

Masterclass on Climate Adaptation Finance

Session 2: Climate Science and Risk: Foundations for
Financial Decision-Making



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CENTER ON
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BANK OF TANZANIA ACADEMY

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Frankfurt School
of Finance & Management
German Excellence. Global Relevance.

Trainer



Danilo Amaral Cançado *Climate Adaptation and Resilience Expert*

8 years of experience in climate adaptation and infrastructure projects in Africa, Asia, Latin America and Caribbean. Certified Climate Finance Expert.

Agenda

- Introduction to Climate Change Science
- Main Drivers of Climate Change in Tanzania
- Defining Climate Risk: Hazard × Exposure × Vulnerability
- Impacts of Climate Change in Tanzania
- Importance of Climate Models and Projections
- Complexity and Uncertainty in Climate Risk Assessment
- Implications for Financial Institutions and Investment Decisions

Context for the Masterclass

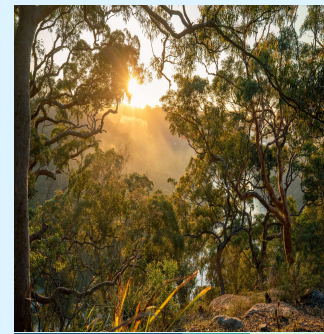
Climate change presents both serious threats and strategic opportunities for financial institutions (FIs).

As physical and transition climate risks intensify, they can severely disrupt **lending operations, erode asset values, increase default rates, and ultimately undermine financial stability.**

However, the same risks also pave the way for **new business opportunities** in adaptation finance and **climate-resilient investments.**

Learning outcomes

- *Understand the scientific foundations and key drivers of climate change in Tanzania.*
- *Assess how climate hazards, exposure, and vulnerability contribute to societal, environmental, and economic risks.*
- *Evaluate the relevance and limitations of climate science and models in financial risk assessment and decision-making.*



Module 2: Understanding
Climate Change Science

The Masterclass on Climate Adaptation Finance



Purpose: Global Center on Adaptation (GCA) and European Bank for Reconstruction and Development (EBRD) in partnership with Frankfurt School of Finance & Management, RebelGroup, and Haskoning develop the Masterclass to engage the private sector in climate adaptation finance, unlocking market growth, protecting portfolios, and creating long-term value through innovative tools. The Masterclass positions adaptation as both a strategic opportunity and a risk management priority.

The Masterclass is built on a 6-module Body of Knowledge (BoK) to equip financial institutions (FIs) to understand physical climate risks and design bankable adaptation investments that build resilience, align with national priorities, and benefit millions of people.

M1: Rationale for Investing in Adaptation

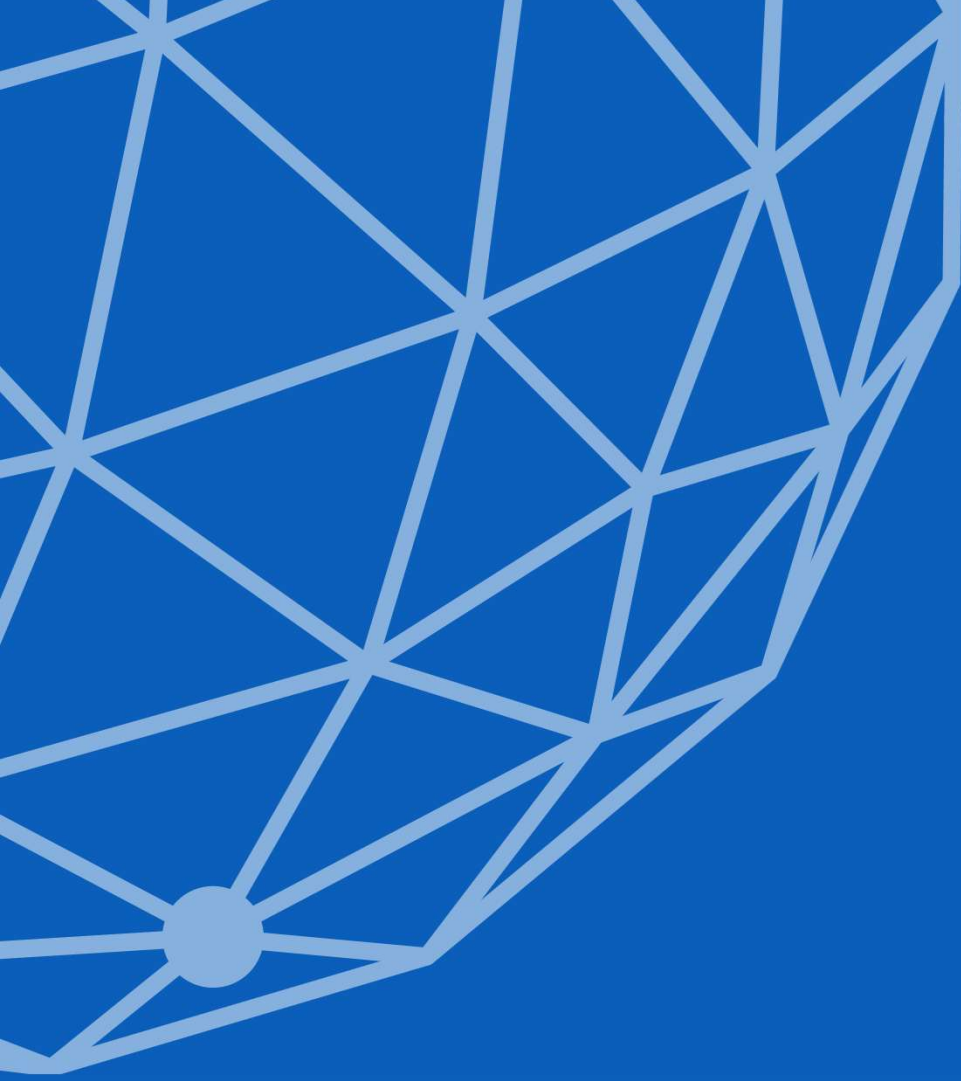
M2: Understanding Climate Change Science: what FIs* must know

M3: Climate Risk Modeling for FIs

M4: Adaptation Needs, Finance Solutions & Tools

M5: Climate Adaptation Product and Pipeline Development in FIs

M6: Stakeholder Engagement and Policy Support for Scalable Climate Finance



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Introduction to climate change science

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Introduction to Climate Change Science



What is climate change?

Climate change can be defined as...

“...a change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer”¹

These changes are dynamic and depend on **natural climate variability** and **atmospheric changes caused by human activities**.

Introduction to Climate Change Science

Natural climate variability vs. atmospheric changes

Natural climate variability

Cycles or fluctuations that can lead to changes in climate patterns of climate variables such as temperature, precipitation and wind

Atmospheric changes

Caused by **human activities**, driven by concentration of **carbon dioxide** (CO₂) in the atmosphere and the **emission of greenhouse gases** (GHG).



Introduction to Climate Change Science

Greenhouse Gases (GHGs)

- GHGs are gases that absorb and emit heat, contributing to the greenhouse effect.
- The increase in the concentration and emissions of GHGs in the atmosphere is the key driver of climate change.
- Many different types of gases have a greenhouse effect and contribute to global warming.
- The **main gas** that causes this effect is **CO₂** due to its **long-lasting presence** and significant impact on **increasing the Earth's average annual temperature over time**.

CO₂ stays in the atmosphere for centuries.
GWP : 1

CH₄ lasts about 12 years in the atmosphere.
GWP : 27.9

Metrics to quantify impact of different GHGs on global warming

Global Warming Potential (GWP)

Measures how much heat a GHG traps in the atmosphere over a specific period compared to CO₂, which stays in the atmosphere for centuries.

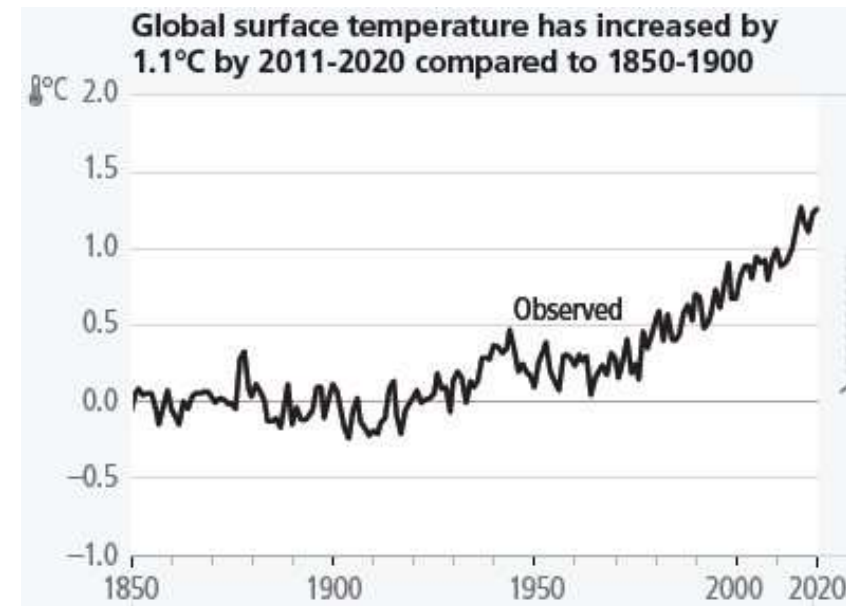
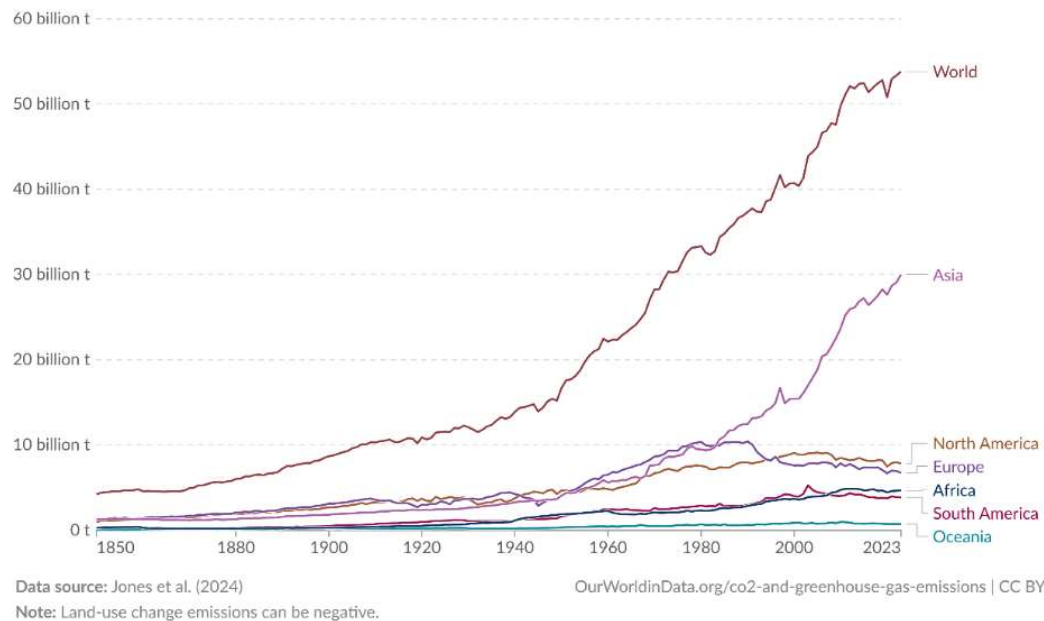
CO₂ equivalent (CO₂ eq)

expresses the impact of different GHGs on global warming in a common unit, making it easier to compare and aggregate emissions.

Introduction to Climate Change Science

The increase in GHG emissions

Since the mid-20th century, GHGs have increased from 4.2 billion tons of CO₂ equivalent to 53.8 billion tons. This represents a **11-fold increase worldwide!**



Quiz Question

Which greenhouse gas is identified in the slides as the **main driver of long-term climate change** due to its long-lasting presence in the atmosphere?

A) Methane (CH_4)

B) Nitrous oxide (N_2O)

C) Carbon dioxide (CO_2)

D) Water vapor (H_2O)

CO_2 is the main greenhouse gas driving climate change because it remains in the atmosphere for centuries and has a significant cumulative impact on increasing Earth's average temperature over time, even though some other gases may be more potent in the short term.



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Main drivers of climate change

Sources of GHGs

The emission of GHGs occur in all economic sectors and anthropogenic activities.

Carbon Dioxide (CO₂)

Combustion of fossil fuels, deforestation & industrial processes, and changes in the balance of CO₂ due to vegetation loss and land use changes

Nitrous Oxide (N₂O)

From use of nitrogen fertilizers in agriculture, (a byproduct of) fuel combustion, and wastewater treatment processes²

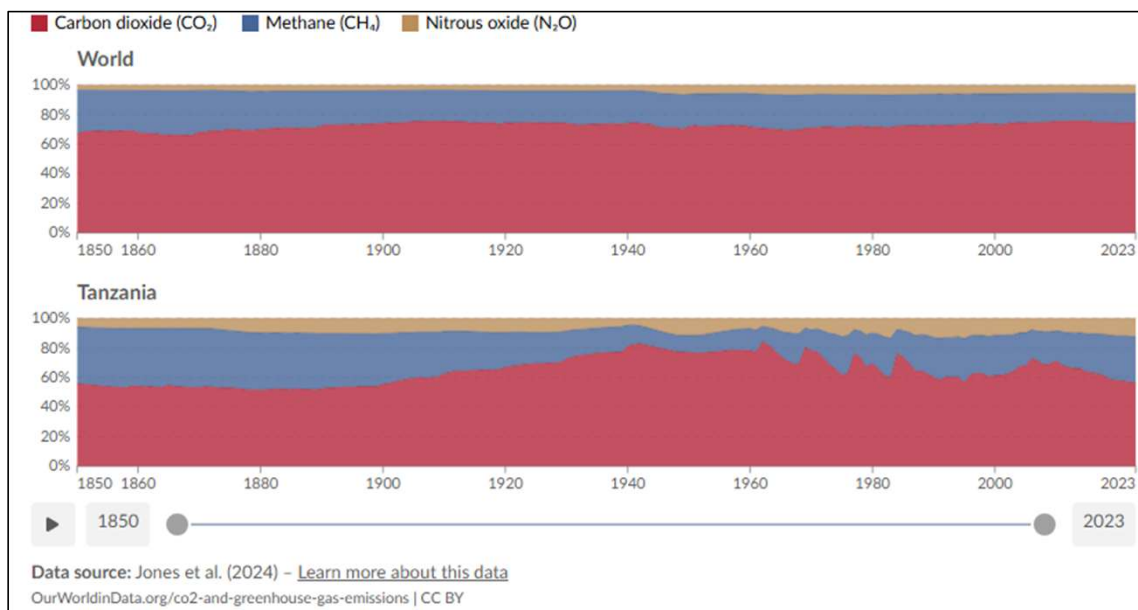
Methane (CH₄)

From agricultural production, livestock, manure management, and from oil & gas production and distribution¹

Gases with fluor

From the replacement of other ozone-depleting substances (refrigerants from electrical appliances) and aluminium or semiconductor manufacturing²

Relative change in concentration of GHGs worldwide and in Tanzania from 1850 to 2023¹.



Sources

1. (Lau, 2022)
2. (United States Environmental Protection Agency, 2025).
3. (Ritche, H., Rosado, P. & Roser, M. (2020) via OurWorldinData)

Key sectors responsible for GHG emissions^{1 2}

Energy

Related to burning of fossil fuels for energy production and industrial production of materials such as cement. Firewood is used by 71.2% of households for cooking. Oil is the greatest contributor to sector GHG emissions.

Agriculture

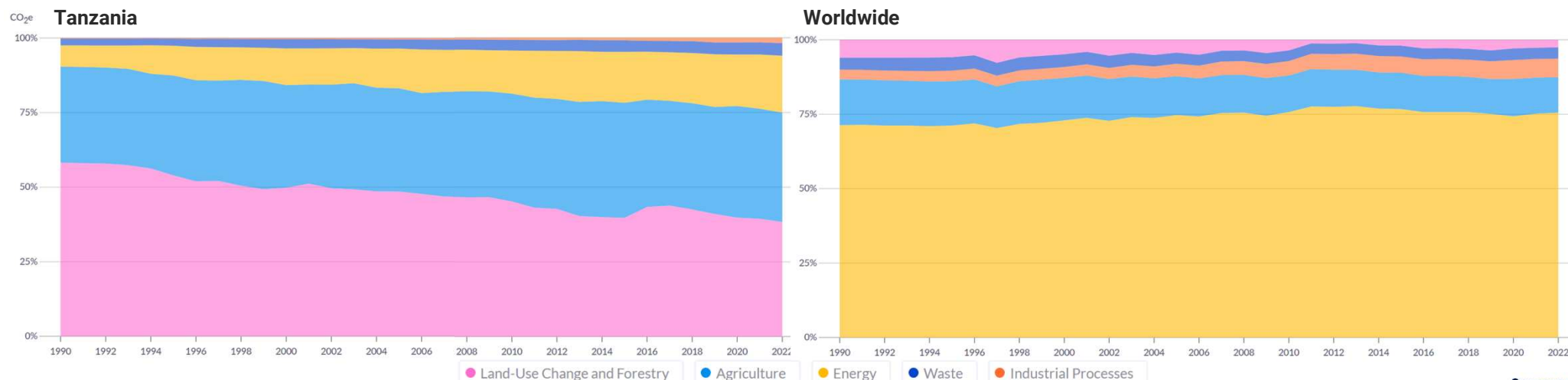
Dominated by smallholder farmers reliant on rain-fed agriculture, major export crops and livestock. Characterized by low productivity due to soil degradation, inappropriate technology use and traditional cropping methods.

Land-use Change and Forestry

Driven by agricultural expansion and population growth, leading to high rates of deforestation. Significant reliance on forestry resources providing 90% of energy supplies, 75% of building materials and 100% of traditional medicines.

Land-use change, agriculture and energy accounts for 94% of total GHG emissions in Tanzania in 2022.

Historical GHGs emissions per sector in Tanzania and Worldwide²



Sources:

1. Our World in Data. (n.d.). Tanzania Country Profile. <<https://ourworldindata.org/co2/country/tanzania>>.

2. Climate Watch. (2023). Historical GHG Emissions. <<https://www.climatewatchdata.org/>>.

3. Irish Aid. (2018). Tanzania Country Climate Change Risk Assessment Report. <<https://www.ied.org/sites/default/files/pdfs/2023-11/22086g.pdf>>.

How understanding GHG emissions is linked to climate adaptation

Understanding GHG sources is essential for prioritizing **effective adaptation solutions** that consider the **vulnerability of investments** to climate risks and enable FIs to **prioritize projects** that have a mitigation co-benefit (reduction in GHG emissions).

For example, **land-use change** is an anthropogenic activity often used to facilitate many sectors today. It has significant impacts on GHG emissions and can have consequences to FIs. It is mainly caused by:

- Deforestation
- Urbanization

This results in...



Less natural areas, leading to lower biodiversity and less trees absorbing carbon dioxide

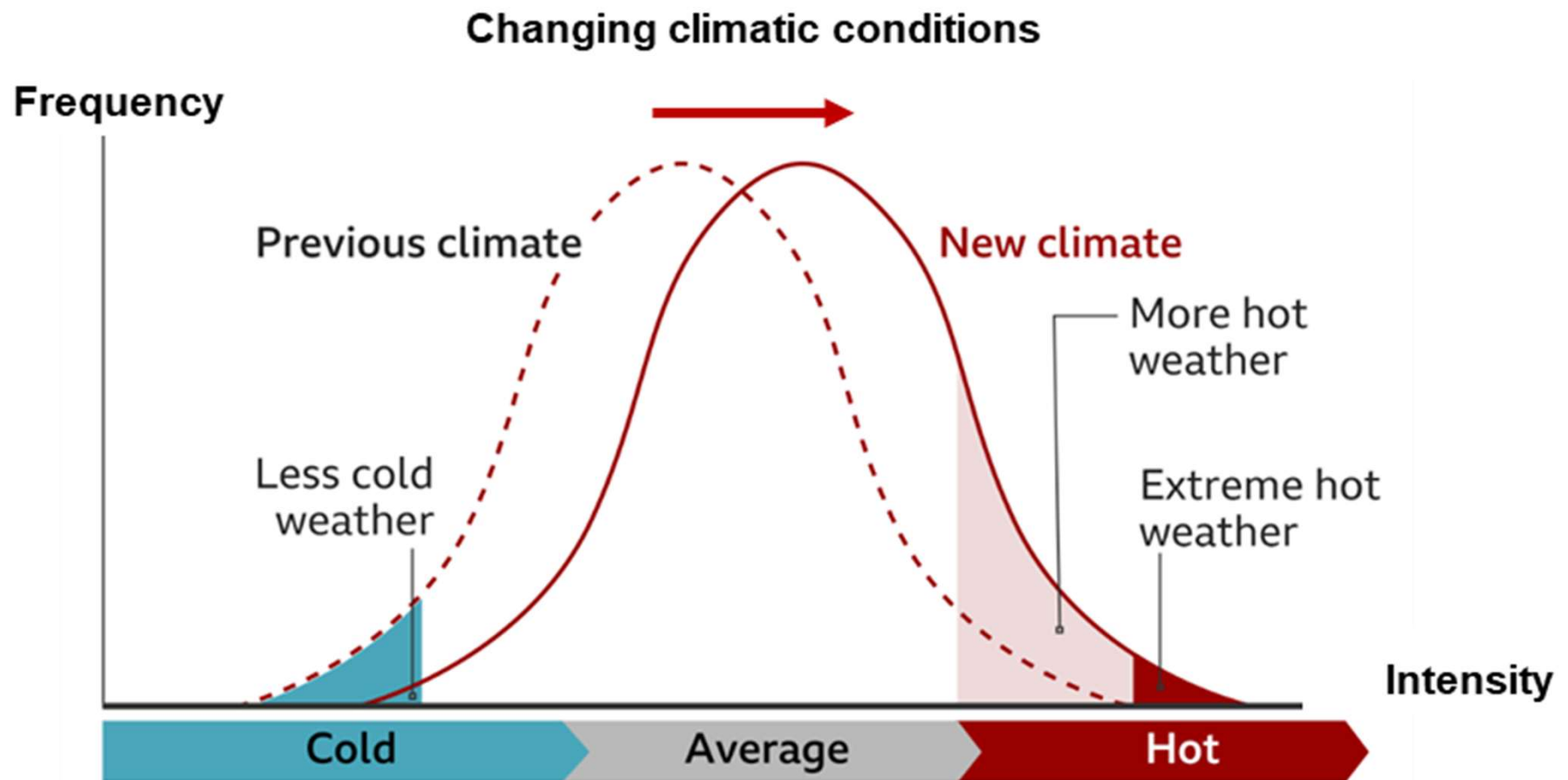


More emissions from energy consumption and industrial activities



Methane and nitrous oxide from livestock and fertilizer use

How climate change is affected



Quiz Question

Even if average temperatures increase, the frequency of extreme hot weather events may remain unchanged as long as greenhouse gas emissions are stabilized.

A) True

B) False

climatic conditions shift, the entire temperature distribution moves toward hotter conditions. This increases the frequency and intensity of extreme heat events, even when changes in the average appear small, meaning extremes do not remain unchanged.



Hover over each option and click on the answer you think is correct.



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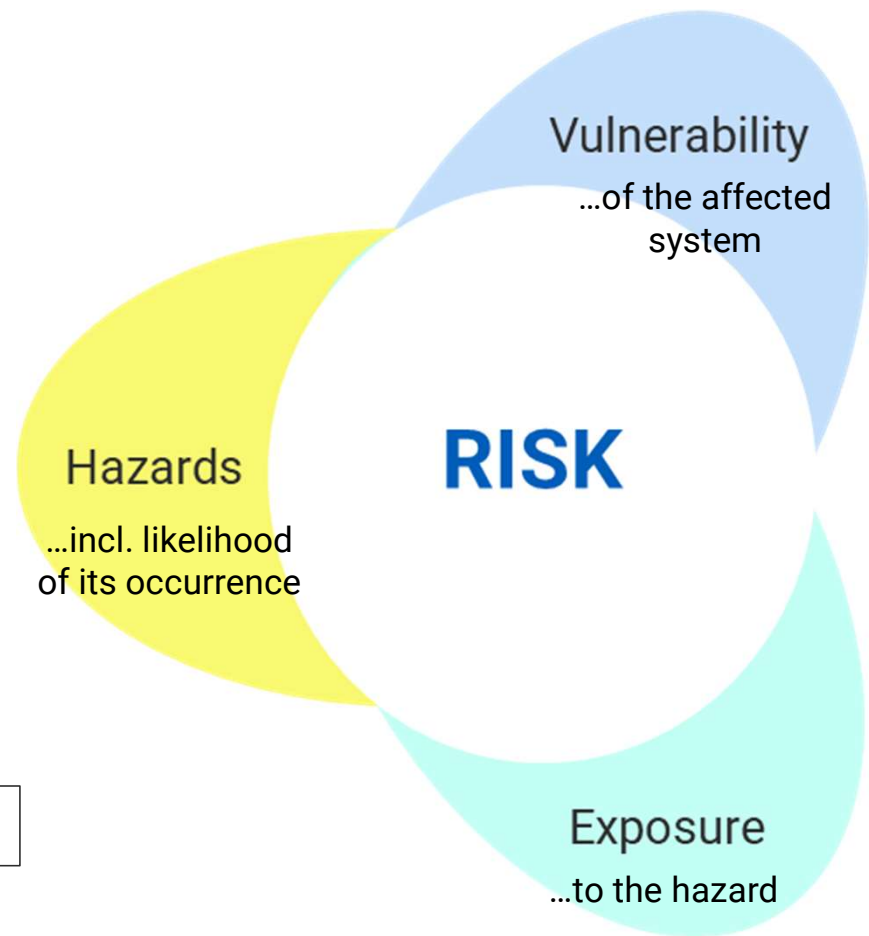
Defining climate risk

Risk is the potential for adverse consequences to *lives, livelihoods, health and well-being, ecosystems and species, economic, social and cultural assets, services (including ecosystem services), and infrastructure.*

‘maybe something bad will happen’

...results from interaction of the climate-related **hazard**, **vulnerability** and its **exposure** over time.

$$\text{Risk} = \text{Hazard} \times \text{Exposure} \times \text{Vulnerability}$$



Defining climate risk

Hazards

Natural (or human-induced) processes, phenomenon, or events that cause damage or disruption.

Hazard is a function of:

- 1) **Frequency** of occurrence; and
- 2) **Intensity** of the event

Hazards

- Floods
- Tropical cyclones
- Storms
- Wildfires
- Lightning
- Landslides
- Sea level rise
- Drought
- Heat
- Earthquake
- Volcano
- Tsunami

Characterisation

Related to extreme weather events
- *Acute Climate-related Hazards*

Related to gradual shifts in climate
- *Chronic Climate-related Hazards*

Not directly caused by climate factors
- *Non-climate-related Hazards*

Lead to Climate Risk?



Defining climate risk

Exposure

The presence of assets in places and settings that could be adversely affected.

'What is exposed to the hazard?'

- People;
- Livelihoods;
- Species or ecosystems;
- Environmental functions, services and resources;
- Infrastructure; or
- Economic, social, or cultural assets



Flooding of roadway in Tanzania



Ongoing drought in Northern Tanzania where most Maasai pastoralists live



Heavy rains inundate Dar es Salaam

Defining climate risk

Vulnerability

- The propensity or predisposition to be adversely affected.
- Vulnerability encompasses a variety of concepts and elements including **sensitivity** and **adaptive capacity**

'How things are affected by the hazard'

Sensitivity

Degree to which a **system** is (harmfully) impacted by exposure

Examples:

- Livelihoods based on agriculture are sensitive to climate-related drought
- Tourism sectors is highly impacted by coastal flooding and loss of biodiversity

Adaptive Capacity

The ability of **systems, institutions, humans and other organisms** to adjust to potential damage, take advantage of opportunities, or respond to consequences.

Examples:

- Industries adjusting schedule of work to deal with extreme heat days and reduce health risks to workers

Quiz Question



Which combination below would most effectively reduce climate risk, assuming the climate hazard (e.g., frequency and intensity of heatwaves) remains unchanged?

A) Reducing vulnerability by increasing adaptive capacity, even if exposure remains high

B) Reducing exposure only, while vulnerability remains high

C) Increasing exposure but lowering sensitivity

D) Focusing only on hazards without addressing exposure or vulnerability

When hazards cannot be controlled, strengthening adaptive capacity (a key component of vulnerability) can significantly reduce overall risk—even if exposure persists.

Quiz Question

A system can have high exposure to a climate hazard but still experience low climate risk if its vulnerability, particularly its adaptive capacity is low.

A) True

B) False

Strong adaptive capacity can reduce how severely exposed systems are affected, lowering overall climate risk despite high exposure.



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Climate change impacts in Tanzania



Impacts of climate change in Tanzania

- Tanzania reported a total of **34 natural disasters** between **2013 and 2020**.
- It has been estimated that the **cost of a drought year** is around **1% or more of GDP**.
- Agricultural economic losses from climate change impacts are estimated at **US\$200 million every year**; much greater than is required for building sector resilience, estimated at US\$ 100-150 million per year.
- A 15% decrease in rainfall may mean as much as a **16% decrease in agriculture yields by 2030** (1 million tonnes/year).
- Tanzania is described as having a very high level of undernourishment, with **43% of the population being under nourished directly because of drought related food shortages**.
- During the 1997-98 El Niño, **sea surface temperature rise coupled with excessive flooding** were the key factors in **cholera epidemics** in Djibouti, Somalia, Kenya, Tanzania, and Mozambique.
- Floods and earthquakes accounted for estimated losses of US\$463.8 million between 1980 and 2022.

Key natural disasters in Tanzania, 1980-2024.

Natural Hazard	Events (#)	Total Deaths (#)	Total Affected (#)	Total Damage ('000 USD)
Drought	8	0	14,654,000	0
Earthquake	6	32	148,092	581,455
Epidemic	32	8,993	225,599	0
Flood	53	1,037	4,140,160	10,631
Infestation	3	0	0	0
Mass movement (wet)	3	124	6,491	0
Storm	8	56	2,046,670	0
Wildfire	1	0	0	0

EM-DAT database
 International Monetary Fund. (2024). United Republic of Tanzania. IMF Country Report No. 24/349, Fourth Review. <https://www.imf.org/en/-/media/files/publications/cr/2024/english/1tzaea2024002-print.pdf.pdf>
 World Bank Group. (2025). Climate Change Knowledge Portal – Tanzania. <https://climateknowledgeportal.worldbank.org/country/tanzania/natural-disasters-historical>.
 GIZ. (2021). Climate Risk Profile: Tanzania. https://www.adaptationcommunity.net/wp-content/uploads/2021/02/GIZ_Climate-Risk-Profile-Tanzania_EN_final.pdf.
 Irish Aid. (2018). Tanzania Country Climate Change Risk Assessment Report. <<https://www.iied.org/sites/default/files/pdfs/2023-11/22086g.pdf>>.

Quiz Question

Climate change impacts include both slow-onset events such as drought and sudden extreme events such as floods, landslides, and wildfires, which together affect livelihoods, food security, and economic losses.

A) True

B) False

Climate change alters long-term climate patterns while also intensifying extreme weather events. The combination of these effects can reduce agricultural productivity, disrupt livelihoods, increase disaster losses, and strain economies over time.



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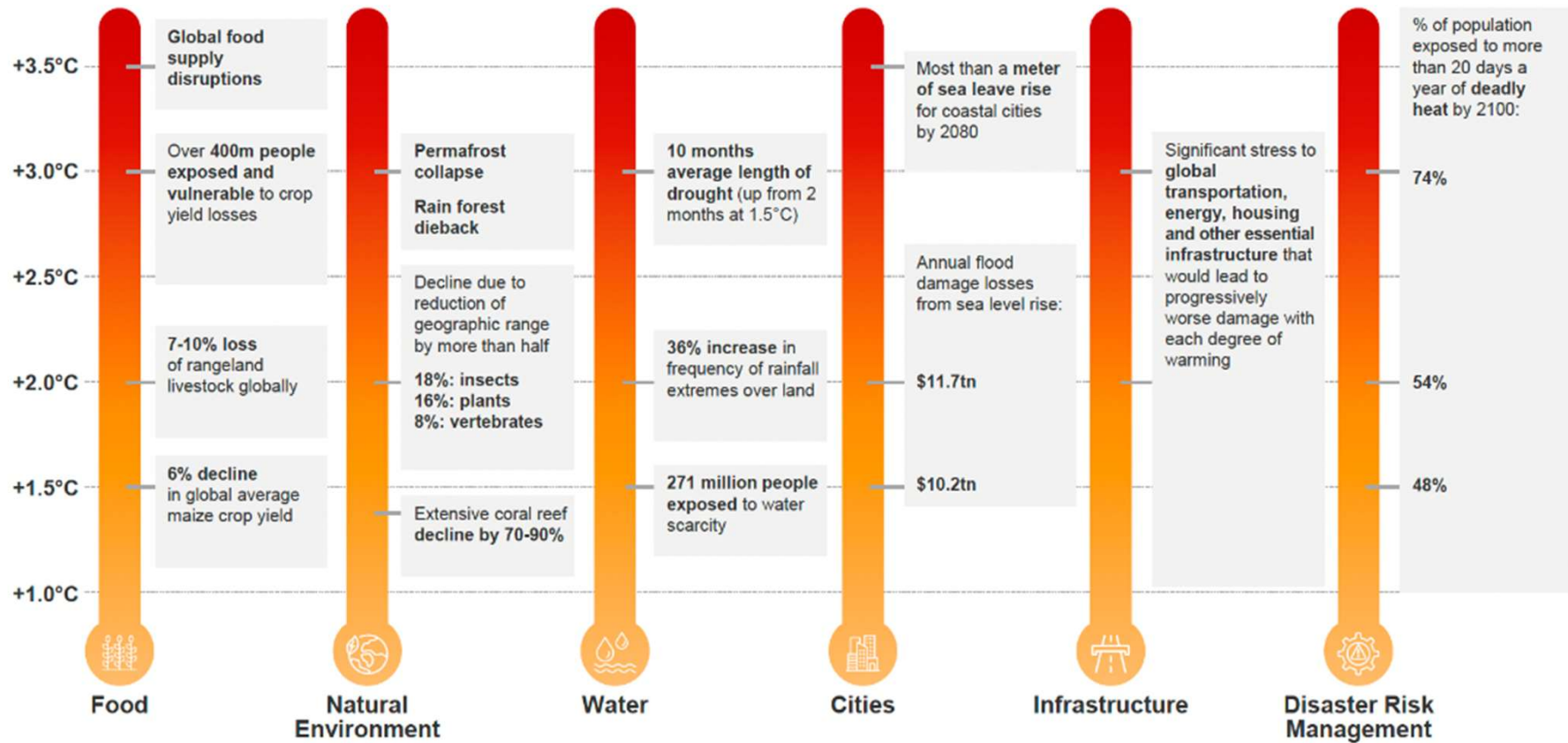
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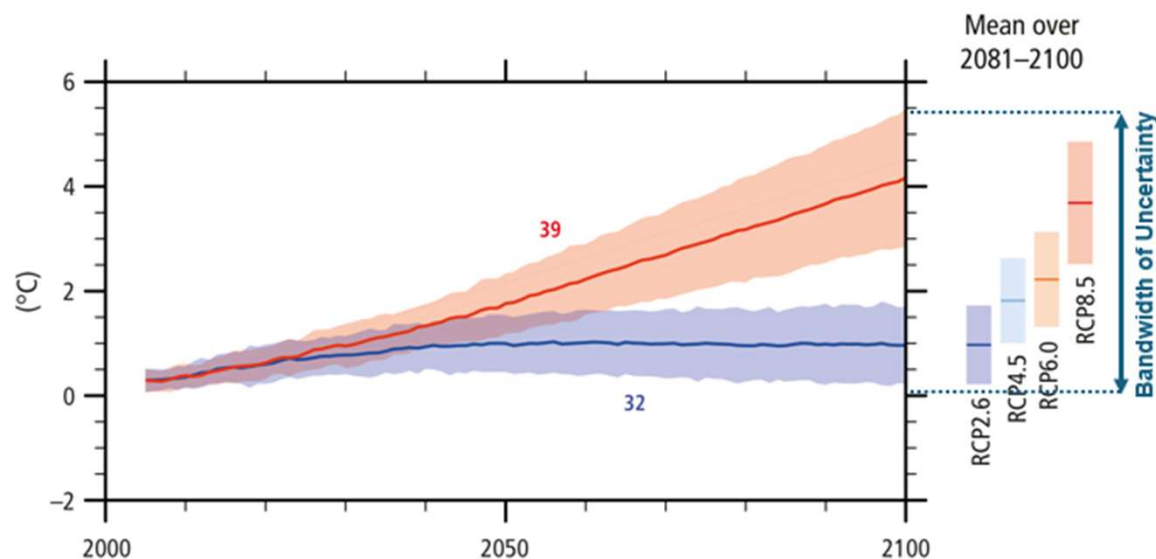
There is no safe future climate scenario



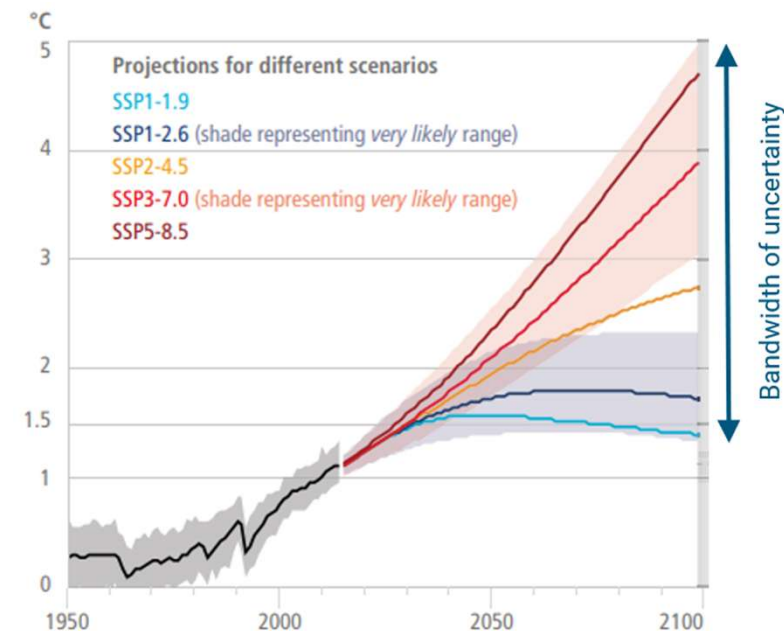
Source: IPCC, 2023: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change

Importance of Climate Models and Projections

Climate projections help us to understand the broad impacts of climate change on the planet, including extreme weather events, biodiversity loss, and global economic shifts. They help policymakers, companies and FIs to understand **potential impacts** of different actions on climate change.



RCPs focus on different levels of **GHG concentrations** in the atmosphere, **air pollution**, and **land use change**.



SSPs consider various socioeconomic factors like **population growth**, **urban growth**, **economic development**, and **technological advancements**.

Importance of Climate Models and Projections

Climate models



Scientists analyse historical data and current trends to create climate models which are programs that **simulate how the Earth's systems may respond under different conditions** (UCAR, 2024; NASA, 2024).

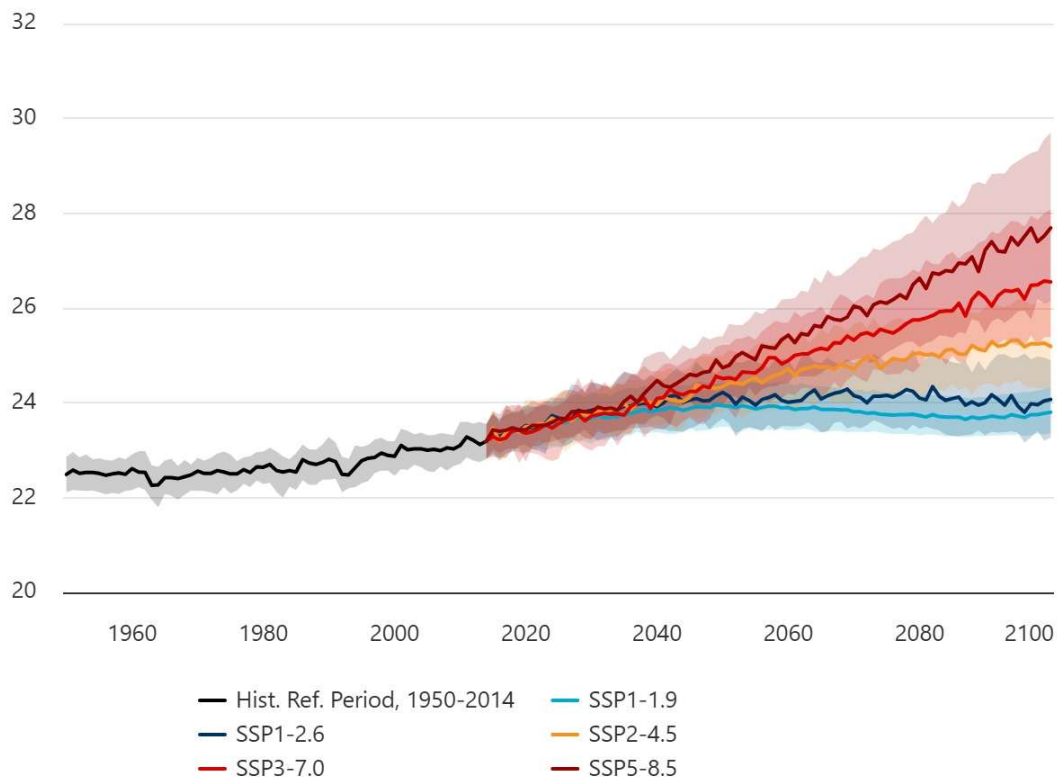


Climate models are tools that can help in understanding **potential impacts** on ecosystems, weather patterns, and human activities (Zehnder, et al., 2018).



In doing so, we can assess sector- and geography-specific **vulnerabilities**.

Projected Timeseries of Average Mean Surface Air Temperature
Tanzania 1950-2100 Multi-Model Ensemble Ref. Period: 1995-2014



Tanzania - Mean Projections Expert | Climate Change Knowledge Portal

Importance of Climate Models and Projections

- Climate projections are derived from climate models based on specific scenarios. Projections provide **detailed estimates of future climate variables, such as temperature and precipitation, under various scenarios.**
- Climate scenarios can be analysed at different levels, including global, regional, or sector-specific levels which allows for a broad understanding of global trends through projections.
- This also enables more **precise, actionable strategies** at local or sectoral levels where specific impacts and vulnerabilities may vary significantly.

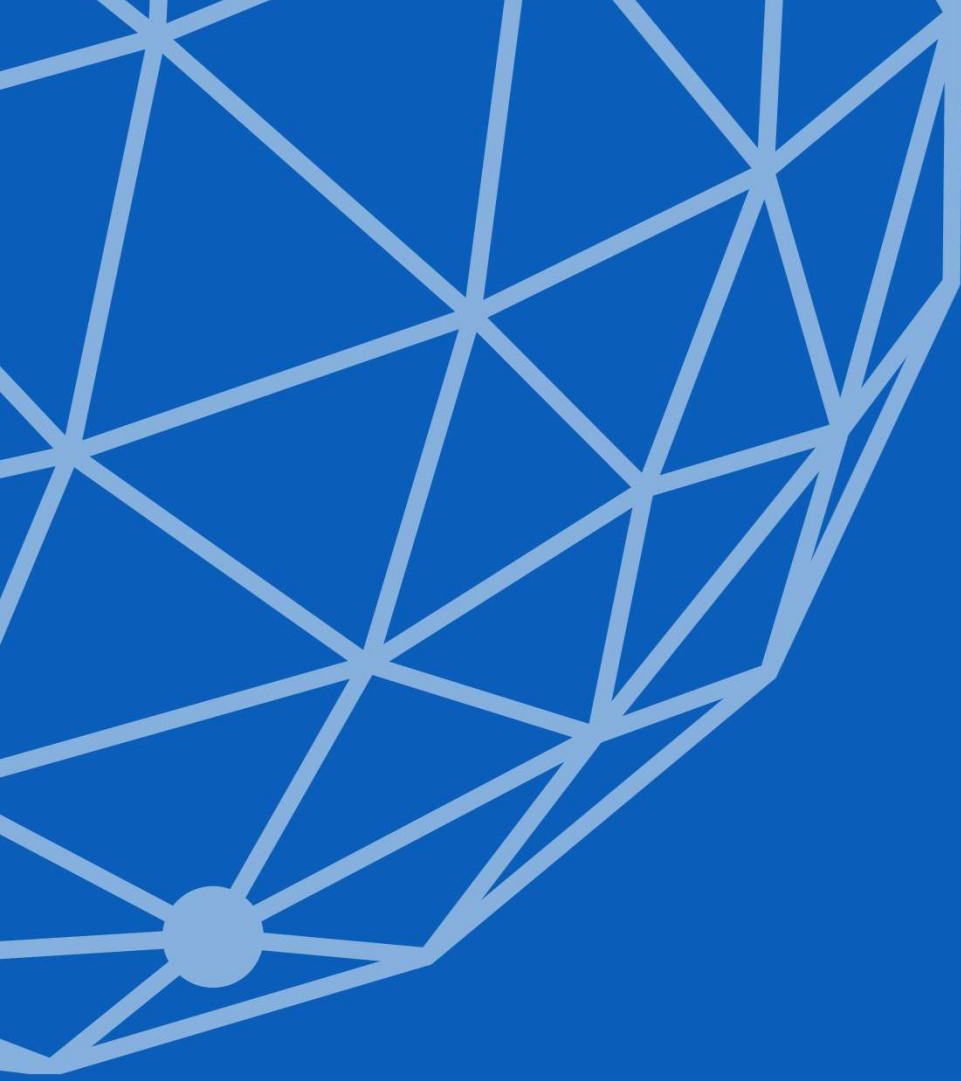
	Focus	Key Features	Purpose
Global	Greenhouse gas emissions, global temperature, and sea level rise.	- Broad climate trends. - Global models. - Planet-wide impacts (e.g., biodiversity loss, economic shifts).	Understand overarching impacts of climate change for global policy and coordination; competent of FI climate risk modelling.
Regional	Local climate conditions and vulnerabilities.	- Region-specific projections. - Localized adaptation strategies. - Community-level planning.	Support tailored responses to local climate risks and build regional resilience.
Sector-specific	Impact on specific industries (e.g., agriculture, energy, transport).	- Industry-relevant variables (e.g., crop yields, energy demand). - Targeted adaptation strategies.	Help sectors prepare for and adapt to climate-related disruptions.

Quiz Question

Which statement best explains why climate projections use multiple scenarios (RCPs/SSPs) rather than a single “most likely” future?

- A) Climate models cannot simulate temperature accurately without socioeconomic assumptions
- B) Using multiple scenarios eliminates uncertainty in climate projections
- C) Scenario-based projections are only needed for global-scale analysis, not for regional or sectoral planning
- D) Different emissions pathways and development choices lead to divergent long-term impacts, and projections capture this range of possible futures and uncertainties

Climate projections rely on multiple scenarios because future climate outcomes depend on varying greenhouse gas emissions, land-use change, and socioeconomic development pathways. Using several scenarios helps decision-makers understand uncertainty, compare risks, and design robust adaptation and mitigation strategies across sectors and scales.



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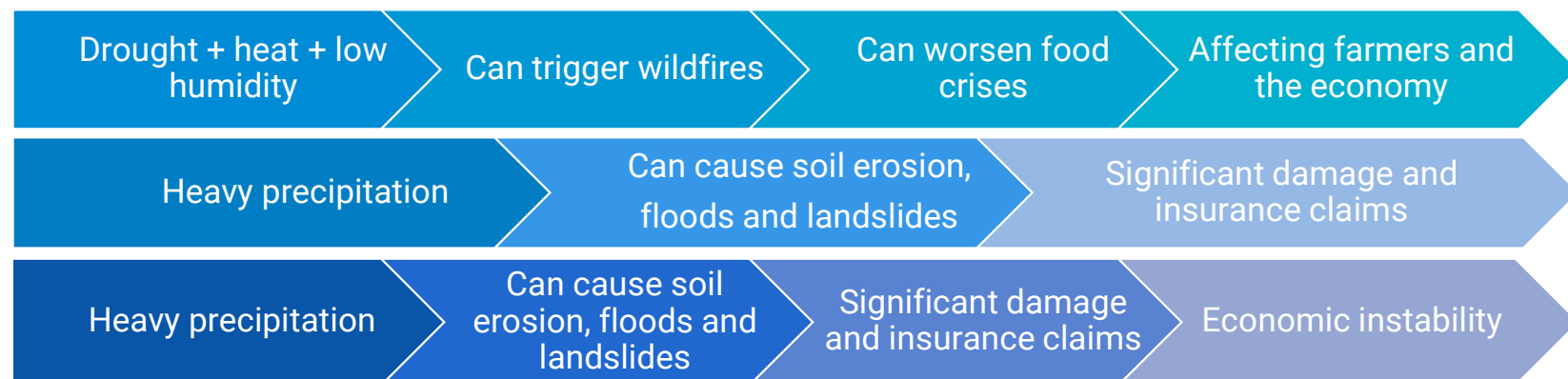
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Complexity and Uncertainty in Climate Risk Assessment

Climate change impacts not only encompass direct threats but can also lead to **compounding or cascading impacts**. Cascading impacts can be defined as...

“...the impact of a physical event or the development of an initial technological or human failure generates a sequence of events in human subsystems that result in physical, social or economic disruption” (Pescaroli & Alexander, 2017).



These complex interactions **create uncertainty about climate impacts**, as predicting the exact consequences on ecosystems, economies, and societies **involve many variables and assumptions**.

Cascading effects of climate change in Tanzania

Key climate trends

Rising average temperatures and very hot days (up to 100 days/year in eastern Tanzania by 2080).



As temperatures rise potential evapotranspiration increases, and soil moisture decreases, along with reduced contribution to rivers from glaciers, thus reduced water availability.



Increased water needs associated with agricultural expansion/intensification due to population growth, places extreme added pressure on water availability.



Results in energy disruptions, damage to agricultural production and environmental degradation will lead to significant economic losses and human casualties.



Projected average sea level rise of 11cm in 2030, 21 cm in 2050 and 41cm in 2080 (RCP6.0)



Rising sea levels threaten coastal communities and may lead to saline intrusion in coastal waterways and groundwater reserves.



Increased salinity will make water unusable for domestic use, and degradation and death of vegetation and wildlife, greatly harming biodiversity.



Extreme dependence on forestry resources makes population extremely exposed to biodiversity loss.



Complexity and Uncertainty in Climate Risk Assessment

Uncertainty is an inherent feature of climate models and projections, arising from the **complexity of the climate system and the variability of natural processes**. This must be factored into decision-making, as it can influence the financial and economic viability of investments.

Limitations include:

	<u>Description</u>	<u>Implications</u>
Resolution	Climate models typically have coarse spatial resolution , which may not capture fine-scale local variations . Downscaling methods improve resolution but introduce added uncertainty .	High resolution is crucial for project-level analysis to understand localized risks; less critical at the portfolio level, where broader trends are assessed.
Uncertainty	Climate models inherently involve uncertainty due to complex systems and natural variability . This affects the reliability of projections.	Decision-makers must account for uncertainty in scenario planning , as it impacts investment viability and risk assessments.
Data Quality	The effectiveness of projections depends on the quality and completeness of historical climate data . Gaps or inaccuracies can compromise model outputs.	Access to reliable, locally sourced data , e.g., from hydrometeorological stations and climate agencies, is essential to support robust climate analysis and inform localized adaptation or investment strategies.

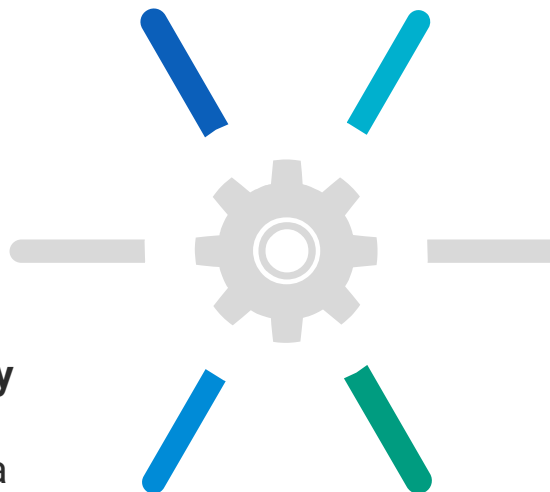
Key principles of decision making under uncertainty

1. No-regret strategies

- Measures that have **positive benefits even in the absence of climate change**, e.g., reducing development in flood prone areas will yield benefits even if CC does not make flooding worse in future

3. Safety-margin strategies

- Measures that **reduce vulnerability at no- or low-cost** by including a cushion for estimates, e.g., using a worst-case estimates of drought frequency to plan farming methods and crops to plant Vs. dealing with hunger later



2. Reversible and flexible strategies

- Measures that **can be undone** if future scenarios prove incorrect, e.g., early warning systems

4. Strategies reducing decision-making time horizons

- Prioritizing measures that have **shorter lifespans to avoid long-term investment lock-in**
- These measures can be reassessed as future states become clearer

Quiz Question

Which adaptation approach is most appropriate for managing climate risks characterized by cascading impacts and deep uncertainty, such as drought triggering wildfires, food insecurity, and economic disruption?

A) Investing only in large, irreversible infrastructure designed for a single projected climate outcome

B) Focusing exclusively on hazard reduction without addressing exposure or vulnerability

C) Waiting for precise climate impact predictions before taking action to avoid maladaptation

D) Applying no-regret measures combined with flexible and reversible strategies that can be adjusted as impacts unfold

Decision-making under uncertainty therefore favors no-regret, flexible, and reversible strategies that reduce vulnerability and allow adjustment as conditions and knowledge evolve.



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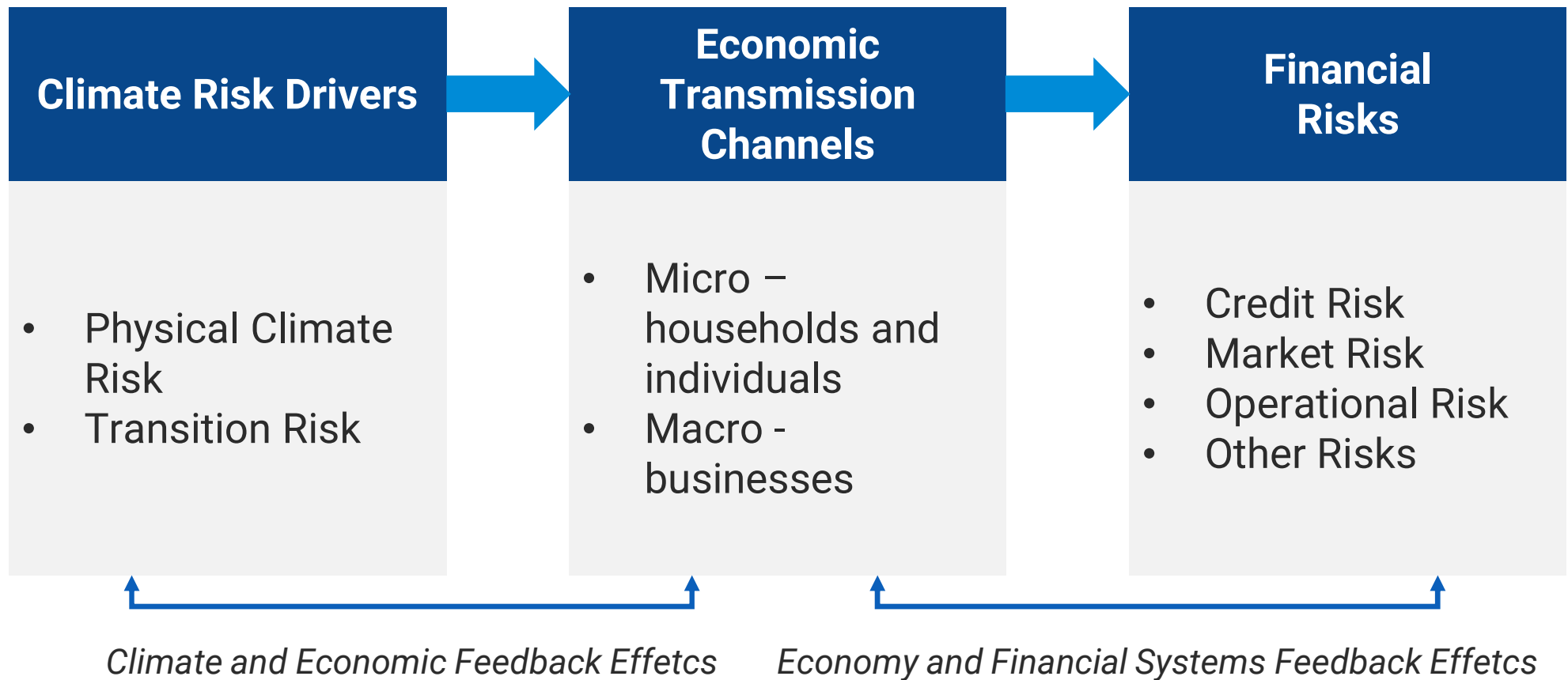
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Transmission channels from climate risks to FIs



Climate risk drivers



Physical Risk

- Risks associated with physical damages to infrastructure assets or losses and supply-chain disruptions to economies and people.

Transition Risk

- Policy, legal, technological, and market changes associated with the transition to a more sustainable and climate-resilient economy.

Economic transmission channels

Climate Risk Drivers

Economic Transmission Channels

Financial Risks

Micro-level

Business

- Property damage and business disruption from severe weather
- Stranded assets and new capital expenditure due to transition
- Changing demand and costs
- Legal liability (from failure to mitigate or adapt)

Households

- Loss of income (from weather disruption and health impacts, labor market frictions)
- Property damage (from severe weather) or restrictions (from low-carbon policies) increasing costs affecting valuations

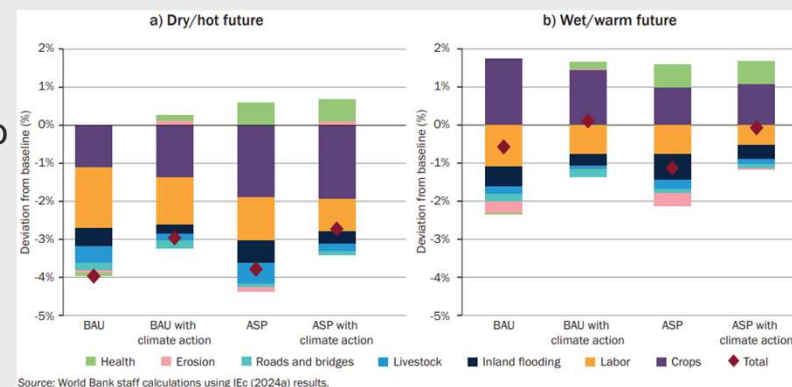


Tanzania faces growing risks from floods, droughts, and extreme weather, which could cost the country 4% of its growth by 2050

Macro-level

Business

- Capital depreciation and increased investment
- Shift in prices (from structural changes, supply shocks)
- Productivity changes (from severe heat, diversion of investment to mitigation and adaptation, higher risk aversion)
- Labour market frictions (from physical and transition risk)
- Socioeconomic changes (from changing consumption patterns, mitigation, conflict)
- Other impacts on international trade, government revenues, fiscal space, output, interest rates and exchange rates



Deviation in real GDP from baseline due to climate change impacts, by damage channel and scenario, 2050

Financial risks



Credit Risk

- Vulnerability of credit portfolio to climate risks.
- Impact on loan defaults and credit quality.

Market Risk

- Fluctuations on prices and interest rates
- Regulatory pressure to address climate risks

Operational Risk

- Poor data quality leading to flawed decision-making
- Business continuity failure due to inadequate climate risk planning
- Underwriting risk from claims due to climate change

Other Risks

- Liability risk
- Changes in business model to address climate change impacts
- Negative media coverage affecting customer trust and investor confidence

Recap

1

Climate change depends on **natural variability** and **anthropogenic actions**

2

Understanding **GHG sources** is foundational to understanding climate science

3

Risk = Hazard x Exposure x Vulnerability

4

Climate projections help to understand how risk can change in the future

5

Climate risks can also lead to **cascading effects**

6

Climate risks transmit through the economy and lead to **financial risks** for FIs

Quiz Question

Which pathway best illustrates how physical climate risk can translate into credit risk for financial institutions through economic transmission channels?

A) Extreme weather damages household assets and income, reducing repayment capacity and increasing loan defaults

B) Climate policy changes increase carbon prices, directly raising interest rate volatility

C) Regulatory disclosure requirements increase reporting costs for banks

D) Technological innovation lowers emissions, reducing long-term transition risk

Physical climate risks (such as floods or droughts) can disrupt livelihoods and damage property at the household and business level. These micro-level impacts transmit through the economy by weakening income and asset values, ultimately increasing credit risk via higher loan defaults and deteriorating credit quality for financial institutions.



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