
- Increased by a factor of three
- Increased by a factor of more than three

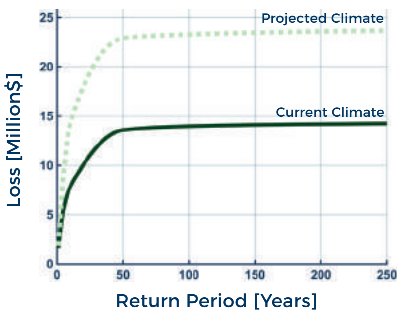
Probable Maximum Loss Curve - Fig. F19



Probable Maximum Loss Curve - Fig. F23



Probable Maximum Loss Curve - Fig. F27



The most affected sectors, in terms of direct economic losses, are the service and agricultural sectors, followed by the transportation sector. The spatial distribution of the annual average losses are very similar for the three sectors and the most affected regions are Morogoro, Tanga and Pwani. High impacts are also expected in the western part of the country for the transportation sector.
The direct economic losses are estimated on average to increase for all sectors under projected climate conditions. Specifically, a distinct increase is expected in the eastern part of the country, especially along the coast. Only in agriculture is a decrease in projected losses visible in the western part.

The PML curves for the three sectors confirm that UR Tanzania is exposed to very frequent floods and the frequency of high impact floods can increase significantly under projected climate conditions.
The impacts of floods with a medium likelihood of occurrence (return period of 50 years) are expected to increase by more than 50% under projected climate conditions.

DROUGHT

Results (Fig. & Tab.)

Drought Risk Analysis

Drought risk in this report is assessed in four different ways: the analysis of drought hazard and potentially affected population and livestock; the estimation of drought vulnerability of the human population; the calculation of current and projected losses for hydropower production; the estimation of current and projected damage to crop production.

From the combination of these four assessments, one can get a comprehensive understanding of the drought risk. Droughts can arise from a range of hydro-meteorological processes that reduce water availability. With varying time gaps between the reduction in availability and a potential impact on the system, these processes can create conditions that are "significantly drier than normal", and limit moisture availability to a potentially damaging extent (WMO 2016). A drought hazard, interacting with the vulnerable conditions of the exposed people and assets, becomes a disaster when it causes a serious disruption of the functioning of society, leading to losses. (UNISDR 2015).

The social, economic and environmental impacts of droughts stem from their severity, duration and spatial extent; and from the situation of people, production capacities and other tangible human assets exposed to the drought hazard; it is a combination of the drought hazard, exposure and vulnerability to droughts (UNISDR 2015). In order to align the risk profiles with the Sendai Targets, the approach focuses on the:

- number of affected people B1;
- sections "Drought hazard, exposure and vulnerability";
- agricultural loss (C2; section "Agricultural losses");
- productive assets (C3; section "Hydropower losses");
- and the direct losses (C1) as sum of C2 and C3.

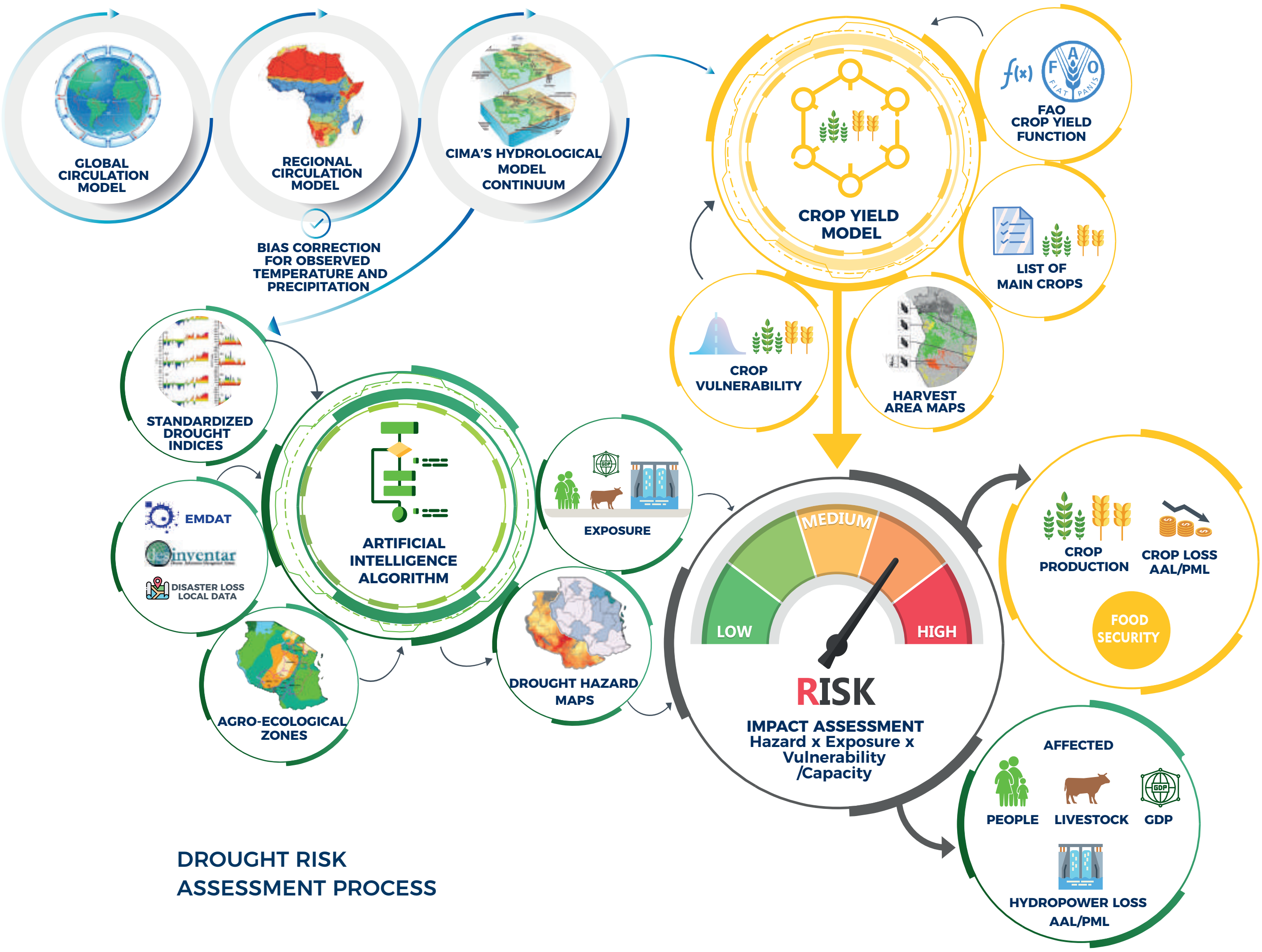
DROUGHT HAZARD, EXPOSURE AND VULNERABILITY

Due to the multi-faceted character of droughts, numerous drought indices exist. One group is the standardized indices, representing anomalies from a normal situation by analysing at least +30 years (preferably 50) in a standardized way. The following five standardized drought indices are used in this risk profile: the Standardized Precipitation Index (SPI), the Standardized Precipitation-Evapotranspiration Index (SPEI), the Standardized Evapotranspiration Index (SEI), the Standardized Soil Moisture Index (SSMI) and the Standardized Stream Flow Index (SSFI). Together, they cover all parts of the hydrological cycle.

Larger, longer and/or more intense droughts are more severe and will result in a larger impact. To include these intensity, duration and spatial extent aspects of drought, the total water deficit (i.e. how much less water than average) is calculated as the cumulative sum of the monthly water deficits. This is done using the different indices and also different deficit intensity thresholds. Then, using an artificial intelligence algorithm applying decision trees, the deficits under different thresholds for different indices are matched with reported drought disaster impacts. This is done for each agro-ecological zone in the country, assuming the vulnerability to droughts is similar under similar agro-ecological conditions. As such, local-tailored indices and thresholds can be used to assess the drought hazard under current and projected climate conditions.

This drought hazard map can be combined with population, GDP and livestock maps so as to calculate how many people or animals are exposed to different drought events. From this, the annual average amount of these potentially affected people and animals can be estimated.

No estimations about mortality and the impact of droughts on livelihoods could be made; nor numbers of how many people would be in need of emergency aid because of the drought impact. While the regional vulnerability is included (droughts are defined based on their effects for each agro-ecological zone), human vulnerability (or livestock vulnerability or GDP sectoral vulnerability) are not accounted for. Quantifying vulnerability to droughts as the relation between severity and the expected impacts requires detailed records on droughts losses and damages which are seldom available. However, one extra proxy for vulnerability was included in the risk profiles: the Water Crowding Index, which quantifies the amount of available water locally available per person.



DROUGHT RISK
ASSESSMENT PROCESS

HYDROPOWER LOSSES

Assessing the drought risk for hydropower is possible when given sufficient information on hydropower dams and their reservoirs. Using the GRAND database, all dams with 1st or 2nd use "electricity" were selected and their characteristics (location, height, surface area, capacity) retrieved. Using the coordinates of the dam, corresponding discharge, evaporation, and precipitation were retrieved from the hydro-meteorological data.

For each time step, the influx (discharge and precipitation), as well as the outflux (outflow and evaporation) were estimated. Outflow is a function of the storage capacity (minimal, maximal and current) and long term mean average inflow. Using a reservoir capacity equation, the height of the water level in the reservoir was subsequently determined, which was an important parameter for determining the energy that can be generated. Using a fixed energy price (0.14 USD/kWh) this was translated to a monetary value.

In order to identify losses, a baseline energy production was established. For this, the average annual production over the baseline period (1979-2018) was used. As such, a year with below average production (and thus revenue) was considered a loss (equal to the difference with the baseline average). This way, annual production and loss series were created, allowing to calculate average annual losses and marginal losses for return periods of 5, 10, 25, 50 and 100 years. This was done for current climate conditions, as well as projected climate conditions (keeping the baseline production the same).

AGRICULTURAL LOSSES

When there is insufficient moisture in the soil to meet the needs of a particular crop at a given time and location, drought-induced crop losses can occur. To estimate the risk of droughts on the arable sector and the risk to food security, the major crops for each country were selected based on (1) their contribution to the Gross Production Value of all crops in the country and (2) their importance as food for the population. Data have been acquired from FAOSTAT, MAPSPAM, EARTHSTAT, and supplemented with data derived from UR Tanzania.

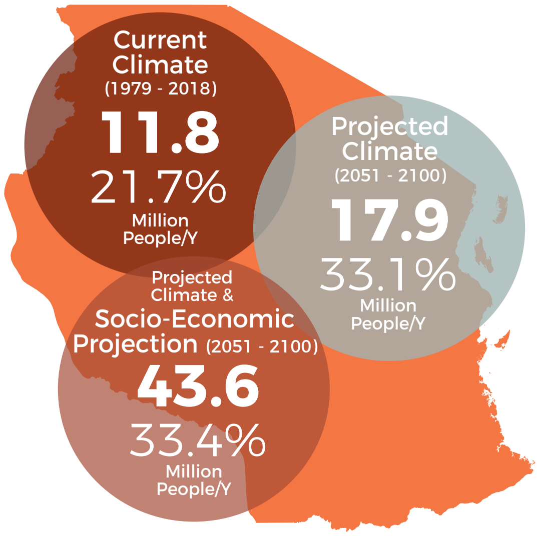
Generally, there is a fairly linear relation between the ratio of actual over potential evapotranspiration and crop yield, as represented by the FAO "water production function". This relation was tailored for all crops by including a local crop drought sensitivity factor - a factor that is also determined by whether the crop is produced under rain fed or irrigated conditions. Further, reference yield values were then defined by matching the calculated crop yields with data from FAOSTAT. Then, the spatially-explicit crop yields' variability as response to changing hydrological conditions could be assessed on a yearly basis, and the annual production could be estimated by multiplying the yields with the harvested areas of the selected crops.

Production losses were calculated as the difference between the production of a year and the 20% lowest value from the current climate. A zero loss was assigned to any year with a production equal or above this 20% threshold. We determined the average annual loss by dividing the summation of these annual losses by the total number of years, including the non-drought years. These calculations can be done in kilograms but also converted to USD by multiplying the production loss with the market price of the evaluated crops .

Additionally, effects of droughts on (1) amount of lost working days (reflecting job opportunities in arable farming), (2) potential loss of food energy supply (in Kcal, calculated as the part of the production which is available for consumption as food for people in UR Tanzania, subtracting the production for export and other uses) and the amount of people who could potentially have been fed by this lost production (assuming Minimum Dietary Energy Requirement of 1730 kcal/cap,day and 10% household waste), and (3) production losses from using drought-adapted varieties (reflecting options for adaptation), have been estimated as well.

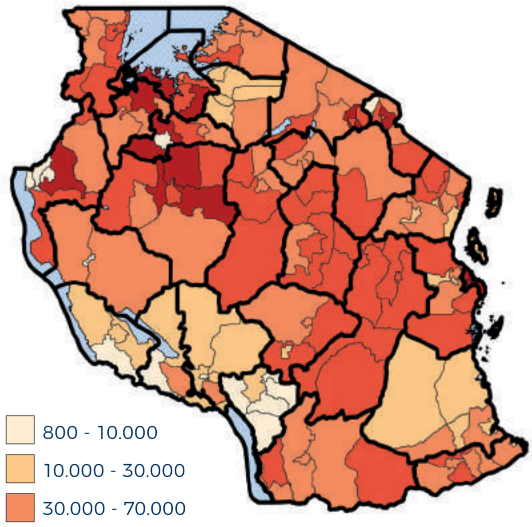
POPULATION

ANNUAL AVERAGE NUMBER OF PEOPLE LIVING IN DROUGHT AFFECTED AREAS



Annual Average Number of People living in drought affected areas - Fig. D01

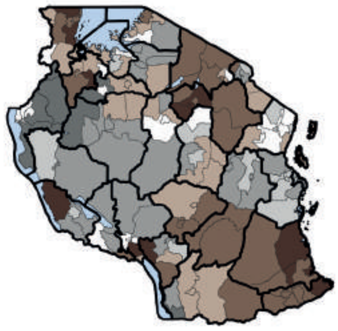
Current Climate Conditions (1979 - 2018) - Fig. D02



800 - 10.000
10.000 - 30.000
30.000 - 70.000
70.000 - 150.000
150.000 - 740.000
[People/Y]

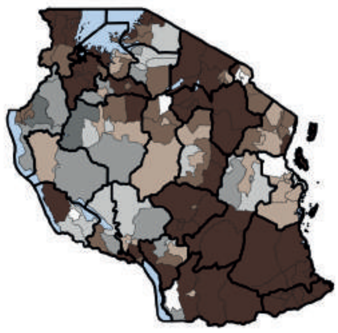
Lakes

Administrative borders according to official layers provided by Tanzania National Bureau of Statistics (nbs.go.tz)



Anomaly in Projected Climate Conditions (2051 - 2100) Fig. D03

Reduced by a factor of more than ten
Reduced by a factor of ten
Reduced by half
No important variation
Duplicates
Quadruplicates
Increased by a factor of more than four



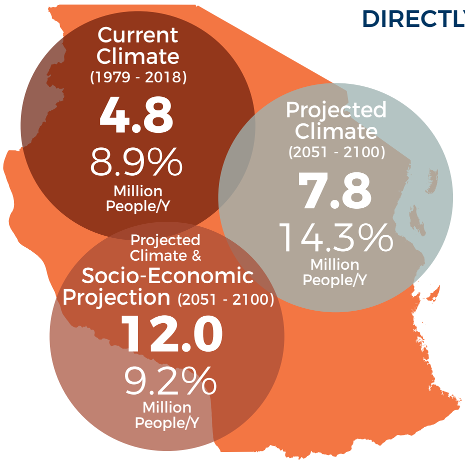
Anomaly Climate and Socio-Economic Projections (2051 - 2100) Fig. D04

With respect to observed conditions (1979-2018 climate), the probability of occurrence of meteorological, soil moisture and streamflow droughts will increase under future conditions (2051-2100 climate). While the average annual precipitation will increase, so will its variability. This, together with the predicted temperature increases, thus higher potential evapotranspiration, will result in longer, more intense and more frequent agricultural droughts. Under current climate conditions, Kinondoni, Temeke and Ilala have the largest numbers of potentially affected people, while Moshi, Uyui and Tabora have the highest percentage of their population exposed droughts. Countrywide, on average 11.8 million people (21.7% of the total population of 2018) are annually exposed droughts. Under projected climate conditions, this number is expected to increase up to 33% (on average 43.6 million people if population growth is accounted for). Hanang and Bukoba and the entirety of the southern part of UR Tanzania are expected to see the highest percentage increases. This number of potentially affected people is an overestimation of the expected number of directly affected data. According to data from DesInventar, it appears that on average around 25% of the population exposed to droughts, is directly affected. (NOTE: This percentage varies from region to region and over the years.)

Individuals' vulnerabilities and coping capacities to drought conditions depend on their physical, social, economic, and environmental factors or processes. People living in urban environments are usually less vulnerable to drought than those living in rural

POPULATION

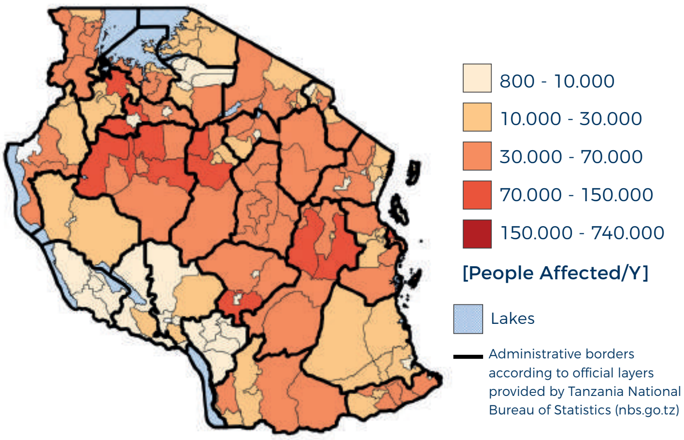
[B1] - ANNUAL AVERAGE NUMBER OF PEOPLE DIRECTLY AFFECTED BY DROUGHT



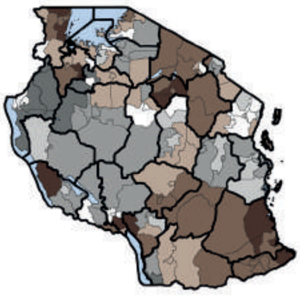
[B1] - Annual Average Number of People directly affected by drought - Fig. D05

	Current Climate (1979 - 2018)	Projected Climate (2051 - 2100)
POTENTIALLY AFFECTED CHILDREN 0-4	0.31	0.46
POTENTIALLY AFFECTED YOUTH 5-14	0.53	0.79
POTENTIALLY AFFECTED ELDERLY >65	0.07	0.11
	Million People/Y	Million People/Y
POTENTIALLY AFFECTED FEMALES	1.01	14.35

[B1] - Annual Average Number of People directly affected by drought - Tab. D06

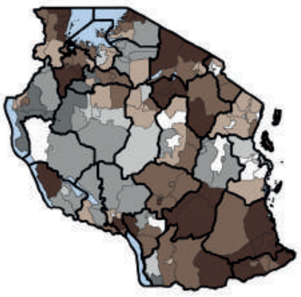


Current Climate Conditions (1979 - 2018) - Fig. D07



Anomaly in Projected Climate Conditions (2051 - 2100) Fig. D08

Reduced by a factor of more than ten
Reduced by a factor of ten
Reduced by half
No important variation
Duplicates
Quadruplicates
Increased by a factor of more than four



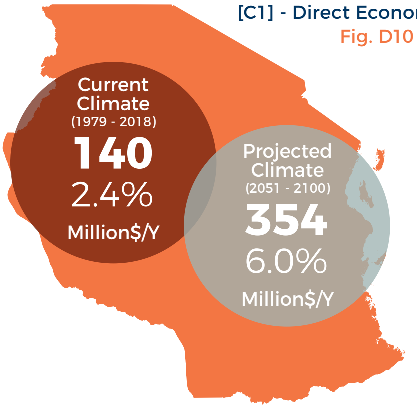
Anomaly in Climate and Socio-Economic Projections (2051 - 2100) Fig. D09

communities. Rural communities tend to have a limited short-term coping capacity and a limited long-term adaptive capacity. These communities strongly rely on national and regional disaster management authorities' efforts to mitigate such adverse effects and, in extreme cases, are forced to migrate elsewhere to satisfy their subsistence needs. In this sense, transport infrastructure plays a key role in providing access to water during an emergency, as remote unconnected communities are more difficult to reach by external relief resources. Based on these assumptions, in this risk profile, the combination of people vulnerability and coping capacity to drought was estimated as a function of rural/urban population concentrations within each district. Rural communities with higher levels of isolation were then assumed to suffer wider drought consequences.

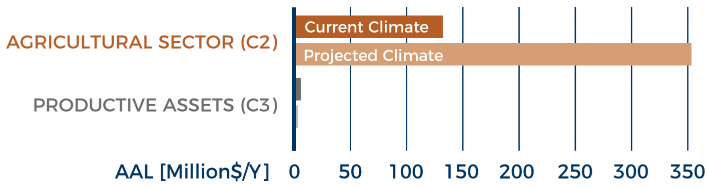
Computations show that among the 11.8 million people (on average, per year) living in areas affected by drought under current climate conditions, an average of 4.8 million people per year are estimated to be directly affected. This number would increase to 7.8 million under projected climate conditions and to 12 million if both projected climate conditions and socioeconomic evolution are considered. This estimation is more uncertain than the absolute number of potentially affected people due to the choices in the weights used to delineate different levels of vulnerability to drought. The spatial distribution can give us another indication on the drought risk-scape. Hotspots are visible in the central part of the country, north of the Dodoma area, and in the northern Morogoro region. It is interesting to note that in the projected climate, the risk of drought in those hotspots is estimated to decrease and in many cases significantly.

[C1] DIRECT ECONOMIC LOSS

[C1] - Direct Economic Losses
Fig. D10

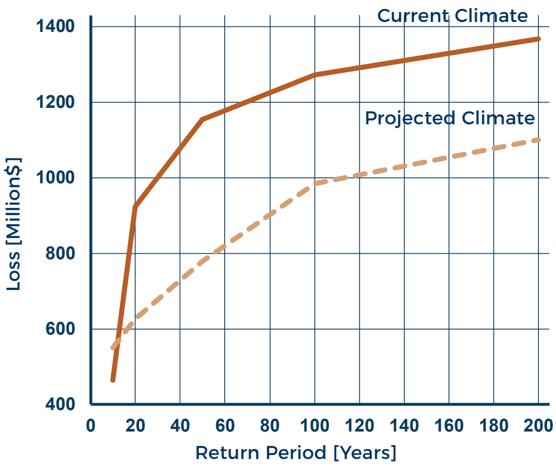


Direct Economic Losses per sector - Fig. D11



Under current and projected climate conditions, a significant part of the annual crop production is lost due to droughts. The Average Annual Loss (direct economic loss from crops) in UR Tanzania is projected to increase from 140 million USD per year to 350 million USD per year. This represents respectively 2.4% and 6% of the average Gross Production Value of UR Tanzania. With climate change, the large increases in crop losses in the west of UR Tanzania, are thus not compensated by the slight reduction in losses which are projected in the majority of the country.

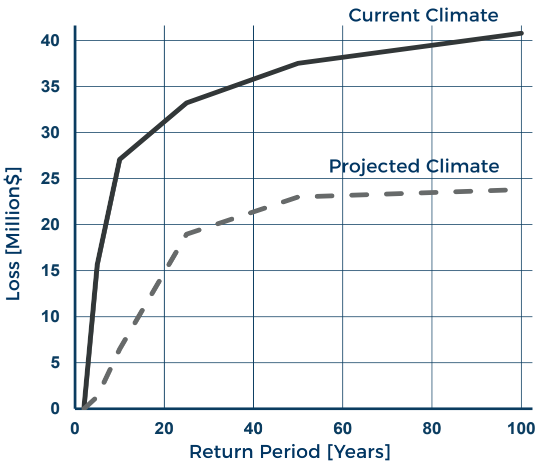
C2 - LOSSES
AGRICULTURAL



[C2] - PML - Fig. D12

Under current climate conditions, the probable maximum loss from agriculture increases gradually when return periods go up from 10 to 200 years. For example, on average once every 10 years, a drought that causes agricultural losses of 450 million USD can be expected, while on average once every 50 years a loss of over 1100 million USD might occur. Under projected climate conditions, frequent events will induce higher losses (on average once every 10 years, a drought might cause losses up to 550 million USD) while the events with longer return periods, are expected to generate less extreme losses (once every 50 years, losses up to 800 million might be experienced). It is worth noting that these results become highly uncertain as we move towards increasingly rare losses.

C3 - LOSSES
HYDROPOWER

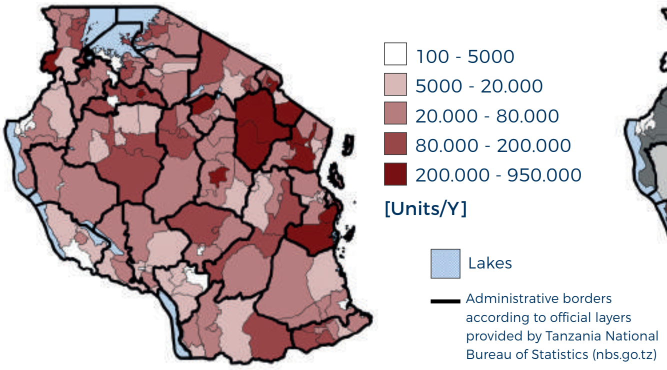


[C3] - PML - Fig. D13

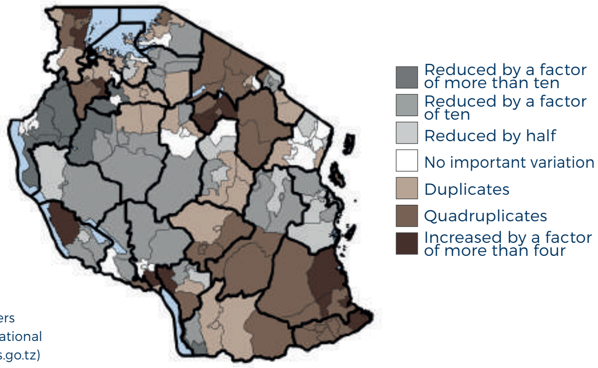
C3 is computed exclusively by considering losses in hydropower production. These are defined as production below levels with average reservoir conditions. Under current climate conditions, on average once every 5 years, a loss of 15.6 million USD can be expected. Hydropower losses are projected to decrease in the future for UR Tanzania. This is a net result of the decrease of annual losses for all dams. Only at the Nyumba dam will the annual losses of more extreme events increase.

LIVESTOCK

ANNUAL AVERAGE NUMBER OF POTENTIALLY AFFECTED LIVESTOCK UNITS



Current Climate Conditions (1979 - 2018) - Fig. D14



Anomaly in Projected Climate Conditions (2051 - 2100) - Fig. D15

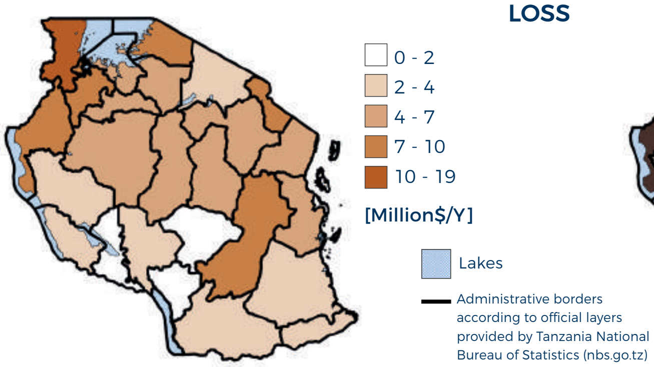
	Current Climate (1979 - 2018)	Projected Climate (2051 - 2100)
Million Unit/Y	11.0	21.0
%	20.1%	38.2%

Potentially Affected Livestock - Tab. D16

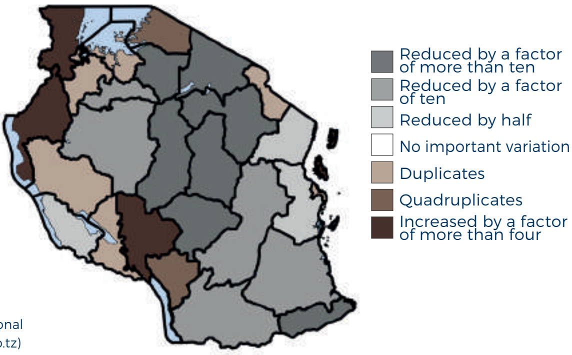
Under current climate conditions, affected livestock (i.e. animals living in areas hit by droughts) amounts to 11 million units (21%). Livestock units are calculated as the sum of all animals in a certain place, weighed by the water and food needs of the animals following FAO conversion factors. Under projected climate conditions, the number of affected livestock is projected to increase to more than 38% of the total livestock population. Some areas such as Sengerema, Hanang, and Babati are projected to experience a large increase in risk.

AGRICULTURE

C2 - DIRECT AGRICULTURAL LOSS



ALL - Current Climate Conditions (1979 - 2018) - Fig. D17



Anomaly in Projected Climate Conditions (2051 - 2100) - Fig. D18

	Current Climate (1979 - 2018)	Projected Climate (2051 - 2100)
Million$/Y	133	352
%	2.30%	6.10%

C2 - Direct Agricultural Loss - Tab. D19

Under current climate conditions, direct economic crop losses are quite modest in the south of UR Tanzania (less than 4 million USD per year), moderate in the central part (between 4 and 7 million USD per year), but higher in the north-west and central-east. In these regions' six districts losses are over 7 million USD per year, which together amount to at least one third of the total loss. The situation in the projected climate, considering the same crop distribution, would cause higher direct economic crop losses in only 9 regions (including two islands), with Kagera and Kigoma most strongly affected. However, the majority in the country would experience an almost equal amount or even lower economic crop losses as compared to current climate conditions.

AGRICULTURE

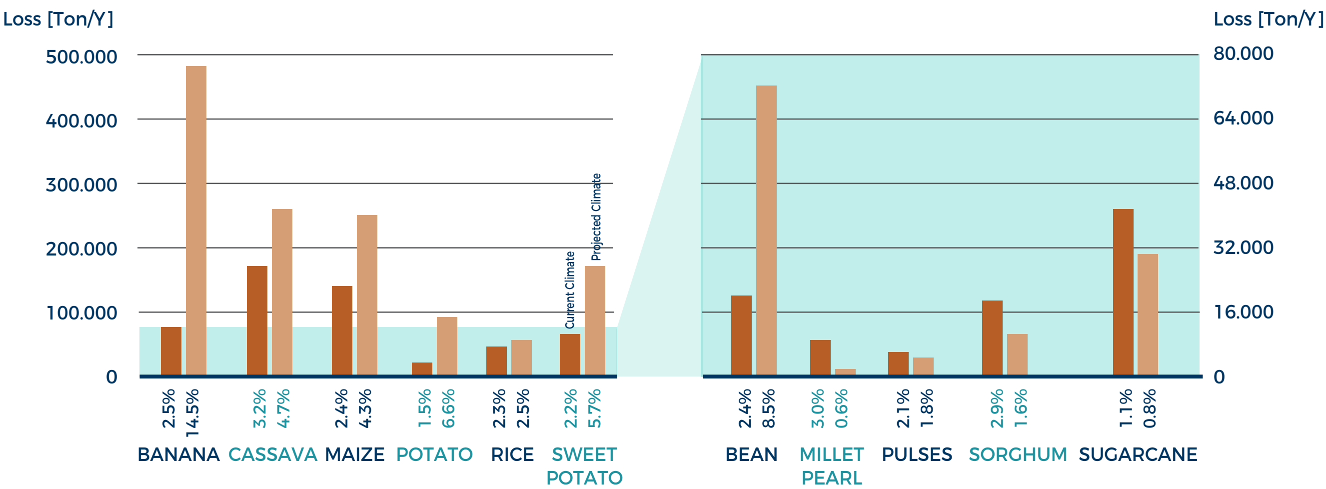
ANNUAL AVERAGE NUMBER OF WORKING DAYS LOST

	Current Climate (1979 - 2018)	Projected Climate (2051 - 2100)
k - days / Y	4430	9634
%	0.44%	0.96%

Annual Average Number of working days lost
Tab. D20

The estimated average number of lost working days on the field is linked to crop production losses because lower crop production is linked to reduced labour requirements, especially during harvest. This loss of working days due to droughts has been estimated at roughly 4.4 million working days per year under current climate conditions. The increase under projected climate conditions more than doubles, reaching 9.6 million days per year. Thus, less farmwork employment opportunities may present themselves in the future. The relative values for lost working days is below 1% in both climates when compared to the total amount of required working days, but increases to 6 % in the projected climate if compared to the average amount of working days required for harvesting.

AGRICULTURAL PRODUCTION LOSS

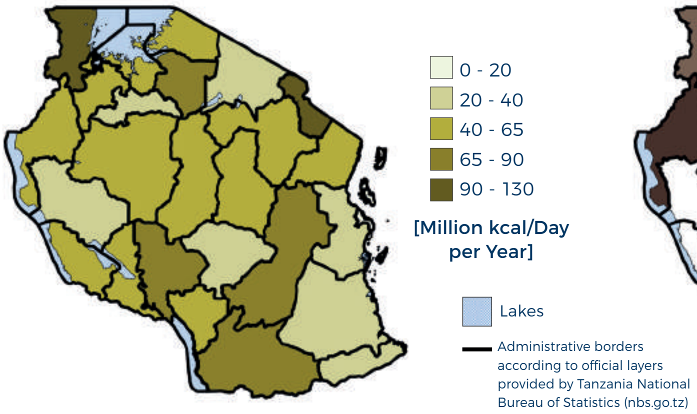


Agricultural Production Loss - Fig. D21

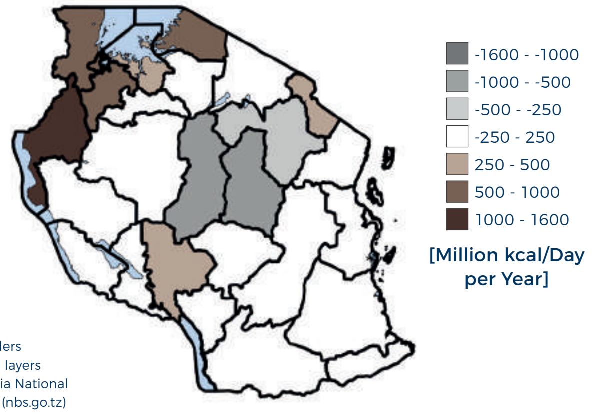
Crop production losses, induced by drought conditions, have been calculated for eleven different crops in UR Tanzania. Under current climate conditions, these losses are dominated by banana, cassava, maize and sweet potato (physical units), and if expressed as a percentage of the average crop production, crop losses remain close to or lower than 3%. Under projected climate conditions, production losses are estimated to rise for most crops (they are notably large for bananas, cassava, maize, sweet potatoes, and beans), due to the intensification of droughts compared to the current climate. On the other hand, four crops are expected to have lower losses (millet, pulses, sorghum and sugarcane). Relative losses range from 0.6% (millet: lower loss) to 14.5% (banana: higher loss), with increase factors ranging from 0.2 (millet) to 6 (banana).

AGRICULTURE

FOOD ENERGY SUPPLY



Current Climate Conditions (1979 - 2018) - Fig. D22



Projected Climate Conditions (2051 - 2100) - Fig. D23

Several arable crops contribute to the food energy supply of households in UR Tanzania. Droughts could negatively affect the food security situation via lower crop production. To estimate which part of the crop production is, on average, available for direct consumption as vegetal food in UR Tanzania, yearly crop production of selected crops has been computed and expressed in kcal per day. Export and other uses (including feed) are subtracted during the computation. Contribution to food energy supply is expressed in kcal per day for the whole country. The food energy supply is projected to be reduced in the north-west and along Lake Victoria. A small increase in the food energy supply is expected in the central area of the country.

FOOD SUPPLY CONSEQUENCES

To illustrate the impact of a lower crop production caused by droughts, the production loss has been expressed in the amount of people that could have been fully fed (assuming a diet of 1730 kcal/cap,day and 10% household waste) with this lost production if there had not been a drought impact. The box plot illustrates the difference in the amount of people who could potentially be fed under current versus projected climate conditions. It is projected that in the future, 2 million less people could potentially be fed. This illustrates the possible negative effect on food security for people in UR Tanzania due to climate change: increased droughts will bring more crop production losses and thus more losses in food energy supply. This number of potentially fed people is an underestimation of the expected number of people likely to succumb to food insecurity because these estimations translate losses into 100% dietary reductions by person. The impacts of droughts are usually more distributed, that is: they affect a larger number of people, but at a smaller level of reduction in food energy.

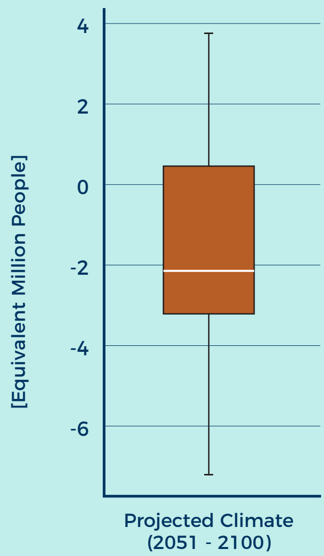


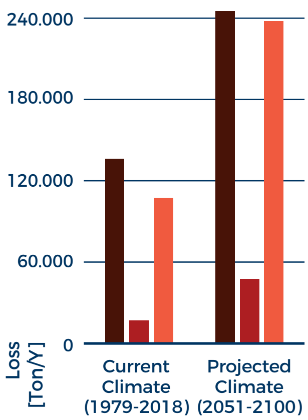
Fig. D24

http://www.fao.org/fileadmin/templates/ess/documents/food_security_statistics/MinimumDietaryEnergyRequirement_en.xls

AGRICULTURE

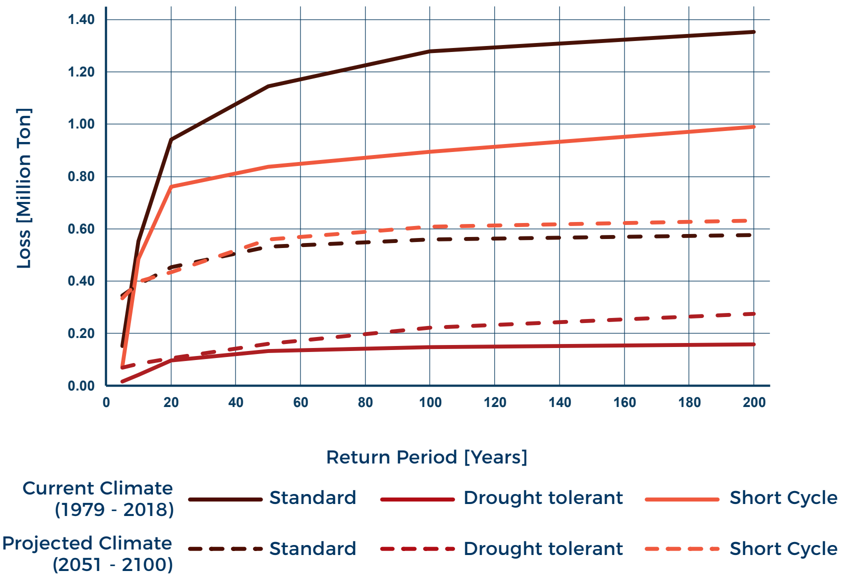
DROUGHT TOLERANT CROPS

MAIZE

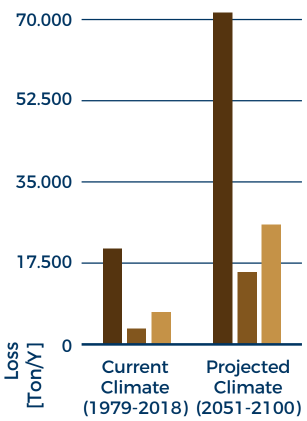


Drought tolerant crops
Fig. D25

Drought tolerant crops - Fig. D26

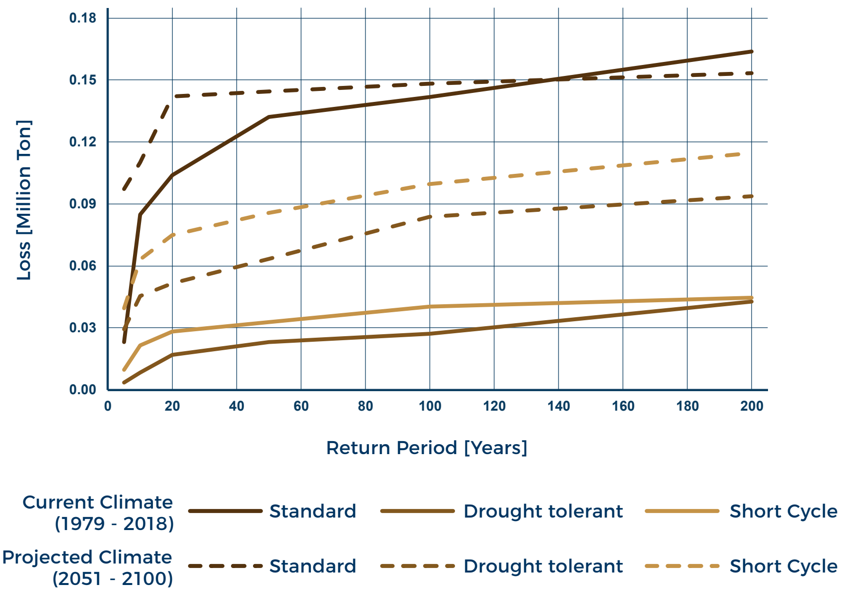


BEAN



Drought tolerant crops
Fig. D27

Drought tolerant crops - Fig. D28



We estimated the effect of drought-adapted varieties on crop production for two selected crops: maize (staple crop) and bean (protein crop) in UR Tanzania. For both crops we introduced a short-cycle variety to avoid planting too early in the season, and a variety that has better characteristics to tolerate periods of drought (e.g. via more extensive root system or physiological response to drought conditions).

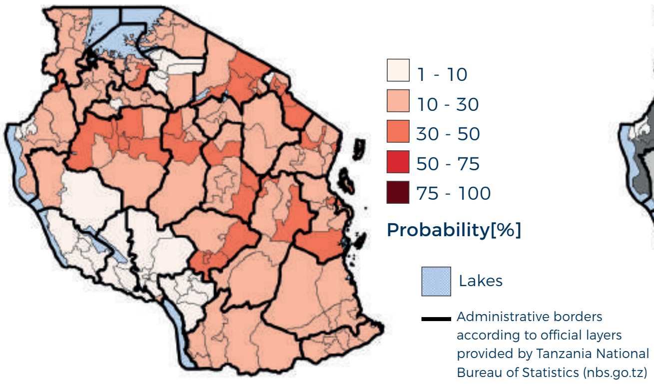
In most cases, the adaptation to drought, gives these varieties an advantage in drier years, but result in lower yields in wetter years. However, the analysis to determine the overall effect with all years in a climate (dry and wet) was not possible within this project. Obviously, this overall effect is strongly influenced by the frequency of occurrence of dry/wet years. In order to reduce the occurrence of lower yields in wet years, an Early Warning System can be used in combination with these varieties: drought monitoring and seasonal outlook can be used to advise a drought-adapted variety when the probability to have droughts in the growing season is high.

A crop production threshold, that is, a level of production under which a loss can be expected, was determined for the standard variety and under current climate conditions. This threshold was used to compute losses in under projected climate conditions and for the two other crop varieties. The results show that for maize, the drought-tolerant variety is very effective in reducing the loss in both climates, but that the short-cycle variety is much less effective, especially under projected climate conditions (loss almost equal to the standard variety). For beans, both varieties substantially reduce losses in both climates, with a stronger effect when using the drought-tolerant variety than the short-cycle variety.

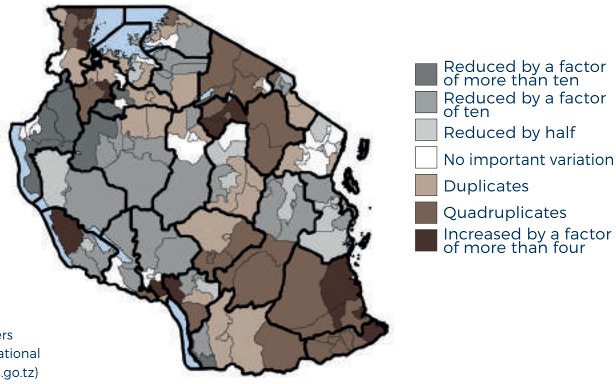
Strong effects are visible in the Probable Maximum Loss estimates for maize: all future losses show much higher values, compared to their counterparts under current climate conditions. Remarkable are the very low losses for the two drought-adapted varieties in the current climate, which illustrates their advantage, compared to the standard variety, in the dry years of the current climate. However, under projected climate conditions, PML values increase for frequent events, while they decrease for rare events. Differences between the different crop choices is less pronounced for sweet potatoes, where both the drought-tolerant and short cycle variety show an improvement compared to the standard variety.

HAZARD

COMBINED DROUGHT HAZARD



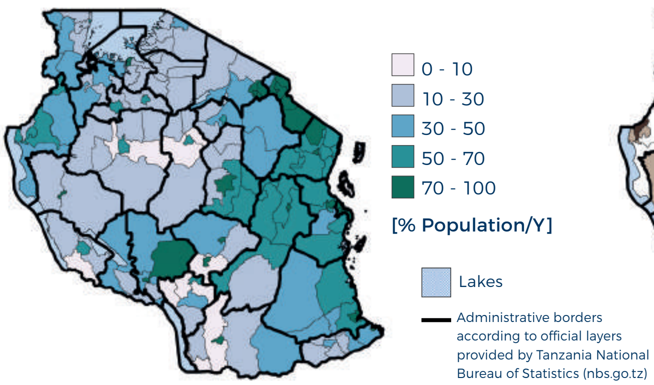
Current Climate Conditions (1979 - 2018) - Fig. D29



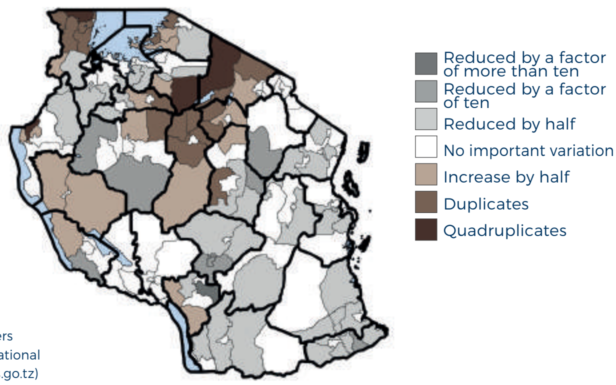
Anomaly in Projected Climate Conditions (2051 - 2100) - Fig. D30

These maps show the average annual chance of experiencing a drought (%). By analysing the deficits in effective rainfall (precipitation minus potential evapotranspiration), in subsurface water (soil moisture), and in the rivers (streamflow), and investigating which deficits caused an impact in the past decades, the vulnerability to water deficits was estimated for different regions in UR Tanzania. Then, the frequency of such meteorological or hydrological deficit under current and projected climate conditions was evaluated. With the combination of the deficit impacts and frequency, we created a drought probability map that showed the annual chance of a harmful drought. With climate change, the probability of severe droughts is expected to increase in areas around Hanang, Bukoba, Babati, Lindi, Misseny and Mpwapwa, while the areas around Kaliua and Kakongo might become less drought-prone. While rainfall will increase with climate change, this increase in drought risk can be assigned to higher temperatures and larger rainfall variability in a projected climate, and to the close link between drought disasters and effective rainfall deficits in UR Tanzania.

WCI - WATER CROWDING INDEX



Current Climate Conditions (1979 - 2018) - Fig. D31



Anomaly in Projected Climate Conditions (2051 - 2100) - Fig. D32

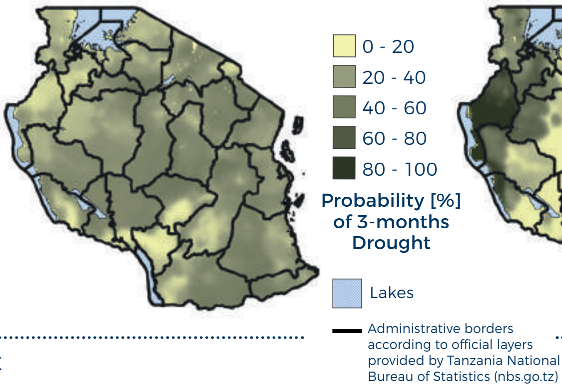
These maps show the percentage of the population per region experiencing water scarcity, based on the available water (precipitation minus actual evapotranspiration) per person per year (<1000 m^3/person/year). Water scarcity indicates that a population depends on water resources from outside their immediate region (~25 km^2). Currently, the highest percentage of population under water scarcity can be found in Arusha, Ilala, Kinondoni, Mbeya, Morogoro, Moshi, Nyamangana and Temeke, where almost the entire population is unable to be self-sufficient in water from their immediate region. Overall, average water availability will decrease under projected climate conditions. Large increases in water scarcity are projected, among other districts, in Shinyanga, Micheweni and Ngorogoro.

HAZARD INDEX

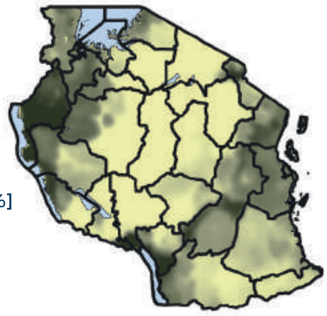
SEI - Standardized Evapotranspiration Index

These maps denote the average annual chance of a meteorological drought occurring (%). Droughts are defined as 3 consecutive months of evapotranspiration values considerably above normal conditions; calculated through the Standardized Evapotranspiration Index (SEI). In almost the entire country, the probability of droughts is above 50%, while in projected climate this tends to decrease in the centre of the country, but considerably increases in the western and eastern regions.

Current Climate Conditions (1979 - 2018) - Fig. D33



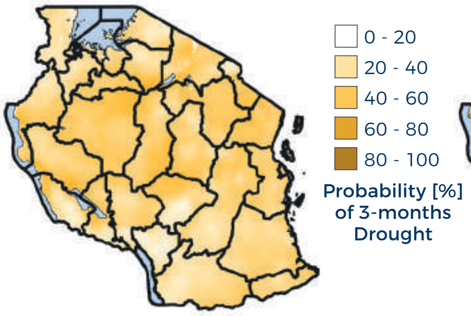
Projected Climate Conditions (2051 - 2100) - Fig. D34



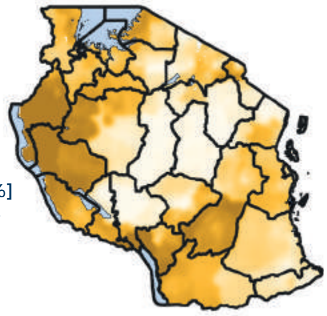
SSMI - Standardized Soil Moisture Index

These maps denote the average annual chance of a subsurface drought occurring (%). Droughts are defined as 3 consecutive months of soil moisture conditions considerably below normal conditions calculated through the Standardized Soil Moisture Index (SSMI). Overall, there is a decrease in drought probability predicted under projected climate conditions, except in the western and eastern regions where the probability is considerably higher. This index is particularly important for agricultural areas and natural ecosystems.

Current Climate Conditions (1979 - 2018) - Fig. D35



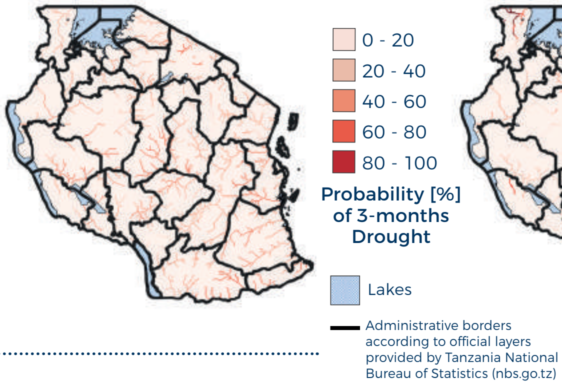
Projected Climate Conditions (2051 - 2100) - Fig. D36



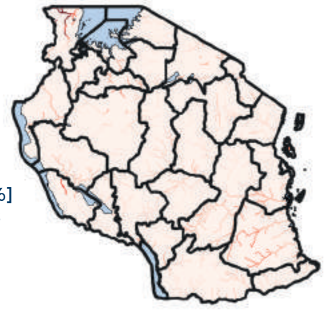
SSFI - Standardized Streamflow Index

These maps denote the average annual chance of a hydrological drought occurring (%). Droughts are defined as 3 consecutive months of stream flow levels considerably below normal conditions calculated through the Standardized Streamflow Index (SSFI). The probability of droughts in rivers is expected to diminish with the exception of some western areas in the country. This is particularly important for areas dependent on rivers for their water resources.

Current Climate Conditions (1979 - 2018) - Fig. D37



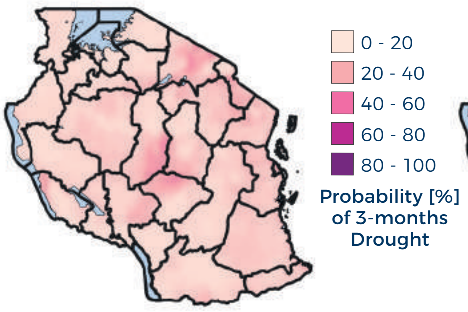
Projected Climate Conditions (2051 - 2100) - Fig. D38



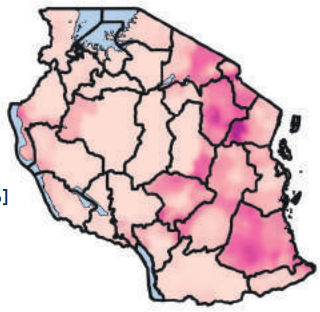
SPI - Standardized Precipitation Index

These maps denote the average annual chance of a meteorological drought occurring (%). Droughts are defined as 3 consecutive months of precipitation considerably below normal conditions; calculated through the Standardized Precipitation Index (SPI). Overall, there is a decrease in drought probability predicted under projected climate conditions, except in the eastern regions where the probability is considerably higher.

Current Climate Conditions (1979 - 2018) - Fig. D39



Projected Climate Conditions (2051 - 2100) - Fig. D40



Risk Profile key messages

CLIMATE

The climate projections (2050-2100) considered in this risk profile (RCP 8.5) foresee a marked increase in temperature in UR Tanzania, especially in the final part of the century (2071-2095) when it could reach over three degrees at the country scale. While highly uncertain, the rainfall totals are also expected to increase by on average 50 mm per year at country scale, with very distinctive patterns in different climatic areas.

FLOODS

The average of 45.000 people affected per year under current climate conditions is projected to increase considerably in the future. Taking into account both climate projections and the population increase, the average affected people per year would increase more than four times (above 200.000 people). The coastal area contains the most affected regions, in both present and projected climate conditions.

Average Annual Loss due to floods is estimated to be just under 28 million USD on average in the present, while it is projected to be over 40 million USD in the future. The most affected sectors are agriculture, services and transport.

An increased frequency of both frequent and extreme events under projected climate conditions is expected: a loss of 100 million USD occurs on average every 100 years in the current climate, while in future the same loss would occur on average every 25 years.

DROUGHTS

On average, almost 4.8 million people are estimated to be directly affected by drought per year. Some districts in Tabora and Shinyanga regions are a hotspot. The situation would worsen under projected climate conditions, where 12 million people are estimated to be directly affected if population growth is also accounted for.

Drought risk is projected to decrease in the western tropical savanna areas, but increase in the northern arid areas and the southern parts of the country.

More than 20% of livestock is currently exposed to risk and is projected to reach close to 40% in the projected climate. Drought risk for livestock is also expected to worsen in the arid areas and in the southern regions of UR Tanzania.

Average annual economic losses in agriculture due to drought is estimated at around 140 million USD under current climate conditions. These would more than double under projected climate conditions, if no adaptation measures were implemented.

Policy Recommendations

1. MAINSTREAMING AND COMMUNICATION

Disasters drain Tanzania's national economy. Floods and Droughts alone determine an average economic loss of about 170M USD every year, burning more than 1% of the total annual budget of the Government of UR Tanzania, and 20% of its annual investments in DRR (including indirect DRR investment according to the OECD budget marker methodology). DRR investments are key to reducing these annual losses. As such, DRR measures have to be integrated across different sectors to obtain a resilient future nation.

i. The government should therefore **promote development actions that take into account disaster and climate risks** in order to reduce flood and drought impacts across all sectors by mainstreaming the findings of the present risk assessment in all related plans and policies. These recommendations assume higher urgency considering that these losses are predicted to triple at the end of this century.

Among the sectors where this mainstreaming effort should focus first, the agricultural sector figures prominently. The agricultural sector is responsible for the majority of the losses when floods and droughts are analysed. This sector is critical, not only because of the direct economic losses that it suffers, but also in consideration of the possible effects that reduced agricultural production can have on food security at the national level.

i. It is therefore recommended to implement **disaster risk sensitive investment and funding in agriculture** to be improved with the aim of fostering climate resilient agricultural practices, investing in climate-resilient seed development especially for the most impacted crops as identified in the risk profile (Banana, Maize, Beans). This increased funding should also come together with improved governance for the management of these funds to ensure the highest possible effectiveness.

ii. To **ensure a transition to drought tolerant varieties and encourage farmers to make the switch through government subsidies**. This would have enormous beneficial impacts, not just for food security, but also for economic losses. Based on data on the effect of drought in the agricultural sector, the country faces losses of up to 140k tons of maize per year when standard varieties are used. If drought-tolerant maize varieties were to be adopted countrywide, a large part of these losses would be avoided. These avoided losses correspond to an estimated 72 billion shillings per year if quantified in economic terms. A policy such as this one, to subsidise farmers so as to adopt drought tolerant maize varieties, should be better evaluated and quantified in a cost benefit analysis framework.

2. PREPAREDNESS AND RECOVERY

Almost 45,000 people are directly affected by floods every year in Tanzania. At the end of the century, considering climate change and population growth, relatively frequently events (on average happening once every decade) can affect 200,000 people. When droughts are considered, these figures increase almost tenfold.

i. The government should therefore **ensure the existence of emergency preparedness and recovery plans** for floods and droughts, from the national to the local level, taking into consideration the areas that are most disaster-prone as identified in the risk profile. Emergency planning and preparedness on how to recover from disasters should explicitly take these challenges into consideration by evaluating the needed coping resources at different levels, from the national to the local level. Different challenges are in fact posed to emergency planning when the number of affected people and their related activities increase. This quantification is made possible by using the risk profiles that offer an estimation of the number of affected people at the district level for both floods and droughts.

3. DRR STRATEGY

It is one of the objectives of UR Tanzania to reduce the number of people potentially affected by floods and droughts of at least 50% in alignment with the Sendai Framework and the SDG targets. To accomplish that target a solid National DRR Strategy needs to be put in place. The risk profile enhances the understanding of disaster risk by identifying and mapping areas that have a high exposure, thus enabling the prioritisation of DRR investments, which is the main objective of the National DRR Strategy. By jointly analysing the PML and AALs it is possible to quantify the resilience of communities and to identify in the NDRRS focused measures on the most impacted sectors in order to increase such resilience.

i. It is recommended that the **preparation of DRR plans at any level to consider risk profiles as the basis for evidence so as to guide on strategies and guidelines** to reduce the expected drought and flood disaster impacts. The DRR plans should also consider the increased losses expected in future, foreseeing appropriate investments in DRR measures. The quantifications included in the risk profiles should inform resources mobilisation both at government level and from the international community.

4. AWARENESS RAISING AND EDUCATION

The risk profile is a powerful way to visualise risk and therefore can be used to increase the awareness of risk at all levels. The government should conduct awareness programs at the national and local level as an integral part of preparedness and emergency response mechanisms to disasters.

i. It is recommended to **reinforce the disaster risk awareness and education programs and use the results in the risk profiles for flood and drought as reference material**.

5. CONTINGENCY BUDGET ALLOCATION

Contingency funds cannot be considered as a stand-alone solution, but should be connected to the DRR investments so that the need for contingency funding allocation will decrease in the future.

i. The government should **plan, together with the competent public and private institutions, a contingency budget allocation or risk transfer mechanisms** for each sector to guarantee a fast recovery of losses from floods and drought. This should account for the fact that climate change impacts in some key sectors have a spillover effect to the other sectors. A first dimensioning of the needed resources to be stored for the most relevant sectors can be derived by the quantification of the losses provided by the risk profiles. When these estimations are connected with the budget availability per sector, an optimal combination between contingency funds and risk transfer mechanisms can be also derived for each sector.

Glossary

AFFECTED PEOPLE and GDP

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

AVERAGE ANNUAL LOSS (AAL)

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.

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 represented by a combination of various standardized indices, covering a range of drought types (meteorological, subsurface and surface (hydrological) droughts). In this disaster risk profile, droughts are analysed in terms of hazard, exposed population, GDP and livestock. Drought induced losses are explicitly estimated for crop production and hydropower generation, by linking hazard, exposure and vulnerability (H x E x V)

STANDARDIZED DROUGHT INDICES

Standardized drought indices represent the 'abnormality' of certain water deficits, assessed by analysing the meteorological, sub-surface or surface water balances. Using these indices, drought can be defined as at least three consecutive months with standardised index values below a certain drought threshold, indicating conditions that are significantly dryer than normal for a certain region, given the reference period 1979-2018. On the drought indices maps, the drought probability is calculated using a varying drought threshold [coincidencing with the 5%-25% lowest water availabilities ever recorded]: the dryer the area, the less extreme the water deficit needs to be in order to be considered 'a drought'.

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

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 projected climate. Losses at national level have been estimated as the sum of all Admin 1 losses.

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. Typically, PML is relevant to define the size of reserves which, insurance companies or a government should have available to manage 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.

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*

Notes

www.preventionweb.net / resilient-africa

www.undrr.org

RISK PROFILES ARE AVAILABLE AT:

riskprofilesundrr.org

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