Modeling of Biophysical-Macroeconomic Systems for Policy

Insights and Challenges from World Bank Country Climate and Development Reports (CCDRs)




Brent Boehlert

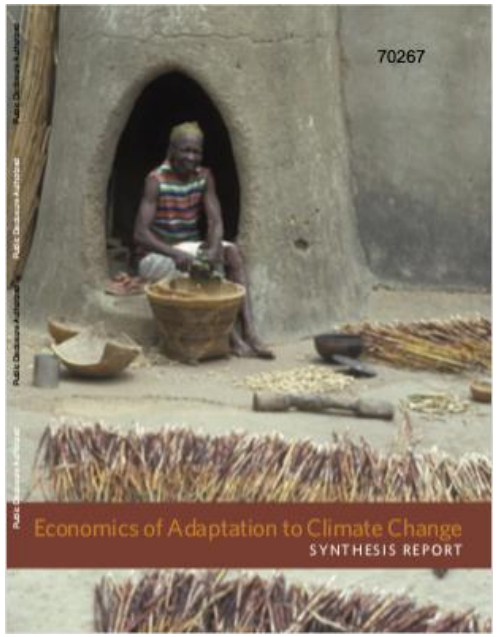
INDUSTRIAL ECONOMICS, INC.

March 27, 2025

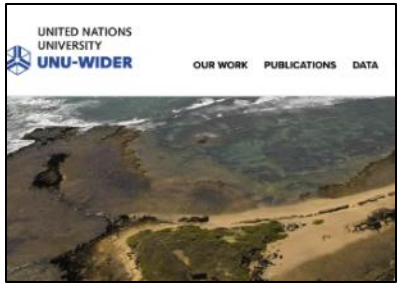
MIT Global Change Forum: Panel on *Sustainability Science: Integrated Modeling of Nature-Society Systems*

Recent history of linked biophysical-macro applications

EACC (2010) → **SACReD (2012)** → **Applications (2012-2024)** → **CCDRs (2021-Present)**



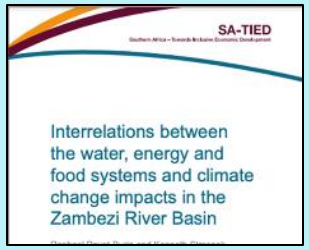
Economics of Adaptation to Climate Change



Systematic Analysis for Climate Resilient Development Framework

Vietnam

Zambezi

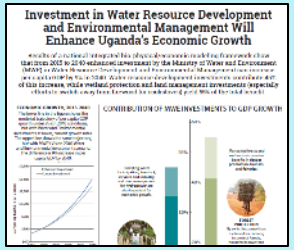


Egypt

Zimbabwe

Indonesia

Uganda



World Bank Group
COUNTRY CLIMATE AND DEVELOPMENT REPORTS

IEc

Collaborators

United Nations University
WIDER
World Institute for Development Economics Research

IEc
INDUSTRIAL ECONOMICS, INCORPORATED

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE
IFPRI

MIT JOINT PROGRAM
SCIENCE POLICY

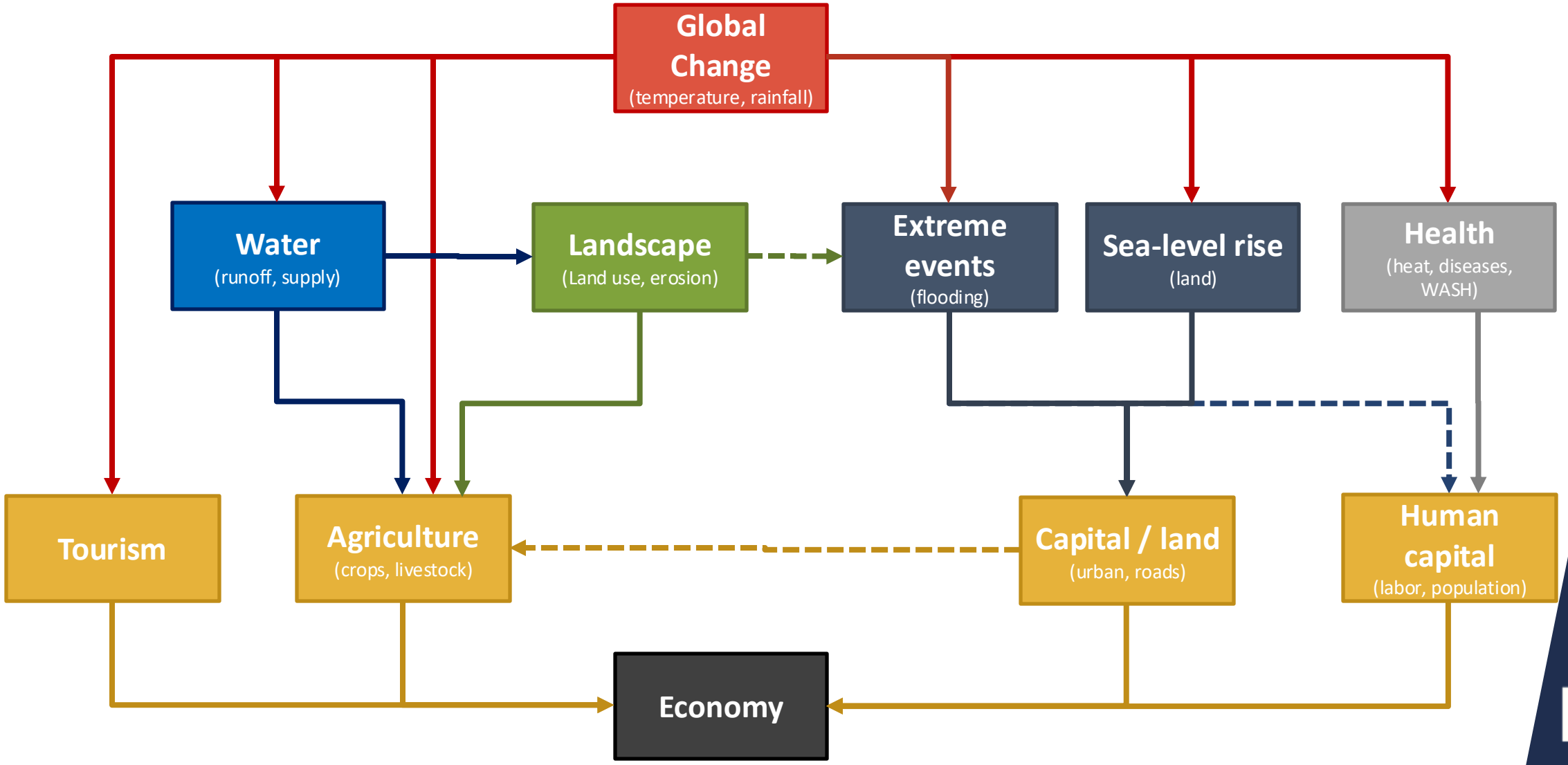
Center for Sustainability Science and Strategy
of GLOBAL CHANGE

J-WAFS
Abdul Latif Jameel Water & Food Systems Lab

OXFORD MARTIN SCHOOL
UNIVERSITY OF OXFORD

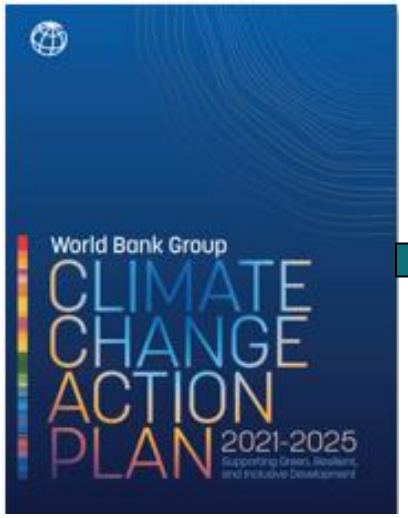
IEc

SACReD channels framework: Linkages between climate, biophysical, and macro models



IEc

What are the World Bank's CCDRs and what is our role?



COUNTRY PARTNERSHIP FRAMEWORK

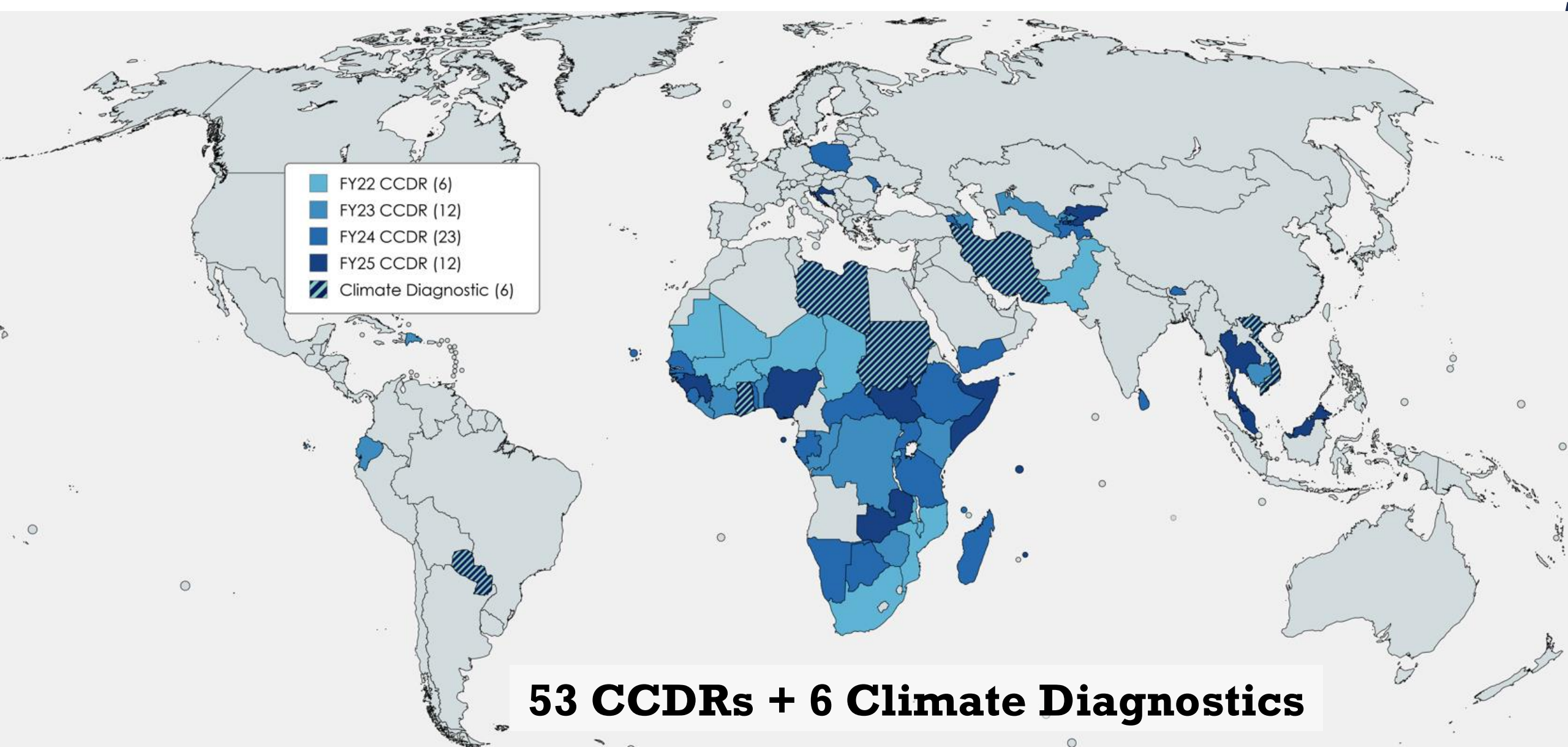
THE WORLD BANK

CONTENT OF THE CCDRs

CCDRs are informed by a broad set of questions, around **climate and development**, **adaptation and resilience**, the **low carbon transition**, and **financing the transition**. They are structured to cover* **four overarching areas of analysis** and conclude with **climate-related policy and investment recommendations** and assess their costs and benefits.

1. DEVELOPMENT GOALS & CLIMATE
2. CLIMATE COMMITMENTS
3. MACRO POLICIES FOR CLIMATE
4. SECTOR ANALYSES

Country coverage, 2021-2025

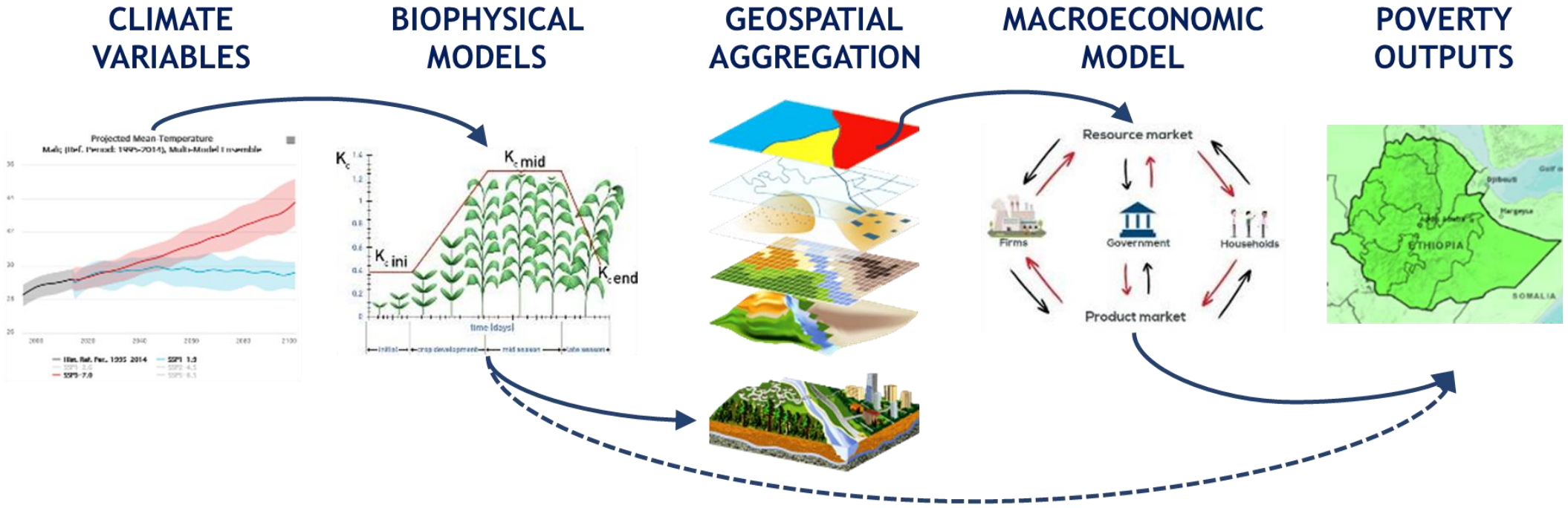


53 CCDRs + 6 Climate Diagnostics

Typical Impact Channels in the CCDRs

Impact channel	FY22						FY23													FY24				
	SSA					SA	SSA								LAC		EAP	ECA		SSA				
	MWI	MOZ	ZAF	RWA	G5	PAK	BEN	COG	CIV	COD	GNB	LBR	KEN	ZWE	DOM	ECU	KHM	UZB	AZE	ETH	CAF	SEN	SLE	TGO
Human Health and Development																								
Labor heat stress	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓
Human health	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓		✓	✓	✓	✓	✓
WASH	✓					✓	✓		✓					✓	✓		✓			✓	✓	✓	✓	✓
Clean cooking					✓		✓		✓	✓	✓	✓	✓	✓						✓	✓		✓	✓
Tourism				✓			✓		✓						✓		✓							✓
Water, Ag, Energy, and Land Use																								
Rainfed crops	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓	✓
Irrigated crops	✓												✓	✓	✓	✓		✓		✓				
Livestock	✓	✓	✓		✓	✓	✓	✓	✓				✓	✓		✓		✓	✓	✓				✓
Erosion	✓			✓			✓	✓	✓		✓	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓
Carbon storage													✓							✓				
Hydropower	✓	✓										✓	✓	✓		✓				✓				
Water supply	✓												✓		✓					✓				
Infrastructure and Extreme Events																								
Inland flooding	✓	✓	✓	✓	✓		✓		✓		✓		✓		✓	✓		✓	✓	✓				✓
Urban flooding	✓	✓			✓			✓		✓		✓								✓	✓	✓	✓	
Roads and bridges	✓	✓			✓	✓		✓		✓	✓	✓	✓	✓		✓		✓	✓	✓	✓	✓	✓	
Sea-level rise							✓	✓	✓		✓	✓			✓	✓						✓	✓	✓
Tropical storms															✓									

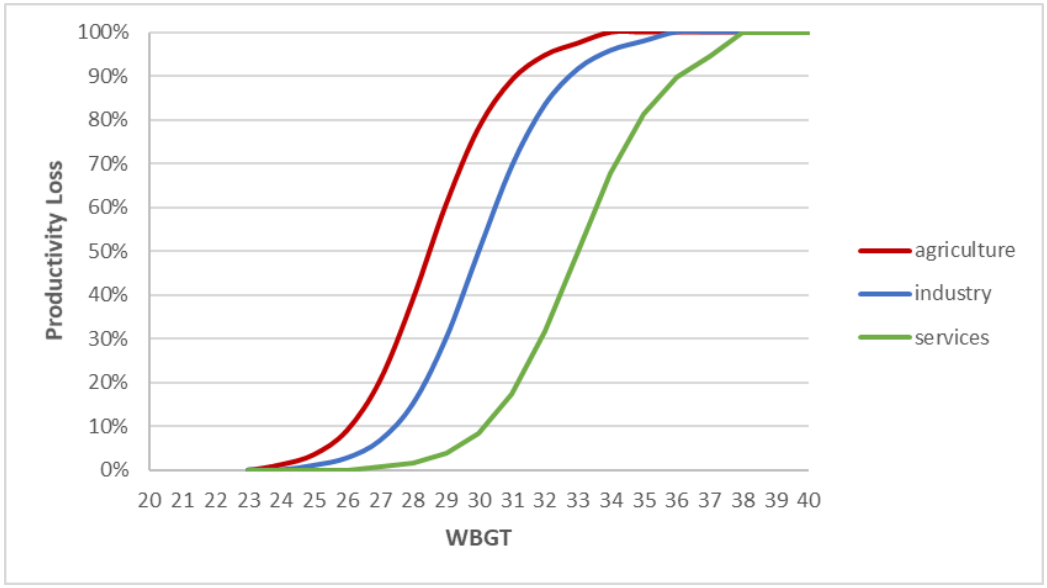
Impact channel workflow

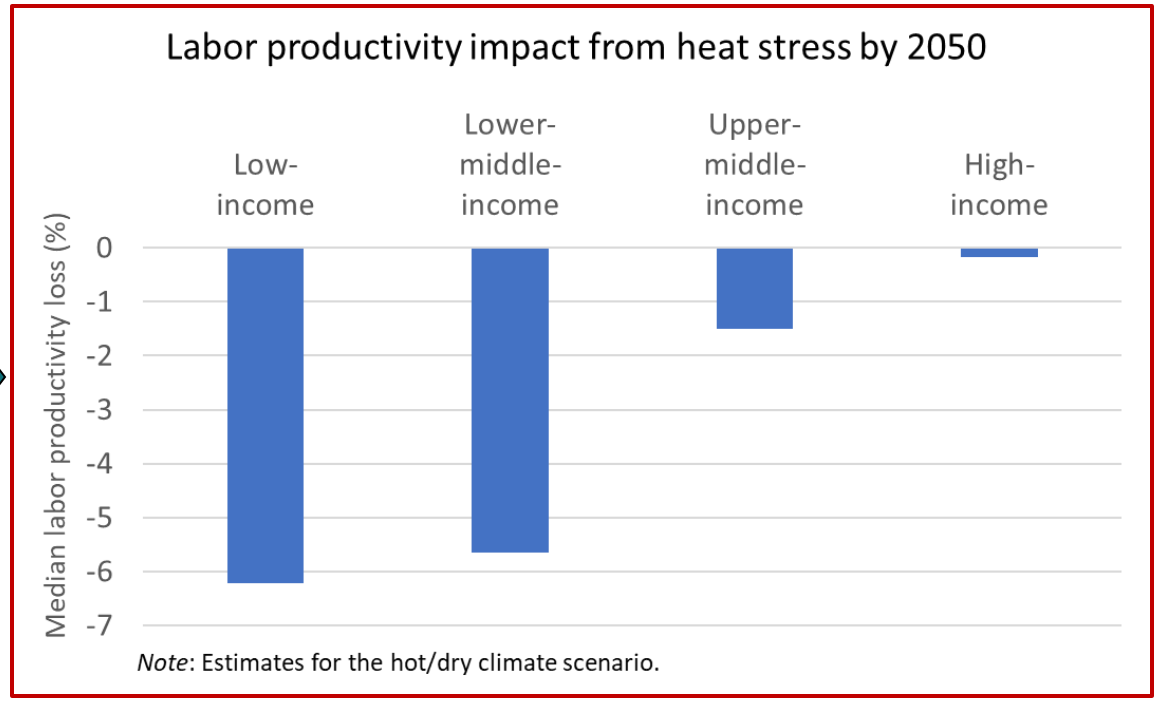


Insight #1: Macroeconomic impacts often did not align with sector-based expectations

Particularly climate change effects on labor productivity (high) and flooding (low)

Heat Effect on Labor Productivity





Insight #1: Macroeconomic impacts often did not align with sector-based expectations

Particularly climate change effects on labor productivity (high) and flooding (low)

For Channels driven by Water Availability:

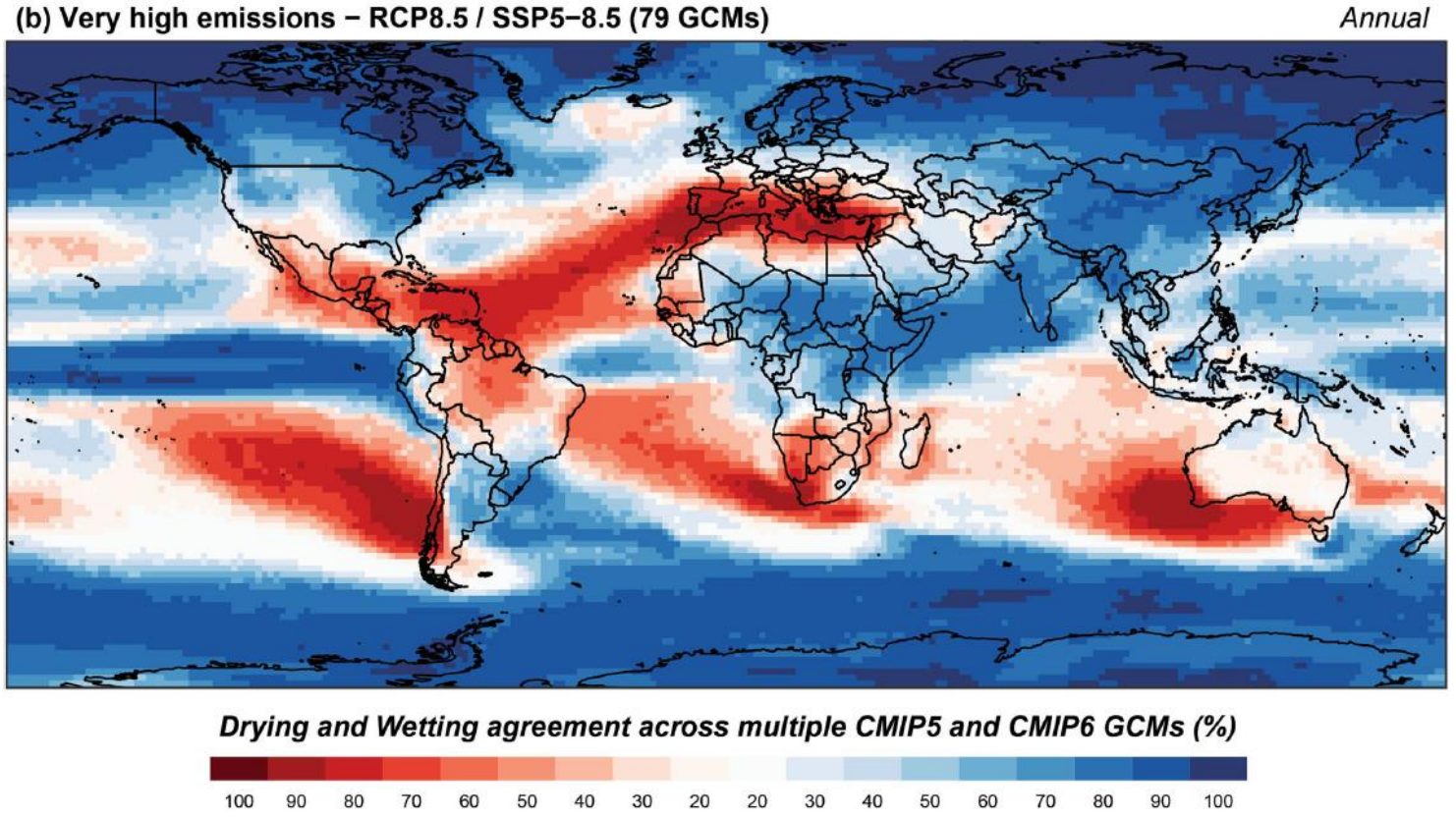
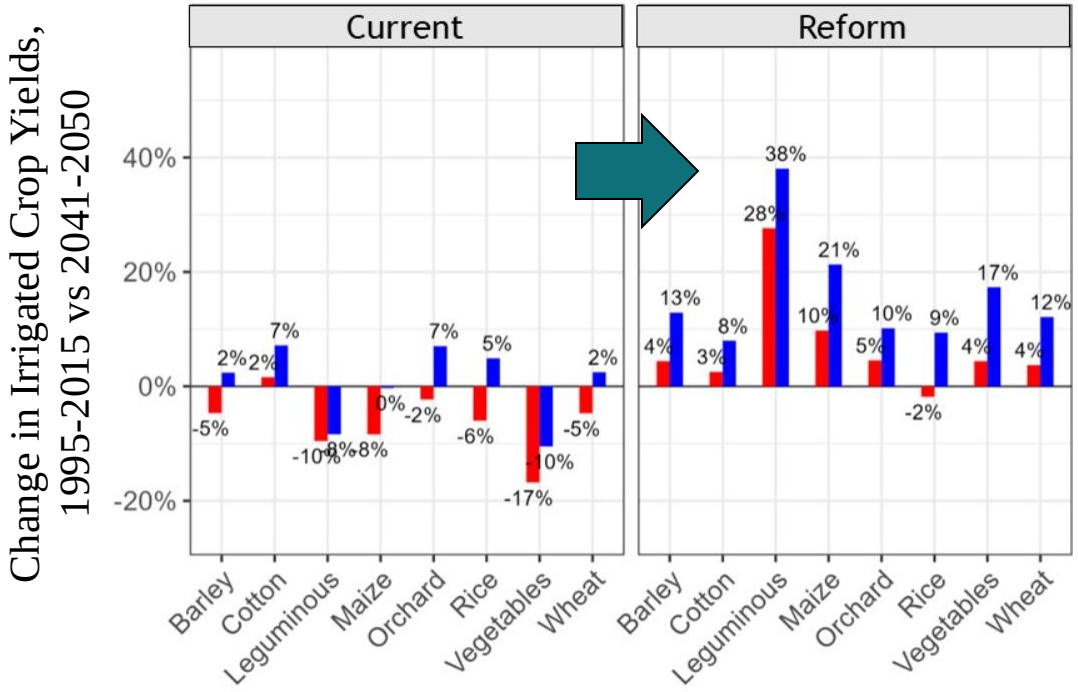


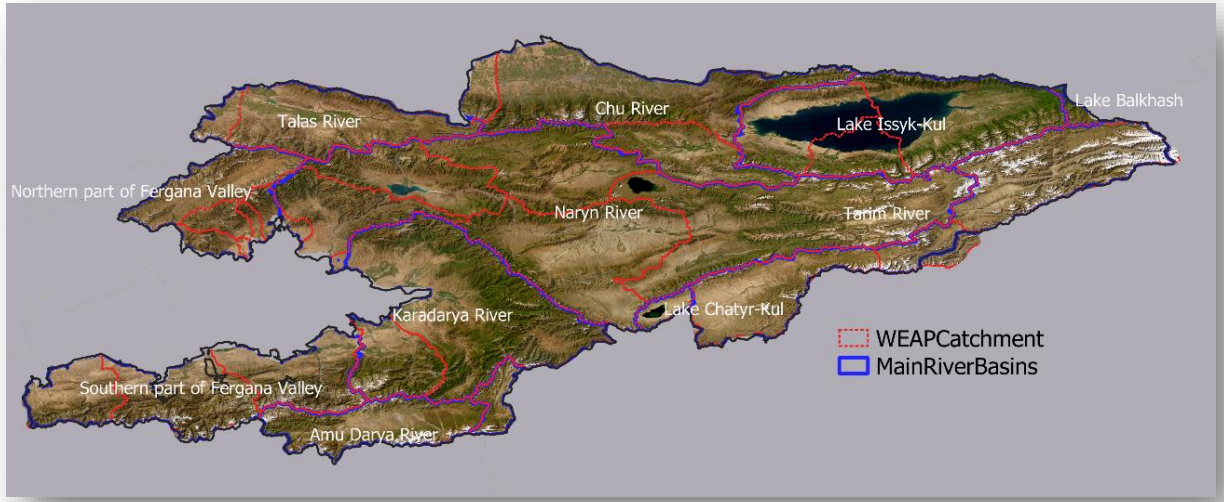
Fig. 3 | Multi-model (CMIP5 and CMIP6) drying and wetting agreement of robust trends in annual precipitation. a Intermediate (67 GCM runs) and **b** high emissions (79 GCM runs). Shades of red denote drying agreement and shades of blue indicate wetting agreement.

Source: Trancoso et al. 2024, Significantly wetter or drier future conditions for one to two thirds of the world's population. *Nature Communications*

Insight #2: Generally, development is an effective adaptation strategy

Illustration: Water storage and irrigation efficiency investments in Kyrgyzstan



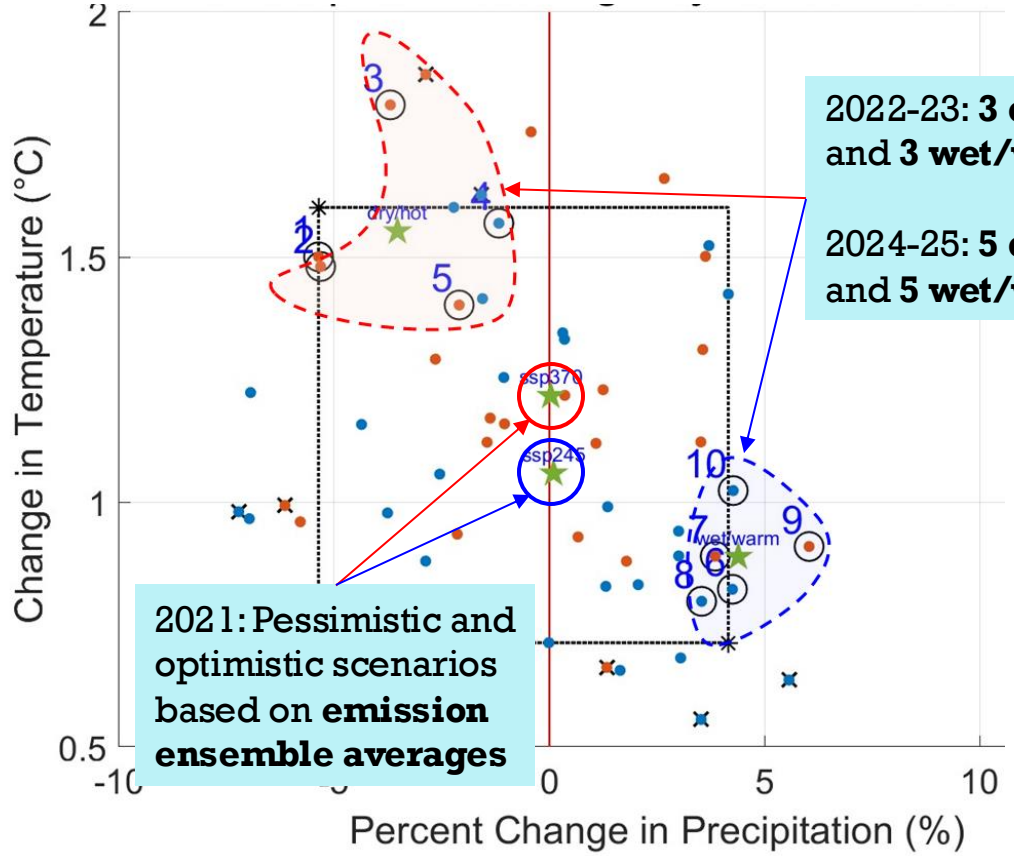


- **Most effective adaptations** are often development-oriented, e.g., increasing maintenance or farmer training

Challenge #1: Scenario design

How do we design climate and development policy scenarios to balance simplicity and rigor?

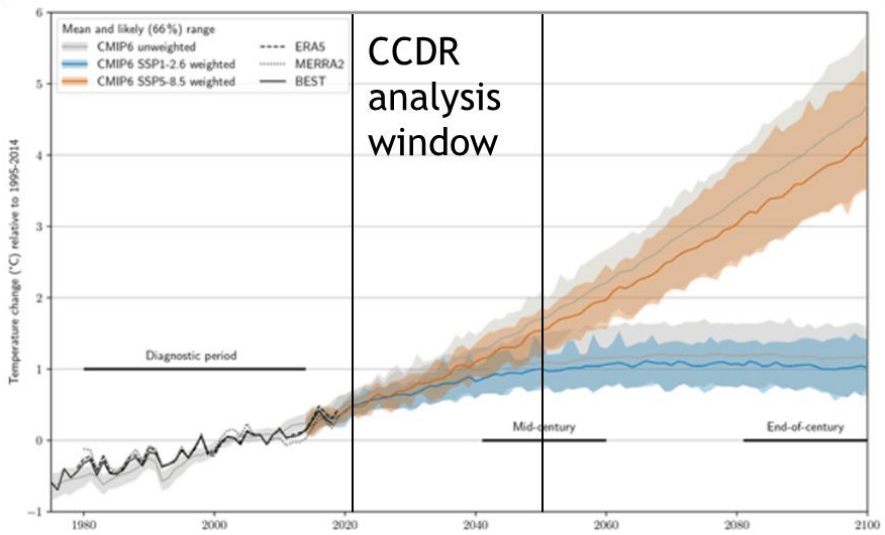
Projected Changes in T and P through 2031-2050, Zambia



2022-23: **3 dry/hot** and **3 wet/warm**

2024-25: **5 dry/hot** and **5 wet/warm**

2021: Pessimistic and optimistic scenarios based on **emission ensemble averages**



Next phase → analyses based on **1000s of HFDs**?

Challenge #2: Data and modeling gaps

How can we be confident (and inspire confidence) in our policy recommendations?

Global vs local

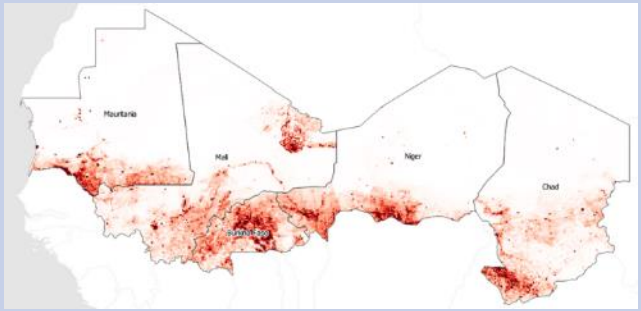
- **Global datasets** are structurally consistent but vary in quality across space/time.
- **Local data** pose challenges, in some cases must be integrated for buy-in

Data and modeling gaps

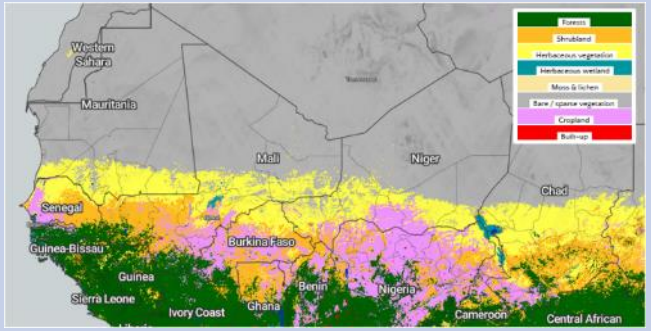
- **Datasets:** e.g.: bridge inventory, homogeneous river runoff, fertilizer application, etc.
- **Models**: e.g., grid infrastructure/ outages, secondary flood impacts, etc.

Illustration of some available sources of global data for the G5 Sahel region

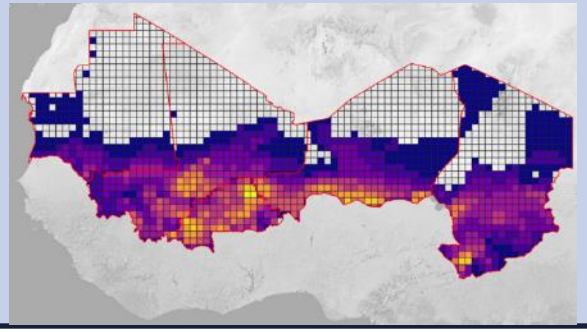
GDP



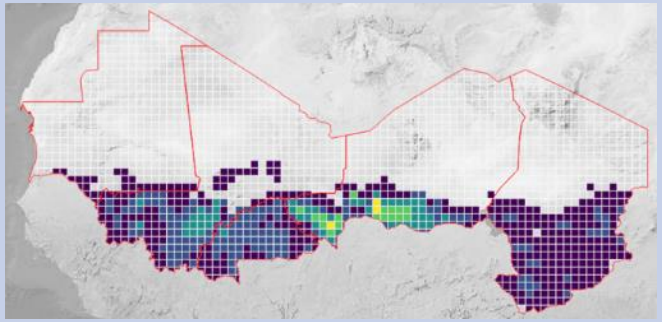
Land Cover



Cattle Density



Millet Production



IEc

Acknowledgments

- **MIT/IEc:** Ken Strzepek
- **IEc:** Diego Castillo, Kim Smet, Chas Fant, Jani Strzepek, Gabriel Bendat, Hugh Easton, Xavier Maier, Sydney Austin, Silvia Colombo
- **World Bank:** Stephane Hallegatte, Craig Meisner, Florent McIsaac, Charl Joost, Lulit Beyene, Andrew Burns, Kanta Kumari Rigaud, Yue Man Lee, Urvashi Narain, Julie Rosenberg, Diji Chandrasekharan Behr, Kodzovi Senu Abalo, Tijen Arin, Dominick Revell de Waal, Ana Bucher, Stephen Ling
- **Stanford/UMN NatCap**: Adrian Vogl, Justin Johnson, Jorge Leon

Brent Boehlert:
bboehlert@indecon.com