International Institute for Applied Systems Analysis
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Integrated Solutions for Water, Energy and Land

Technical Meeting, 16 April 2019, UNIDO headquarters

Simon Langan
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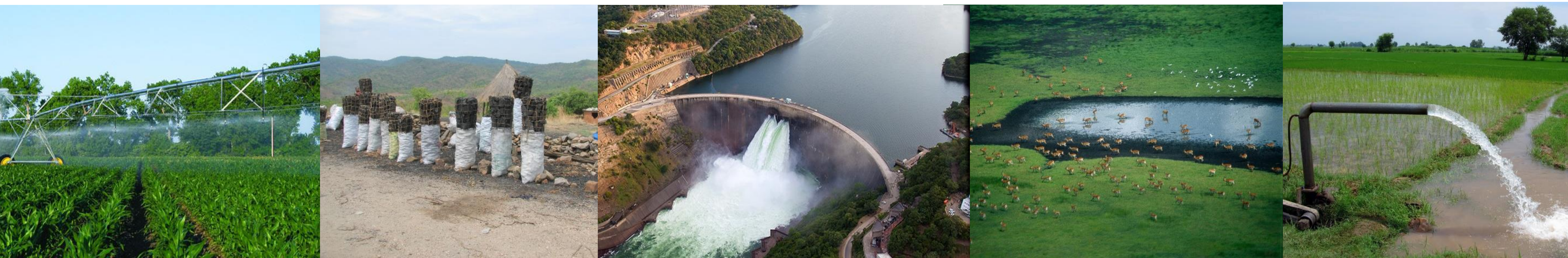
Michiel van Dijk



“Integrated Solutions for Water, Energy, and Land” (ISWEL) Project

2017-2019

Develop tools and capacities that can support the management of the water-energy-land nexus at global and regional scales

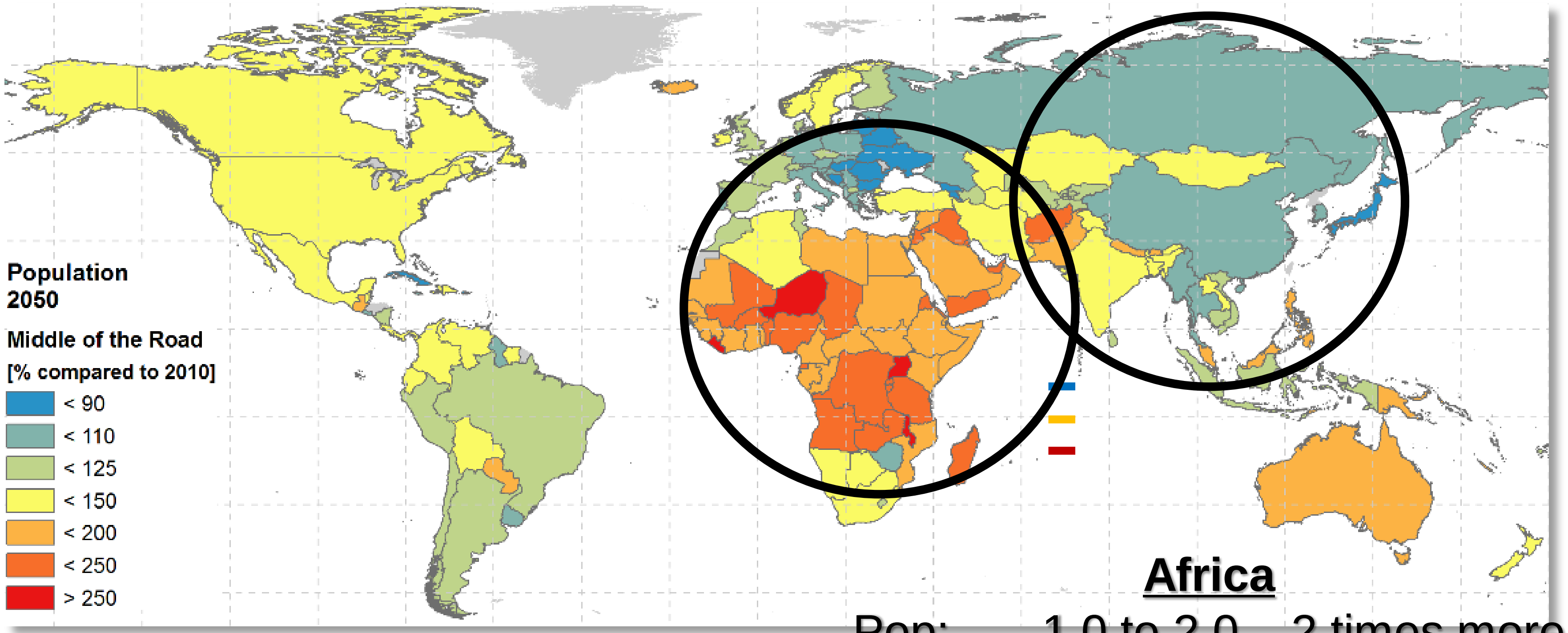
Partners: IIASA, GLOBAL ENVIRONMENT FACILITY INVESTING IN OUR PLANET, UNIDO

GEF Contract Agreement: 6993

Context

- Up to 2 billion more people by 2050
- Need to produce 70 percent more food
- For access to energy to be universal energy generation needs to double
- With increasing energy and food needs water demands are expected to rise by 55 percent
- Up to 40 percent of the world's population will live in severe water stressed regions
- The development of this very uneven in different geographies and different development trajectories
- This all set in context of increasing variability from CC

Population and Development continues



Africa

Pop: 1.0 to 2.0 2 times more
GDP: 2.8 to 19.2 7 times more
GDP pc: 2.7 to 9.5 3.5 times more

Asia

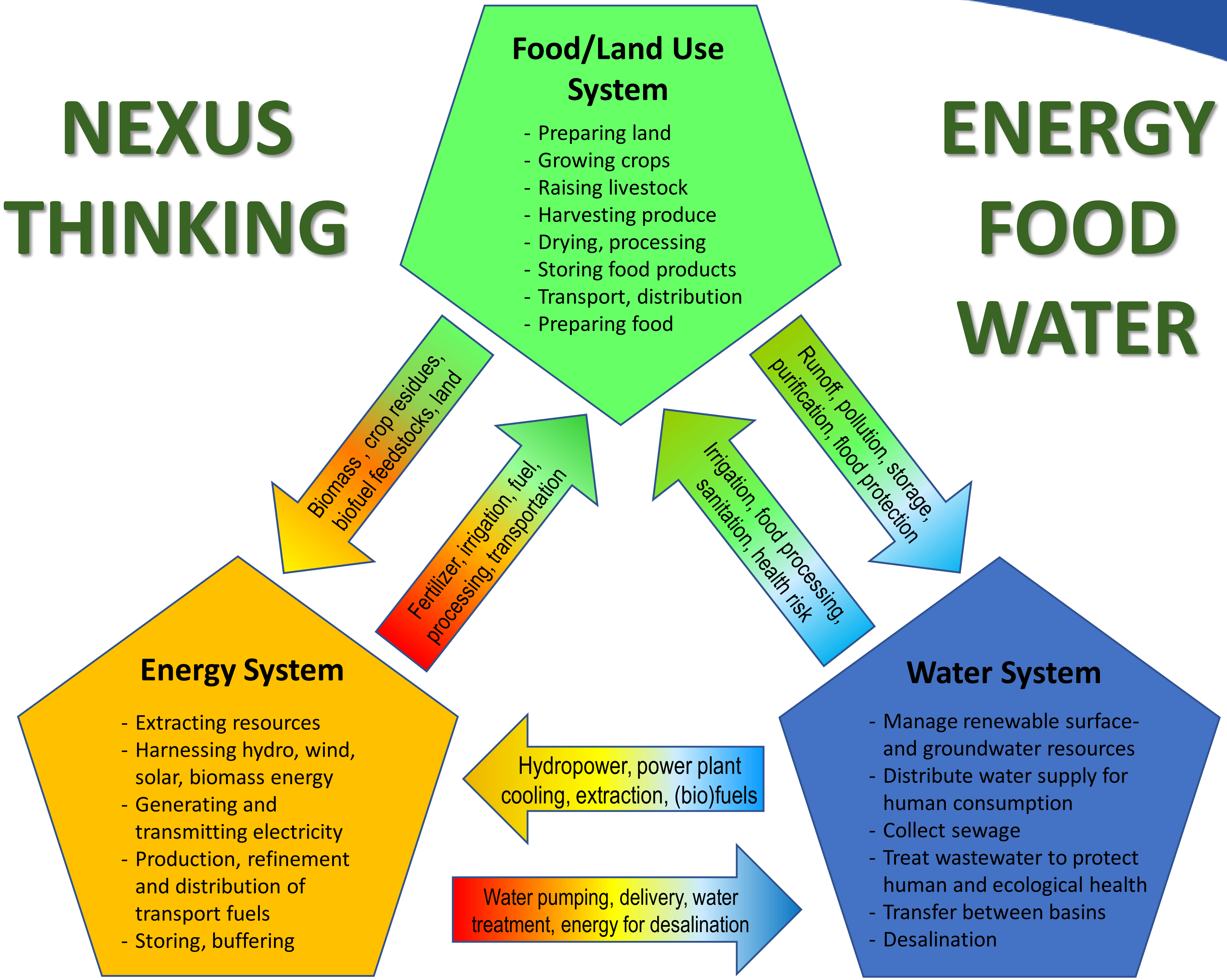
Pop: 4.1 to 5.1 1.3 times more
GDP: 26 to 123 5 times more
GDP pc: 6.2 to 24.1 4 times more

Middle of the Road scenario

Population in [billion]
GDP [1000 billion US$/yr]
GDP per cap (PPP) in [1000US$/cap/yr

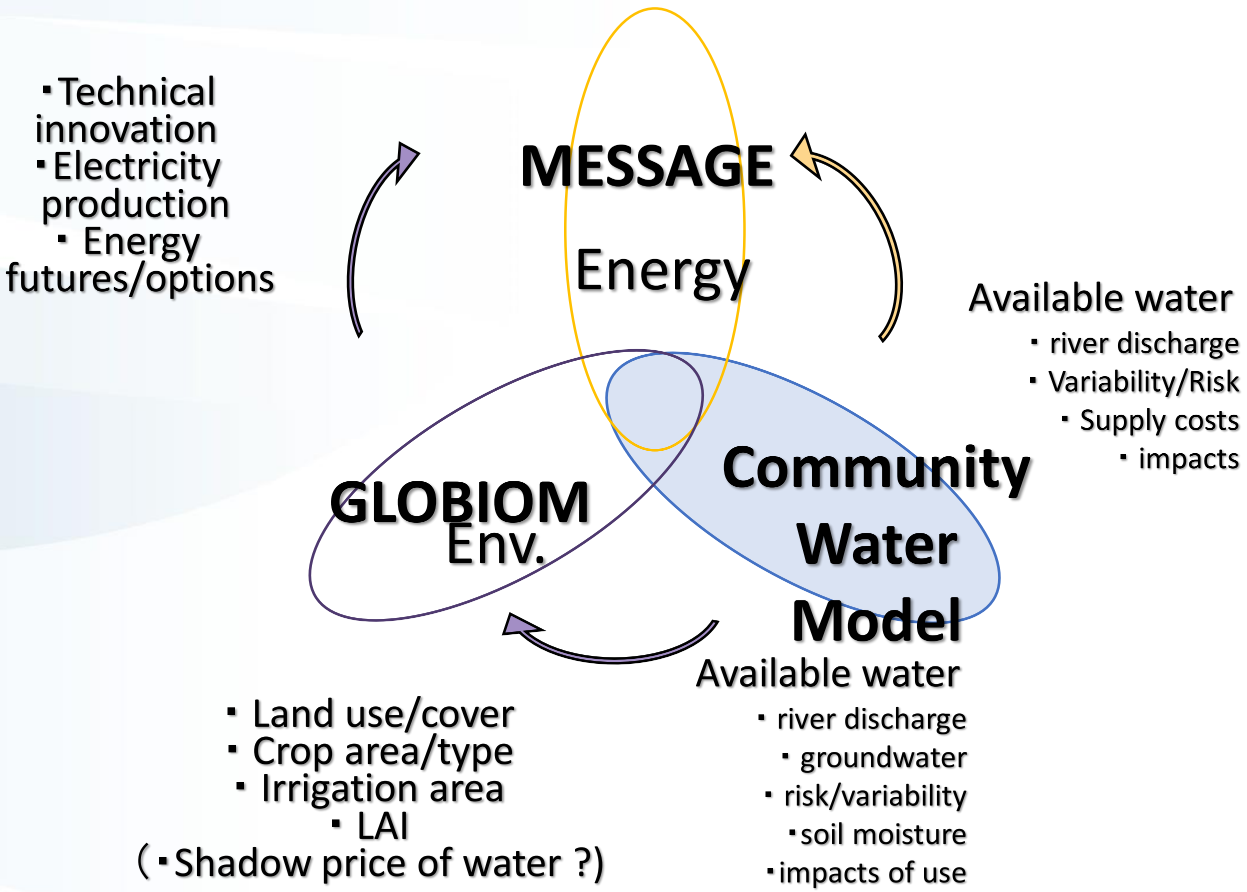
NEXUS THINKING

ENERGY FOOD WATER

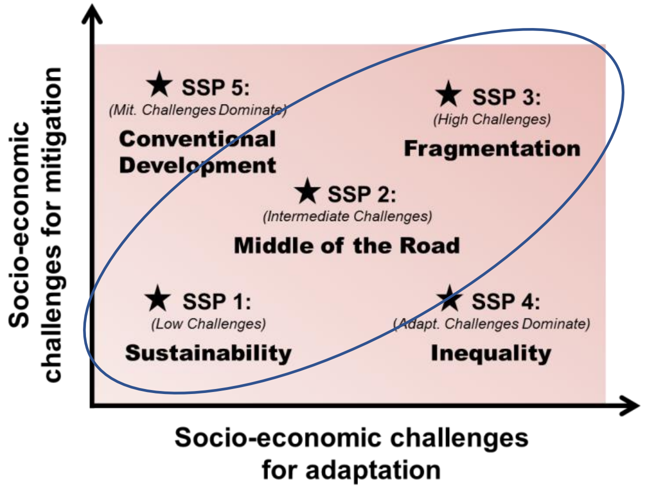


Nexus model Integration towards SDGs

Improved analysis feedbacks



Multiple scenarios: Developing narratives of the future



SSP1: The world is moving toward sustainability

SSP characteristics

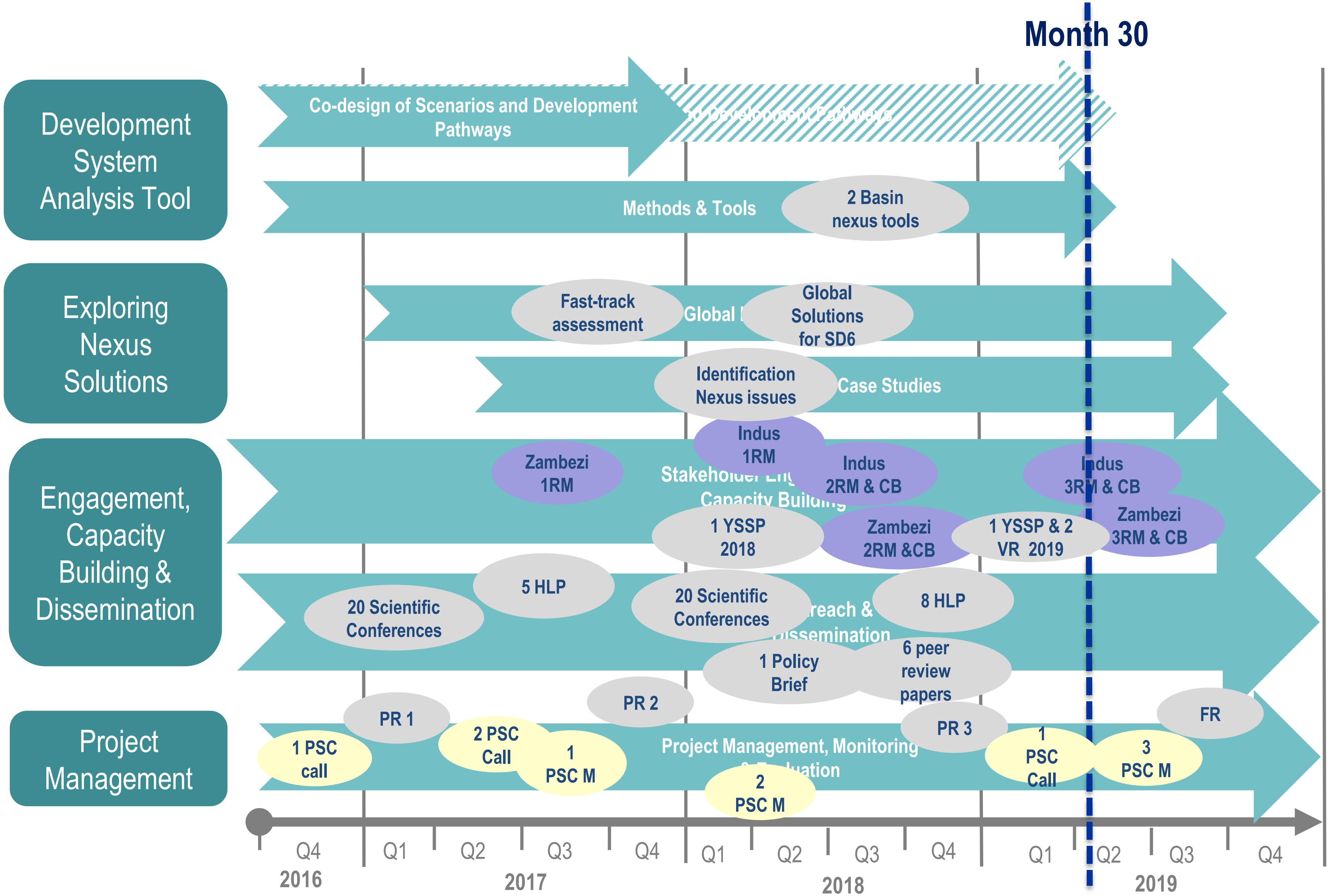
- Improved resource use efficiency
- More stringent environmental regulations
- Rapid technological change is directed toward environmentally friendly processes
- Management of global commons improves.

Implications for Manufacturing Water Use:

- Manufacturing industries with efficient water use and low environmental impacts are favored.
- Enhanced treatment, reuse of water, and water-saving technologies;
- Widespread application of water-saving technologies in industry

ISWEL Timeline

Abbreviations:
RM: Stakeholder regional meeting
CB: Capacity Building
PSC M: PSC meeting



Outcomes, outputs and synergies

Basins

- IBKF
- Zamcom WEF strategy
- (SA, SADC, AMCOW)

Globally

- IPCC
- Int. Waters GEF
- World Bank

Knowledge base and capacity building

Research meetings/conferences	20
Research papers	6
Training events	4

Insights and messages for implementation

At global level

- Spatial concentration and driven by socio economic drivers
- Reducing exposure / vulnerability = inequality / poverty

At basin level

- Trade-offs between sectors and risks under diff. SSP
- Frameworks needed to build pathways and capacity
- Stakeholder scenario development tool provides method to identify specific issues and ownership
- Significant interest other basins for tools and methods

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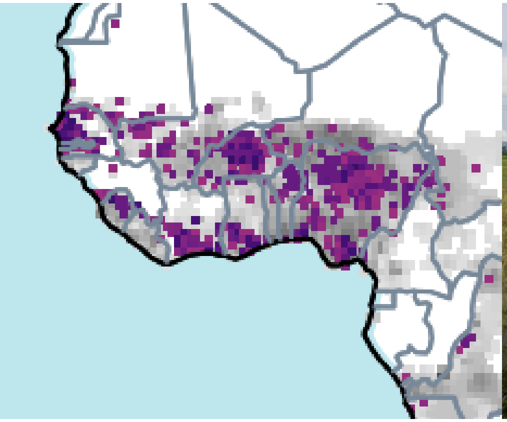
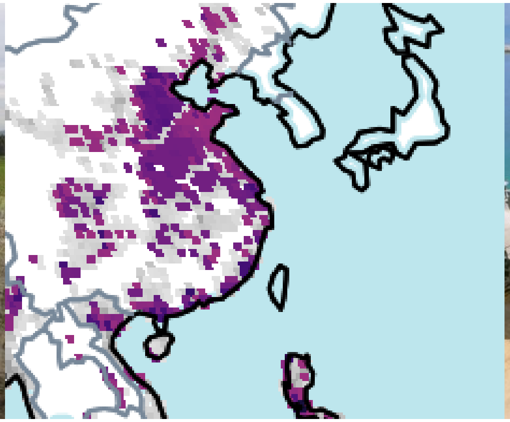
Global hotspots assessment and explorer tool




UNIDO
16/04/2019

gef
GLOBAL ENVIRONMENT FACILITY
INVESTING IN OUR PLANET

UNIDO

A flexible global vulnerability hotspots framework

Understanding the underlying challenges

i. multiple development-climate pressures across multiple sectors
ii. Impacting vulnerable people, and/or large populations
iii. i + ii = *vulnerability hotspots*

…from multiple perspectives

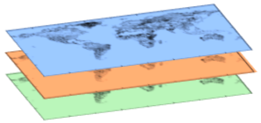
Global
IPCC regions
River basins
Countries

- **Answering diverse questions**
- Sectoral assessment and comparison
- Subset indicators and sectors
- Low income, high vulnerability and the low-latitude nexus
- Climate extremes and hydroclimate complexity
- Rural and urban, drivers of migration
- MEAs (SDGs, Sendai, Paris, etc.)

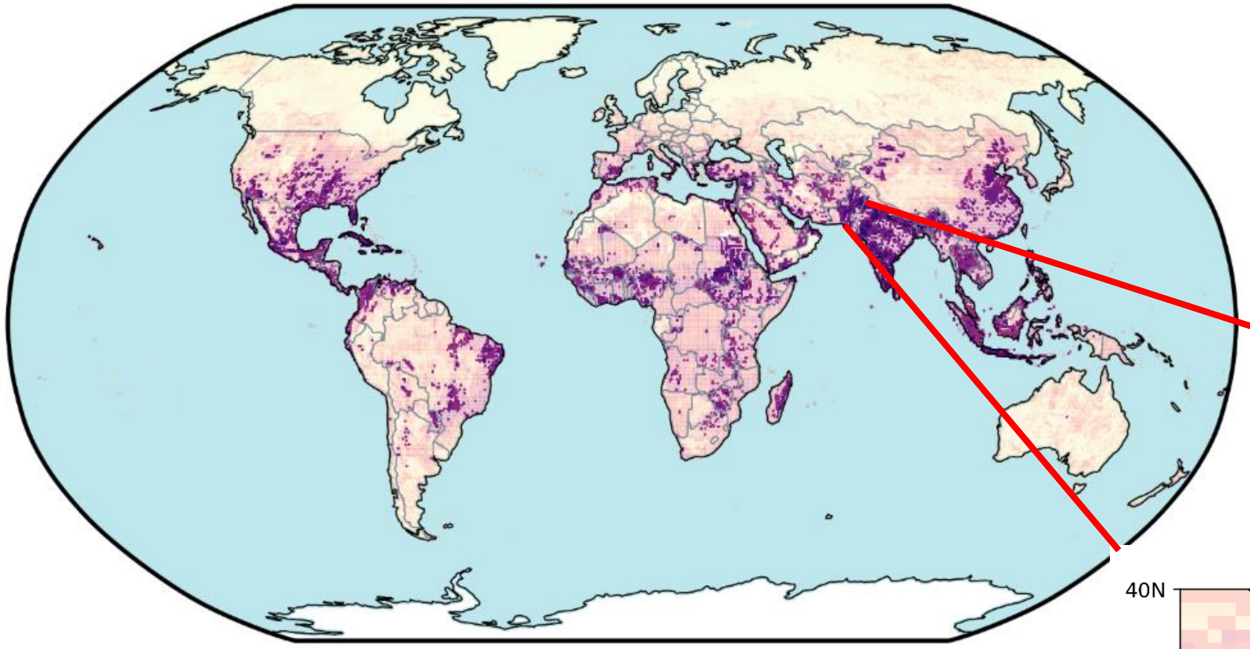
Dissemination, building capacity and increasing impact

- Development funders and knowledge institutions
- Practitioners and stakeholders
- From scientist… to student

ISWEL: Global analysis of vulnerability hotspots



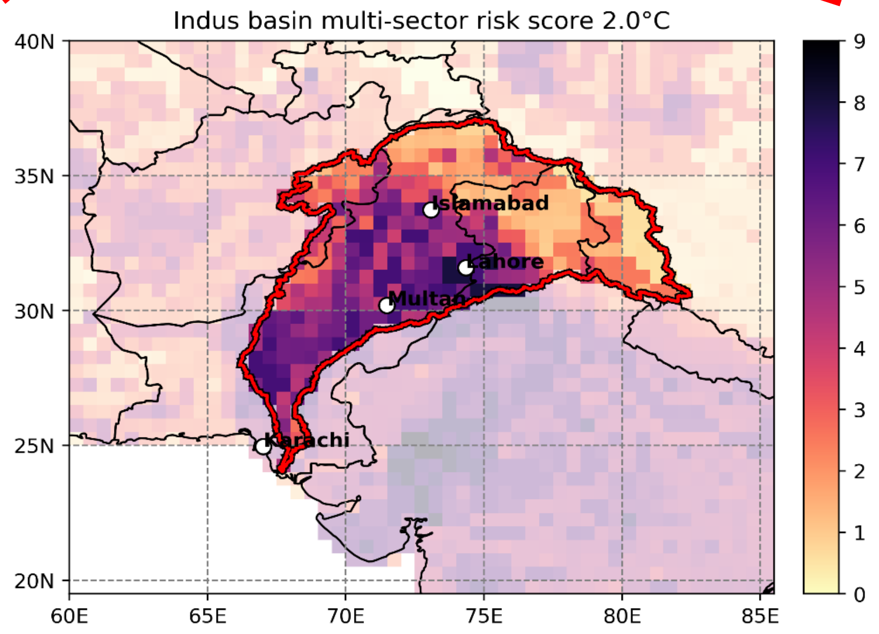
3.0°C



Byers et al. (2018, ERL)
IPCC (2018, Ch3.)

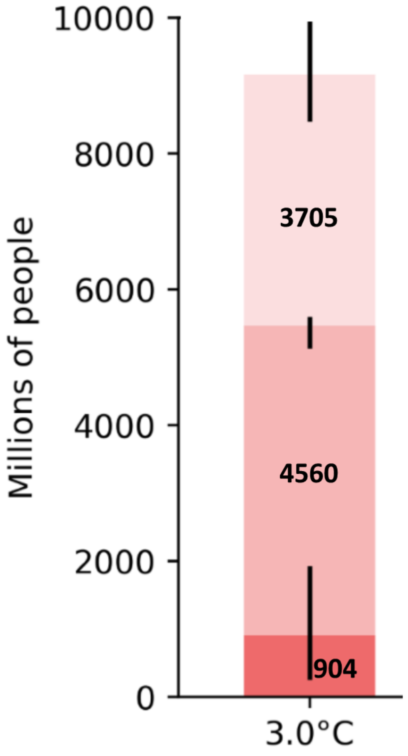
Need 1.5°C to minimize risks to all

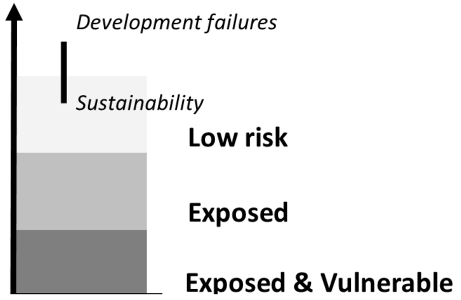
Need targeted poverty reduction to reduce vulnerability



Water	***Energy***	***Land***	***Socioeconomics***
Water stress index	Clean cooking access	Crop yield change	Population density
Non-renewable GW abstraction	Heat event exposure	Environmental flow exploitation	Income levels
Drought intensity	Cooling demand growth	Habitat degradation	
Peak flows risk	Hydroclimate risk to power	Nitrogen leaching	
Seasonality			
Inter-annual variability			

Avoided impacts of 1.5°C*





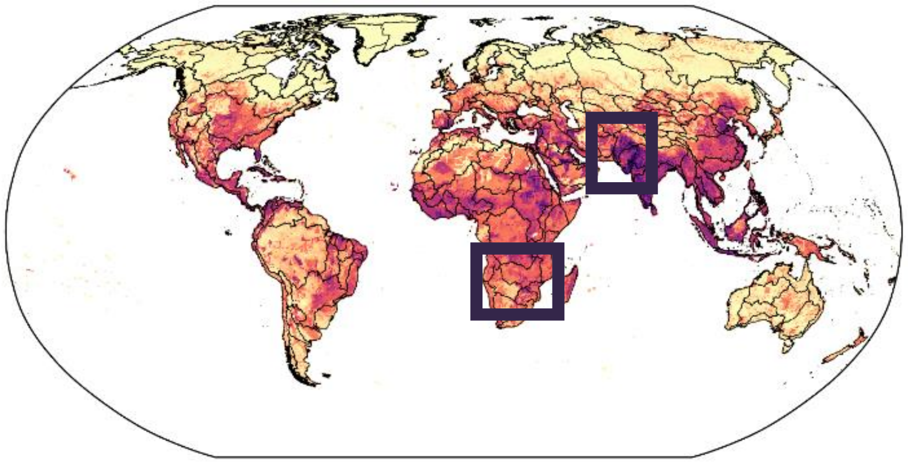
But climate and development scenario uncertainties are considerable… and vary from place to place

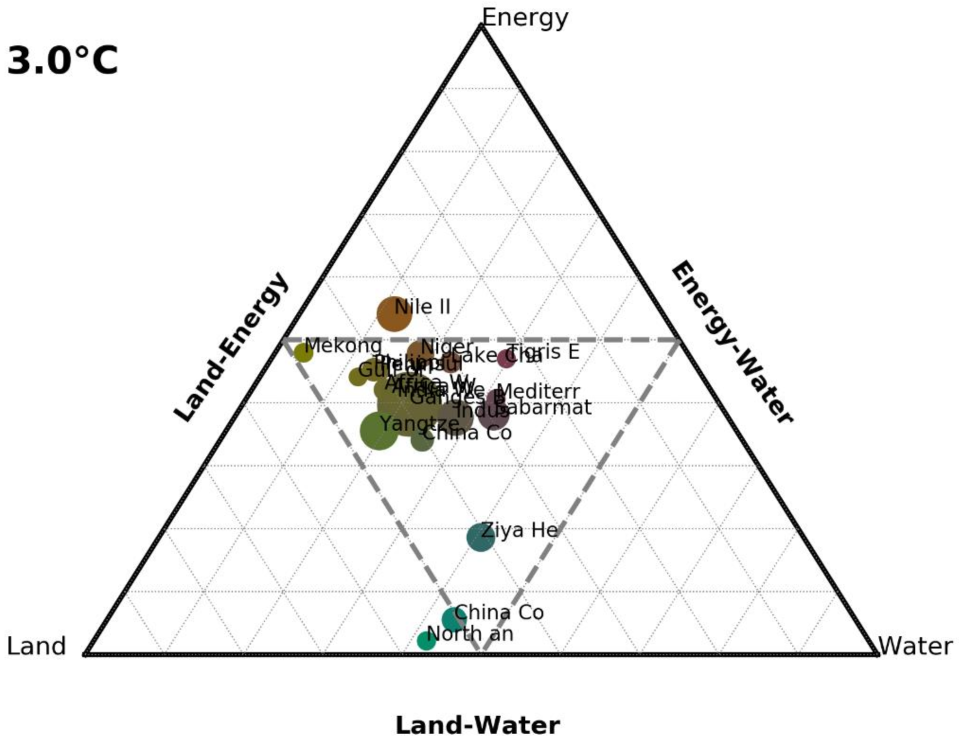
** In the 2050s*

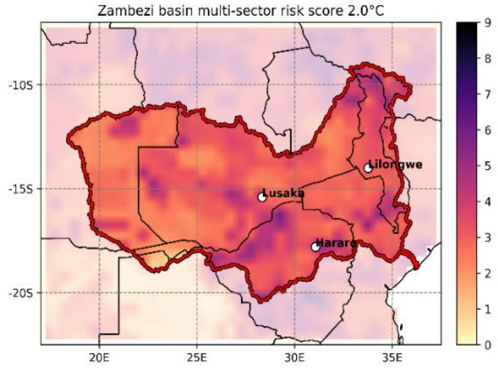
Byers et al. (2018, Environmental Research Letters)

Hotspots basin analysis

Large distributional differences across the world

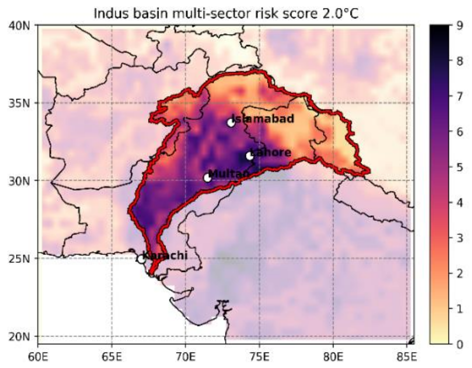






Zambezi river basin

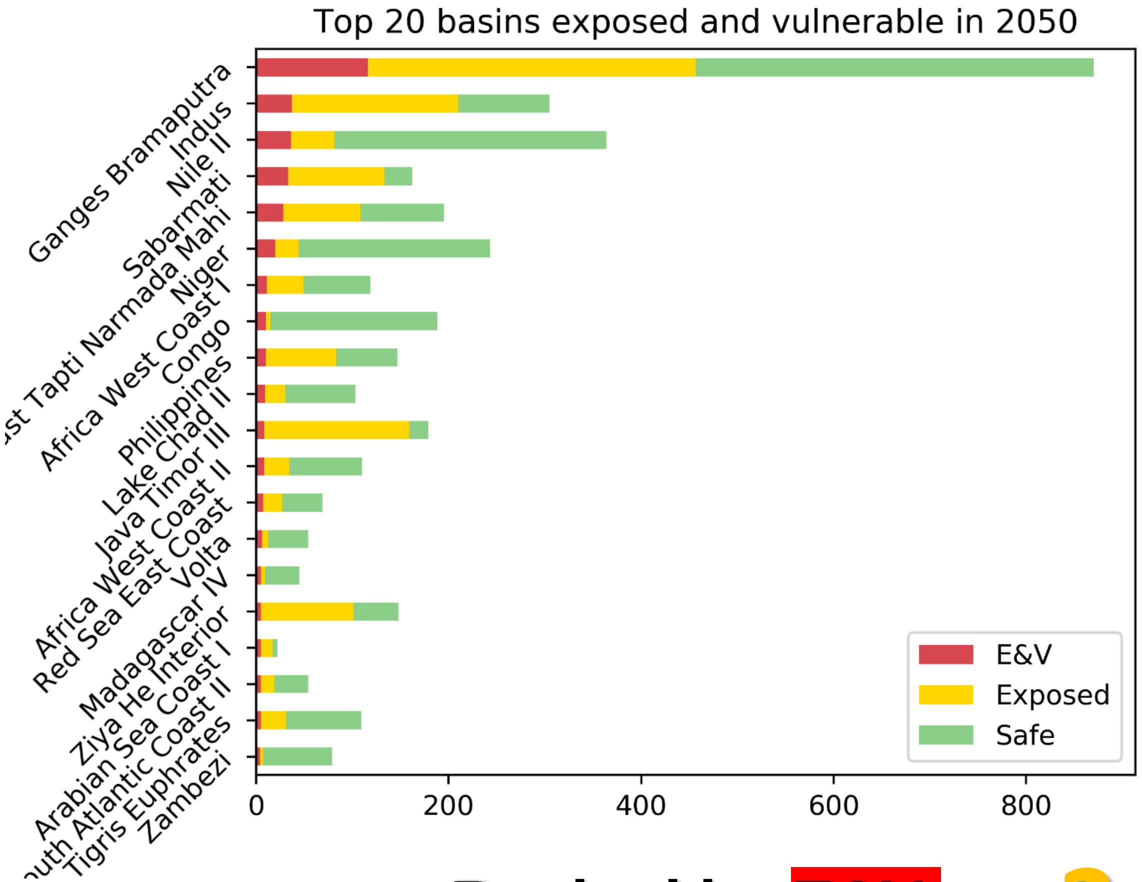
Indus river basin



Basin & country scale exposure

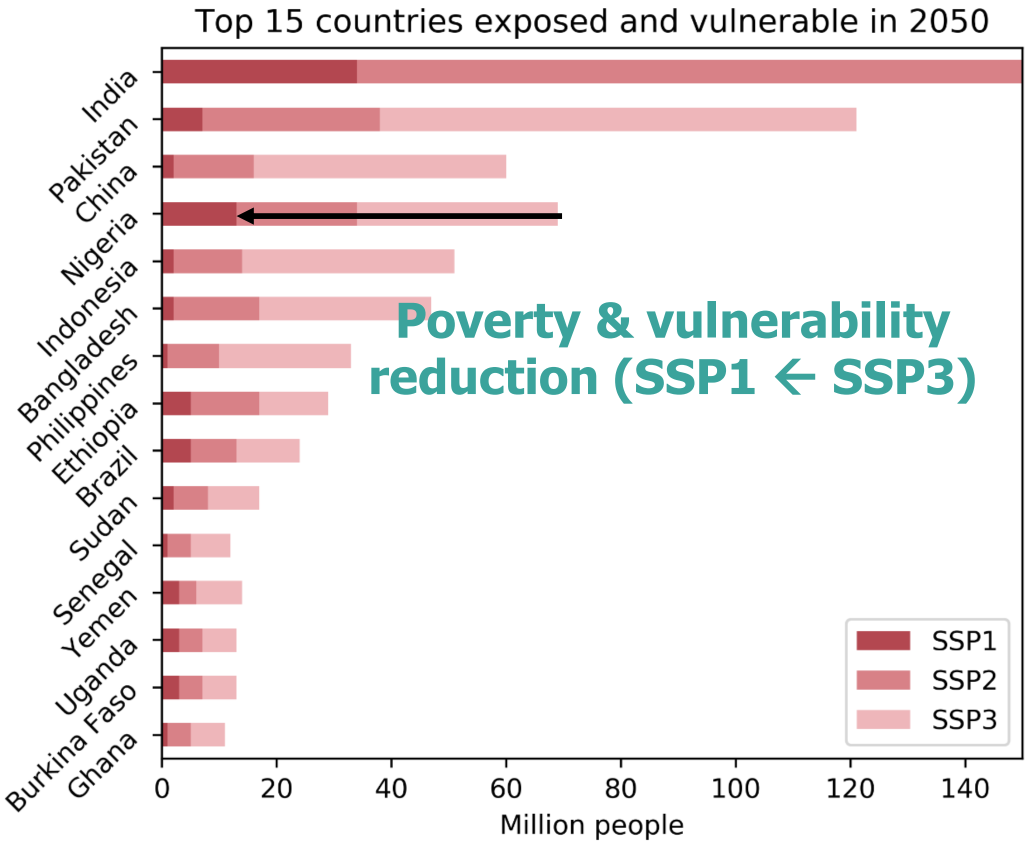
Which **basins** have most people exposed and vulnerable, *in absolute numbers?*

Which **countries** would benefit most from targeted poverty and vulnerability reduction and adaptation assistance?



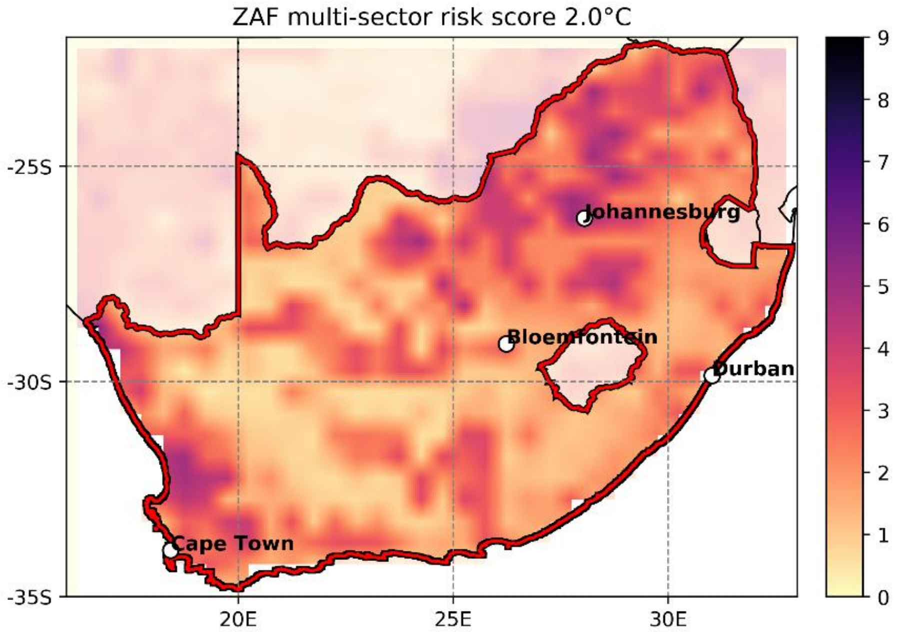
Ranked by E&V

2.0 °C



Ranked by Δ SSP 3-1

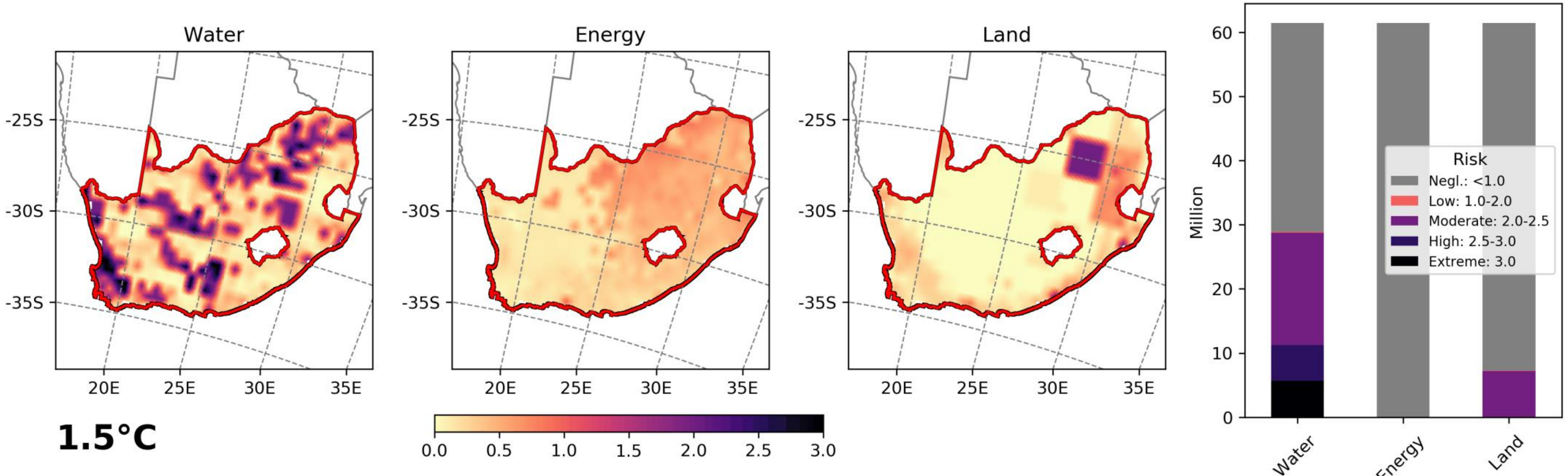
Break-out example: South Africa



Water risks already prominent (1/3rd of population)

Higher global warming:

- exposes most of the population to energy risks (cooling & heat stress)
- Up to 2/3rds population exposed to water risks



Dissemination and impact

Conferences & events

Scientific conferences

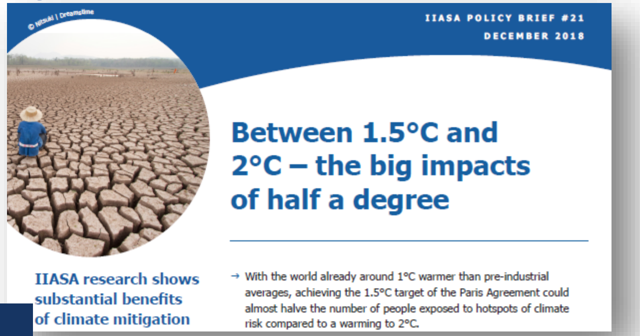
- Impacts World 2017
- Integrated Assessment Modelling Consortium 2017, 2018
- International Energy Workshop 2018
- European Geosciences Union 2018, 2019
- American Geophysical Union 2018 (x2 invited talks)
- Asian Energy Modelling Workshop 2018 (invited)
- Scenarios Forum 2019

Science-policy fora

- COP 23
- World Water Forum 2018
- GEF 6th Assembly STAP
- GEF/ World Bank seminar
- US Department of Energy / EU JRC workshop

Published outputs and reach

- Paper in Environmental Research Letters (7000+ downloads)
- IIASA Annual Report, Options Magazine
- IIASA press releases & social media
- Policy Brief



IPCC Special Report on 1.5°C
Chapters 3 & 5

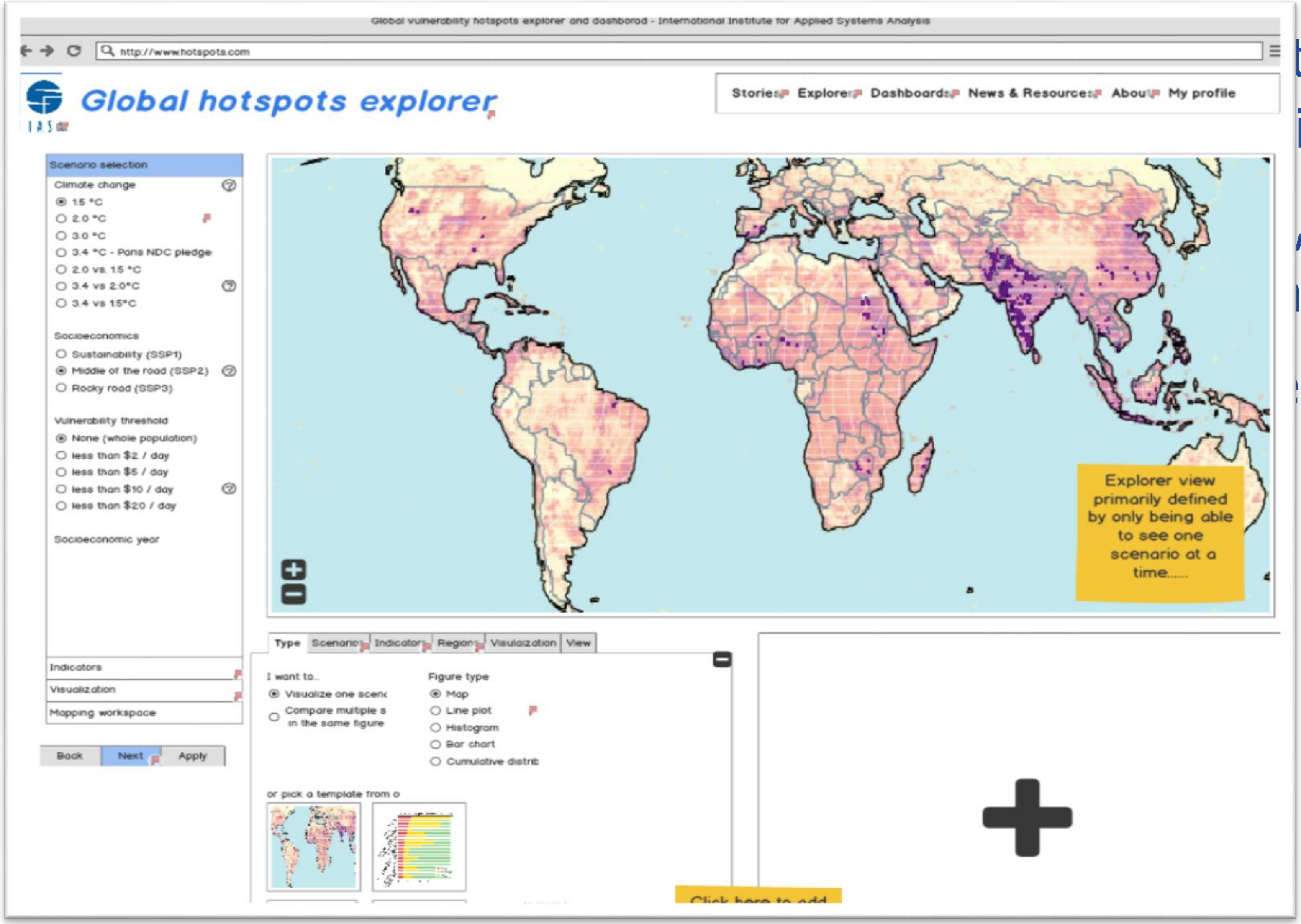
IPCC Special Report on Land

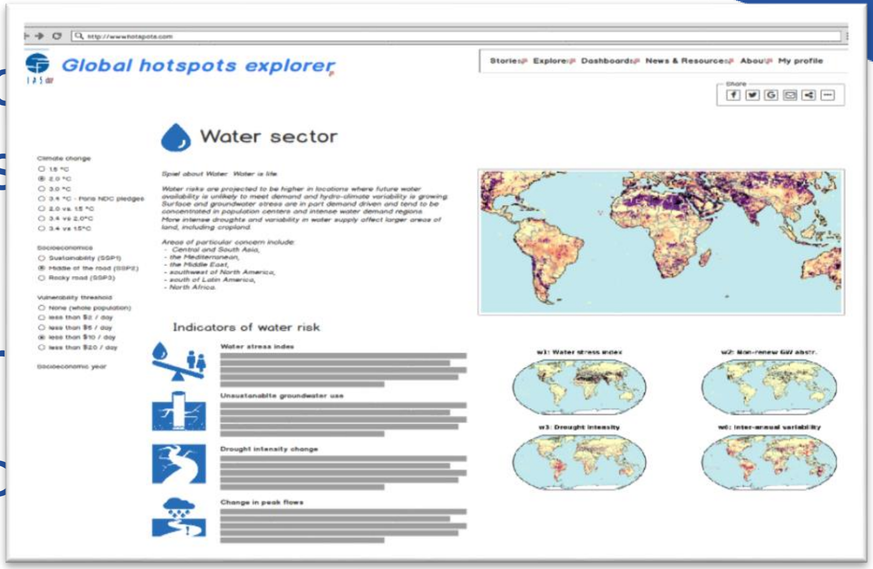
- Interactive impacts of climate change at 1.5°, 2.0° and beyond

CarbonBrief
CLEAR ON CLIMATE

THE WORLD BANK GROUP
Climate Change Knowledge Portal
For Development Practitioners and Policy Makers

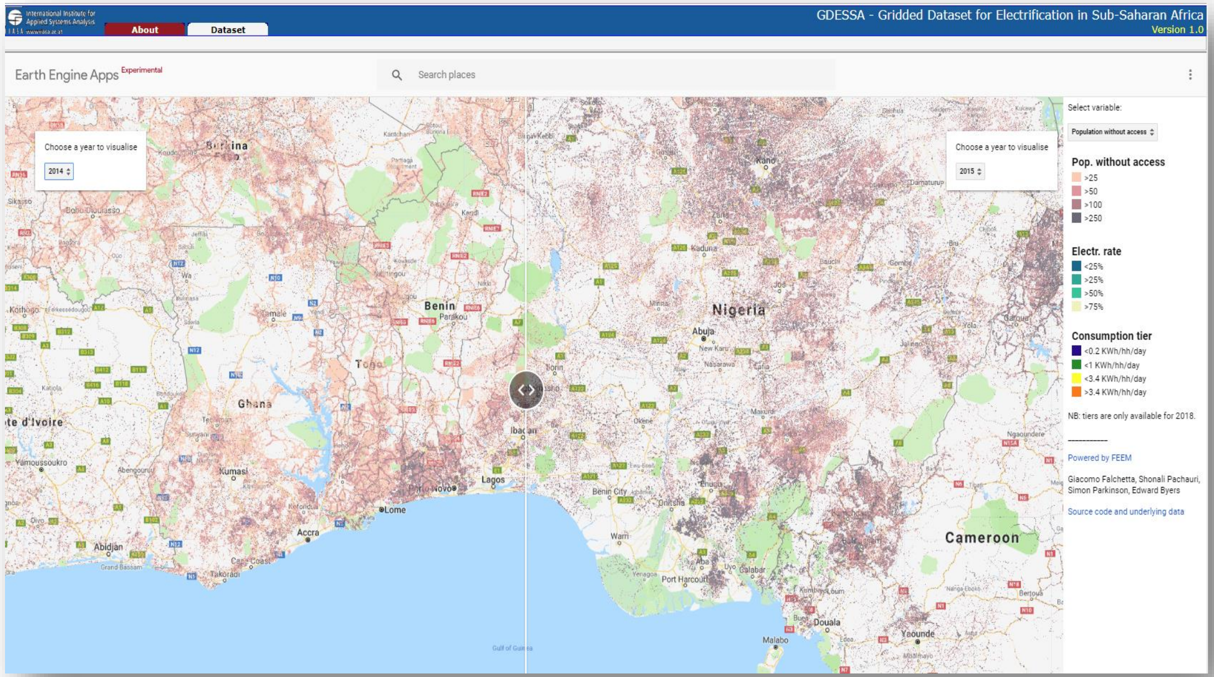
Global hotspots explorer





Two recent similar examples

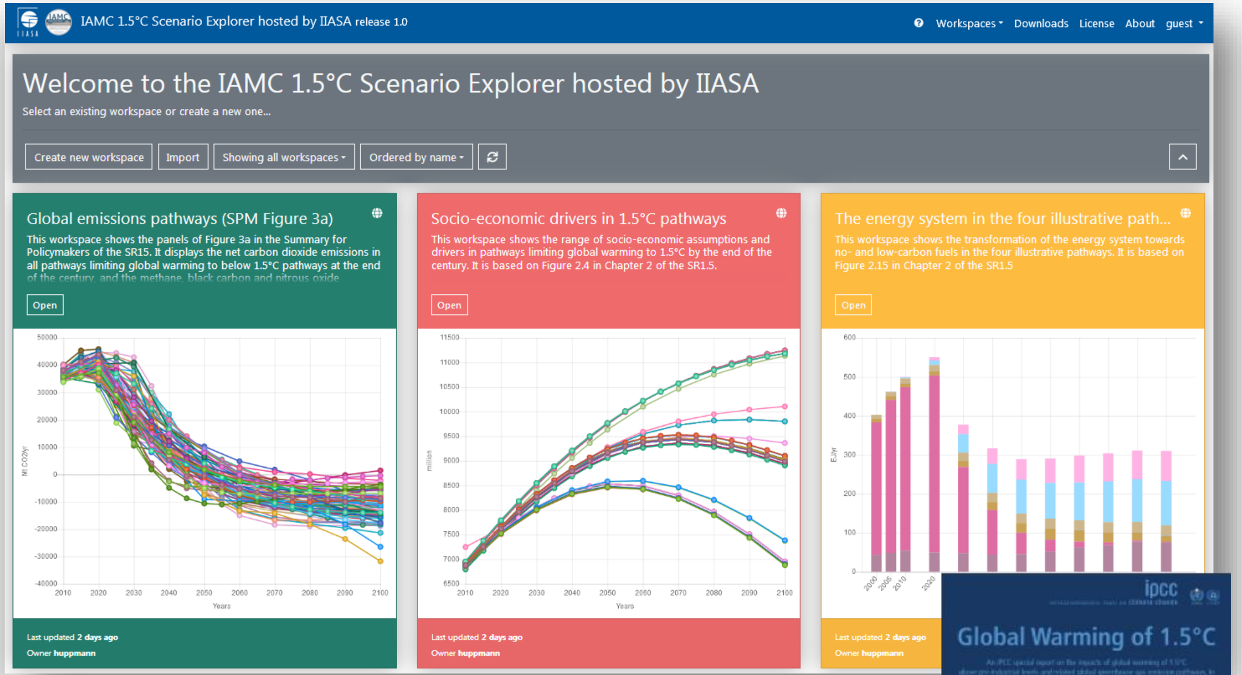
Gridded Dataset for Electrification in sub-Saharan Africa

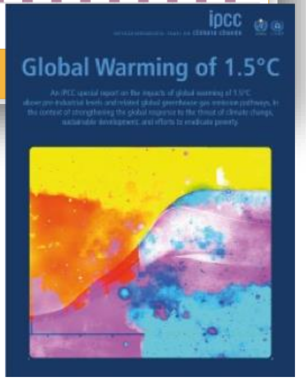


https://data.ene.iiasa.ac.at/kolp/GDESSA/gdessaDataset.html

(draft – do not distribute)

IAMC 1.5°C Scenario Explorer





https://data.ene.iiasa.ac.at/iamc-1.5c-explorer

Next steps for 2019

Global Hotspots Explorer website

Publications on:

- Hotspots & river basins
- Hotspots and extreme vulnerabilities
- Climate-development sensitivities and uncertainties

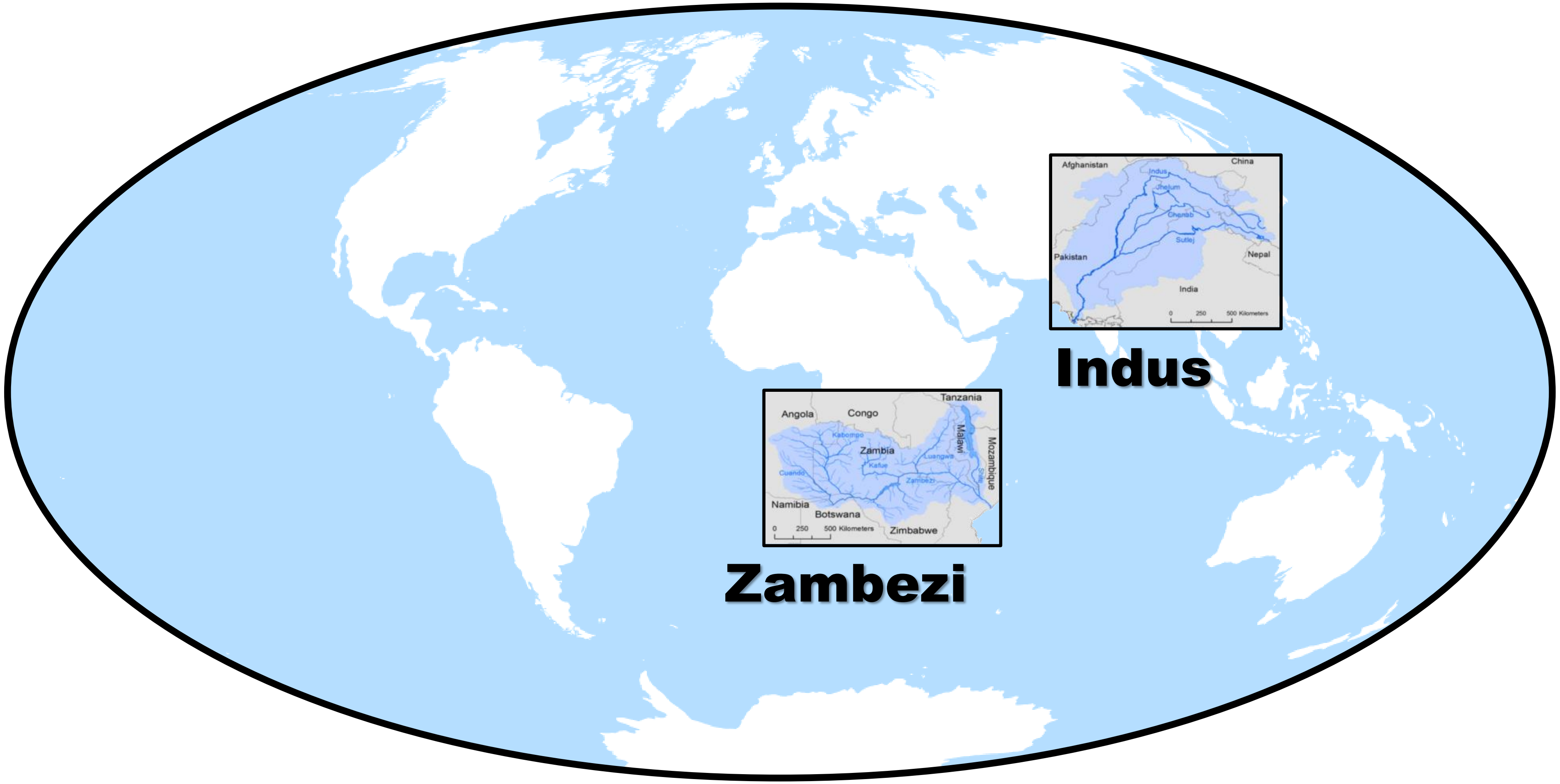
Questions?!

Global exposure and vulnerability to multi-sector development and climate change hotspots

Byers E, Gidden M, Leclere D, Burek P, Ebi KL, Greve P, Grey D, Havlik P, et al. (2018). Global exposure and vulnerability to multi-sector development and climate change hotspots. *Environmental Research Letters* 13: e055012. DOI:10.1088/1748-9326/aabf45.

http://www.iiasa.ac.at/web/home/resources/publications/IIASAPolicyBriefs/pb21-web.pdf

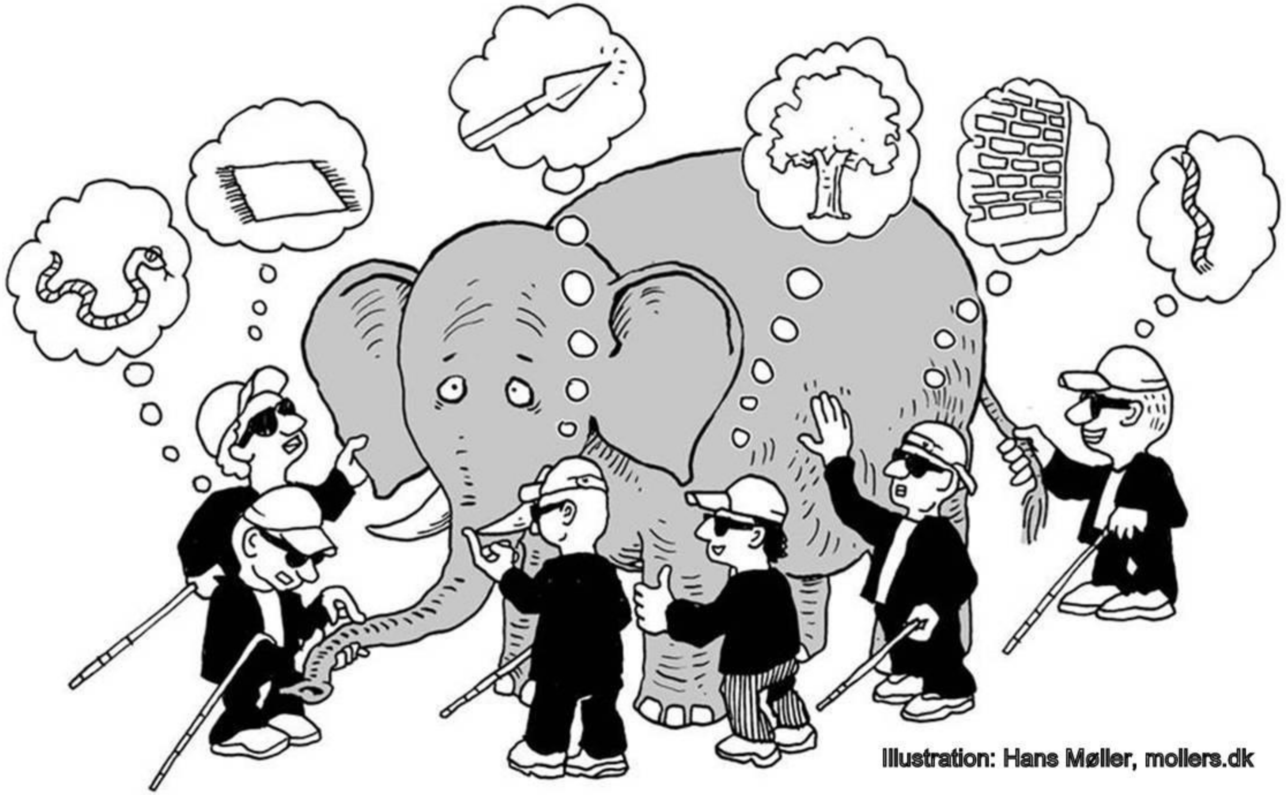
Basin Assessment



Outputs and outcomes

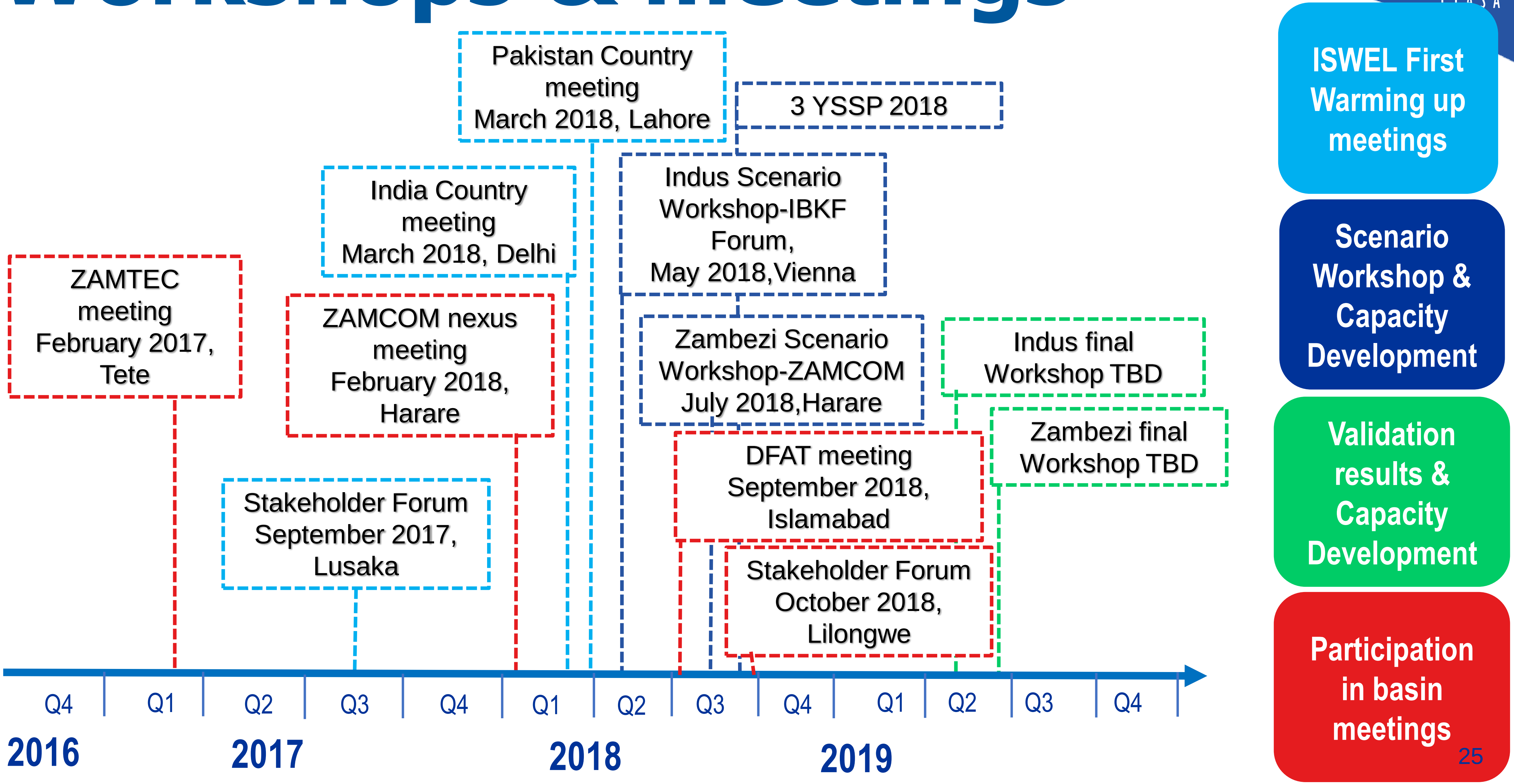
- Two types of tools to address WEL nexus development challenges
  - Regional basin planning model (policy optimization IAM)
  - Policy exercise to develop stakeholder visions and pathways
- Stakeholder informed scenarios
- Enhanced capacities for nexus management and research

Stakeholder Engagement



Barbara Willaarts, Project Officer & Research Scholar

Workshops & meetings



Stakeholders

IIASA

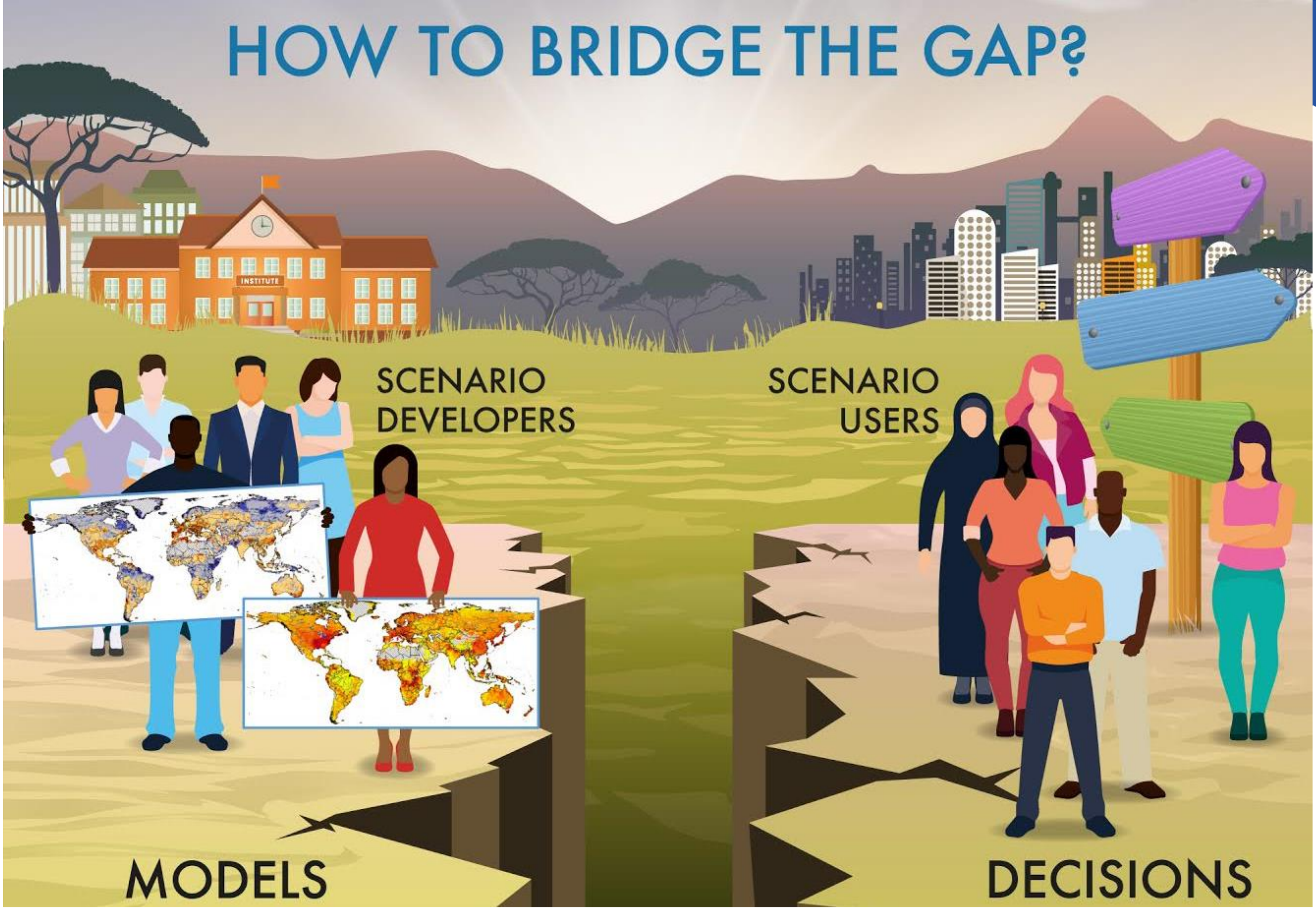
LUMS
National Institute of Hydrology
Ministry Energy & Water
WAPDA
Water and Power Development Authority
中国气象局
China Meteorological Administration
teri
ICRIER
Ministry of Planning Development & Reform
Planning and Development Department
Pakistan Meteorological Department
Govt. Punjab
Integrated Research and Action for Development (IRADe)
University of Kashmir
नीति आयोग
Balochistan.gov.pk
PARC
PCRWR
Council on Energy, Environment & Water (CEEW)
teri univers
Government of Khyber Pakhtunkhwa
The Pakistan Business Council
Fostering Economic Growth
USAID
From the American People
Institute for Defence Studies and Analyses (idsa)
IDRC CRDI
lead
LEAD Pakistan
Inspiring leadership for a sustainable world
TIFAC
Technology Think Tank
Capturing Aspirations
ICIMOD
Government of Pakistan
Ministry of Science and Technology
Xinjiang Institute of Ecology and Geography
Chinese Academy of Sciences

IAPRI
Indaba Agricultural Policy Research Institute
ZAMCOM
República de Angola
Ministério da Energia e Águas
Ngwato Land Board
MMEWR
Department of Water Affairs
ARA Zambeze
Administração Regional de Águas do Zambeze
INRH
Instituto Nacional de Recursos Hídricos
WWF
Republic of Botswana
Zambezi Regional Council
Ministry of Land Reform
THE WORLD BANK
IBRD • IDA
Malawi Government
Republic of Zambia
Ministry of Energy and Water Development
Ministry of Agriculture
A Smart And Value-Centered Public Service
Republic of Zambia

INDUS

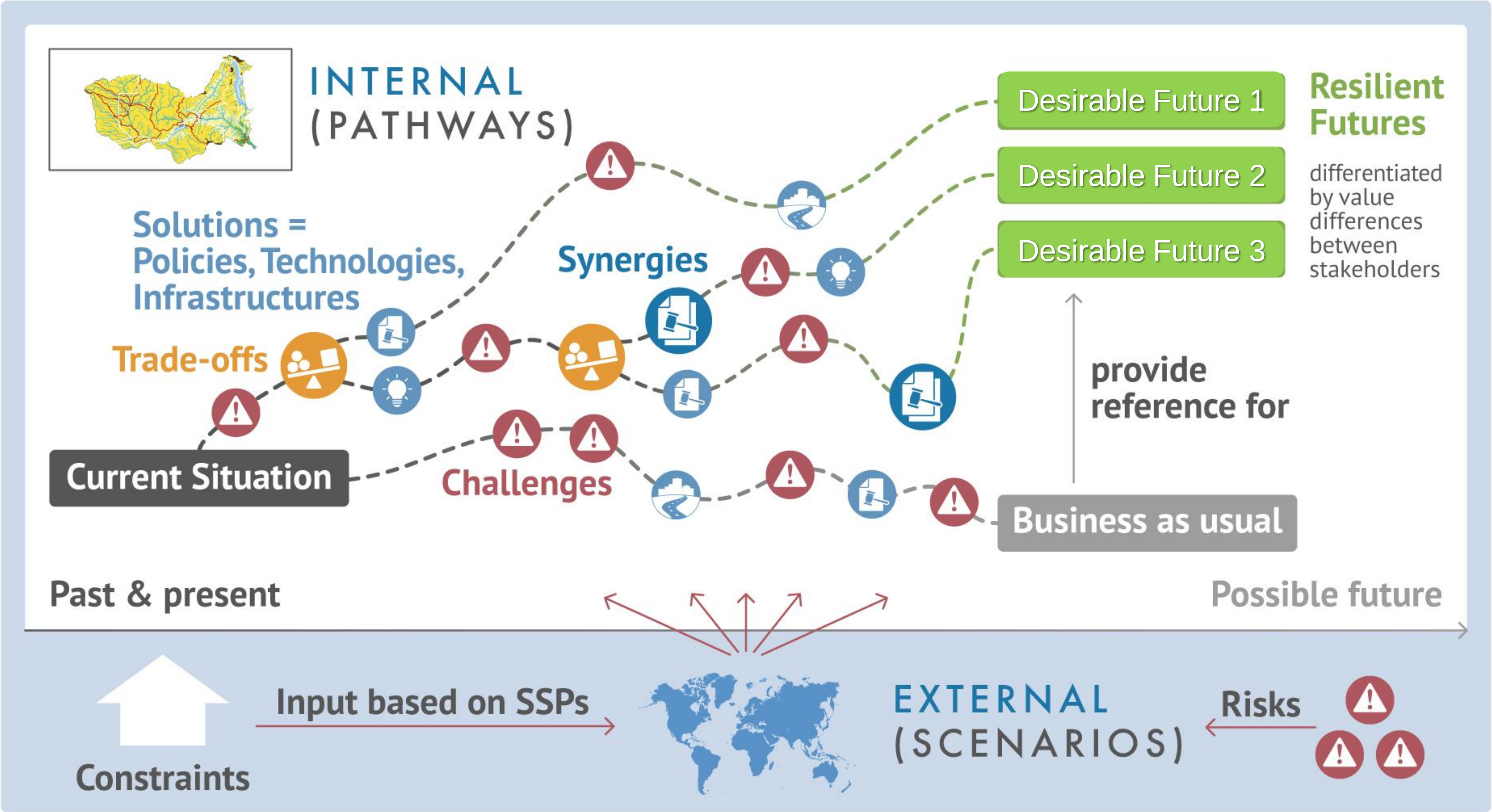
ZAMBEZI

Participatory Scenario Development process



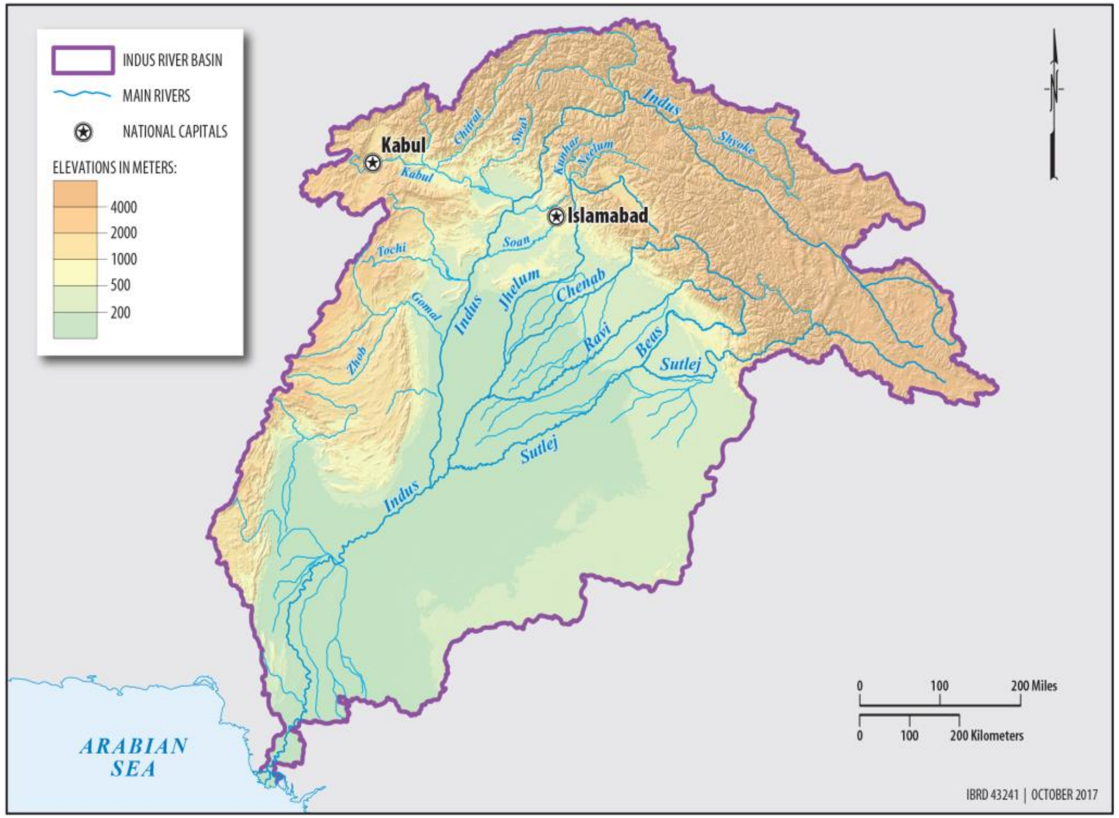
HOW TO BRIDGE THE GAP?
INSTITUTE
SCENARIO DEVELOPERS
SCENARIO USERS
MODELS
DECISIONS

Stakeholder visions and pathways



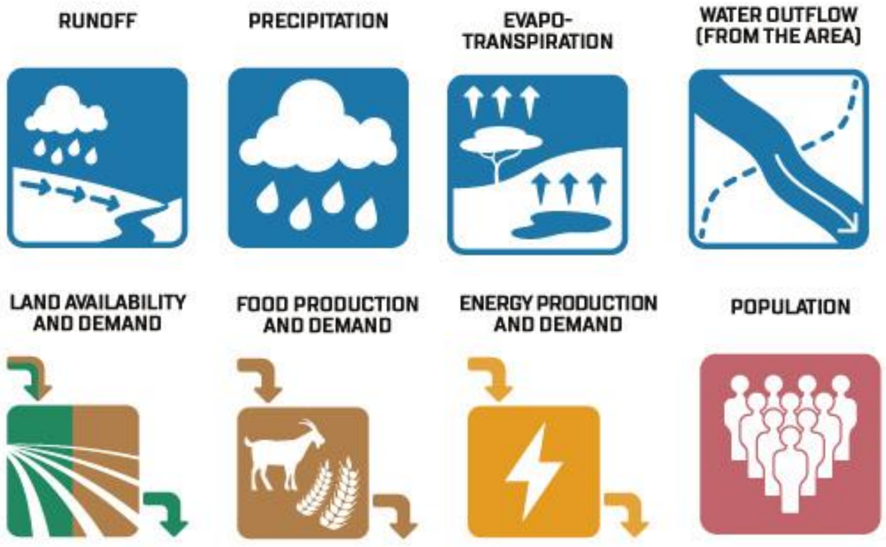
Scenario Elements

Map



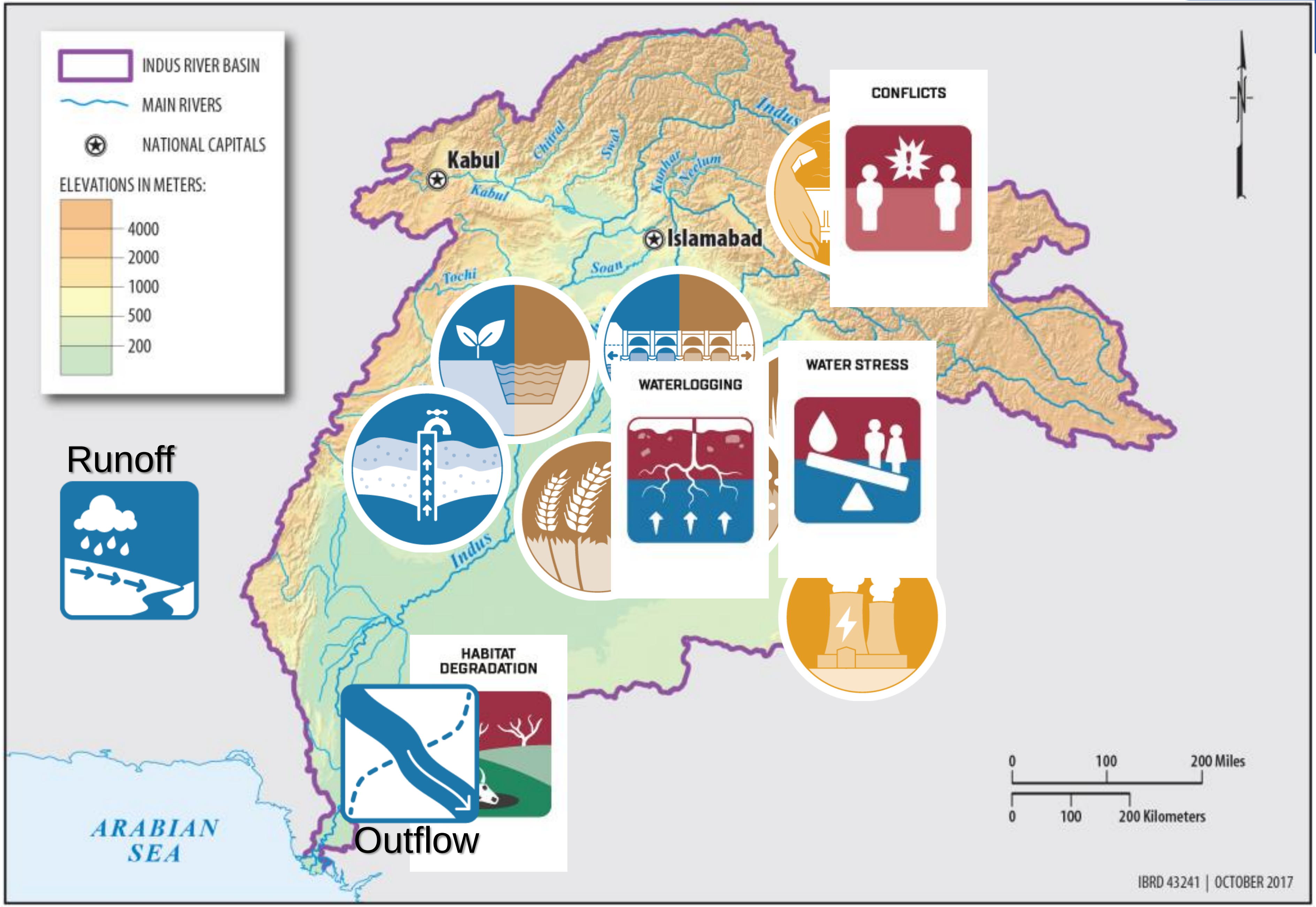
Cards

Indicators



STEP 1

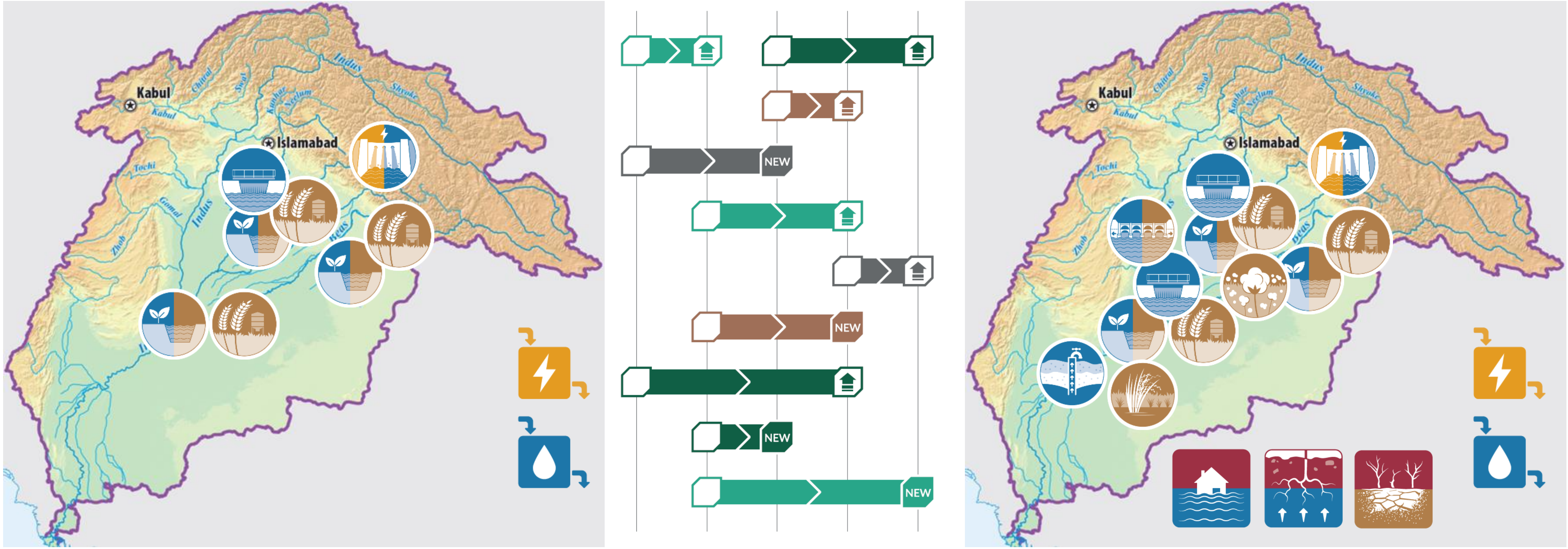
Current Situation



STEP 2

Business as Usual Pathway

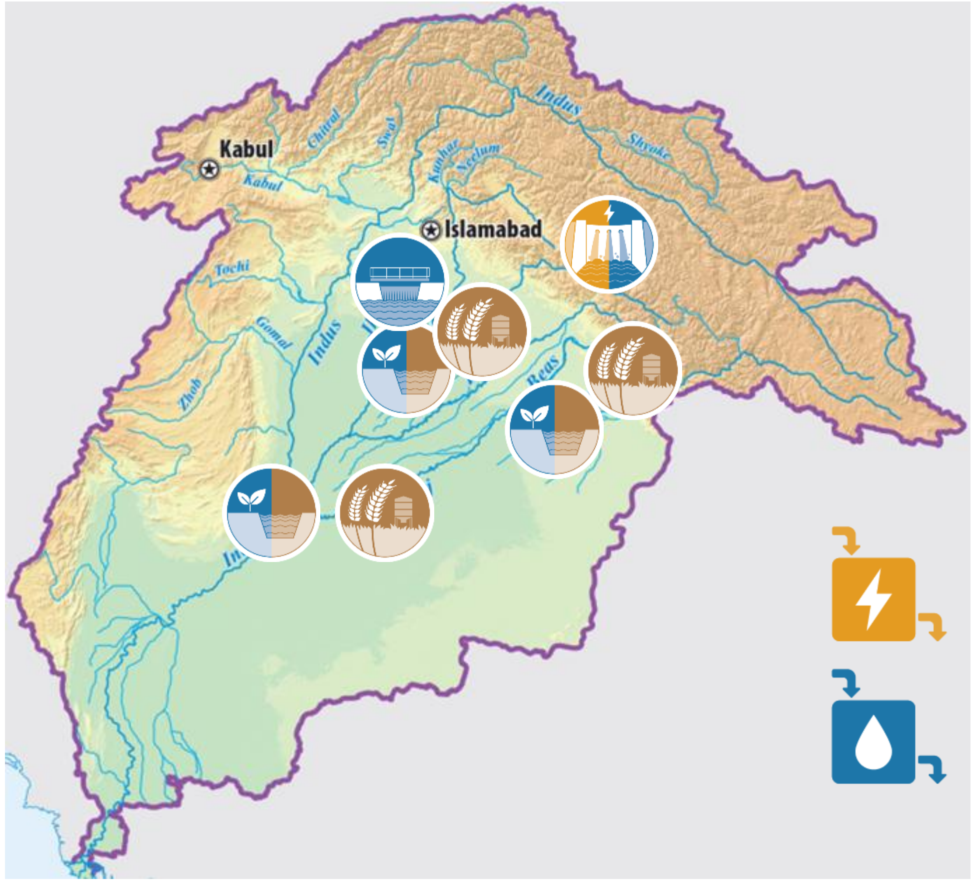
2018 — 2050

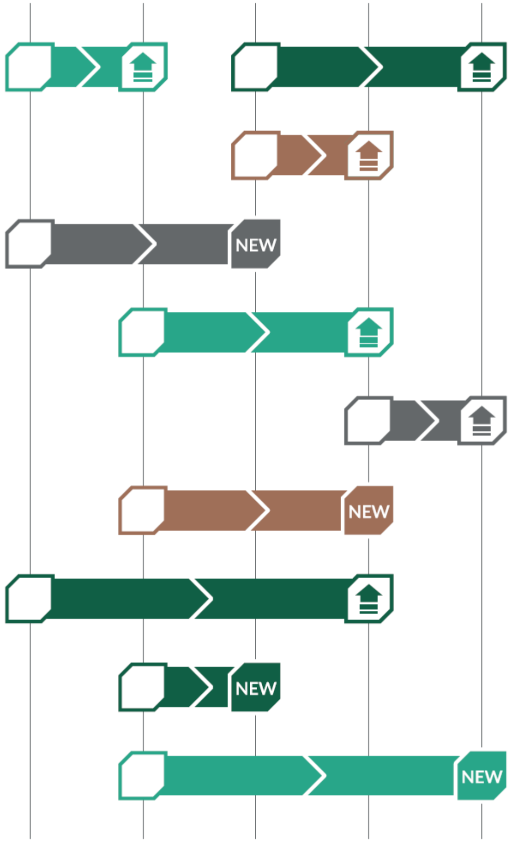


STEP 3

Desired Future Pathway

2018 2050





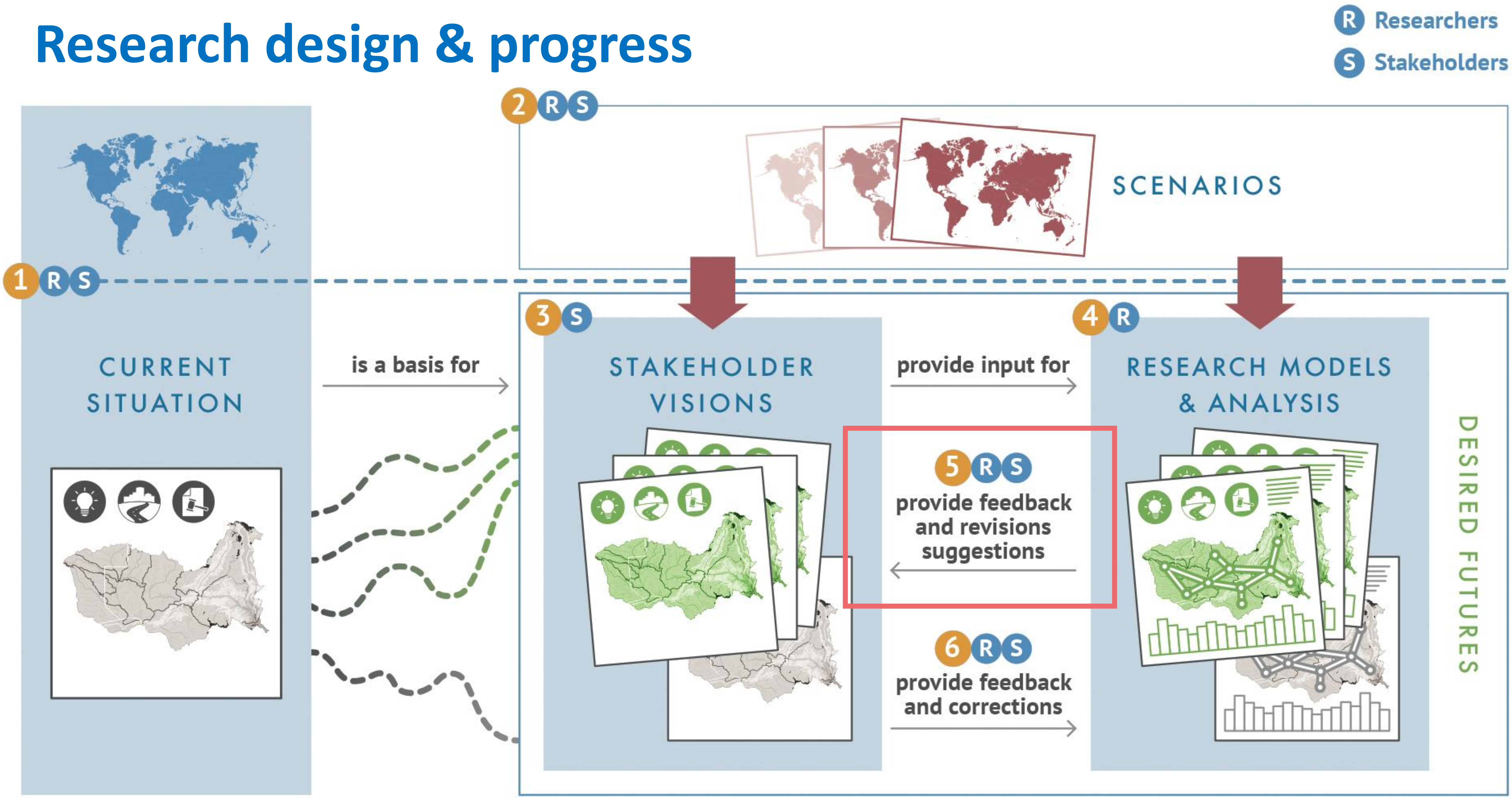
Indus visions and pathways

Economy pathway **Society pathway** **Environment pathway**

From pathways to basin scenarios

Sector(s)	Policy	Target (Economy)	Target (Society)	Target (Environment)	Model Represent.	Model Indicators
Water	**Access to water clean water**	100% in 2050	100% in 2030	100% in 2030	people connected to pipes	infrastructure costs and urban water demand
	Water storage and supply	Development of large storage dams and interbasin transfers	Strategic large storage dams combined with small scale storage	Strategic storage dams; develop groundwater potential	Storage capacity	total storage capacity, min, max and actual level of reservoirs, storage investment costs
	Conservation of water-related ecosystems	Economic water uses attended first	Securing environmental flows	Securing environmental flows + conservation of sensitive wetlands	Allocation prioritization, Restrict land use changes	Volumetric flow by sector (km^3), Share of wetlands protected (%)
	Ensuring water quality	At least primary treatment of industrial and urban water	At least primary treatment of industrial and urban water	Secondary wastewater treatment and recycling;	wastewater tratement and water pollutants	Investments in clean water technologies
	Flood and drought management	Multipurpose-dam management ; Joint surface and groundwater management	Multipurpose-dam management+Transboundary cooperation strategy	Multi-purpose dam management and NBS	Maximum river flows	Activity of river, canals and level of reservoir

Research design & progress



Benefits of the policy tool

1. Well received by stakeholders (great buy-in)
2. Very flexible, can be adapted to explore a wide range of different challenges and pathways
3. It allows to generate sets of regional scenarios that are coherent with global storylines. Inter-comparability
4. Combined with IAMs, suitable for policy issue identification and measure development

Zambezi

VIDEO


The Nexus Game
LUMS, Lahore, March 2018

IIASA Young Scientists Summer Program (YSSP)

Each year: 50 international students working under the supervision of IIASA staff

- 1 June - 31 August, in Laxenburg, Austria
- Open to advanced PhD. students whose research interests correspond to IIASA's research
- Goal: publishable journal article
- Funding available from IIASA's National Member Organizations
- On-line application (Oct – Jan) www.iiasa.ac.at/yssp

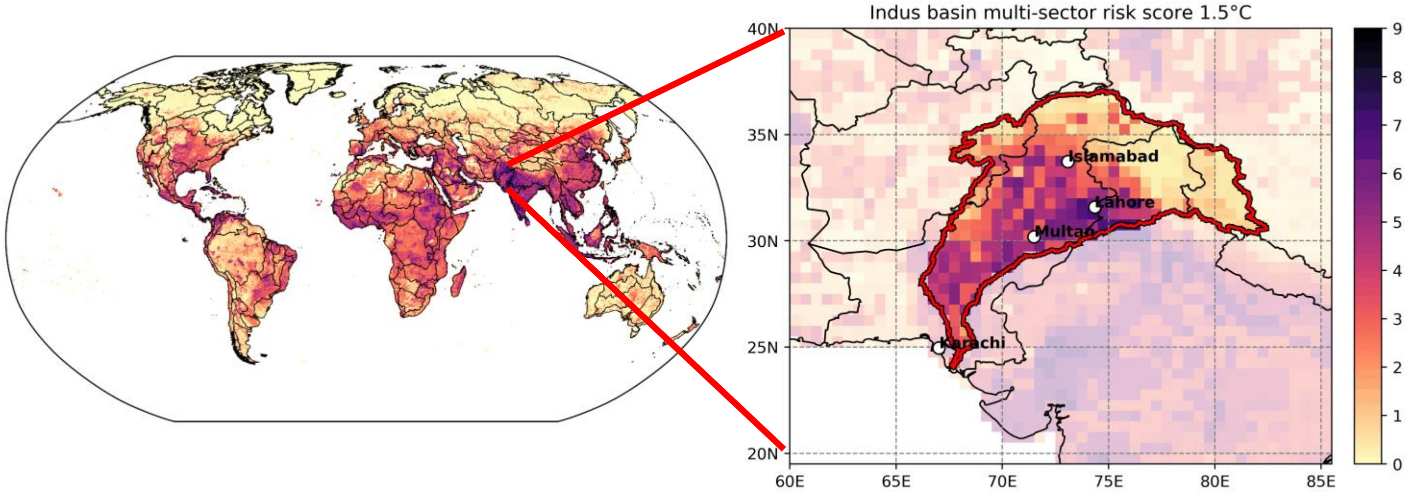
A framework for charting water-energy-land nexus solutions for the Indus basin

Adriano Vinca, Simon Parkinson, Edward Byers, Peter Burek and colleagues
UNIDO, Vienna, April 16 2019

International Institute for Applied Systems Analysis (IIASA)
Laxenburg, Austria

Water stress and other challenges

Combined indicator of vulnerability hotspots
in water, energy and land



Water	Energy	Land	Socioeconomics
Water stress index	Clean cooking access	Crop yield change	Population density
Non-renewable GW abstraction	Heat event exposure	Environmental flow exploitation	Income levels
Drought intensity	Cooling demand growth	Habitat degradation	
Peak flows risk	Hydroclimate risk to power	Nitrogen leaching	
Seasonality			
Inter-annual variability			

Byers el al. (2018),ERL

Challenges

Water and land

- Complex canal and irrigation system
- Groundwater depletion and water storage
- Very little flow reaches the sea
- Lack of wastewater treatment
- Food self-dependence
- Burning of crops leads to air pollution

Energy systems

- Electricity can be unreliable
- Air pollution and GHGs increasing
- Hydropower generation

Stakeholder engagement

First round of meetings (2018)

- Identifying challenges
- Collecting regional data
- Generating scenarios
- Capacity building to PhD students

Second round of meetings (later this year)

- Round of results checking and discussion
- Capacity building

The core model

NExus Solutions Tools (NEST)

Distributed Hydrology

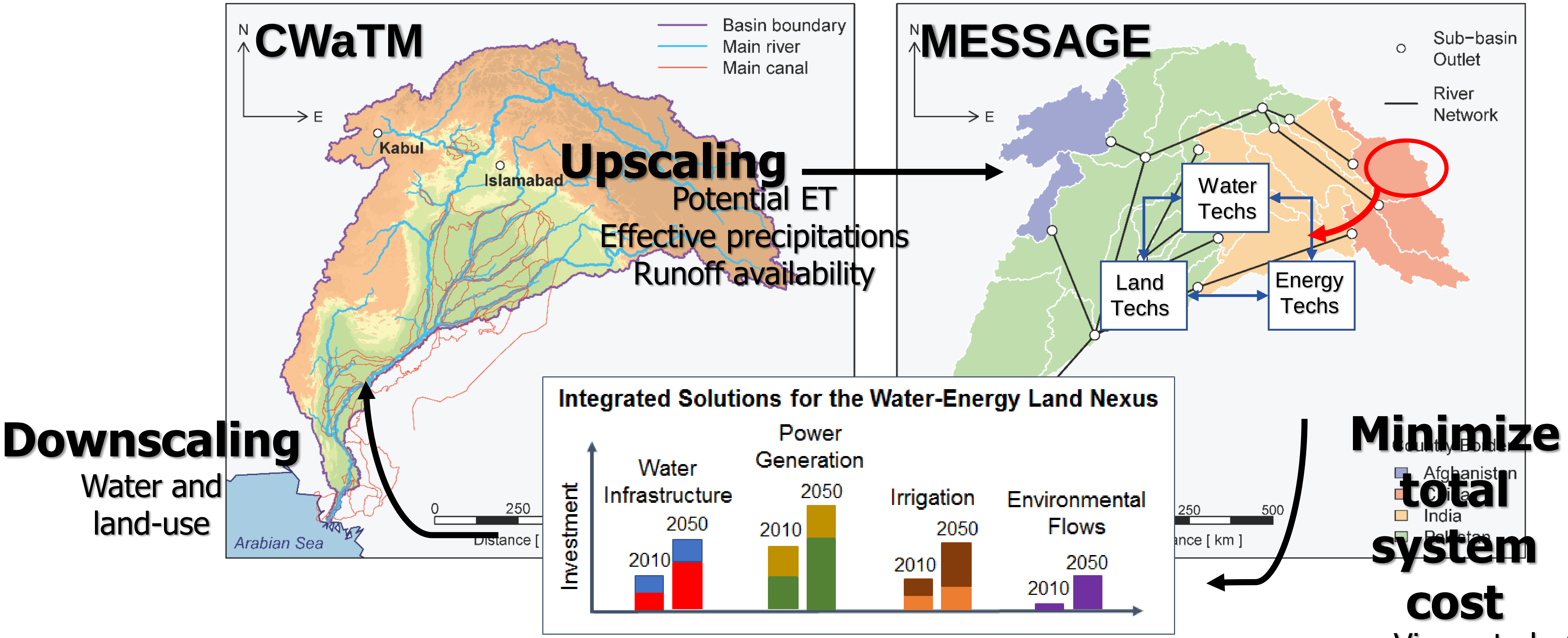
Community Water Model (CWatM)

(Burek et al., 2018)

Infrastructure Planning

MESSAGEix

(Huppmann et al., 2018)



Vinca et al., (forthcoming)

Best practice

What can the model do and its limitations

- Optimal new system transformations required to achieve certain objectives
- Explore different climate and socioeconomic pathways (SSP, RCP)
- Assess proper management of resources (energy-water-land) under stressed conditions
- Focus on sub-areas or on monthly variations (i.e. water storage)

- The model does not predict the future
- Cross-national borders
- Increasing spatial resolution it’s possible, but increase the complexity and solution time

Data flexibility

General Information

- Exclusion Zones
- Roads

Energy System

- Renewable Capacity Factor
- Existing Power plant capacity
- Transmission Lines
- Fuel Production Capacity

Water System

- Water Availability
- Freshwater Extraction
- Water Table Depth
- Storage
- Water Supply Technologies

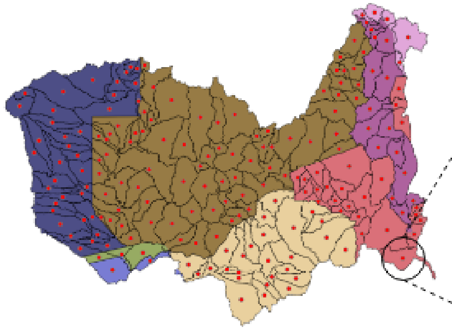
Land System

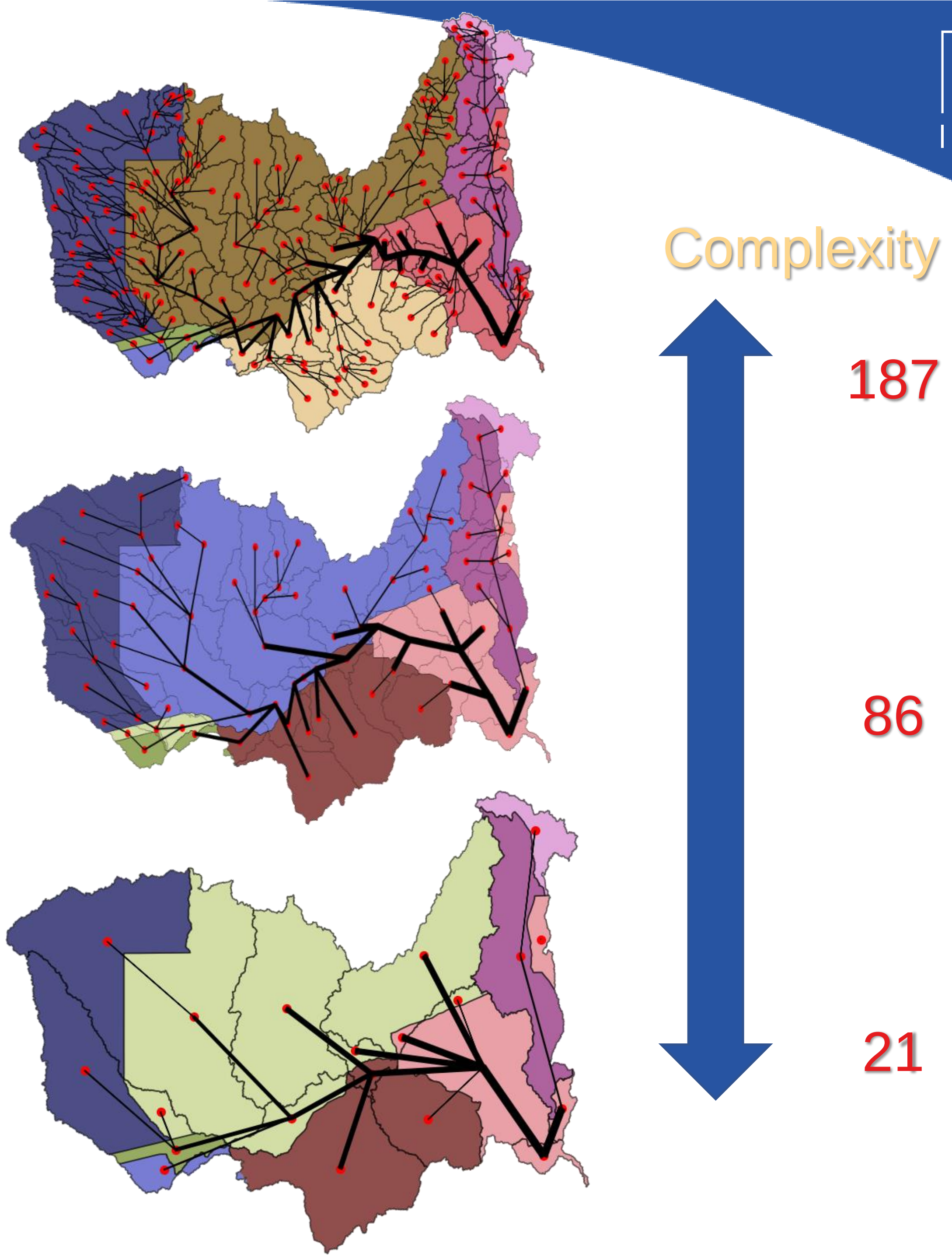
- Available Land
- Crop efficiency
- Irrigation Technologies

Demands

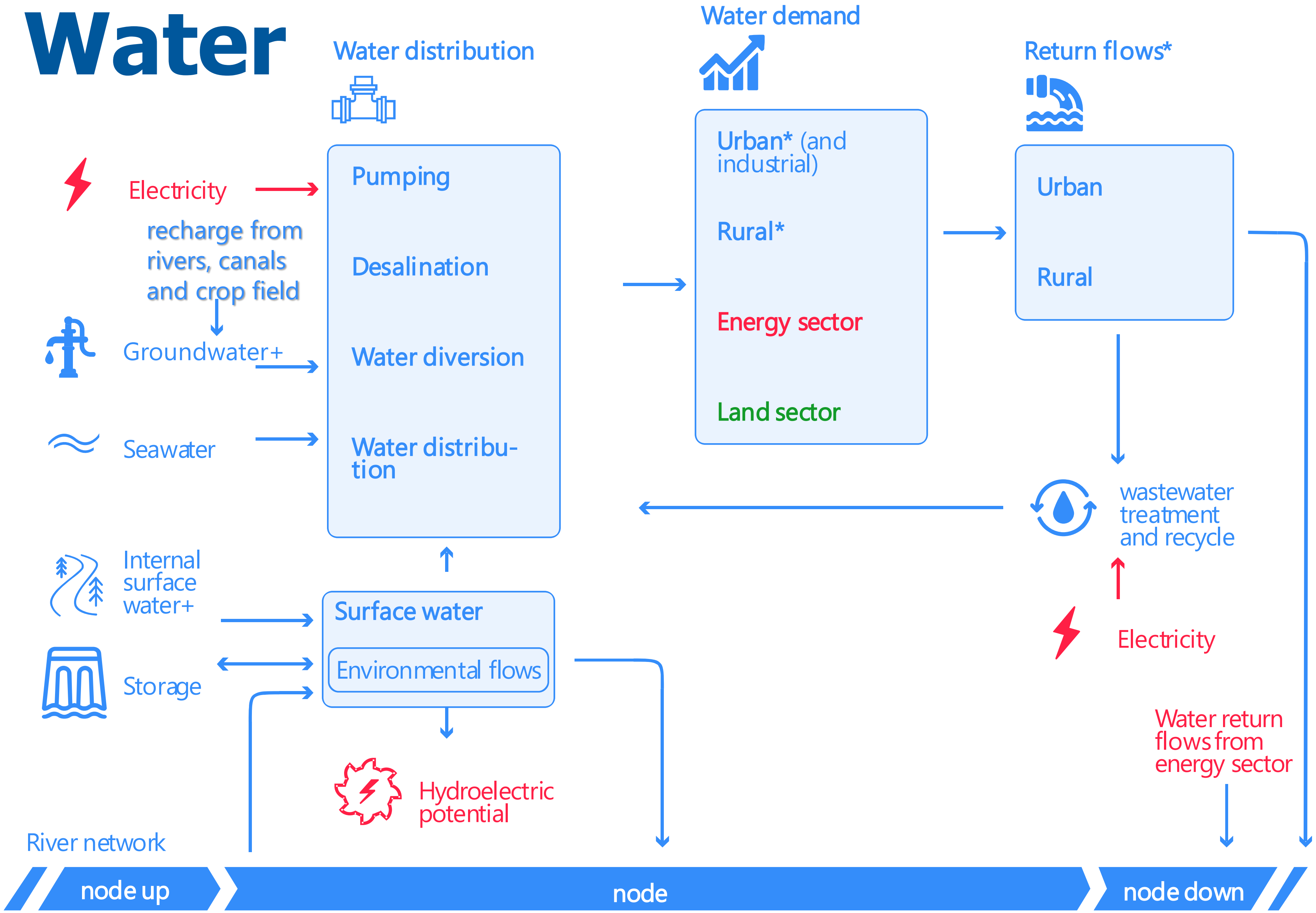
- Energy
  - Electricity
  - Fuels
- Water
- Food

Basin Country Units





Water

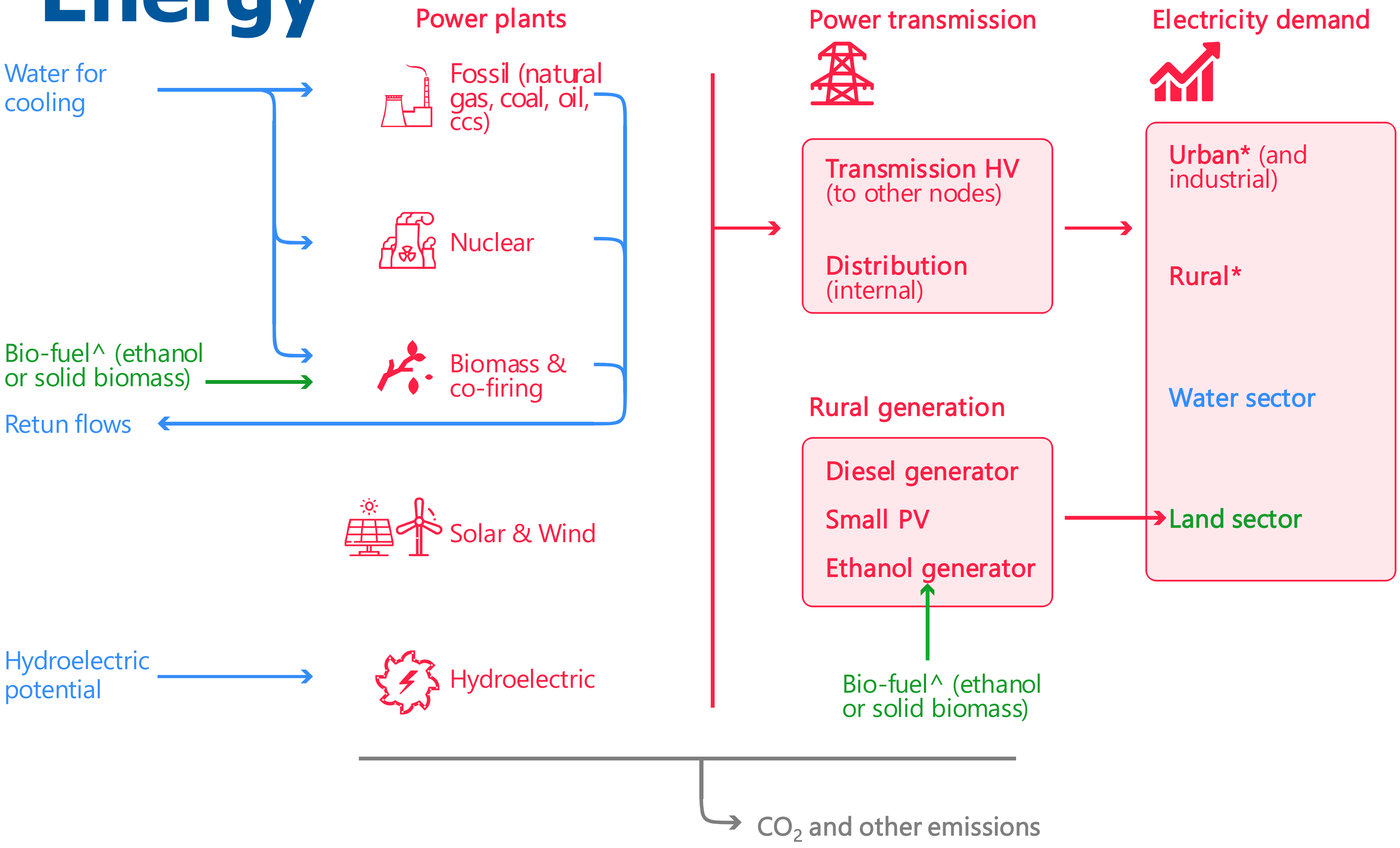


* exogenous
\+ limints are imposed based on information from hydrolocial model

Data:

- SSP-RCP water demand scenarios
- Surface water availability
- Current river flow, canals
- Fossil groundwater, aquifer recharge
- Storage, current and planned reservoir capacity
- Water supply, diversion and treatment technologies
- Indus water treaty allocations

Energy

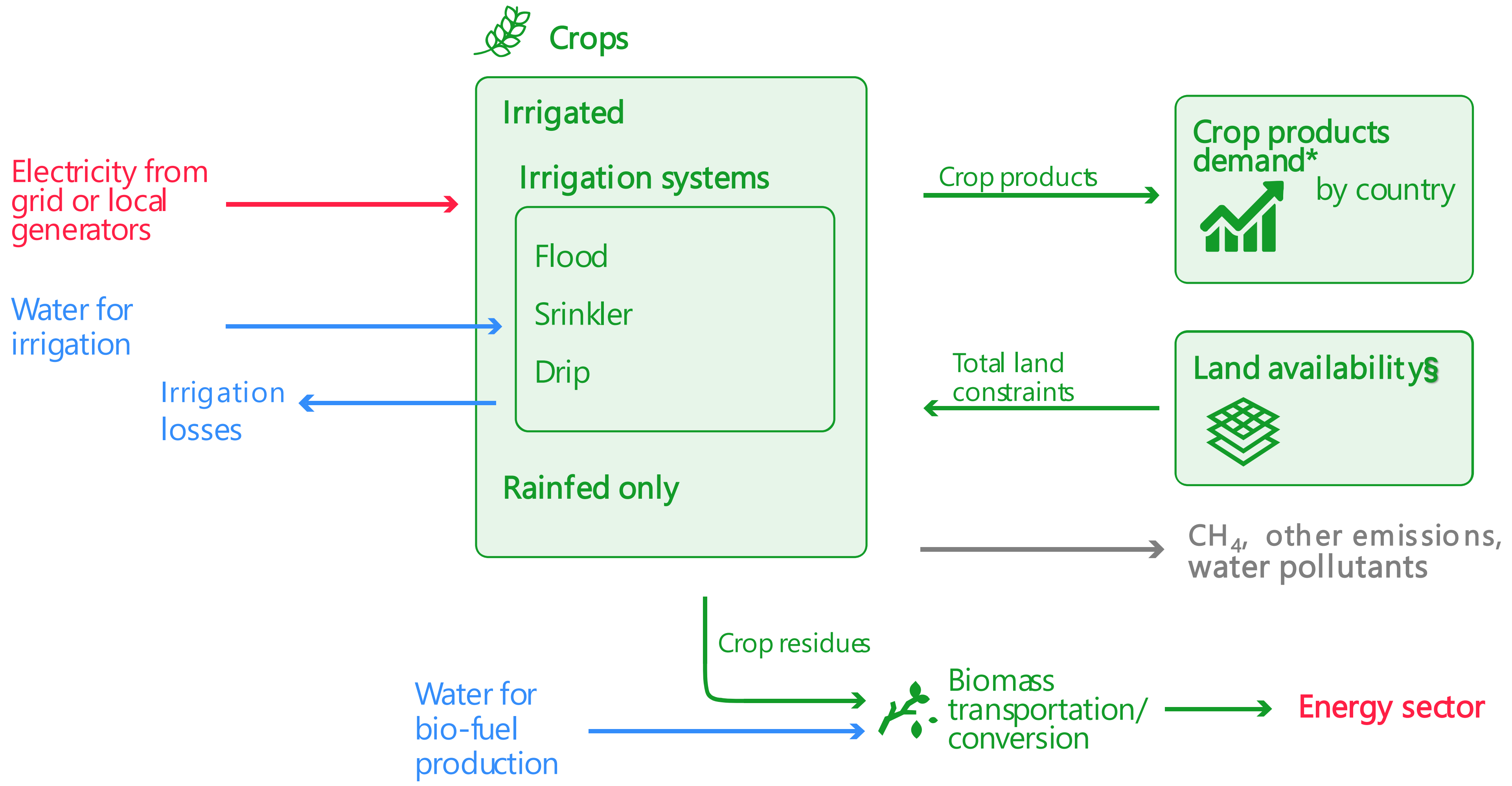


Data:

- Solar, wind and hydropower potential
- SSP electricity sectoral demand
- Transmission and distribution networks
- Power and cooling technology

* exogenous
^ crop residues can be transported as solid biomass or converted in ethanol, technolgies not represented here

Land



Data:

- Land use/ availability maps
- SSP-RCP crop yields
- SSP crop products demand
- Irrigation technologies

* exogenous.
§ total available area for agriculture based on historical data

Integrated Policy Analysis

How to strike a balance between objectives and challenges?
... and at what cost?

SDGs

Transboundary Agreements

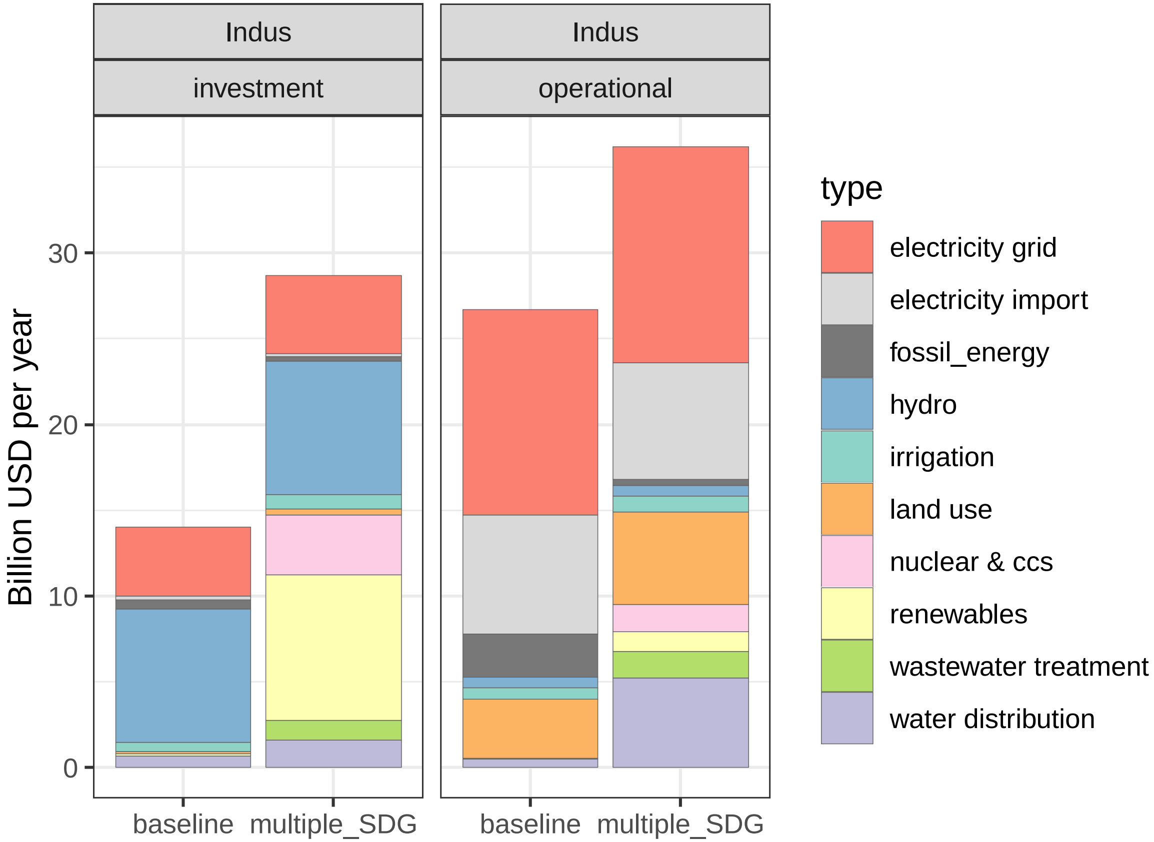
Scenarios

Scenario	Description	Implementation
Common assumptions to all scenarios	SSP2. RCP 6.0. Indus Water Treaty allocations. Planned hydropower projects in 2030. Current renewable energy policies. Maximum electricity imports fixed to baseline Limited fossil groundwater extraction.	Set of different constraints, present also in the baseline (with the exception of those that refer to the baseline)
SDG 2, Achieve food security and promote sustainable agriculture scenarios	SDG 2.4 By 2030, 100% implementation of modern so-called smart irrigation technologies that increase productivity and production relative to 2015	SDG 2.4: No flood irrigation (except for rice) after 2030. Smart irrigation is available. **Baseline**: no smart irrigation technologies adopted before 2030
SDG 6 Water sector development scenarios	SDG 6.6 By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes SDG 6.3 By 2030, improve water quality by reducing pollution, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally	SDG 6.6 Minimum of 20% of natural flow left in rivers and aquifers by 2030. SDG 6.3 Treat half of return flows treated by 2030, recycle one quarter of return flows. **Baseline**: no targets
SDG 7 Clean and Affordable Energy Development Scenarios	SDG 7.2 By 2030, 50% By 2030 the share of renewable energy in the global energy mix = 50% SDG 7.b By 2030, expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all	SDG 7.2 Target on share of renewables (wind, solar, geothermal). Phase out of coal SDG 7.b Phase out of once-through cooling, imposing capacity constraint. **Baseline**: no targets
SDG 13 Climate action	SDG 13.a Implement the commitment undertaken by to the United Nations Framework Convention on Climate Change	SDG 13.a Ghg emission budget and climate scenario accordingly. **Baseline**: no emission targets

Preliminary results

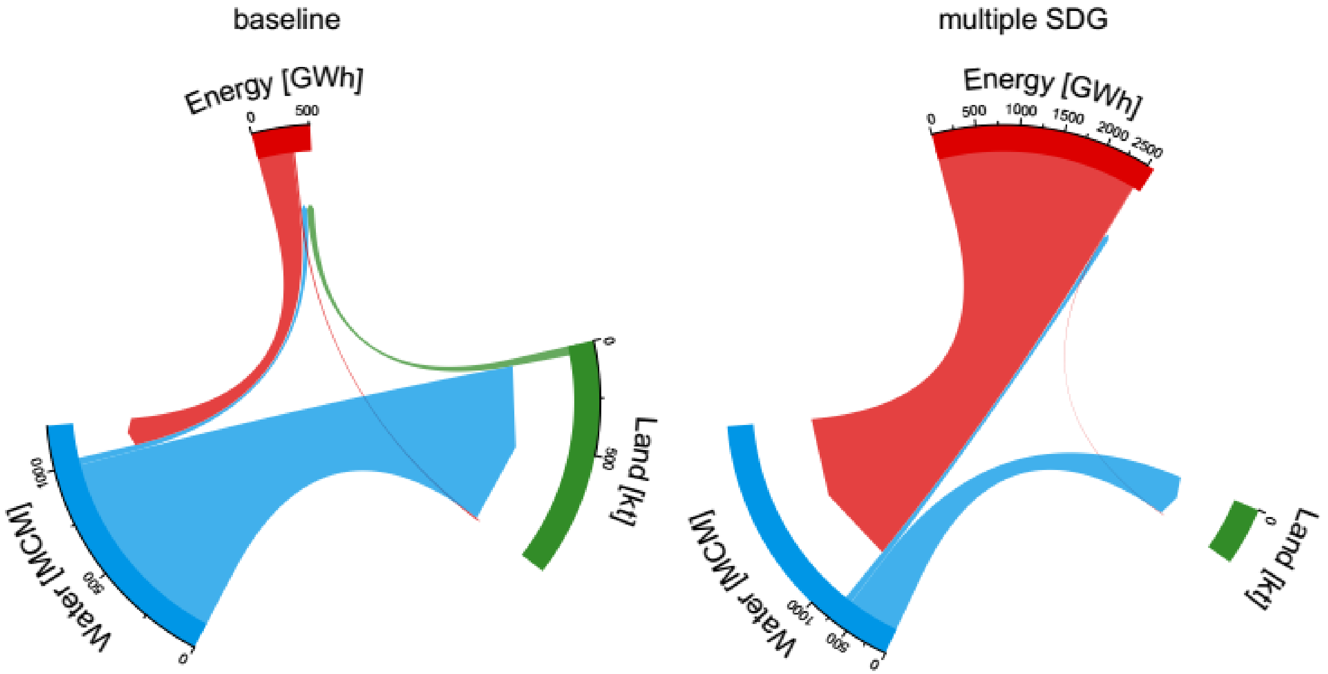
Comparing baseline with preliminary SDG 2+ 6 + 7 + 13 scenario

Average yearly costs for the entire basin (2020-2050)



Low carbon tech and wastewater distribution and treatment.
Use of more efficient, but costly irrigation technologies.
Higher land requirements

Average yearly cross-sectoral energy, water and biomass flows

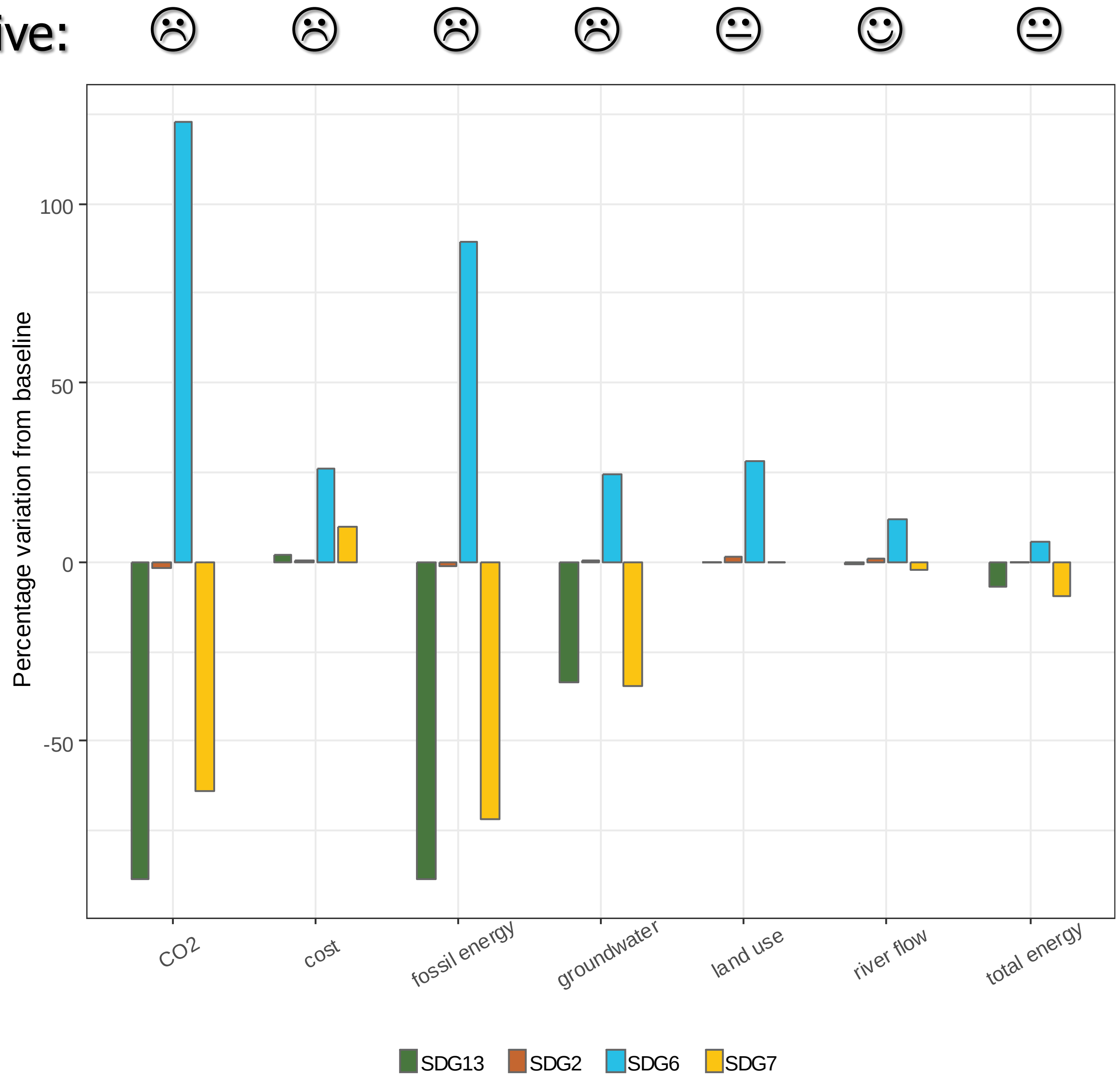


Less water used in agriculture
Much more energy required for pumping, treating, water infrastructure, power plants

Single SDG, multi sector

If positive:

Sum (cost, emissions, energy) or average (others) between 2020 and 2050



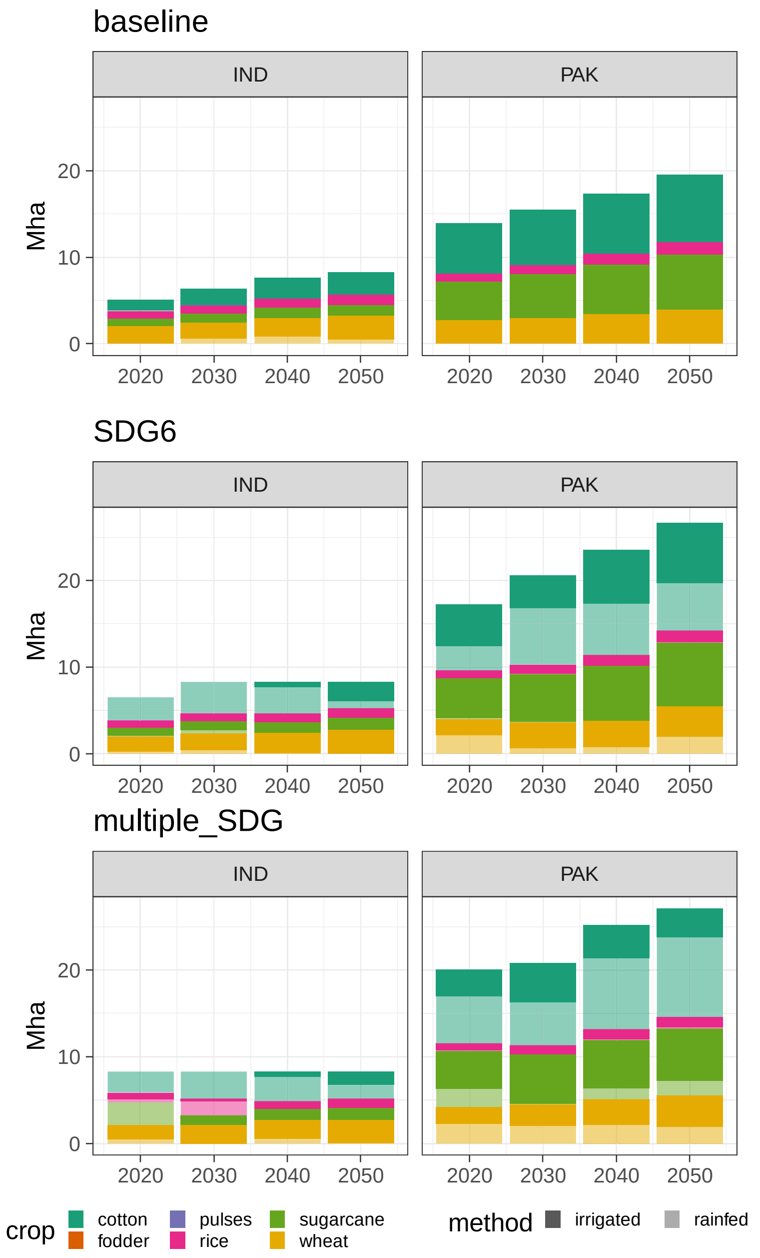
SDG2: no significant changes

SDG6: water constraints, more fossil fuel than in baseline
higher cost for water distribution

SDG7 and 13 similar even though targets are different

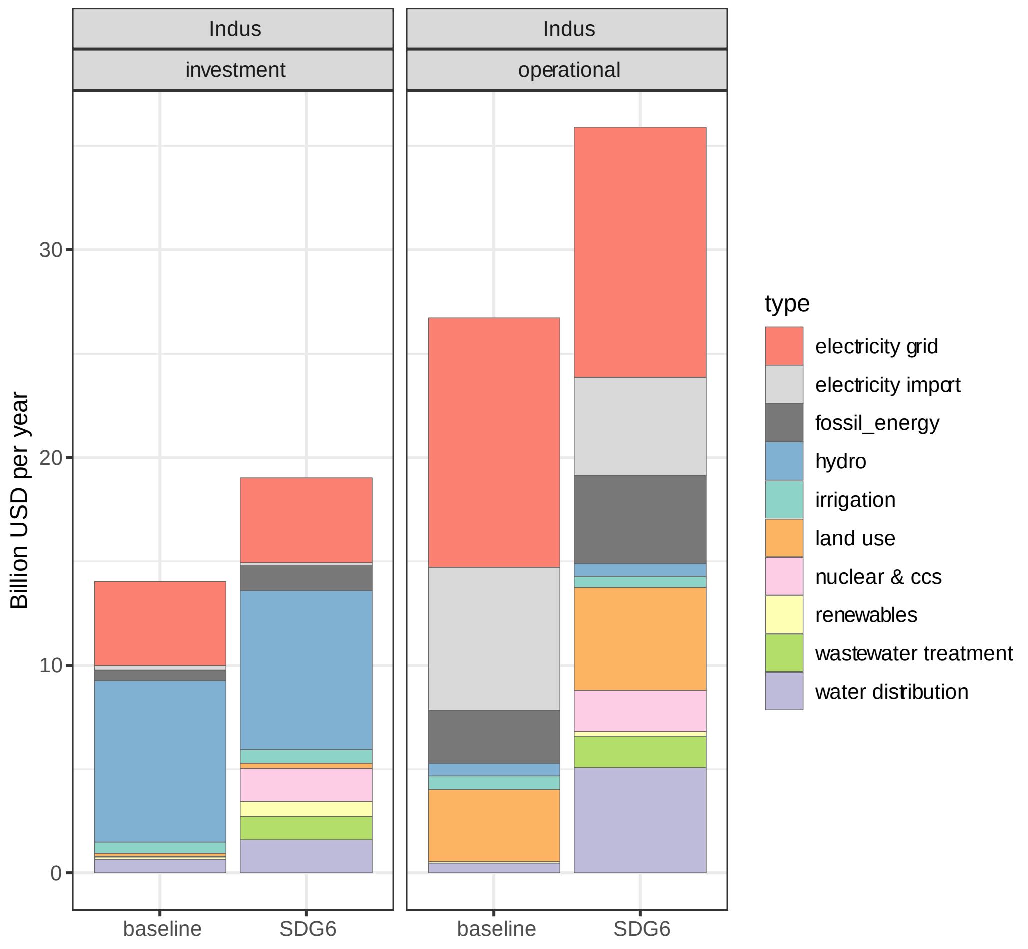
SDG6 (water)

Yearly land allocation for agriculture



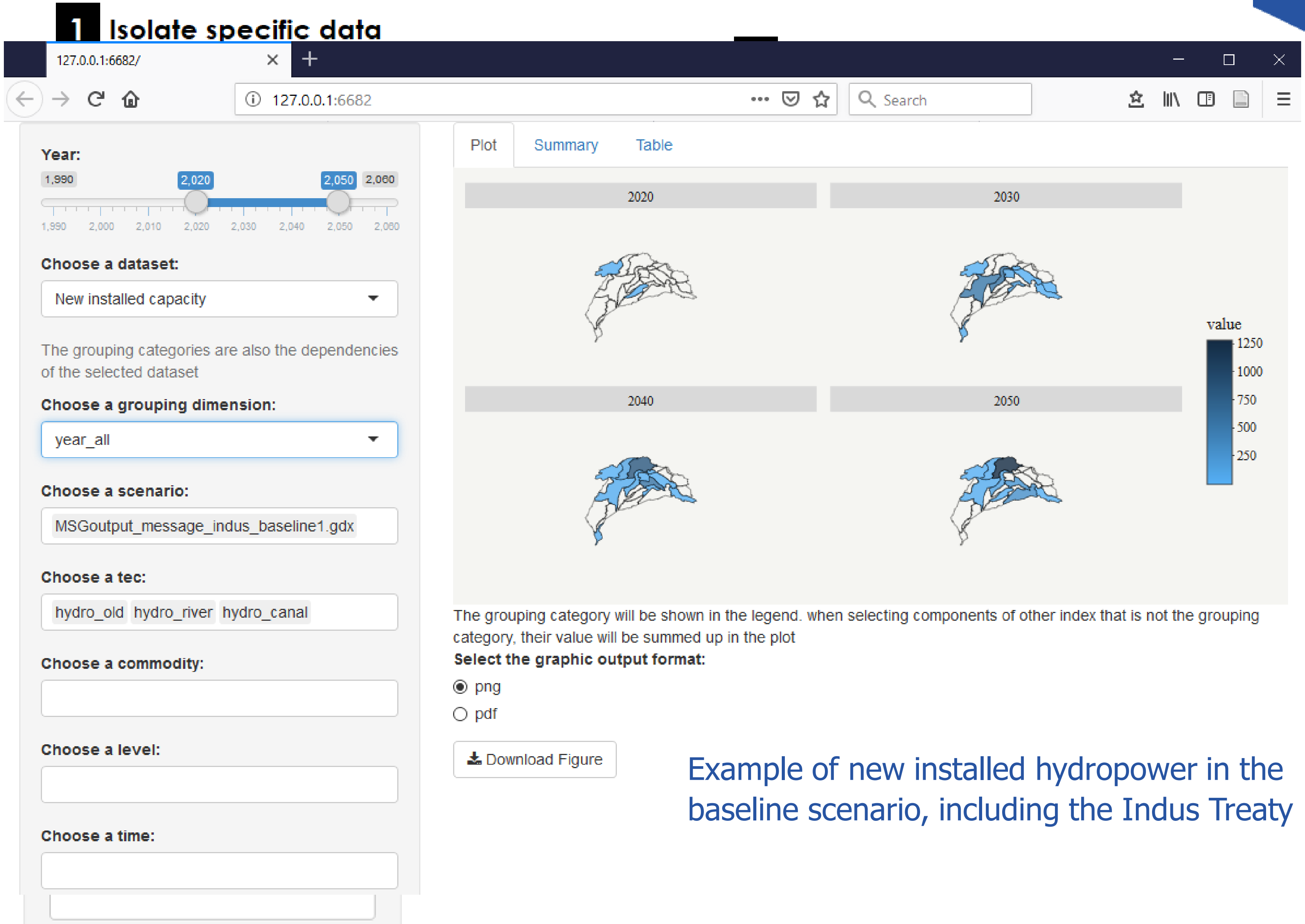
- Less water available for various uses, more groundwater
- Rain-fed agriculture, where land is available
- Land sector more stressed when multiple SDG are achieved (nuclear water consumption)

Average yearly costs for the entire basin



Results explorer dashboard

- High dimensionality of outputs
- Database available for stakeholders
- Compare and explore scenarios:
- Time
- Sub-catchments or country
- Sectors
- Technologies
- Policies & scenarios



Example of new installed hydropower in the baseline scenario, including the Indus Treaty

Conclusions


Indus Valley near Leh, Wikipedia

- Tool to explore future pathways toward cross-sectoral sustainability
- Ready to be applied to other basins (with flexible spatial resolution), by training and building capacity
- Open source and openly documented

SDG insights:

- Environmental flow constraint strongly affect available surface water for energy and agriculture.
- SDG7 and 13 have a clear overlap as mitigation strategy, although different costs and advantages
- Rain-fed agriculture to adapt to water scarcity, more efficient irrigation technologies when the available land is limited.

Next steps:

- Re-discussing critical assumptions with stakeholders (i.e. groundwater, environmental flows, demand projections)
- Multi-criteria optimization
- exploring different scenarios and questions:
  national interests, reservoir expansion, hydropower

An integrated modeling framework for assessing water-energy-food nexus solutions: Application to the Zambezi transboundary river basin

Michiel van Dijk
Ecosystems Services and Management (ESM), IIASA

ISWEL UNIDO meeting, 16 April, 2019

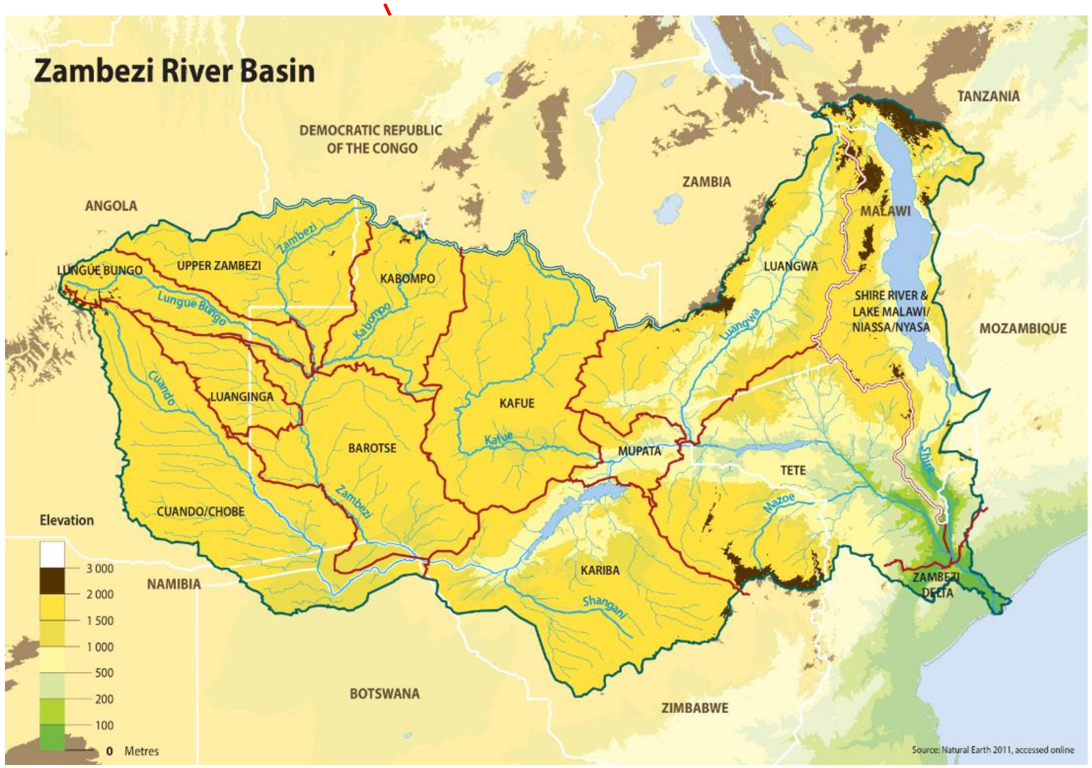
With input from the
ISWEL ZAMBEZI team

Study area: Zambezi Basin

- One of the largest river basins in Africa, covering an area of 1.4 million km^2 and home to around 40 million people.
- A transboundary basin spanning over eight countries and 21 subbasins.
- Existing governance structure: ZAMCOM
- Growing population and economy
- Considerable potential for agriculture and hydropower development

ZAMCOM

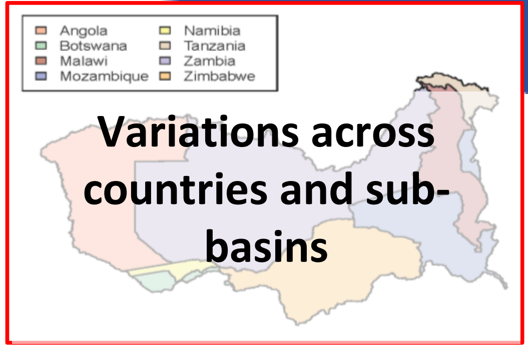
win-win cooperation / cooperacao, ganhas tu, ganho eu

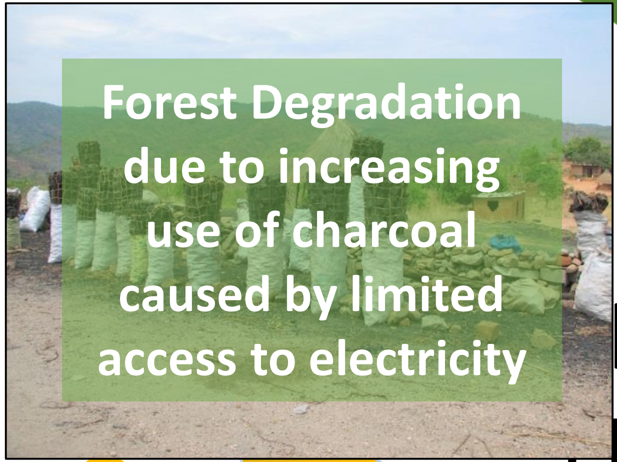


Zambezi nexus:

Literature review & stakeholder input

Food/Land Use System

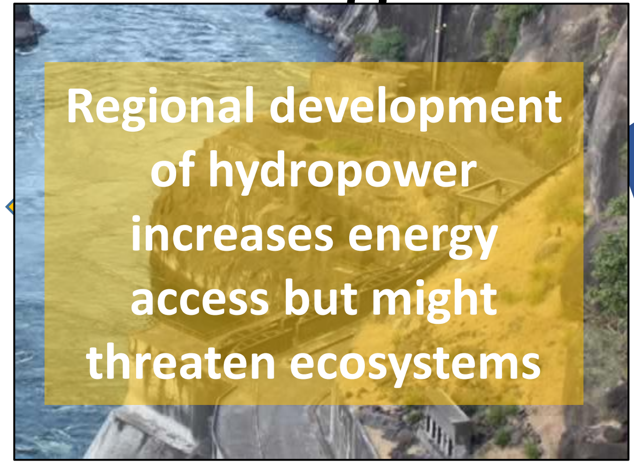




limat

change

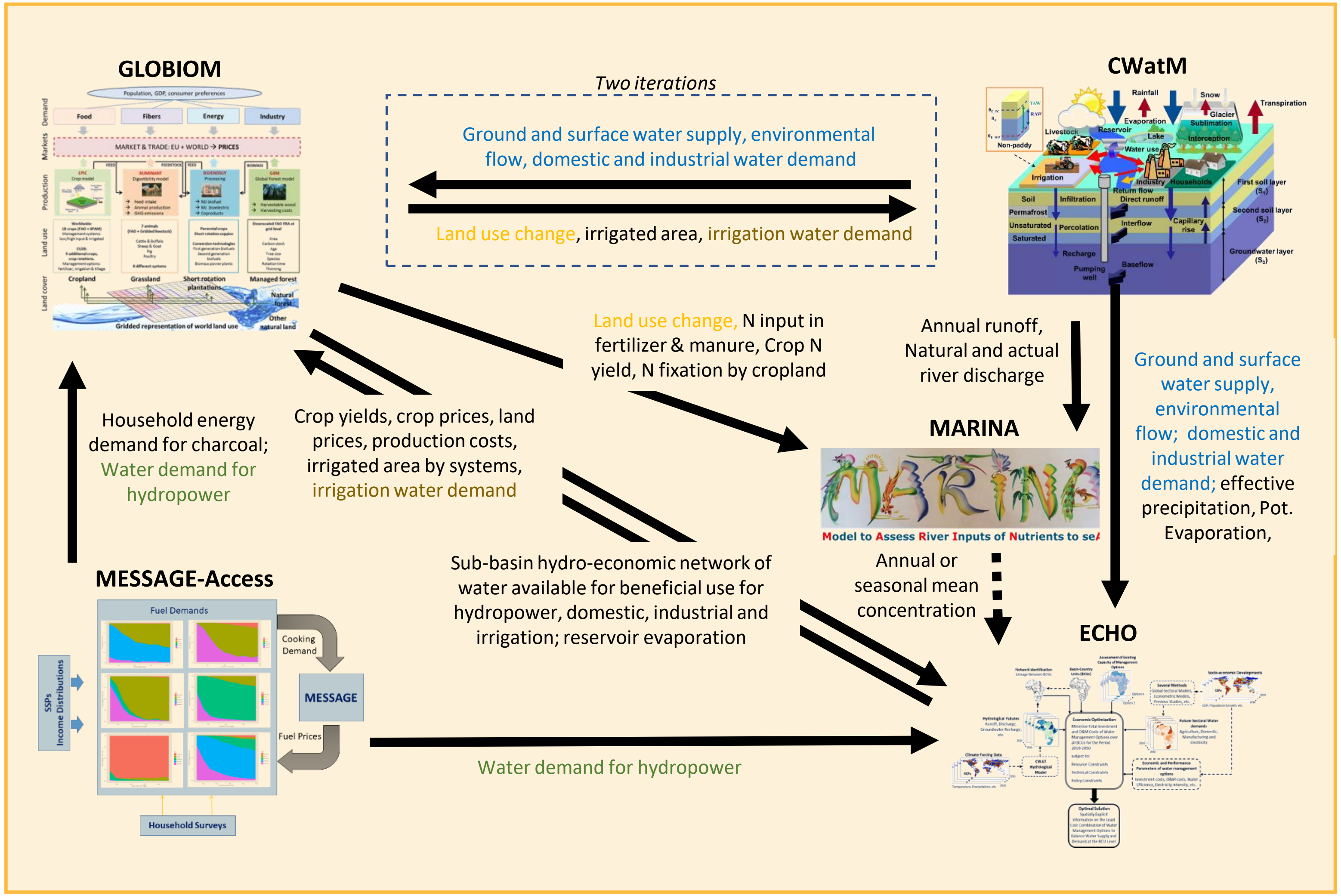
Energy System



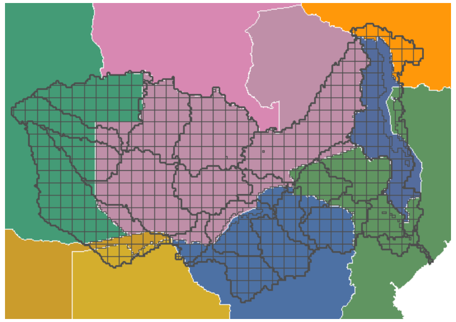
Water System

Nexus Assessment Modeling Framework

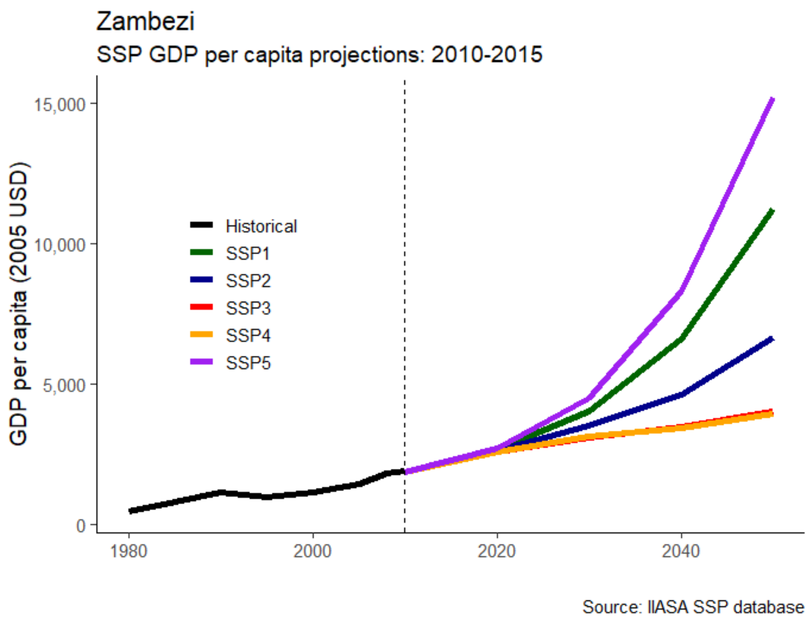
Harmonized input data
Scenario assumptions (e.g. population and GDP growth) and base year data (e.g. subbasin and land use maps)



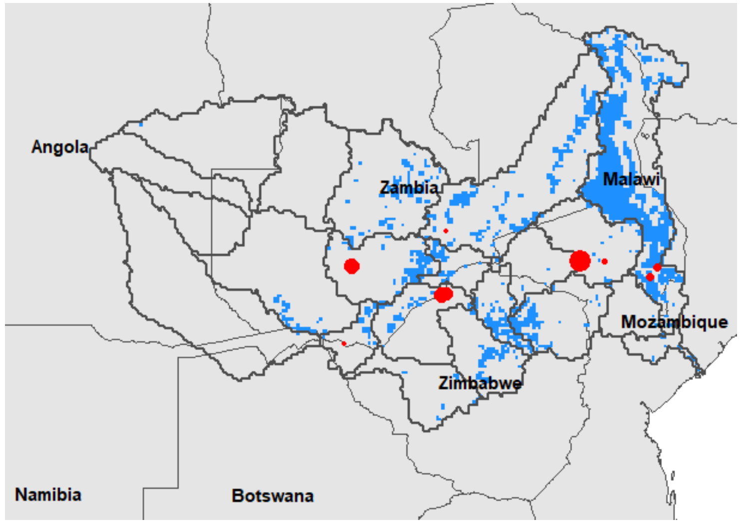
NEXUS scenario outcomes
Energy, water and land pathways and ecosystem indicators



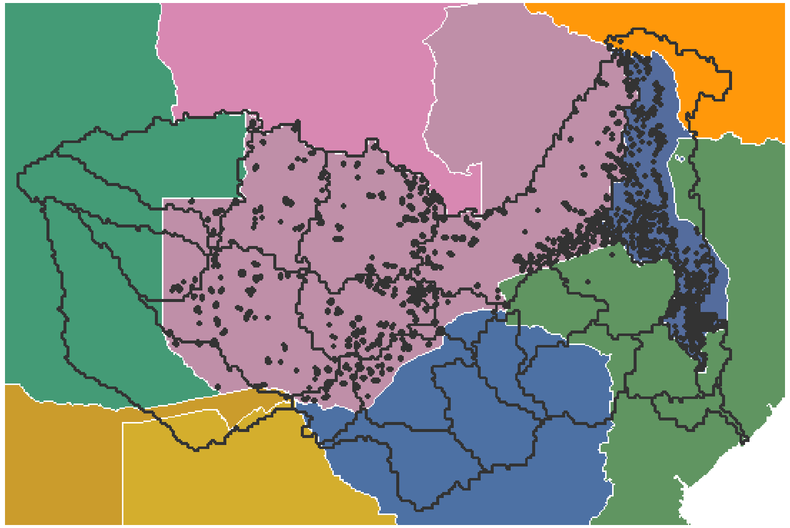
Using regional data sources

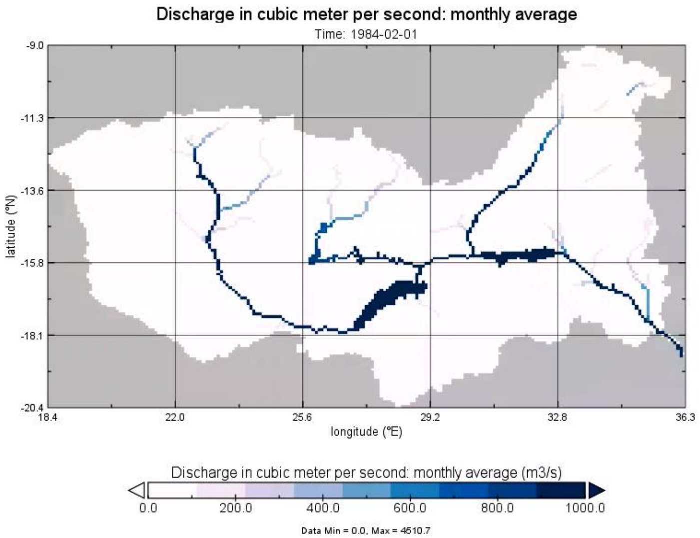


Irrigation and hydropower



Household surveys





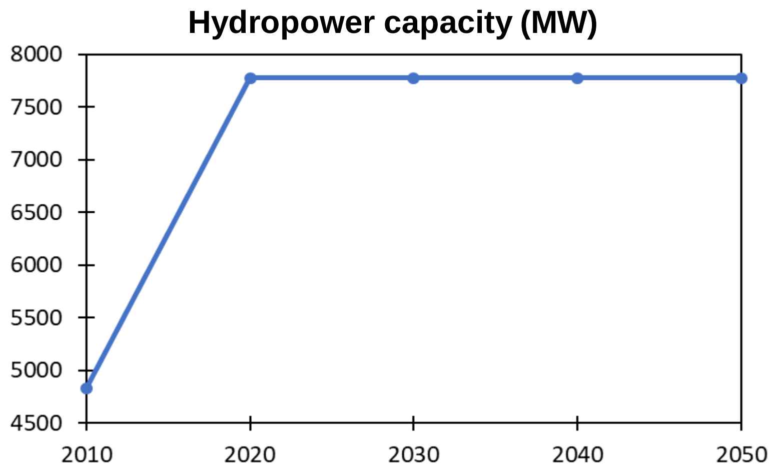
Scenario analysis preliminary

1. Business As Usual (**BAU**): SSP2+RCP4.5 (hydropower capacity and irrigated area are fixed at 2010 level)

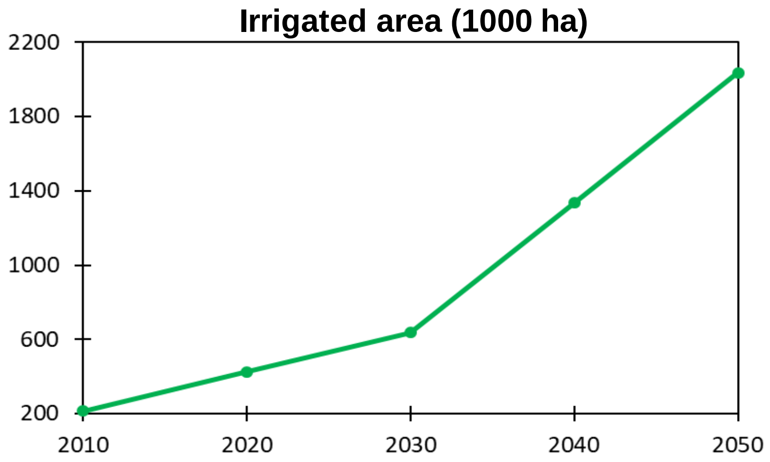
2. Hydropower expansion (**HP**) (from 4,870 in 2010 to 7,780 MW in 2020-2050)

3. Hydropower and irrigation expansion (**HP+IR**) (from 215,000 in 2010 to 600,000 in 2030 (planned), and 2 Mha in 2050 (potential))

4. Hydropower and irrigation expansion under reduced water availability of 10% (**HP+IR+CC**)

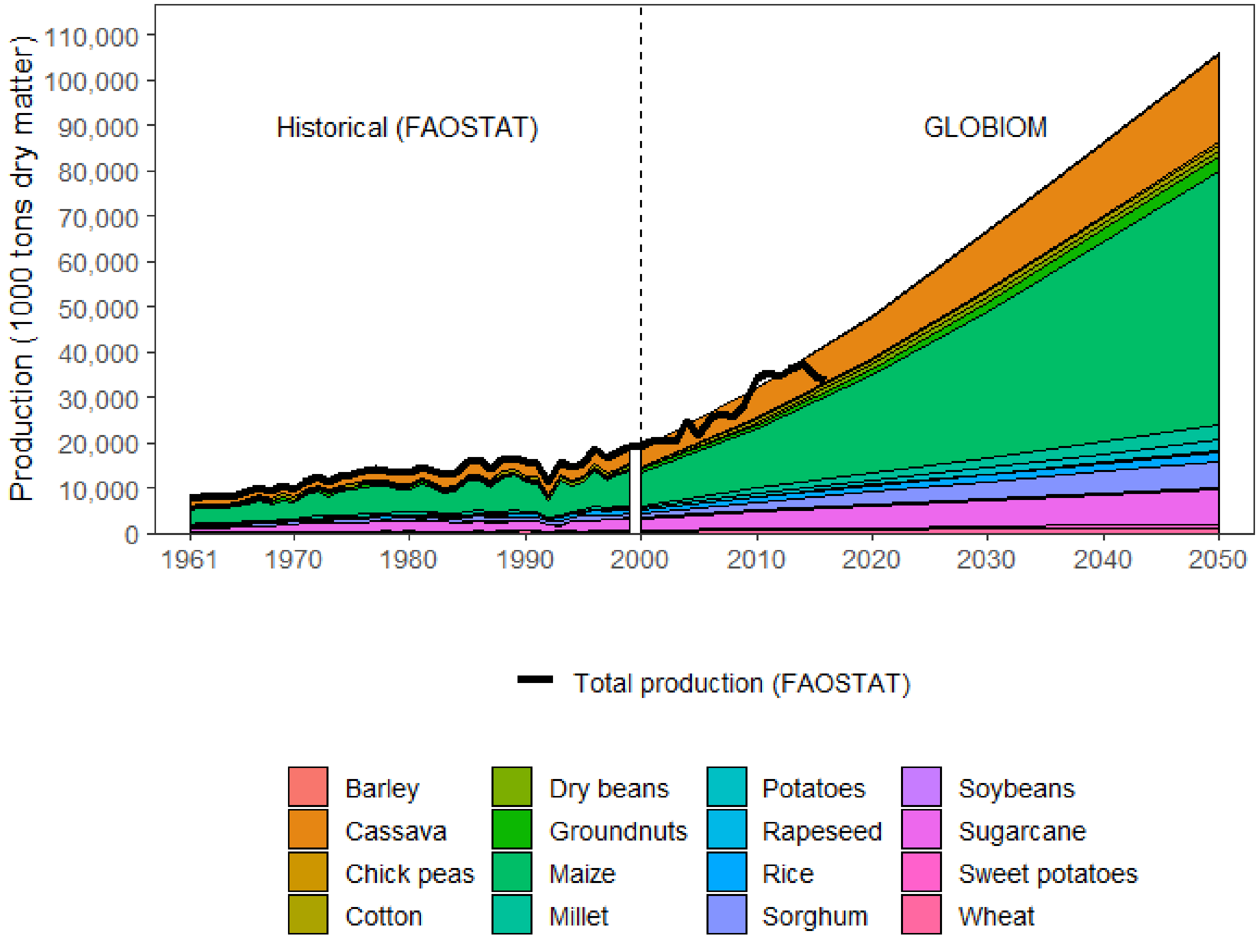


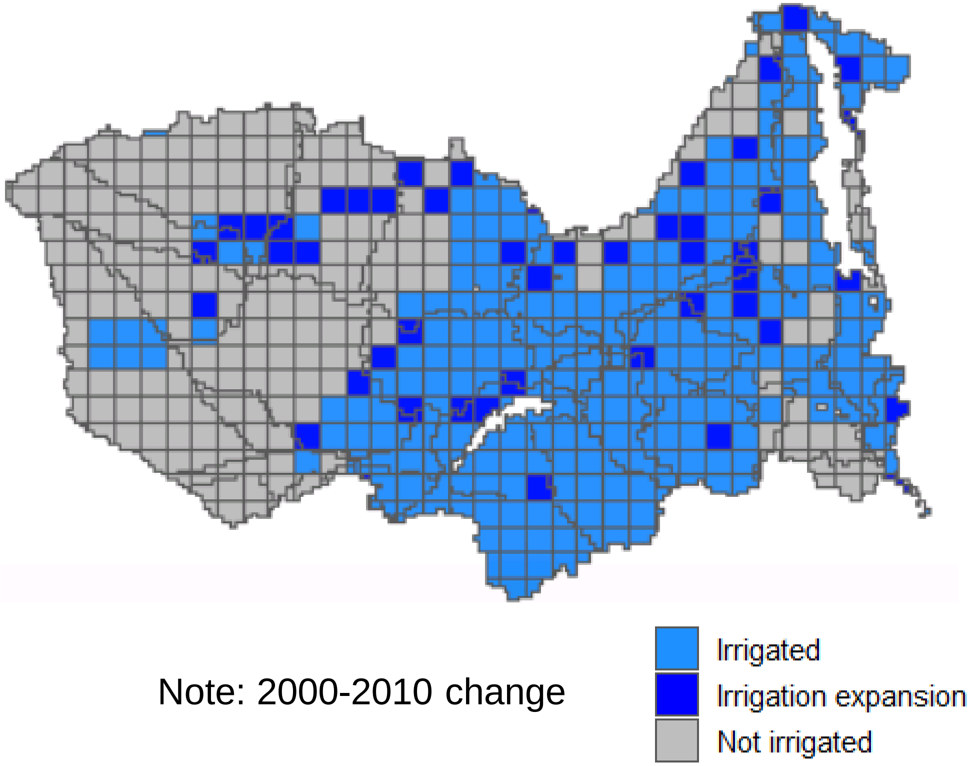
Source: FHReD, Zarfl et al. 2015



Source: MSIOA, World Bank 2010

Preliminary results for BAU: Crop production and irrigated area

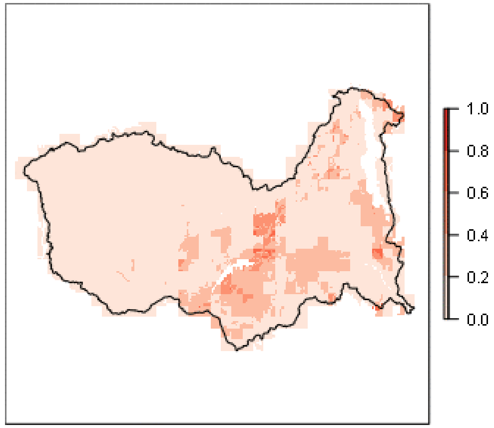




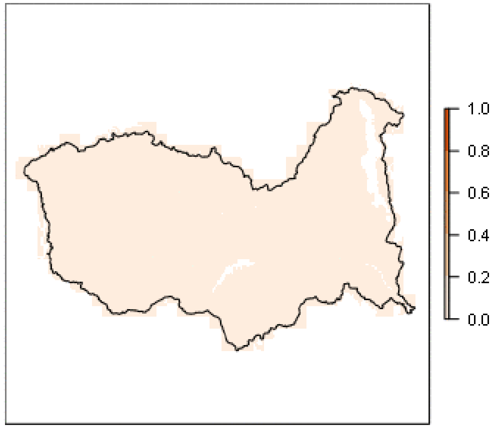
Note: 2000-2010 change

Preliminary results for BAU: Land use change

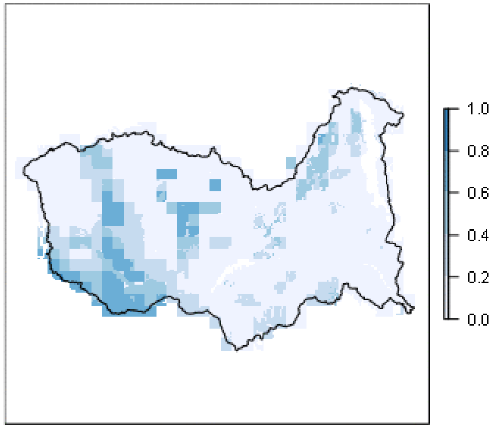
Cropland



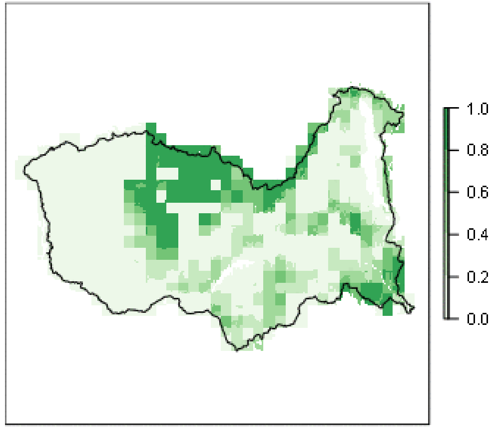
Short rotation Plantations



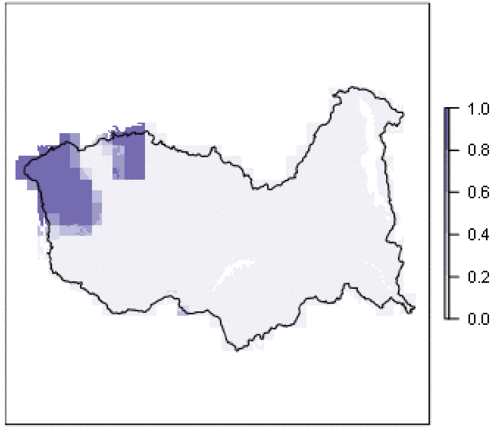
Grassland



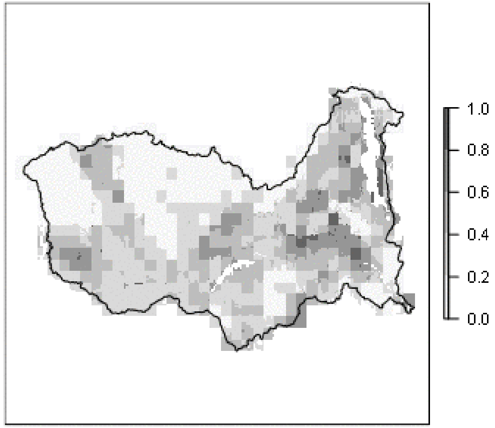
Primary Forest



Managed Forest

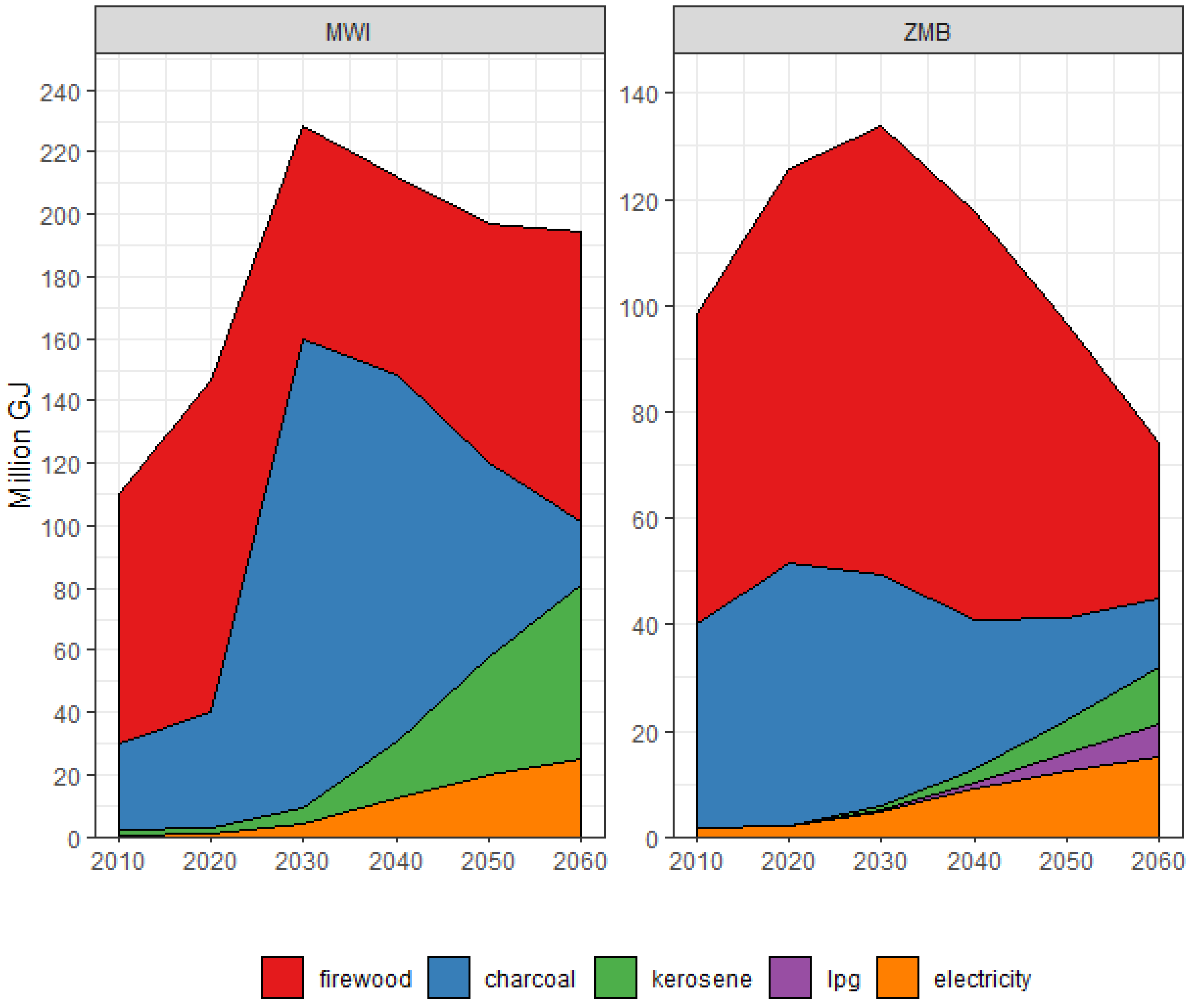


Other natural land

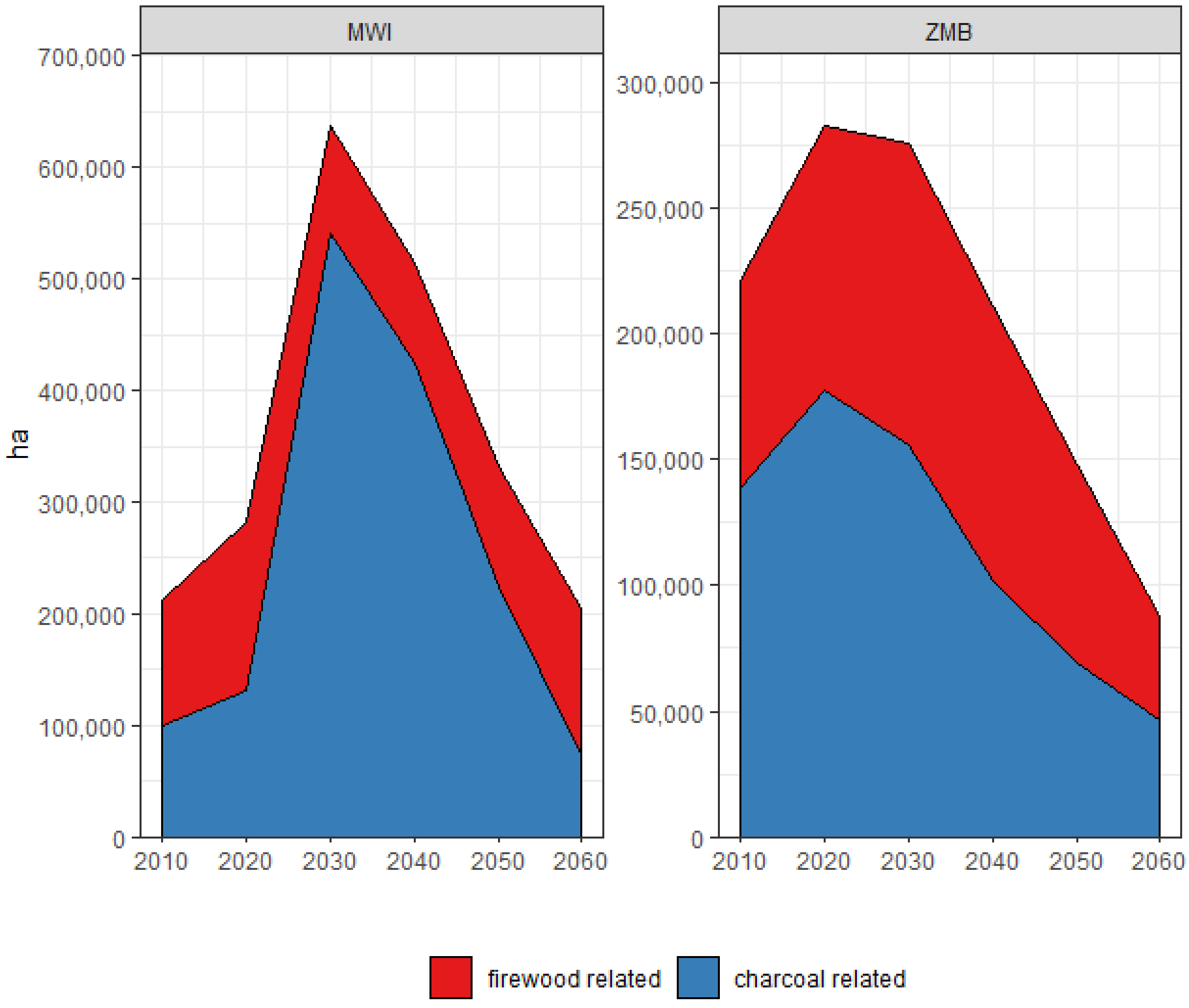


Preliminary results for BAU: Household energy demand and forest area eq.

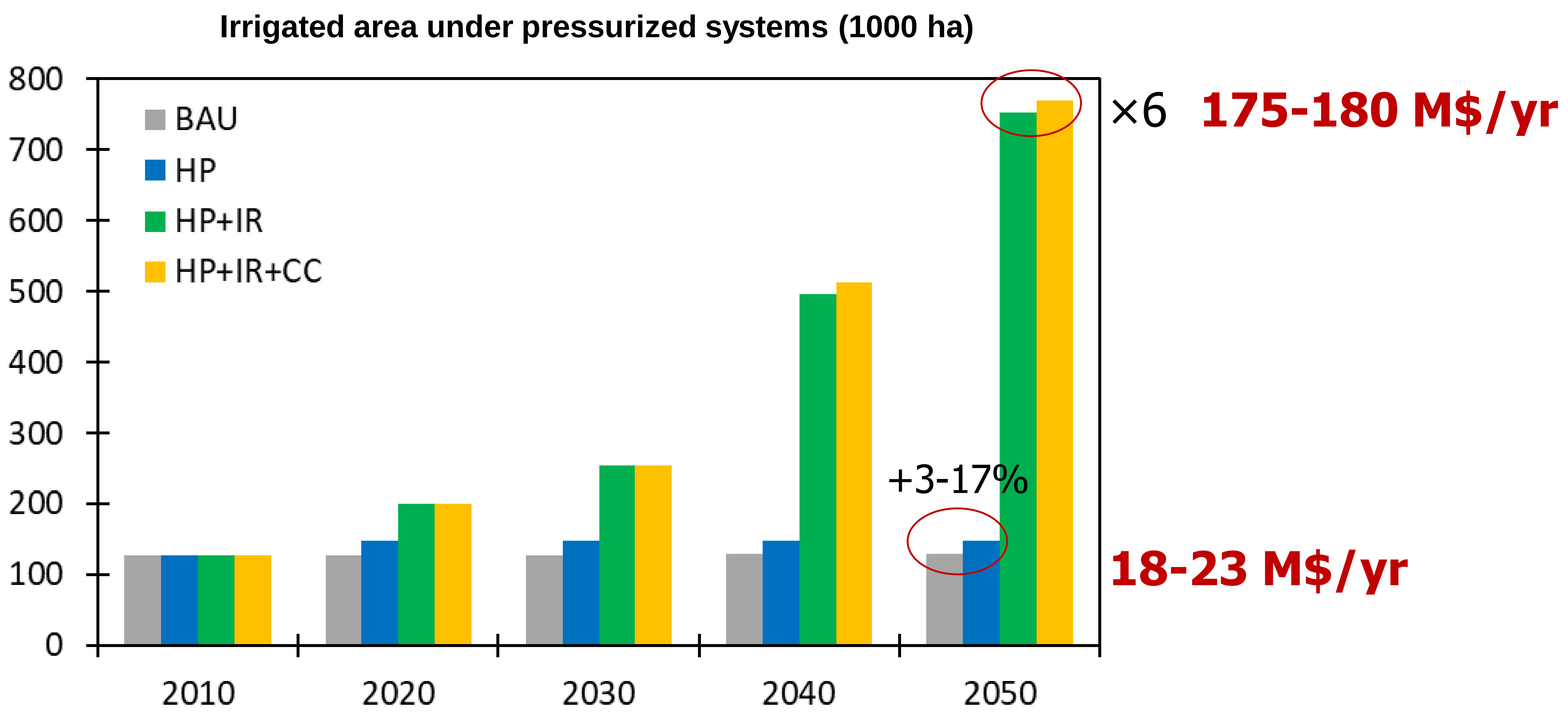
Household energy demand projections (GJ)



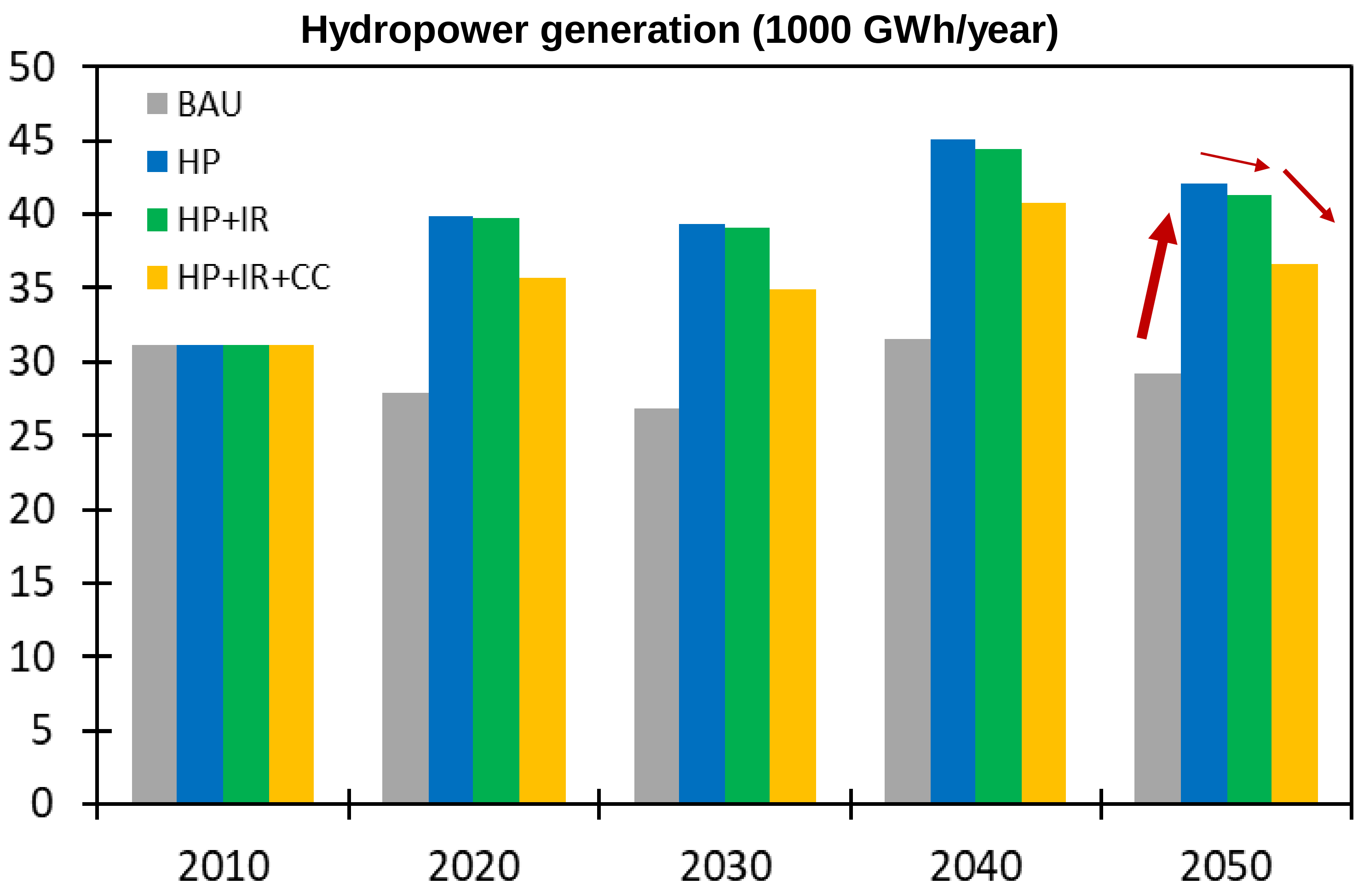
Forest area equivalent (ha)



Preliminary Results
Irrigated area expansion and investment costs



Preliminary Results
Hydropower production



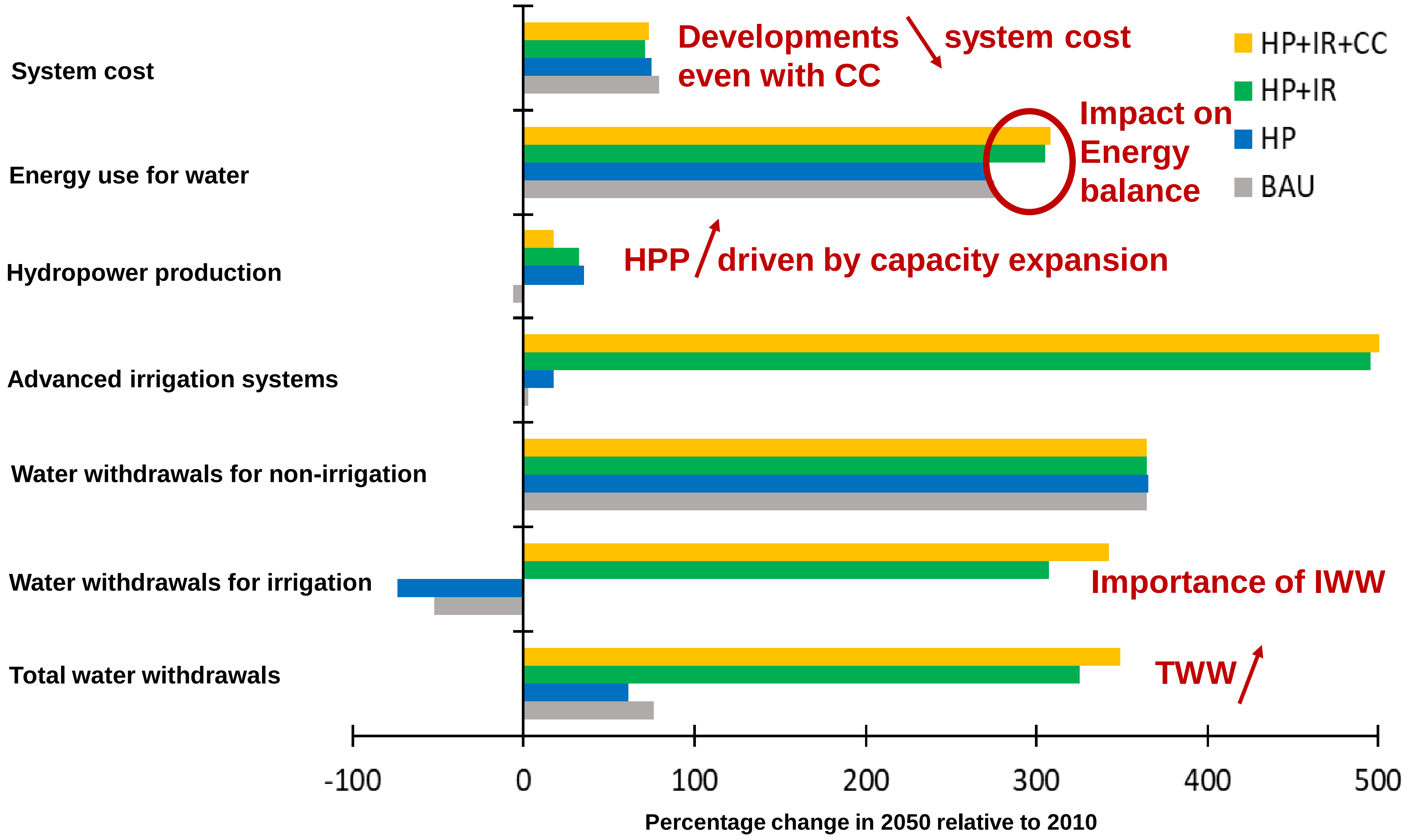
HP: +43:46%
+12,000:13,500 GWh/yr (≈ electricity consumption of Slovenia or Zambia)

HP+IR: -1:2%
-180:780 GWh/yr

HP+IR+CC: -8:11%
-3500:4700 GWh/yr

The impact on HPP of a drier climate is much stronger than irrigation expansion

Scenario results show tradeoffs and synergies that decision-makers have to consider



Next steps

- Run scenarios using fully integrated model framework
- Incorporate stakeholder scenarios and present at event (end of May)
- Address ‘other’ nexus elements
  - charcoal-deforestation/forest degradation
  - Hydropower-ecosystems
- Make results available to stakeholders by means of graphical user interface
- Prepare policy briefs with key results

Thanks