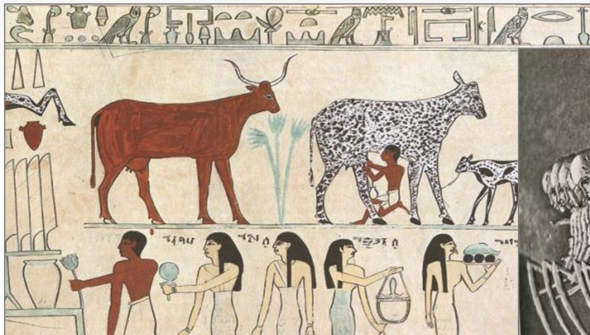
Toward Enhanced Climate Resilience in Water Resources

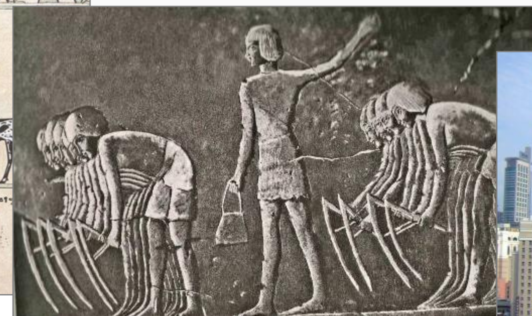
Preliminary results of simulation studies conducted under ADB TA 9191: Building Climate Resilience in Asia's Critical Infrastructure, EWSIP National Workshop, Jakarta October 9-10 2017

Outline of the Presentation

- Climate change impacts in Indonesia – What are we concerned about?
- Objectives of climate risk management in project planning/design
- Climate risk management in EWSIP at country- and basin-scales
- Recommendations for use of climate risk management in future planning/design cycles

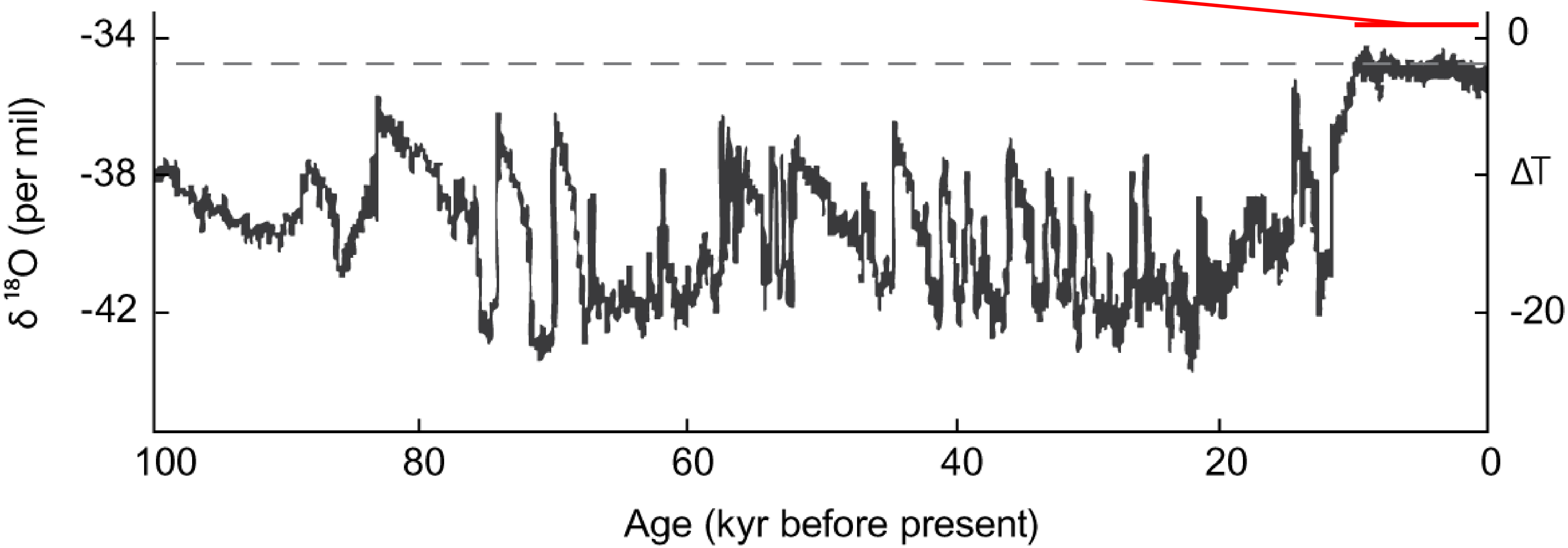
Climate Risk – What Are We Concerned About?



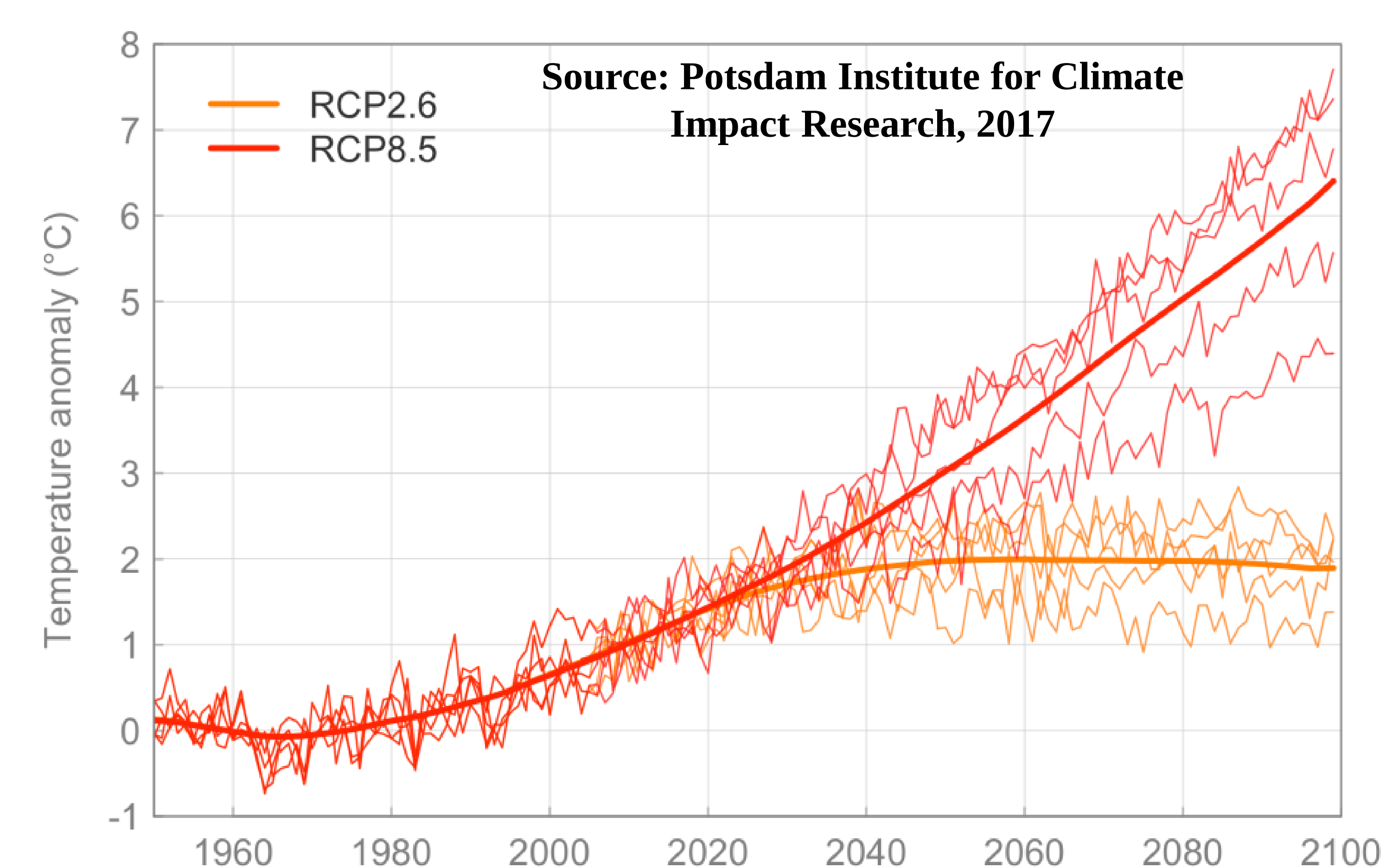


World Population (2020) ~ 7.75 Billion

World Population (10,000 BCE) ~ < 10 Million



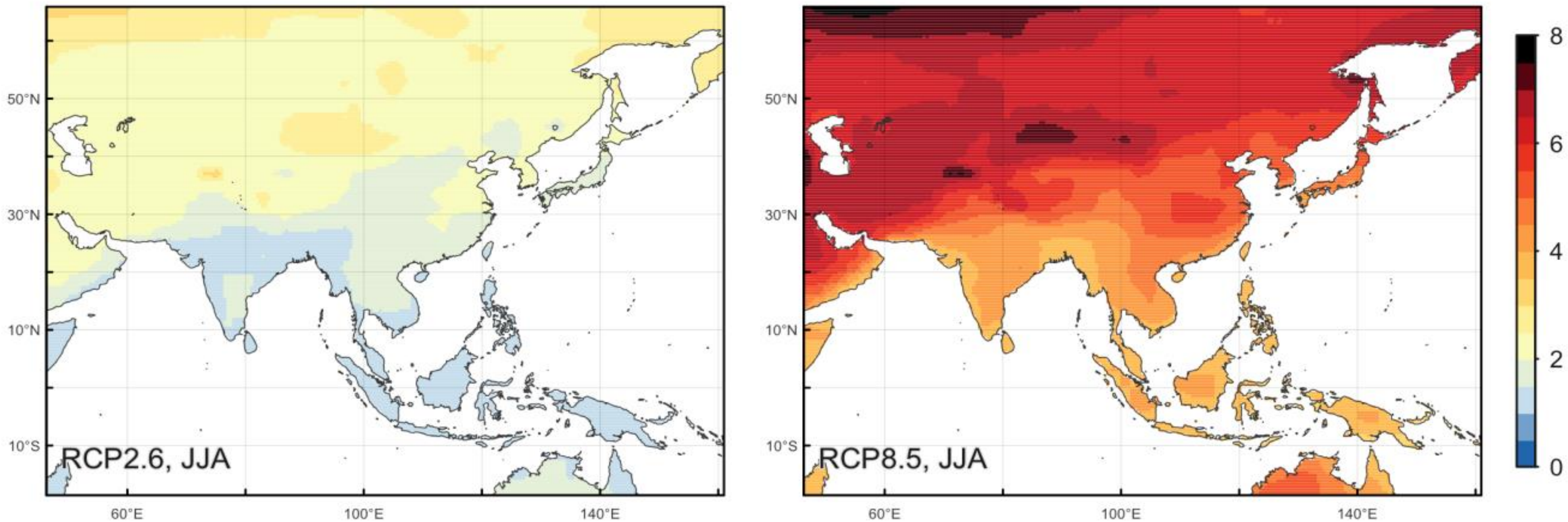
Primary Impact – Rising Temperatures



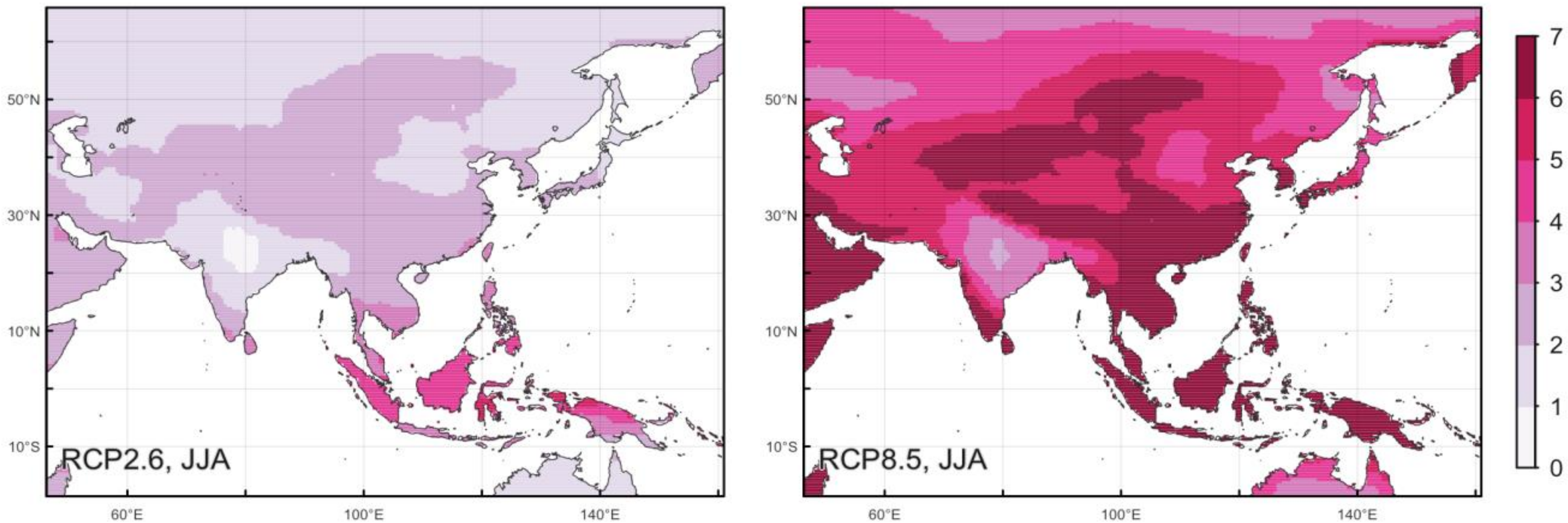
	2030	2050	2070	2100
RCP2.6 **Paris-Path**	**1.6°C** (1.0°C – 2.4°C)	**1.9°C** (1.1°C – 2.7°C)	**2.0°C** (1.1°C – 2.8°C)	**1.9°C** (1.0°C – 2.6°C)
RCP8.5 **BAU**	**1.7°C** (0.7°C – 2.4°C)	**2.7°C** (1.5°C – 3.9°C)	**4.0°C** (2.5°C – 5.5°C)	**6.0°C** (3.9°C – 7.7°C)

Multimodel Average Temperature Anomaly in June–August

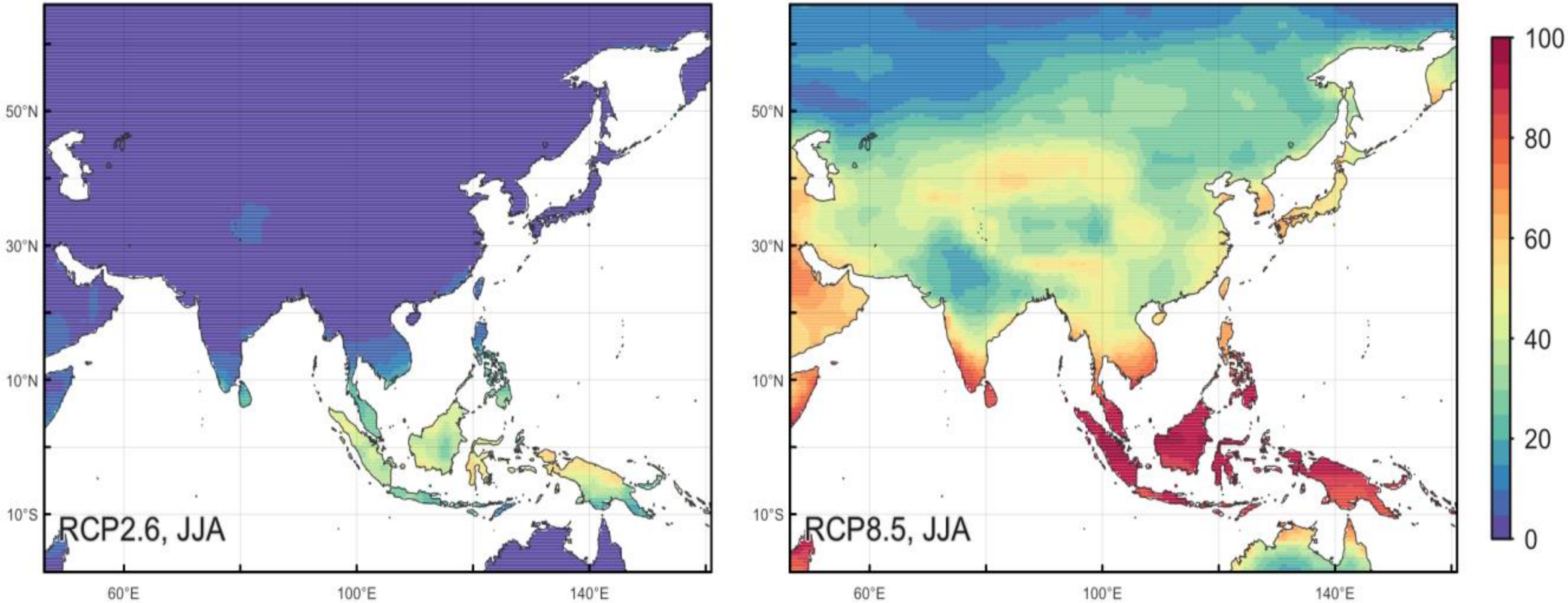
(Upper Panels: ºC, Lower Panels: Sigma; 2071-2099)



Source: Potsdam Institute for Climate Impact Research, 2017

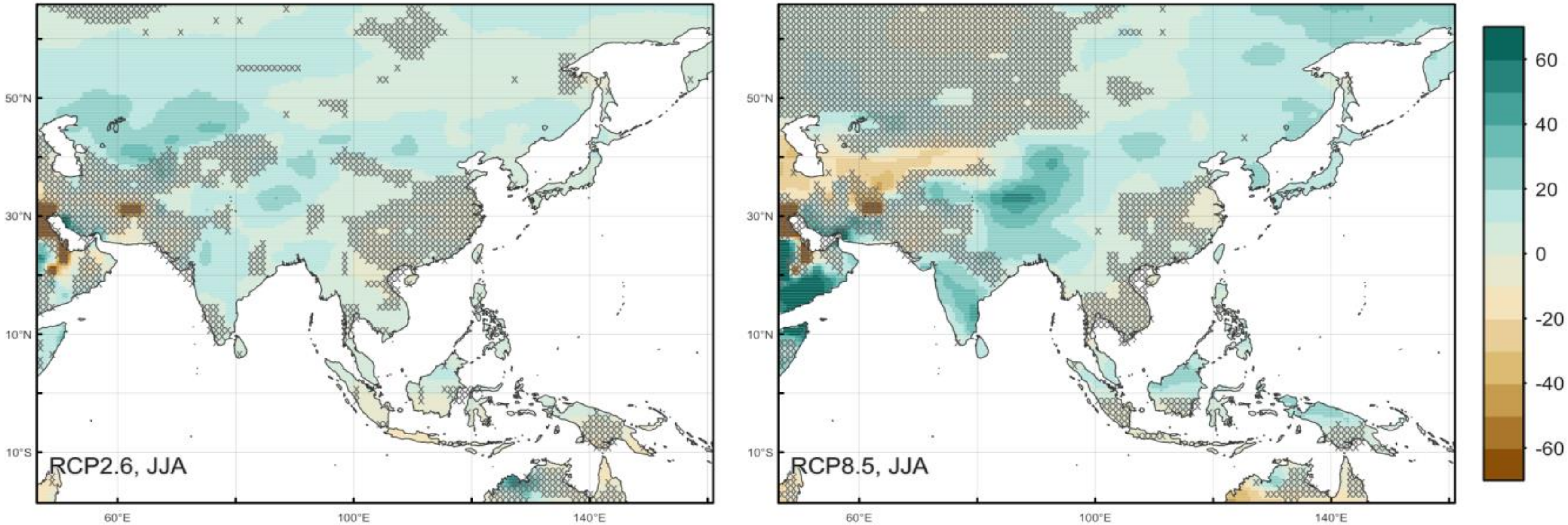


Projected Frequency of Heat Extremes – 5 Sigma Events
(Percentage of Months, 2071-2099)

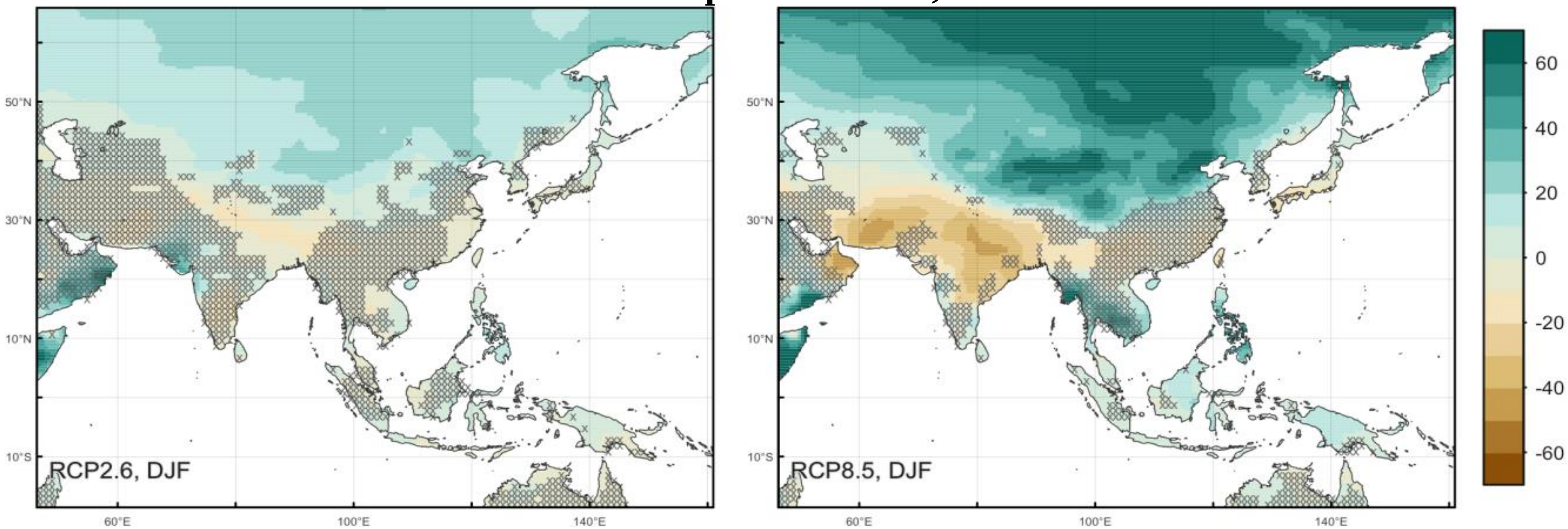


Source: Potsdam Institute for Climate Impact Research, 2017

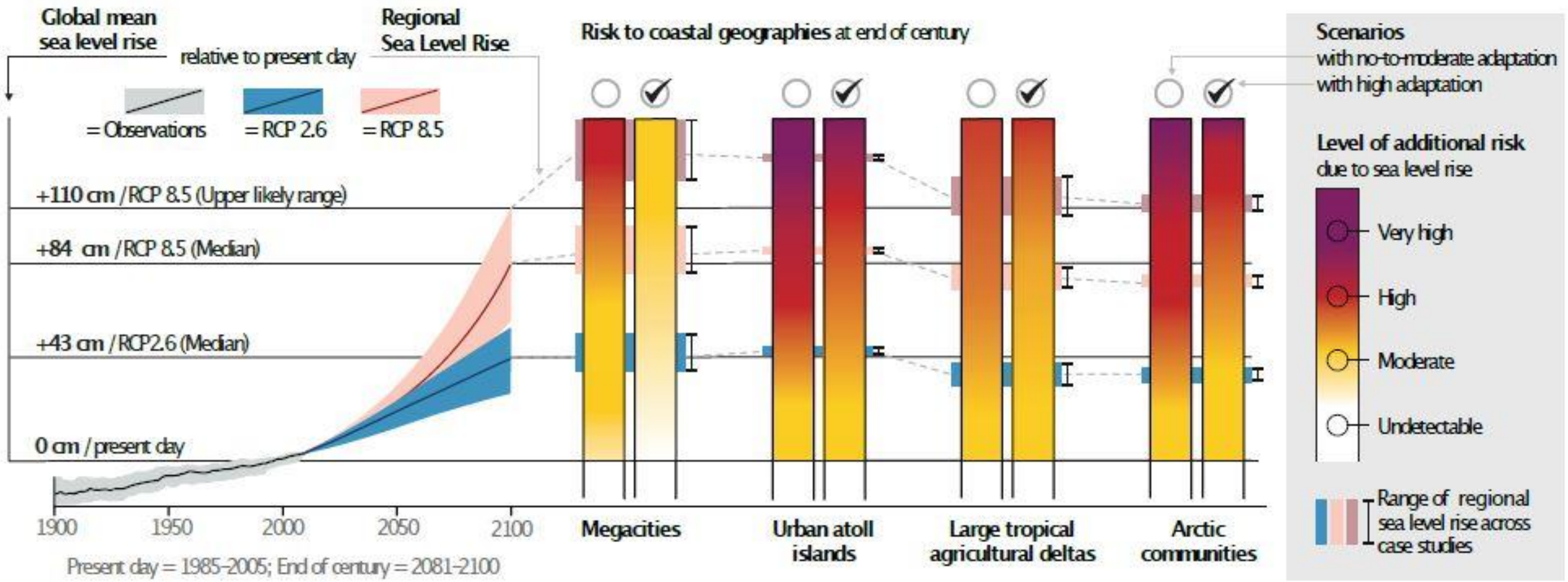
Projected Change in Precipitation
(Percent change relative to historical, 2071-2099)



Source: Potsdam Institute for Climate Impact Research, 2017



Additional risk related to sea level rise for low-lying coastal areas by the end of the 21st century



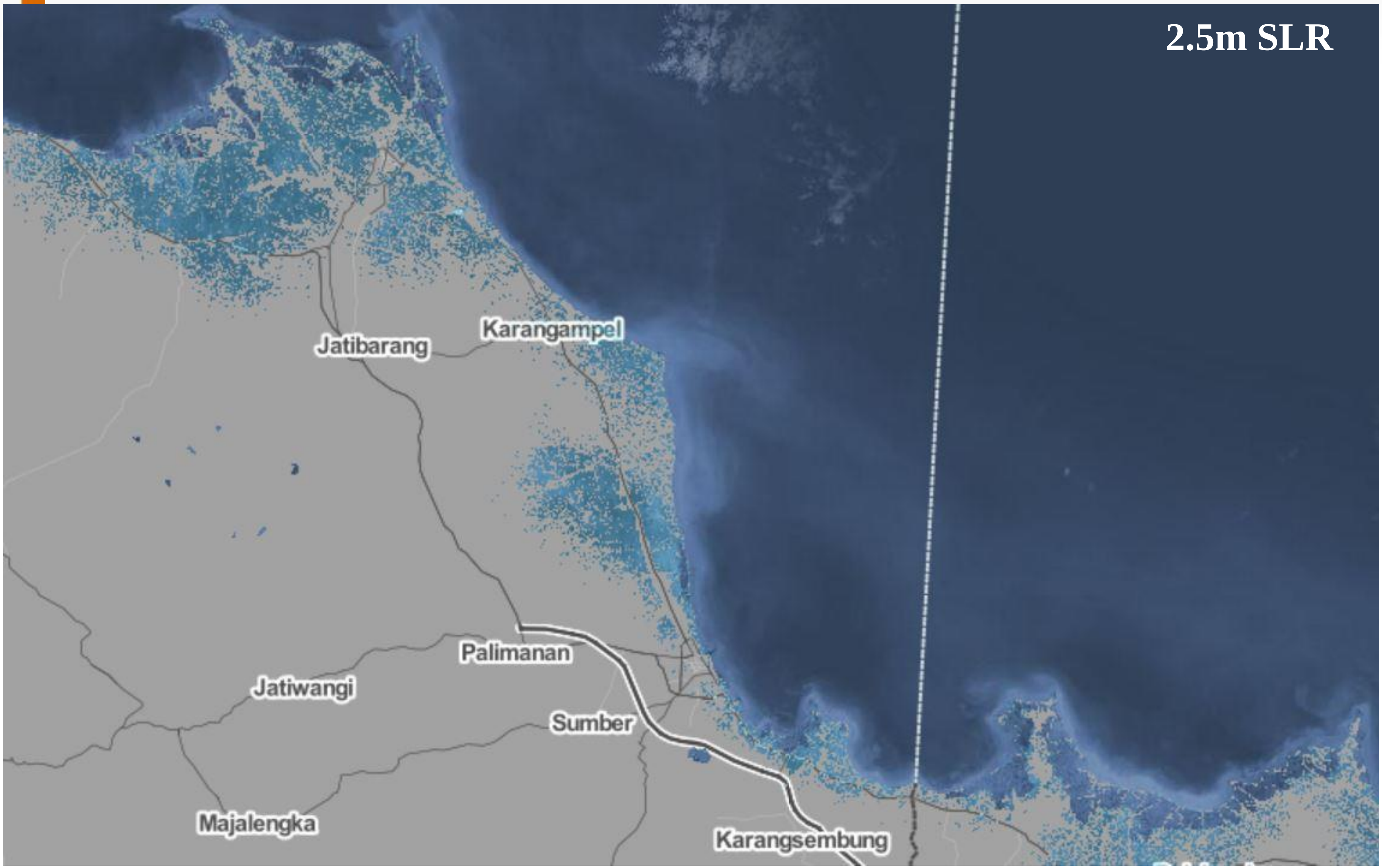
Australian Aid

ADB

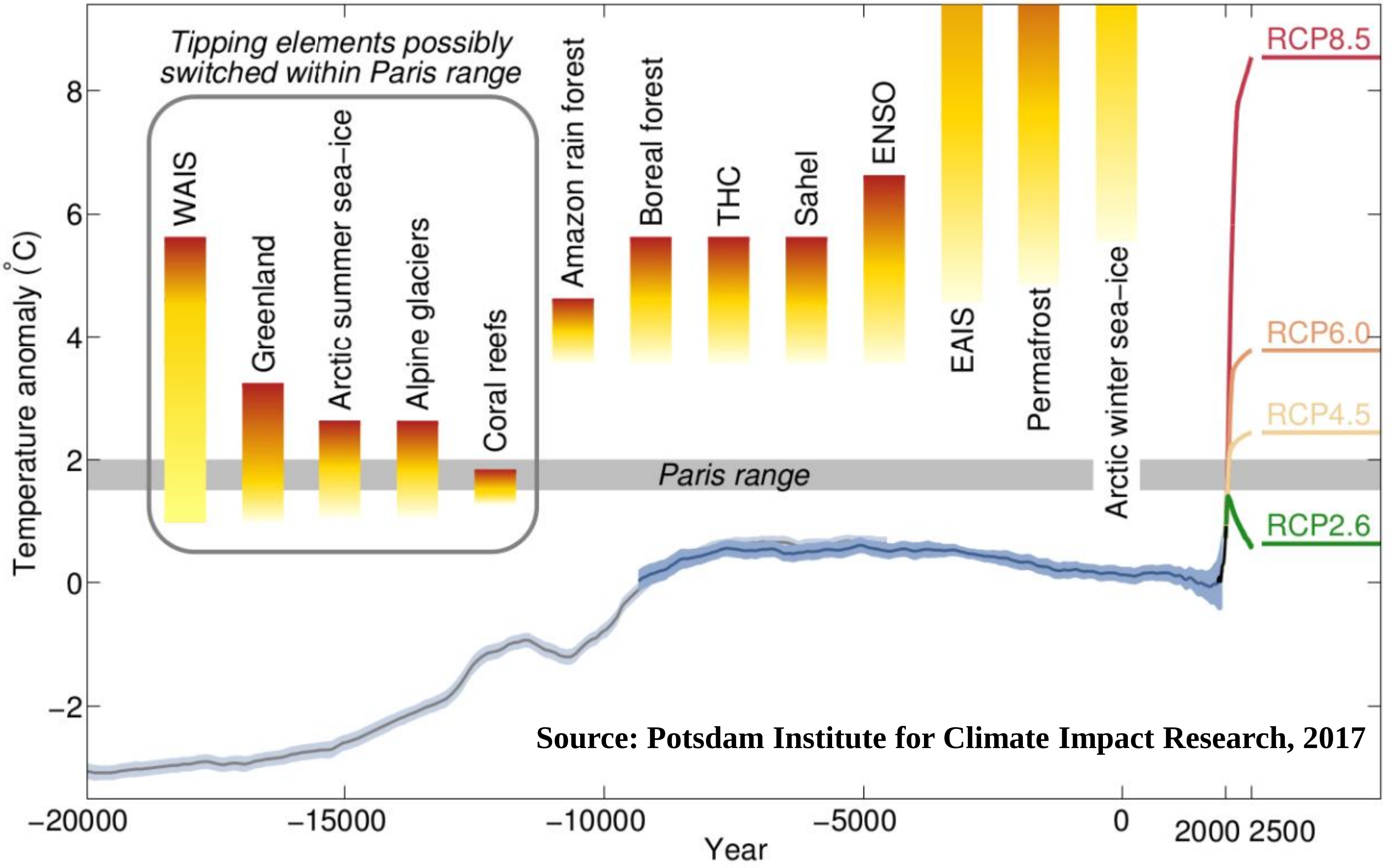
Figure 4.3 IPCC Special Report on the Ocean and Cryosphere, 2019

Surging Seas – N. Cimanuk Basin and SLR

https://ss2.climatecentral.org/



Paris Range, Tipping Points and Destabilization



Source: Potsdam Institute for Climate Impact Research, 2017

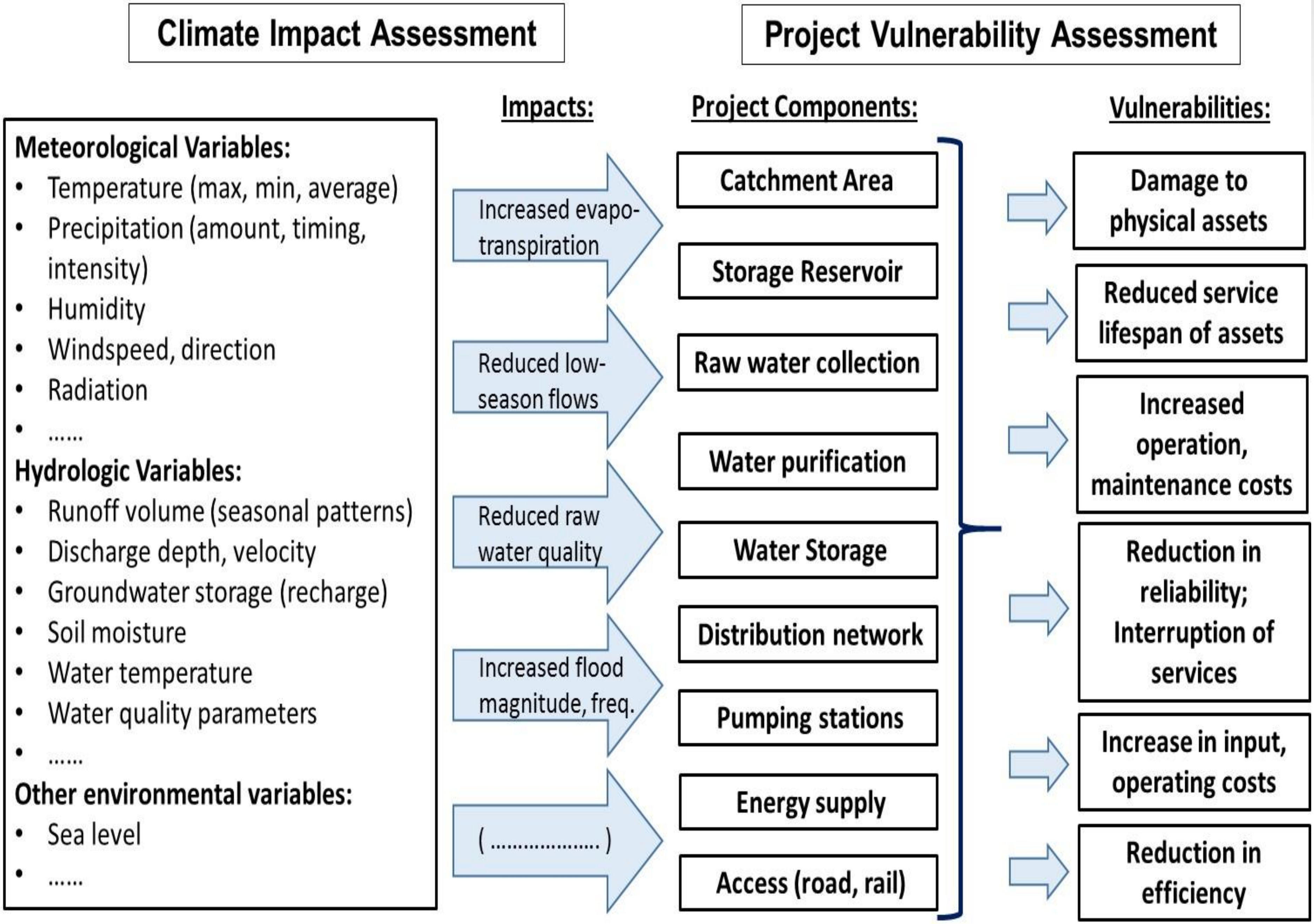
Climate Impacts	Potential Impacts on Water Resources
Sea Level Rise	• Increased saline intrusion into coastal aquifers • Increased salinity of brackish surface water sources
Warmer Temperatures	• Changes in watershed vegetation may alter the recharge into aquifers; and quantity and quality of surface water runoff • Increased evapo-transpiration from surface water, vegetation • Increased biological, chemical degradation of water quality • Increased frequency and/or intensity of drought • Increased risk of wildfire in catchments • Changes in watershed agricultural practices
More Frequent and/or Intense Extreme Weather Events	• Increased turbidity and sedimentation of surface water; accelerated loss of reservoir storage • Changes in rainfall patterns affect groundwater recharge; surface discharge patterns • More frequent, intense flash flooding; infrastructure damage • Increased loading of pathogenic bacteria, parasites • More frequent combined sewer overflows (cso)
Changes in Precipitation	• Possible reductions in surface runoff, manageable water resources • Possible reductions in groundwater recharge, water tables

Objectives of Climate Risk Management in Project Planning and Design

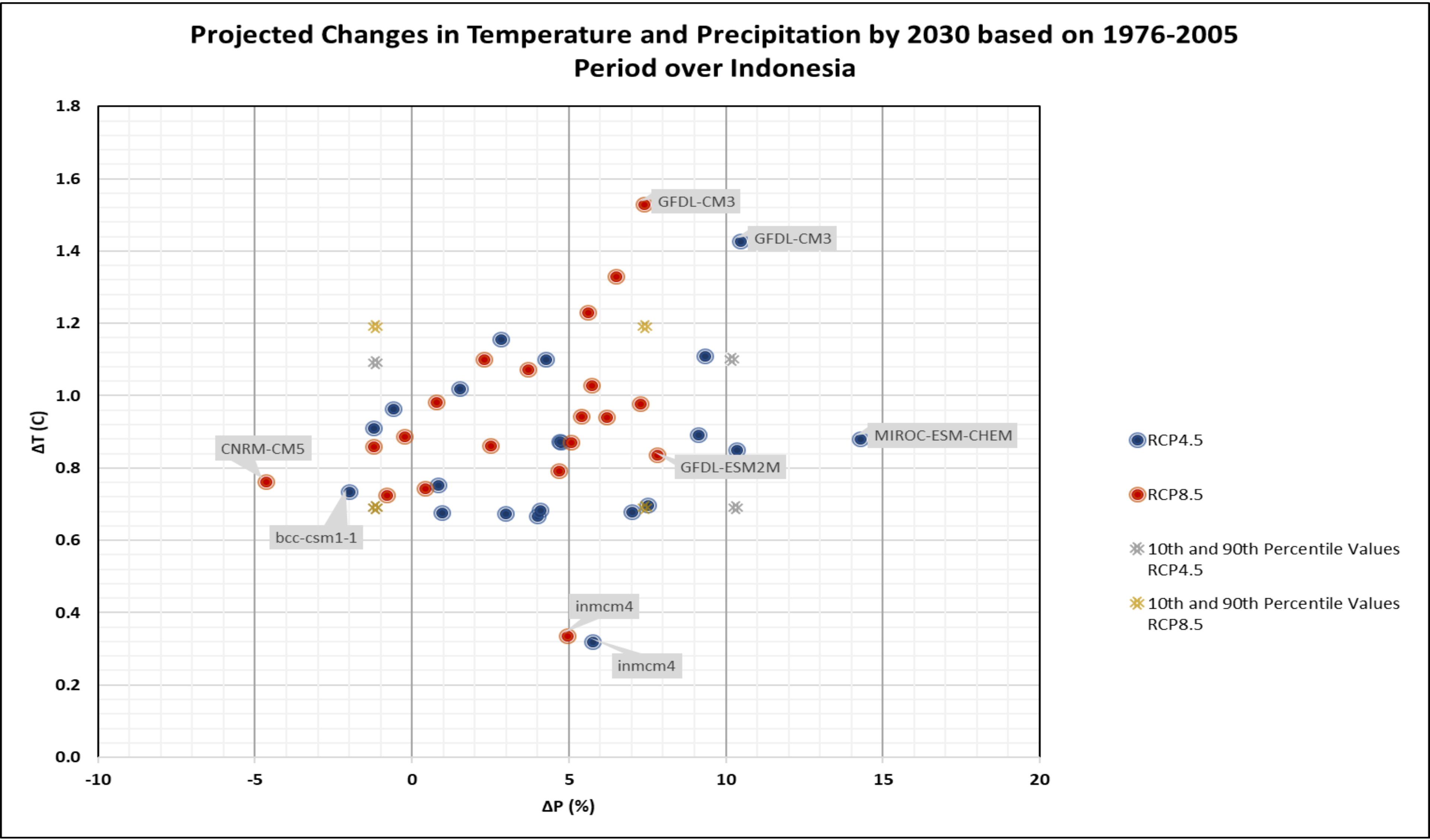
- ***Climate Impact Assessment:*** **how is climate changing and how will natural, human and engineered systems be affected?**
- ***Project Vulnerability Assessment:*** **which aspects of the project (systems, structures, functions) are exposed and sensitive to changes in climatic parameters, and in what ways?**
- ***Assessment of adaptation options:*** **how can we design the project, using both structural ("hard") and management ("soft") approaches, to minimize or manage the risks?**
- ***Adaptive management plan:*** **how do we manage climate risks over the project lifetime? What do we need to do at initial design stage? How can we build in flexibility?**

Australian Aid

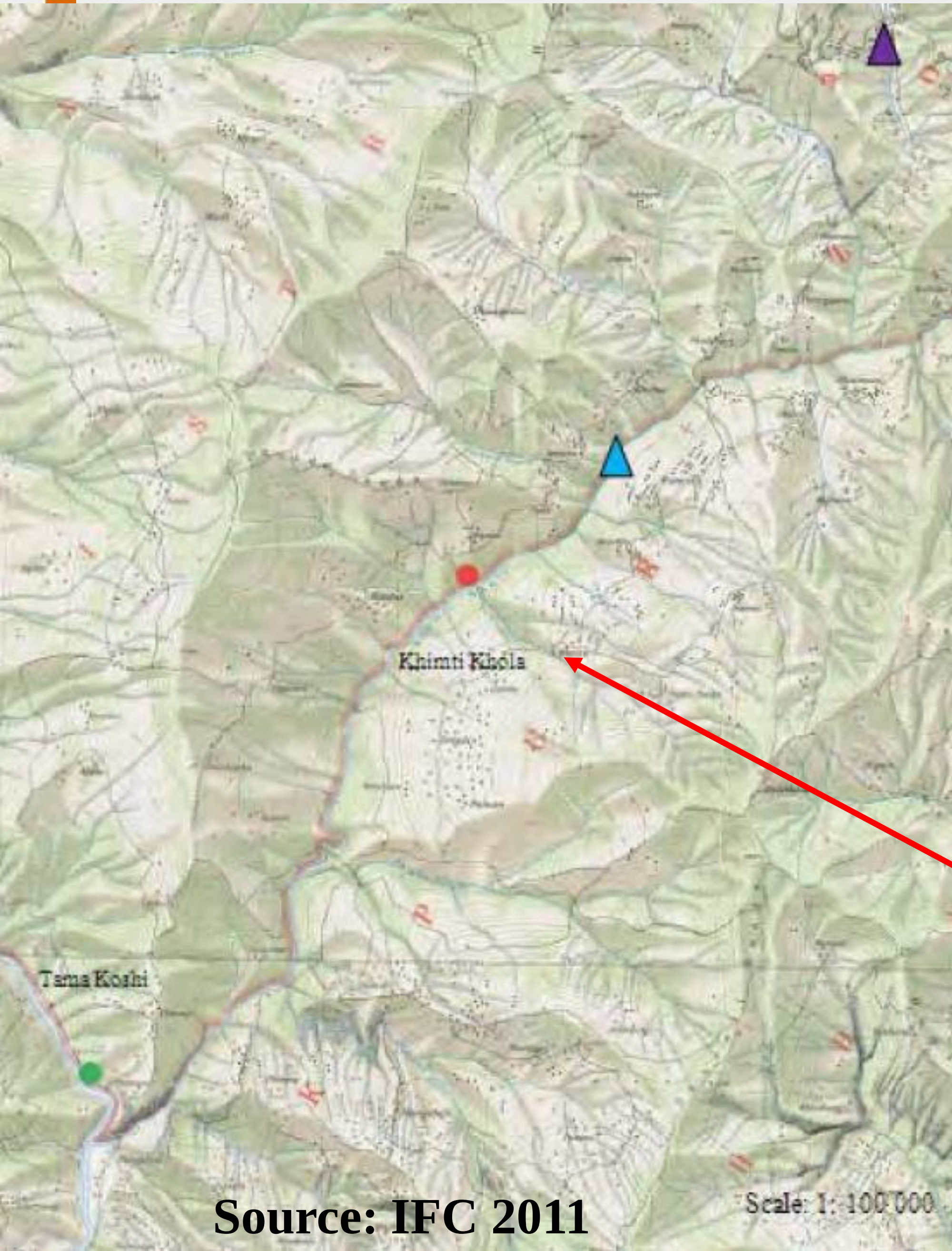
ADB


Climate Impact Assessment
Project Vulnerability Assessment
Meteorological Variables:
Temperature (max, min, average)
Precipitation (amount, timing, intensity)
Humidity
Windspeed, direction
Radiation
……
Hydrologic Variables:
Runoff volume (seasonal patterns)
Discharge depth, velocity
Groundwater storage (recharge)
Soil moisture
Water temperature
Water quality parameters
……
Other environmental variables:
Sea level
……
Impacts:
Increased evapo-transpiration
Reduced low-season flows
Reduced raw water quality
Increased flood magnitude, freq.
(………………..)
Project Components:
Catchment Area
Storage Reservoir
Raw water collection
Water purification
Water Storage
Distribution network
Pumping stations
Energy supply
Access (road, rail)
Vulnerabilities:
Damage to physical assets
Reduced service lifespan of assets
Increased operation, maintenance costs
Reduction in reliability; Interruption of services
Increase in input, operating costs
Reduction in efficiency

Climate Impact Assessment: Ensemble of Models approach



Case Study: Run-of-River Hydropower (NEP)

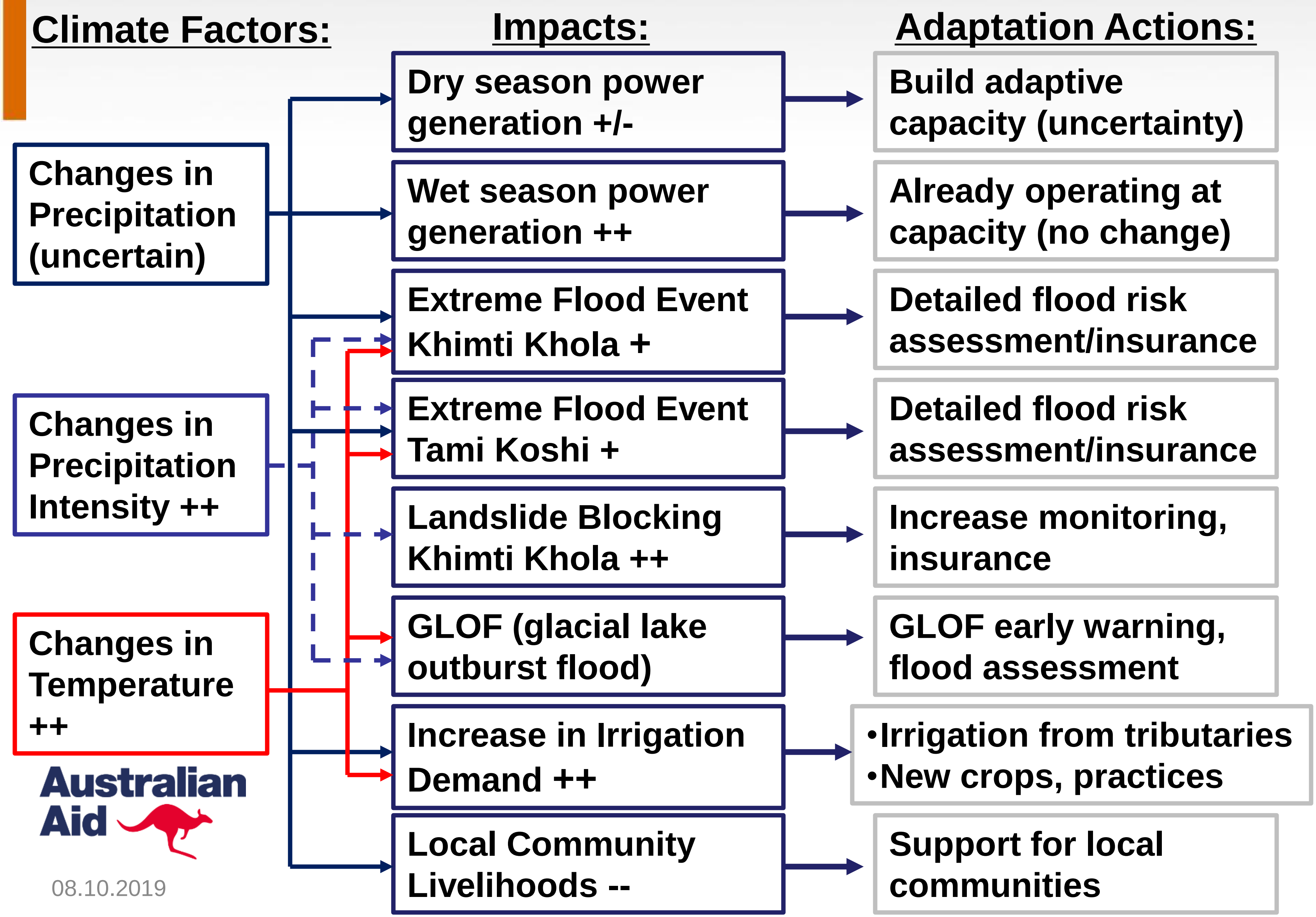


Source: IFC 2011

Khimti 1 Hydropower Plant:

- Run-of-River
- Installed Capacity 60 MW
- Design flow 10.75 m^3/sec
- 5 Pelton turbines
- Underground powerhouse
- Steel-lined penstocks
- Capital cost $140 million
- Commercial operation July 2000

Impact Pathways Run-of-River Hydropower



Australian Aid

Approaches to Adaptation

Adaptation approach	Description of adaptation approach	Expected financial implications
1. Build now for lifetime adaptation	▪ Build all adaptation measures immediately to last the project lifetime.	▪ Relatively high investment initially. ▪ No additional investment for subsequent adaptation required. ▪ Long term security is dependent on actual climate change not exceeding the prediction.
2. Plan for phased adaptation over lifetime	▪ Fully plan an upgrade program to progressively adapt the design as climate changes occur. ▪ Initial design provides functionality to adapt over life span.	▪ Medium level initial investment. ▪ Investment required during asset life cycle. ▪ Implementation of project adaptation phases will occur as designed.
3. Progressive modification to design	▪ Redesign and reconstruct as required in response to verified climate change. ▪ Initial design may not provide functionality to adapt over life span. ▪ Redesign and reconstruction required prior to damage or failure.	▪ Lower initial investment. ▪ Climate changes will force re-design costs and investments for reconstruction during asset life cycle to avoid catastrophic failure. ▪ This is potentially an expensive approach.
4. Build to repair	▪ Accept there will be damage and repair as required. ▪ Initial design does not incorporate adjustments to respond to climate change projections. Should asset be damaged as a result, asset manager accepts damage and carries out repairs.	▪ Low initial investment. ▪ Likely financial loss due to damage of asset. ▪ Relatively high repair cost during life cycle but overall may lead to lower whole of life cost if climate change does not cause substantial damage. ▪ This is the cheapest up-front option but comes with the largest risk and potential cost.

Assessment of Water Adaptation Strategies

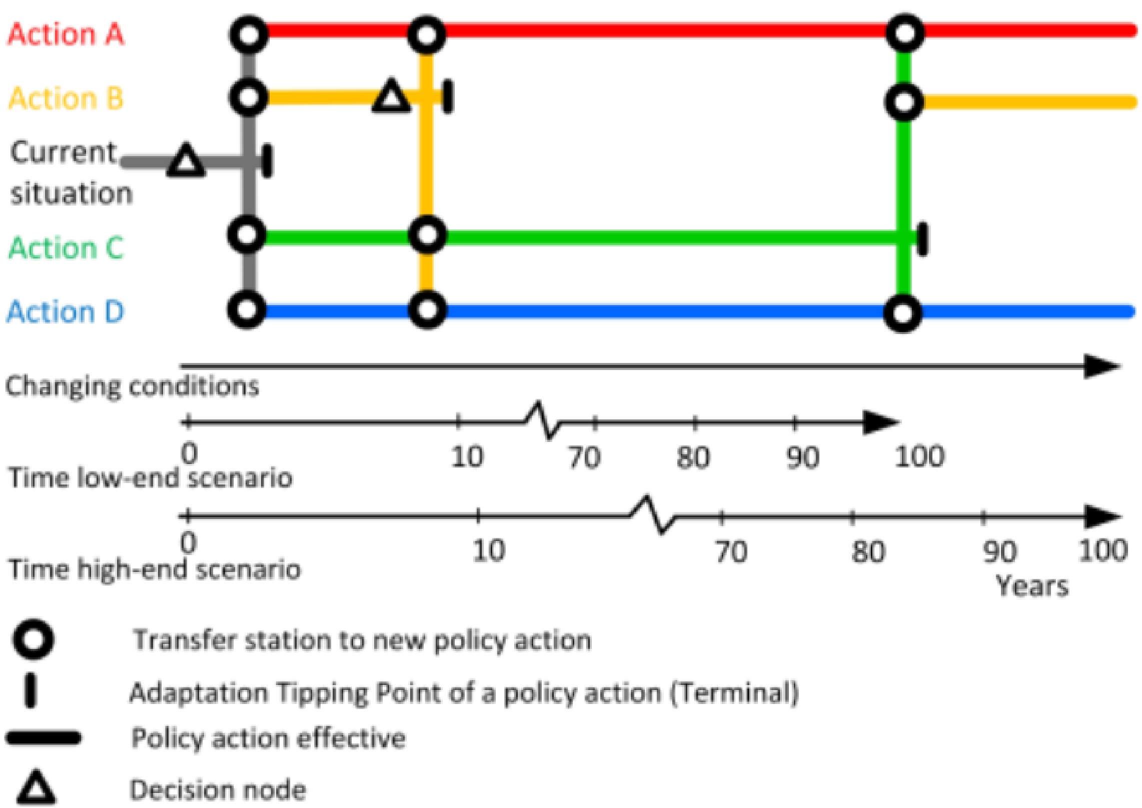
Adaptation Measure	Regrets	Cost	Technical Difficulty
Supply Side:			
Diversification of sources	Low	High	Medium
Construct additional storage	Medium-High	High	Medium
Watershed management, source protection	Win-Win	Low	Low
Advanced water treatment (recycling, desal)	Low	High	Medium
Reduce non-revenue water	Low	Medium	Medium
Demand Side:			
Metering	Low	Low-Medium	Medium
Low-use appliances	Low	Medium	Medium
Consumer behavior change	Low	Low	Low

Source: World Bank (2006) internal document

Water Sector Adaptation Technology	Diversify Supply	GW Re-charge	Extreme Events	WQ Degrad-ation	Storm-water control, capture	Water Conser-vation
Boreholes/Tubewells as a Drought Intervention for Domestic Water Supply			X			
Desalination	X			X		
Household Water Treatment, Safe Storage				X		
Improving Resilience of Wells to Flooding			X	X		
Water-efficient Fixtures and Appliances						X
Leakage Management, Detection and Repair in Piped Systems				X		X
Post-construction Support for Community-managed Water Systems	X		X	X		
Rainwater Collection, Ground Surfaces—Small Reservoirs and Micro-catchments	X	X		X	X	
Rainwater Harvesting from Roofs	X	X			X	
Water Reclamation and Reuse	X	X		X		
Water Safety Plans (WSPs)			X	X		

Preparation of Adaptive Management Strategy

Adaptation Pathways Map



Costs and benefits of pathways

Time horizon 20 years

Time horizon 50 years

Time horizon 100 years

Pathway	Costs	Benefits	Co-benefits
1	+++	+	0
2	+++++	0	0
3	+++	0	0
4	+++	0	0
5	0	0	-
6	++++	0	-
7	+++	0	-
8	+	+	- - -
9	++	+	- - -

Pathways that are not necessary in low-end scenario

Australian Aid

ADB

Climate Risk Management in EWSIP at Country- and Basin Scales

- TA9191 REG: Building Climate Resilience in Asia's Critical Infrastructure
- Climate Change Assessment at National Level
- Climate Risk Assessments in Priority Basins: Cimanuk, Belawan

➢ Analysis of historical climate and climatic events
➢ Projections of future climate
➢ Climate change impacts and vulnerability (bottom up approach)
➢ Adaptation options and recommendations for design

Australian Aid

ADB

TA9191 REG: Building Climate Resilience in Asia's Critical Infrastructure

Objective: To increase knowledge, promote innovation and good practice, and identify priorities for scaling up climate resilient critical infrastructure investments in the Asia.

Geographic focus - South Asia and Southeast Asia

Case study countries:

- **Indonesia**
- **Sri Lanka**
- **Vietnam**

Sector focus in both rural and urban areas:

- **Transport** - focusing on the road and water transport
- **Energy** - conventional energy generation, hydropower
- **Water** - water supply and flood protection subsectors

TA9191 REG: Building Climate Resilience in Asia's Critical Infrastructure - Outputs

Output 1 - Critical infrastructure in the energy, transport, and water sectors identified (through inventory and case studies);

Output 2 - Climate change risks to existing and planned critical infrastructure in the energy, transport, and water sectors assessed (i.e. a detailed understanding of the impacts of climate change on critical infrastructure); and

Output 3 - Policy, financial priorities, adaptation options, and climate resilience standards for the target sectors identified (Identifying and assessing policy, technical, financial and ecological options for addressing climate risks and vulnerability of critical infrastructure).

Australian Aid

ADB

TA9191 REG: Alignment with Infrastructure Investment in Indonesia: EWSIP

Output 1
Critical infrastructure identified in energy, transport, and water sectors in Southeast and South Asia

Output 2
Climate change risks to existing and planned critical infrastructure assessed

Output 3
Policy, financial priorities, adaptation options and climate resilience standards for target sectors identified

ADB's Enhanced Water Security Investment Project (EWSIP)

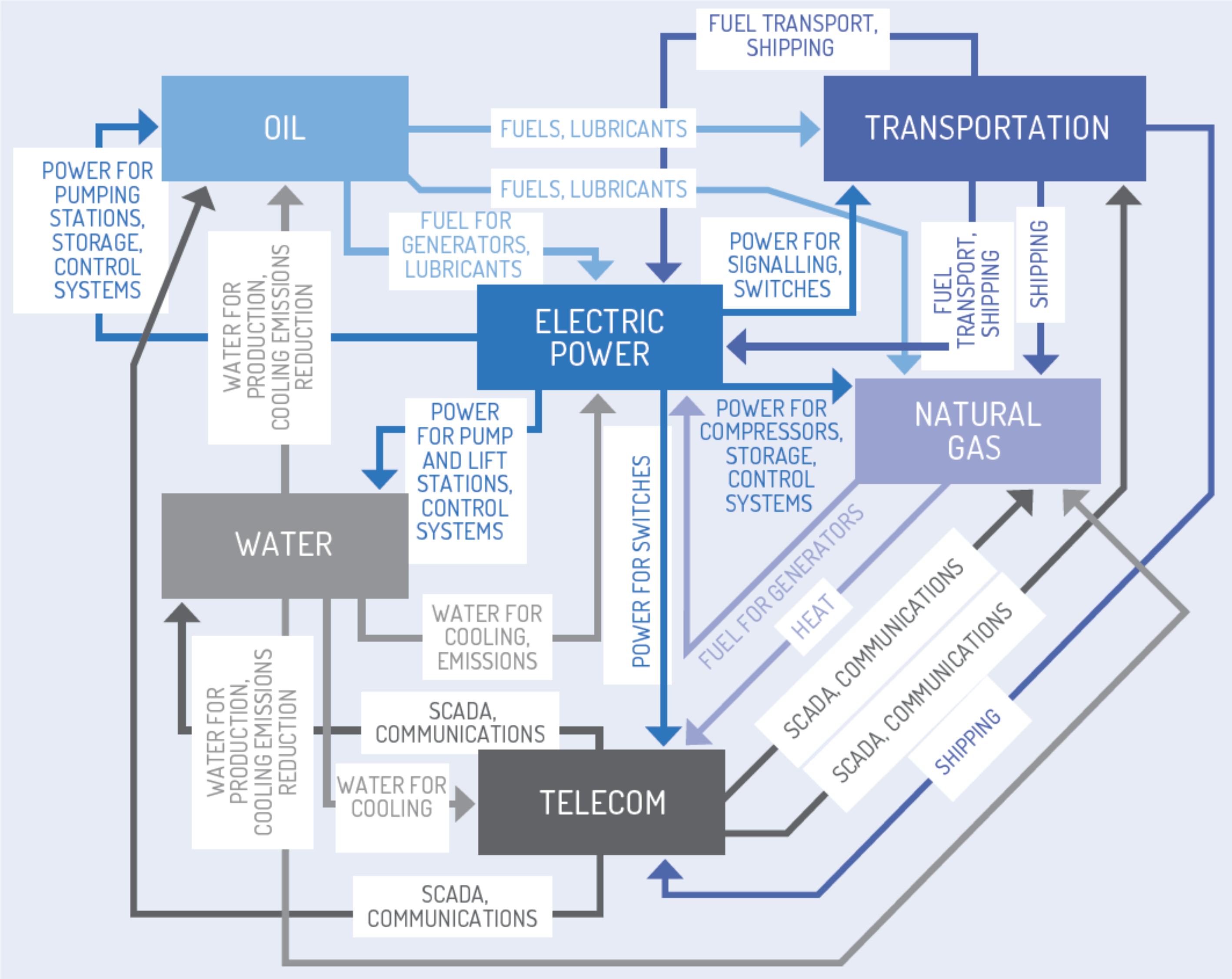
- will support the Government of Indonesia improve selected dimensions of water security (economic water security and resilience to water-related disasters).
- will promote an integrated water resources management approach to:
  - improve water resources planning and management
  - minimize spatial and temporal variations in water availability
  - increase resilience to climate change.

Support for:

- Critical infrastructure methodology and inventory database to provide technical inputs in analyzing the interconnections and relationships among the different infrastructures in Indonesia
- Risk and vulnerability assessments inputs to project plans (i.e. how climate change may affect the project plans)
- Adaptation options and resilience standards as inputs to project design (i.e., designing climate resilient structures)

TA9191 REG: Focus on Interdependence of Infrastructure

Asset failure: A system is as strong as its weakest link – failure in one asset can cause a cascade of system failure

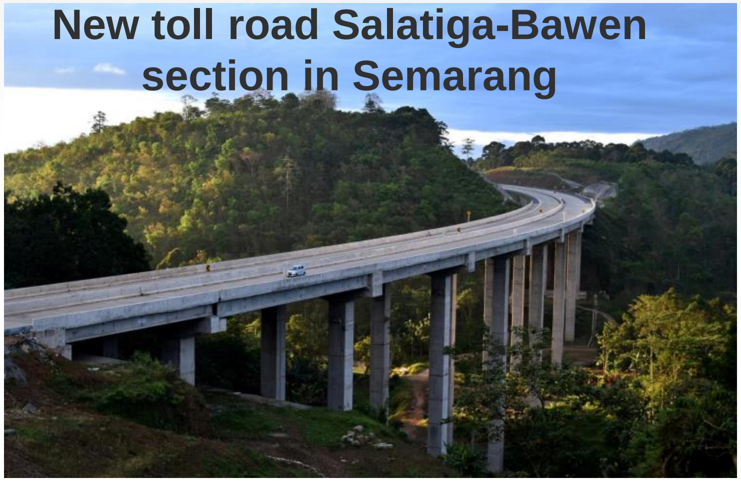


Australian Aid

08.10.2019

TA9191 REG: Progress to Date in Indonesia

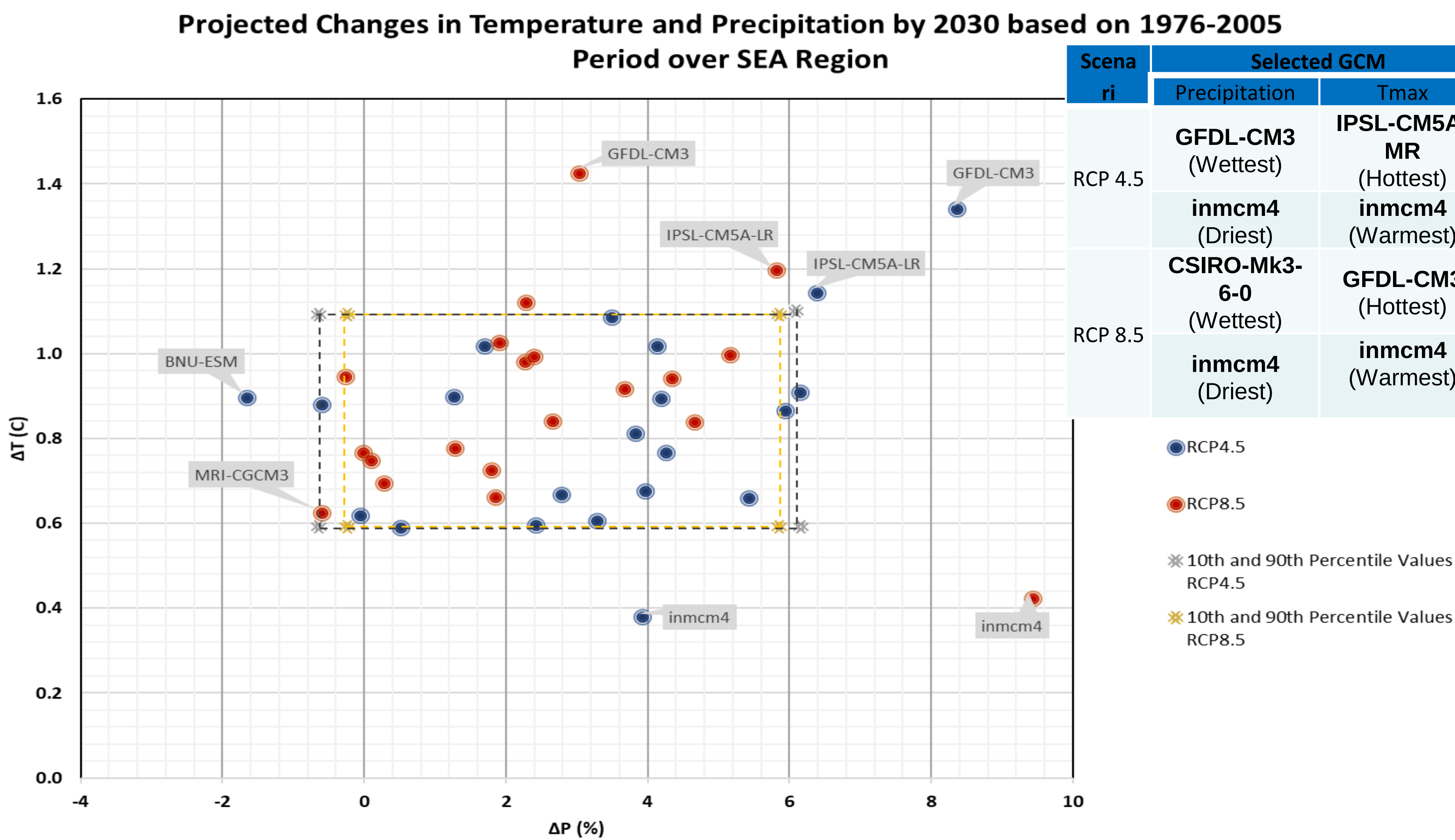
1. Critical infrastructure inventory (completed)
2. Climate change and risk hot spots for floods, landslides, drought, coastal zone and temperature and rainfall (completed)
3. Climate change and hydrological modelling in two river basins (completed)
4. Climate risk assessments for two river basins (draft completed)
5. Listing of critical infrastructure assets located in hot spots (in process)
6. Policy, procedures, tools, adaptation measures – learning from Cimanuk case study



Australian Aid

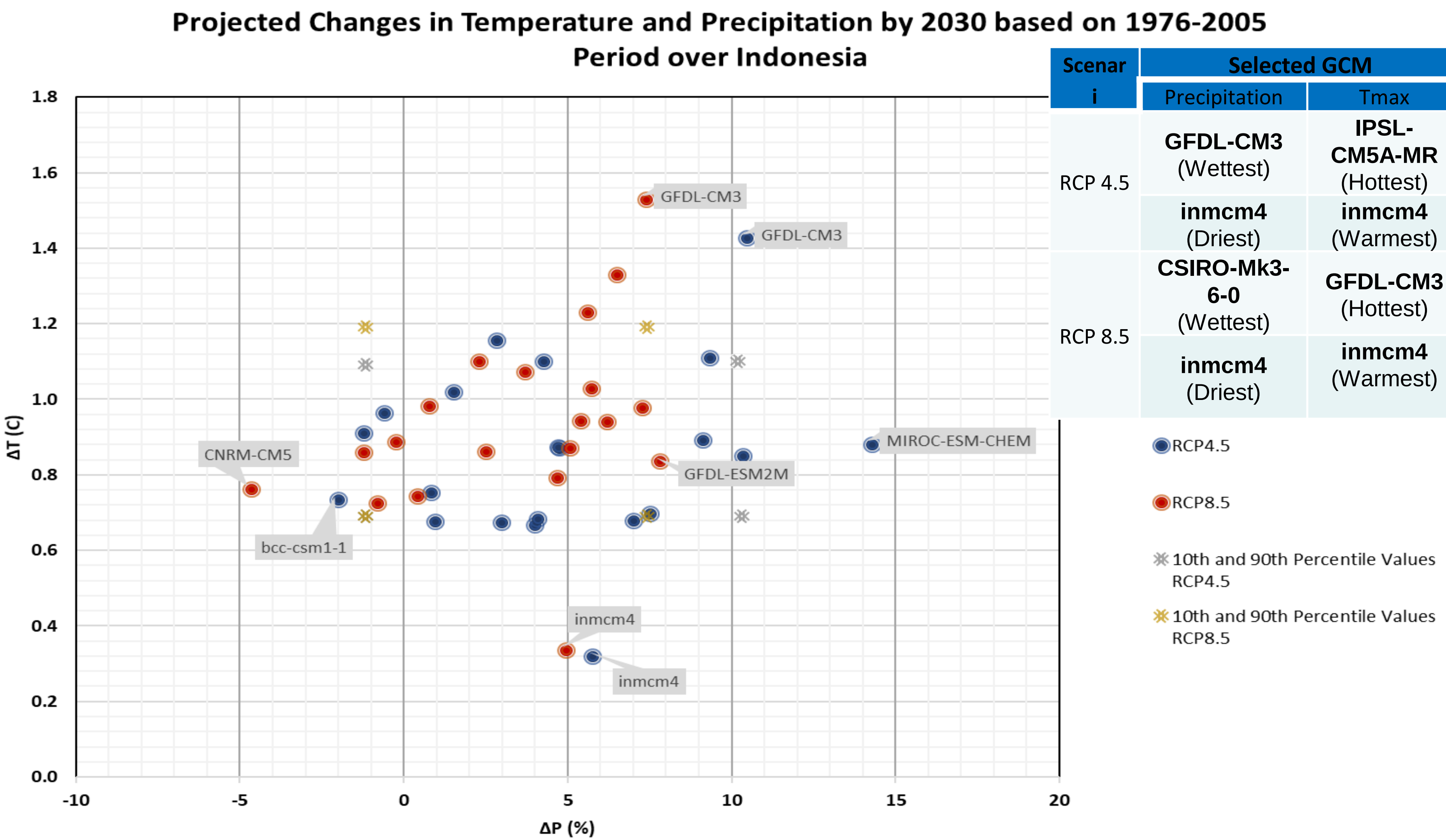
ADB

Climate Change Assessment at Regional Level: Selection of Climate Models for SE Asia



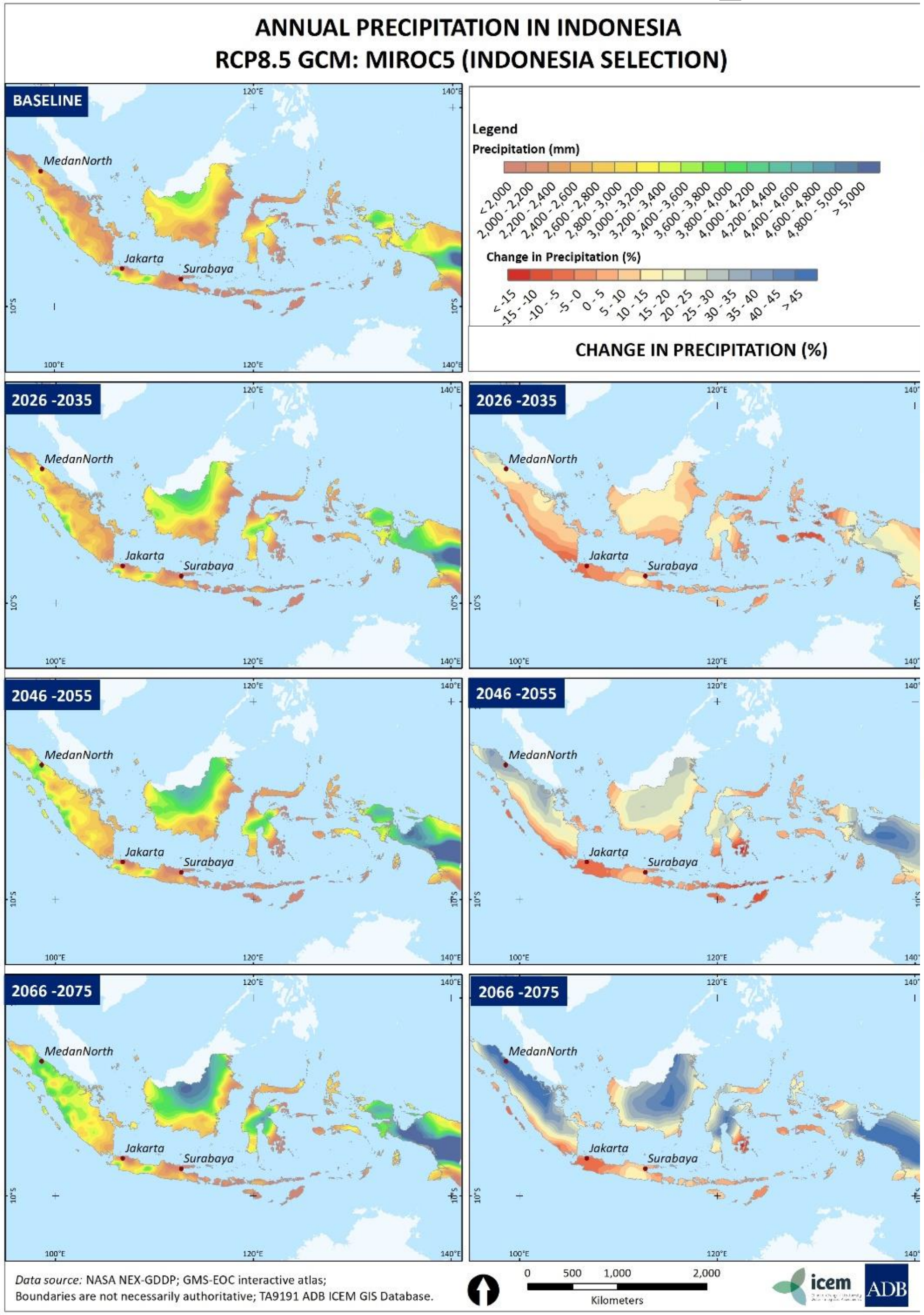
Scenari	Selected GCM	
	Precipitation	Tmax
RCP 4.5	**GFDL-CM3** (Wettest)	**IPSL-CM5A-MR** (Hottest)
	inmcm4 (Driest)	**inmcm4** (Warmest)
RCP 8.5	**CSIRO-Mk3-6-0** (Wettest)	**GFDL-CM3** (Hottest)
	inmcm4 (Driest)	**inmcm4** (Warmest)

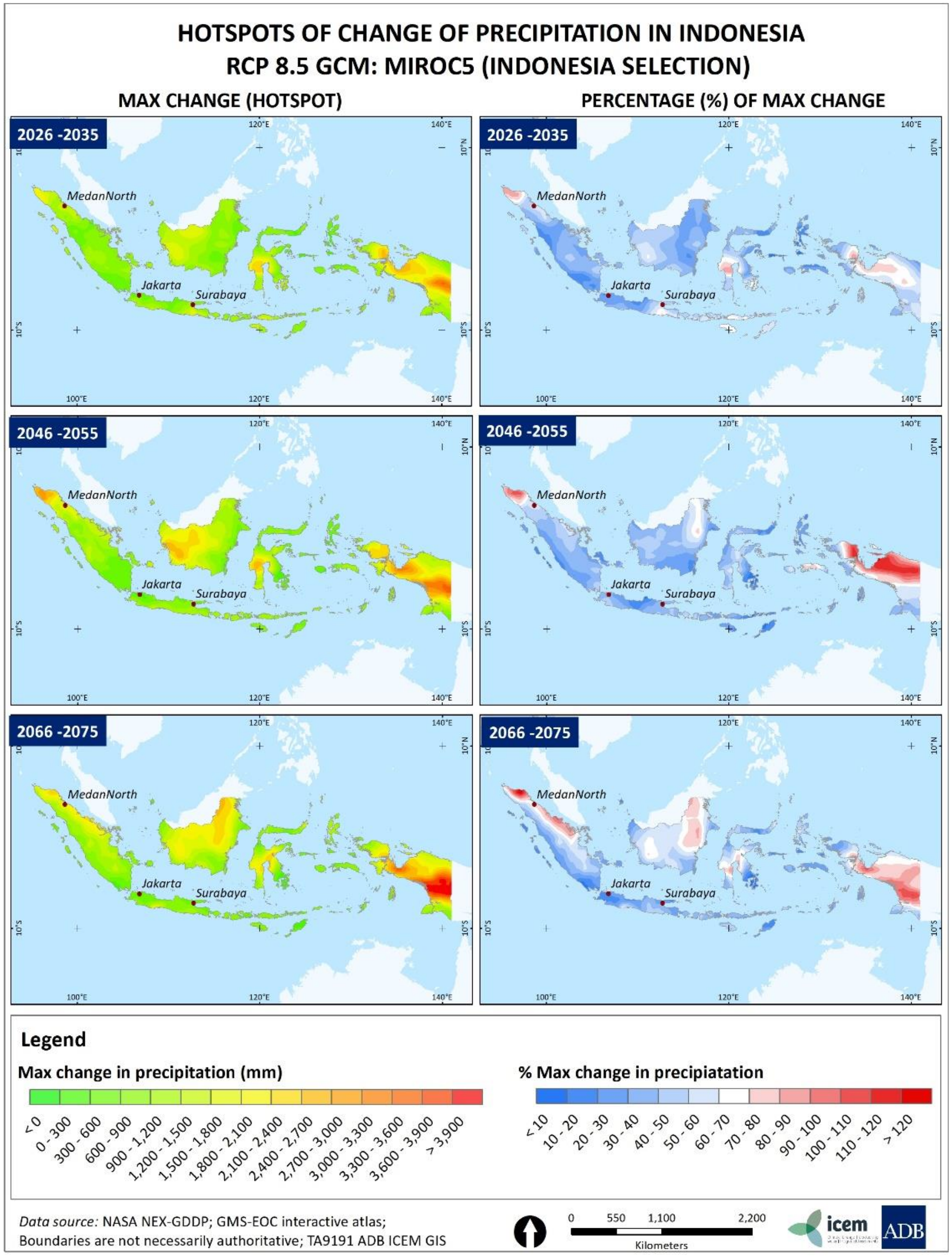
Climate Change Assessment at National Level: Selection of Climate Models for Indonesia



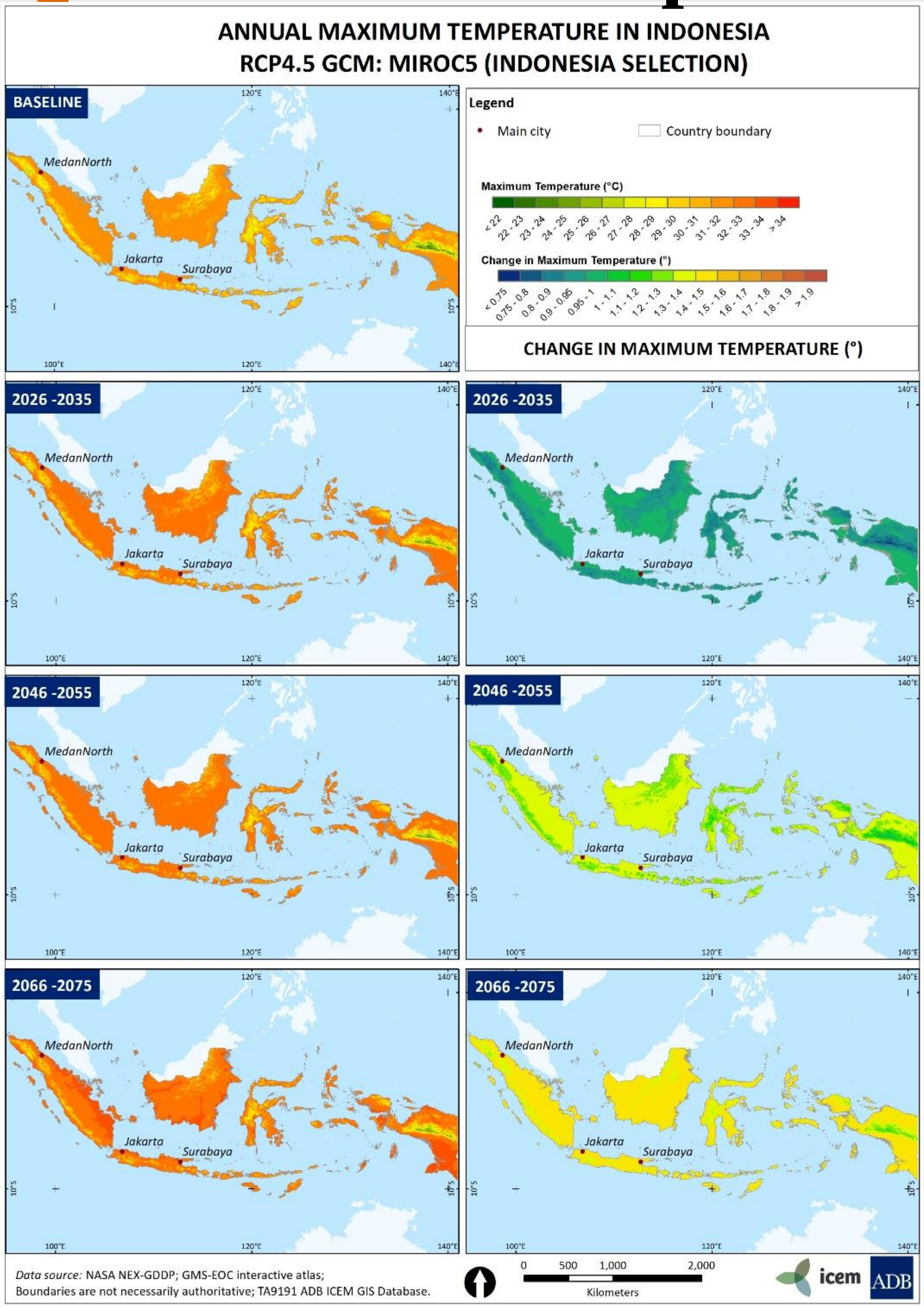
Scenari	Selected GCM	
	Precipitation	Tmax
RCP 4.5	**GFDL-CM3** (Wettest)	**IPSL-CM5A-MR** (Hottest)
	inmcm4 (Driest)	**inmcm4** (Warmest)
RCP 8.5	**CSIRO-Mk3-6-0** (Wettest)	**GFDL-CM3** (Hottest)
	inmcm4 (Driest)	**inmcm4** (Warmest)

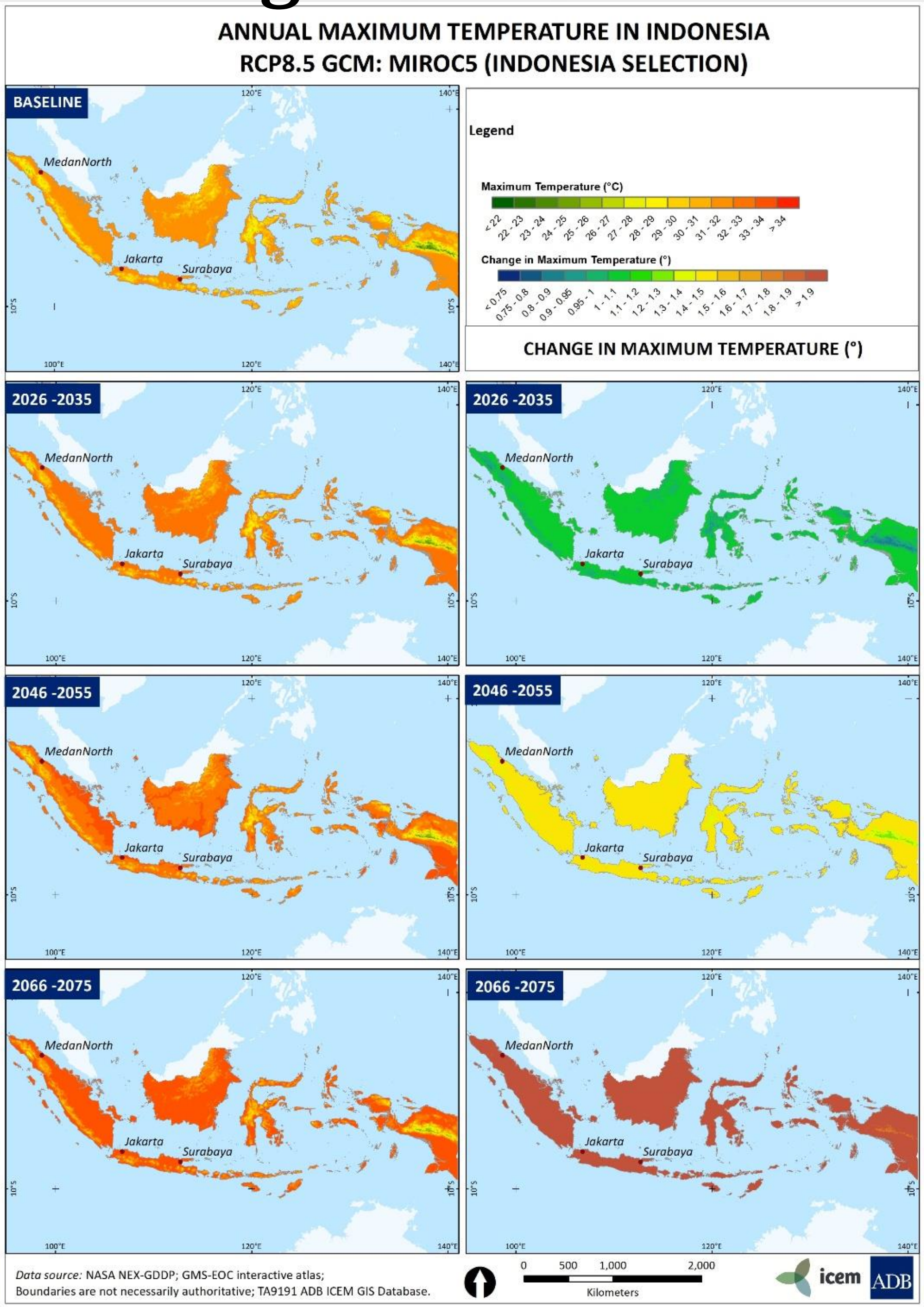
Simulated Precipitation Changes for Indonesia



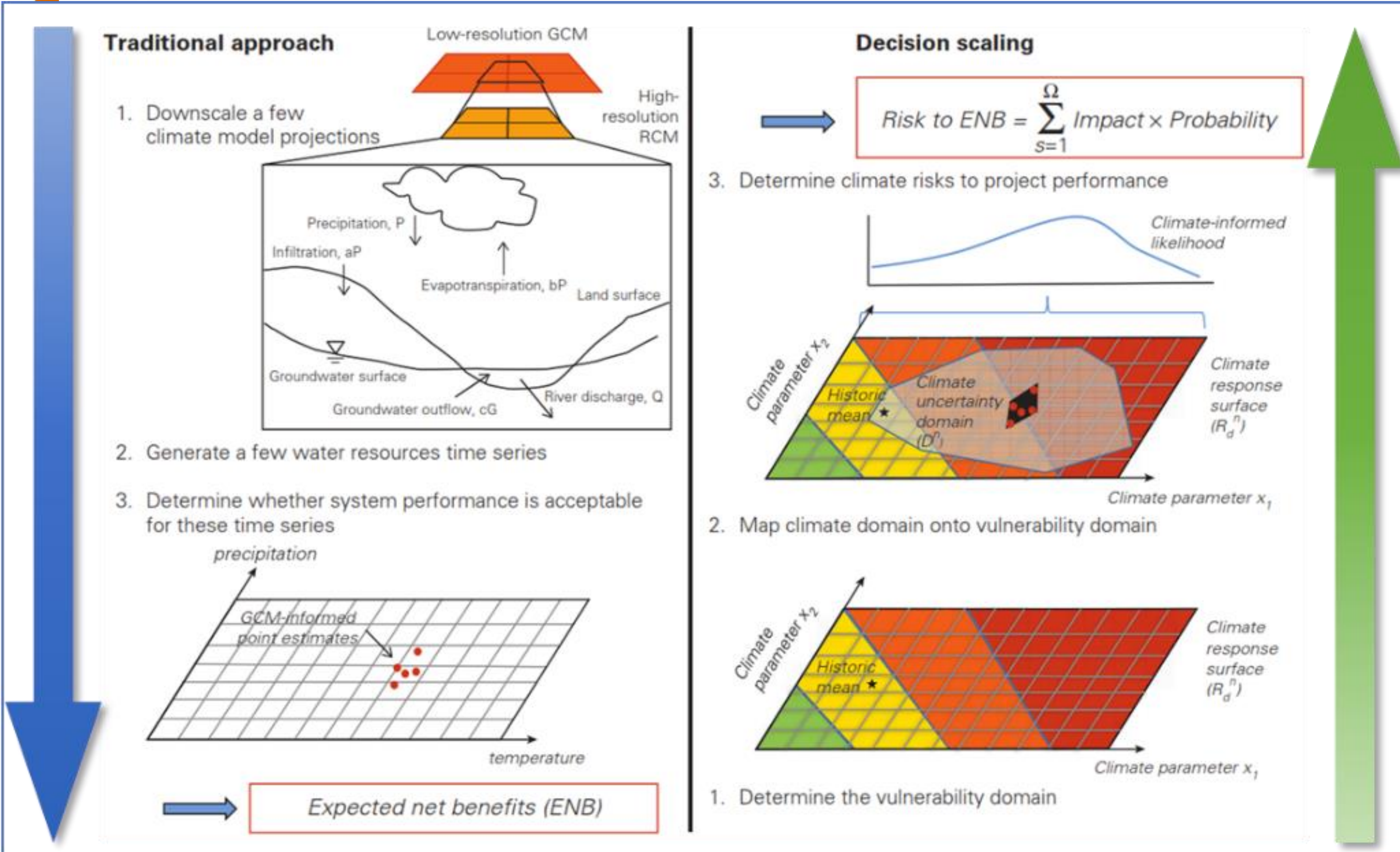


Simulated Temperature Changes for Indonesia

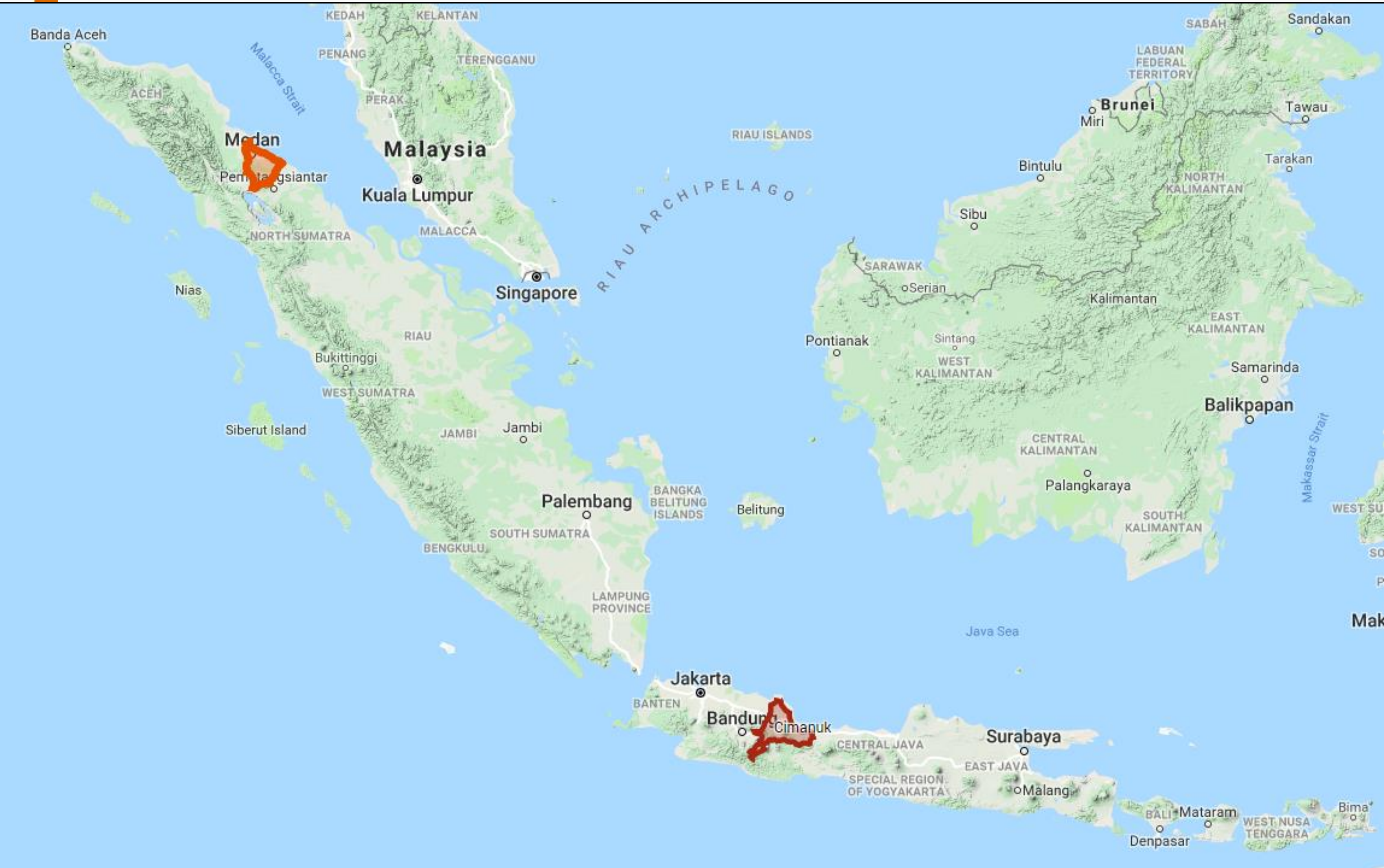




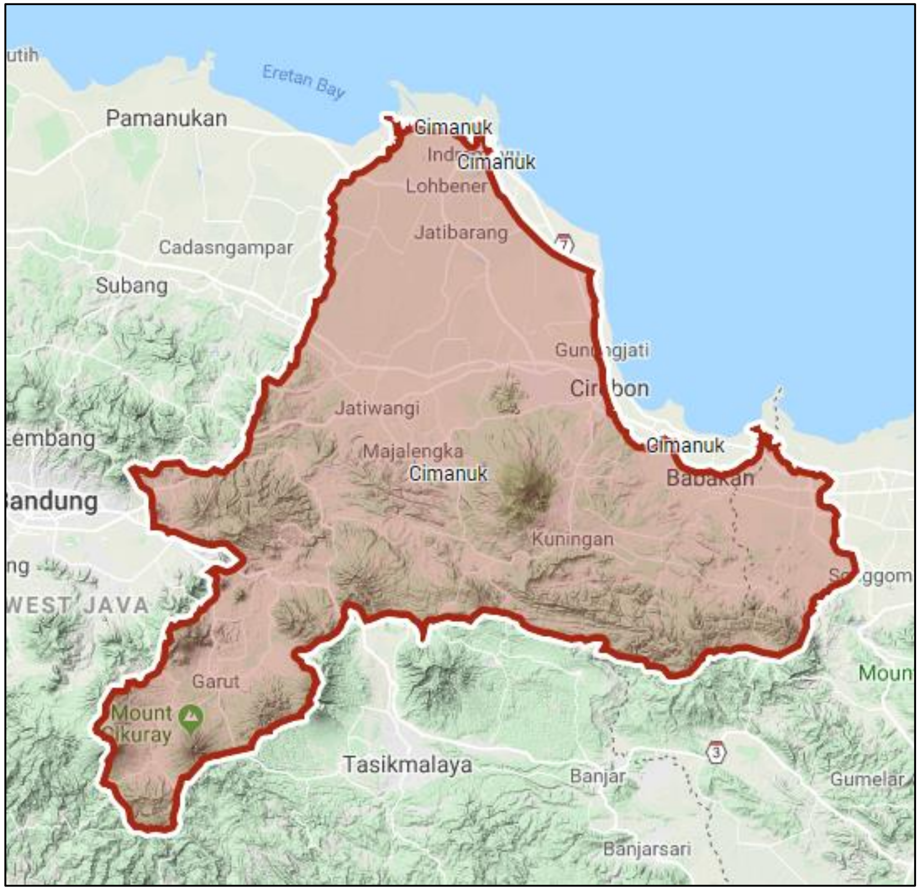
Climate Risk Assessments in Priority Basins: Top-down vs Bottom-up Approaches



Indonesia, indicating Cimanuk, Belawan Basins



Detail on Belawan (Sumatera), Cimanuk (Java)

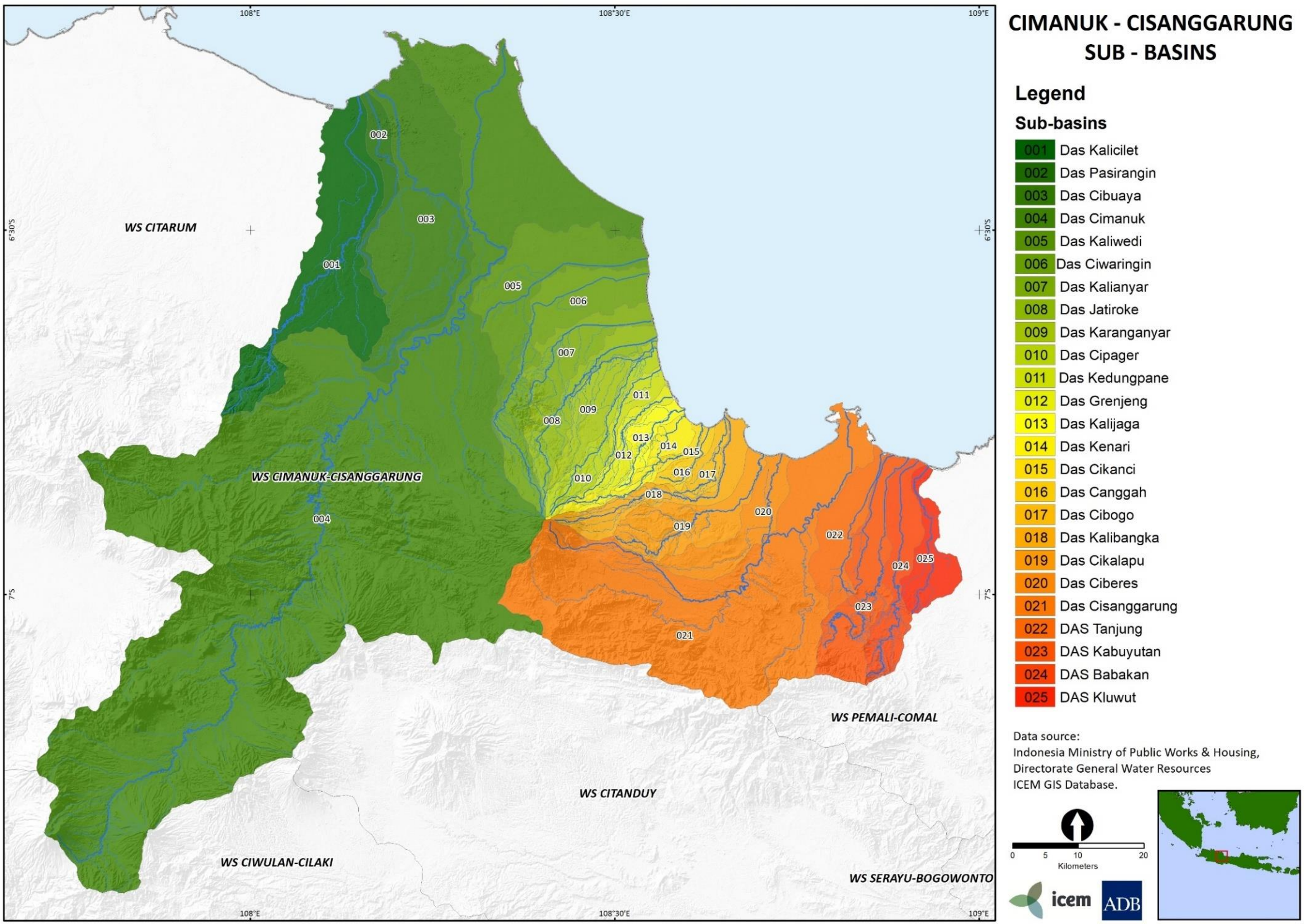


Australian Aid

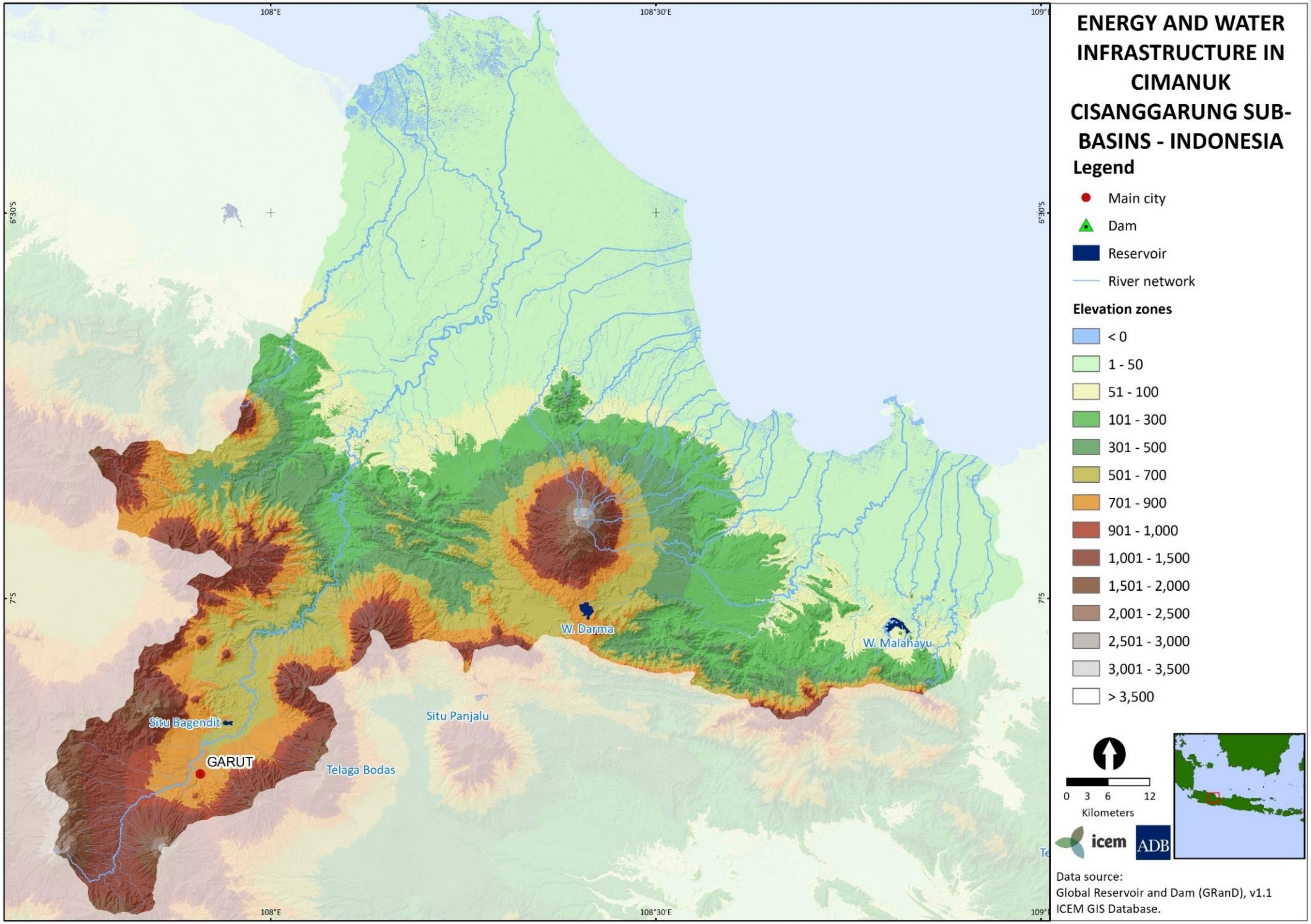
ADB

08.10.2019

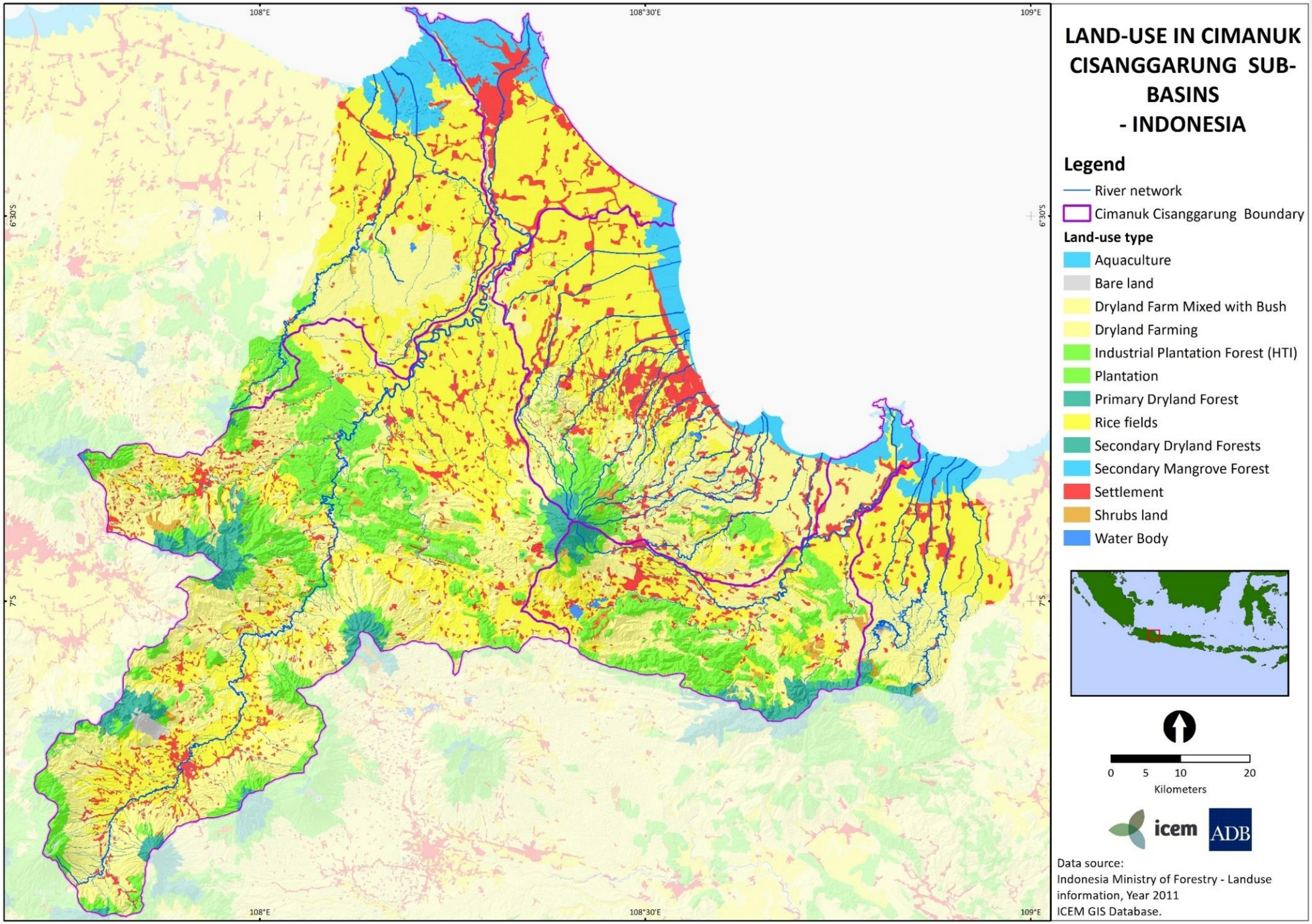
Cimanuk showing Sub-Basins



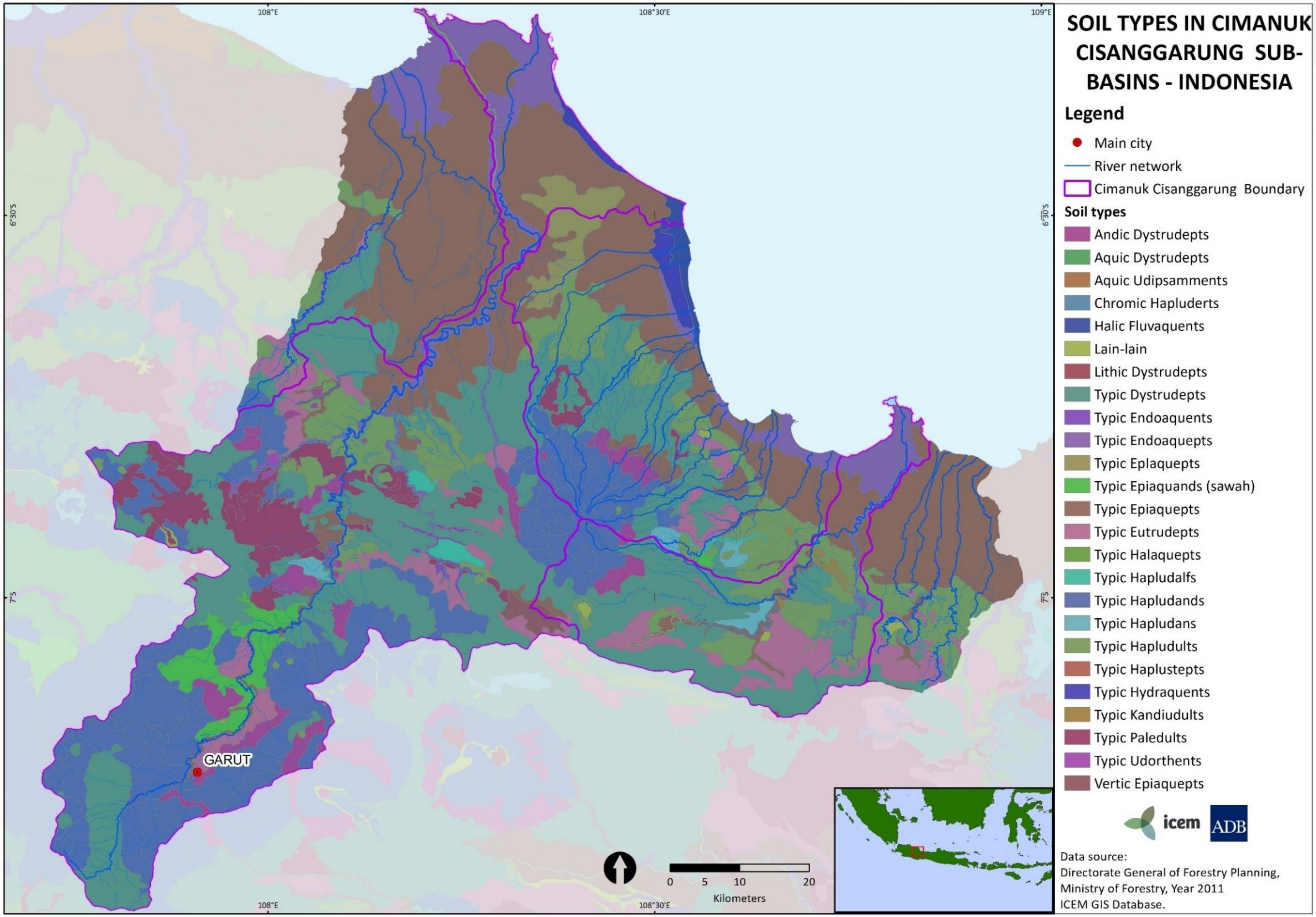
Cimanuk showing Topography, Infrastructure



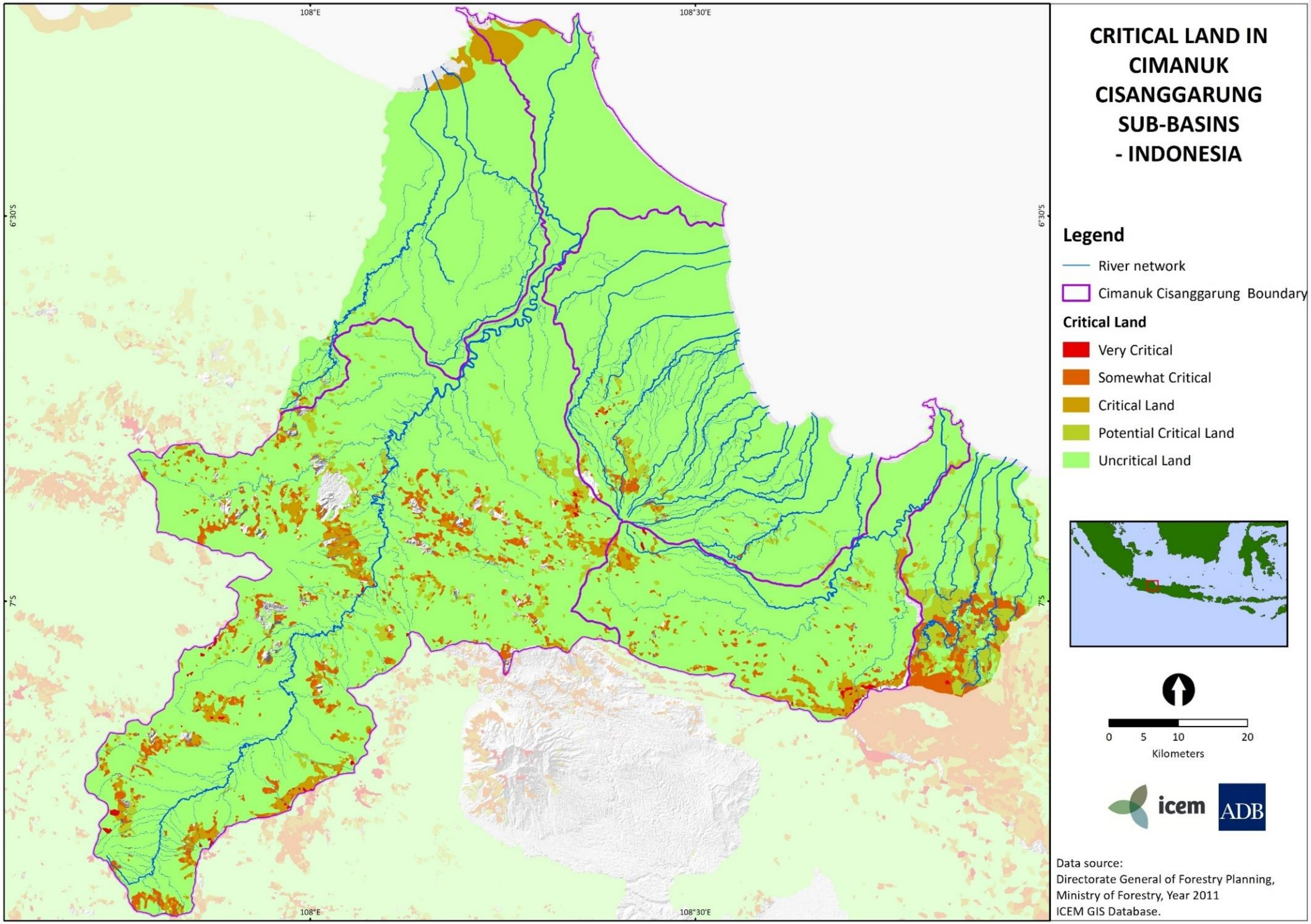
Cimanuk showing Land Use



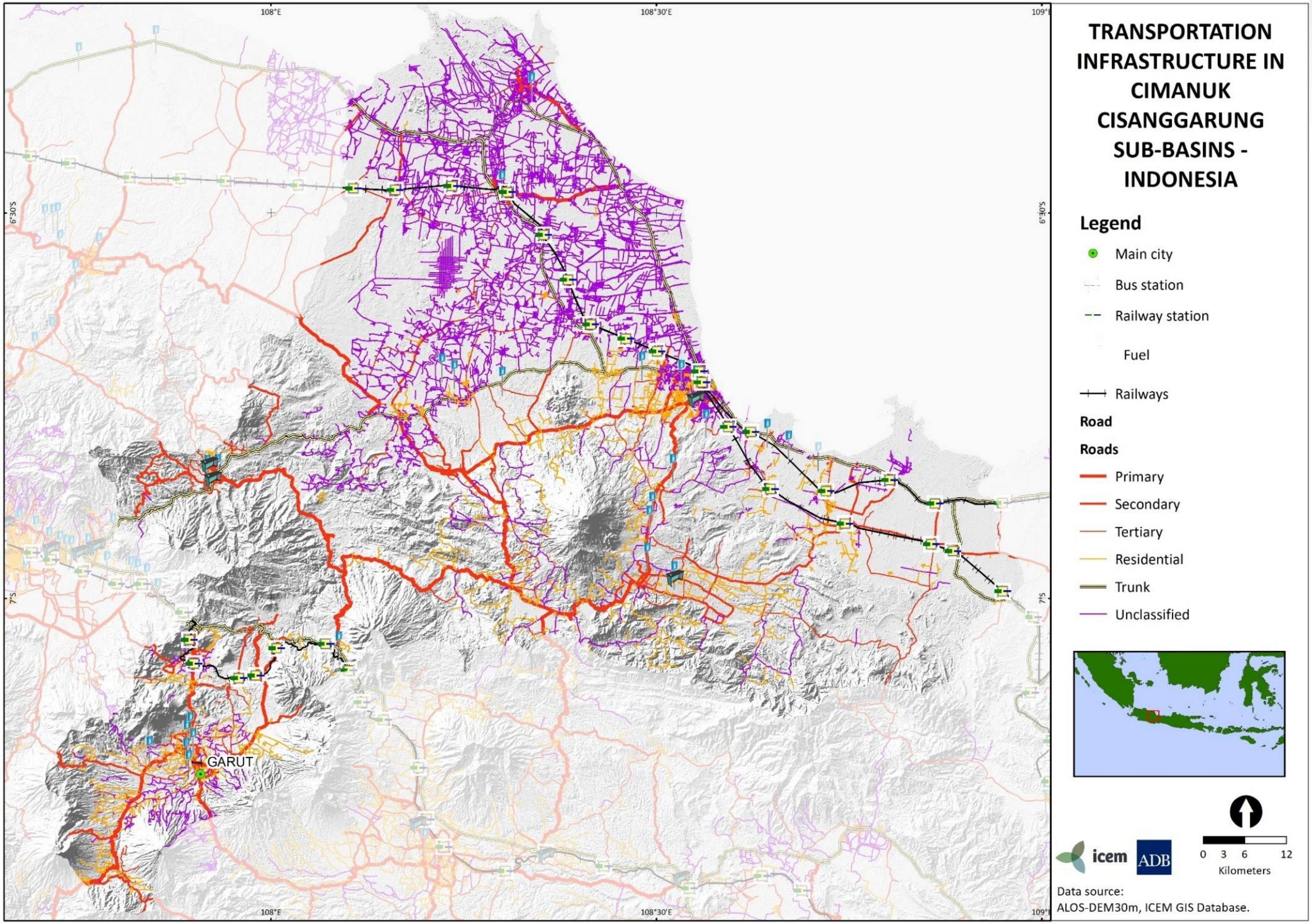
Cimanuk showing Soil Types



Cimanuk showing Critical Land

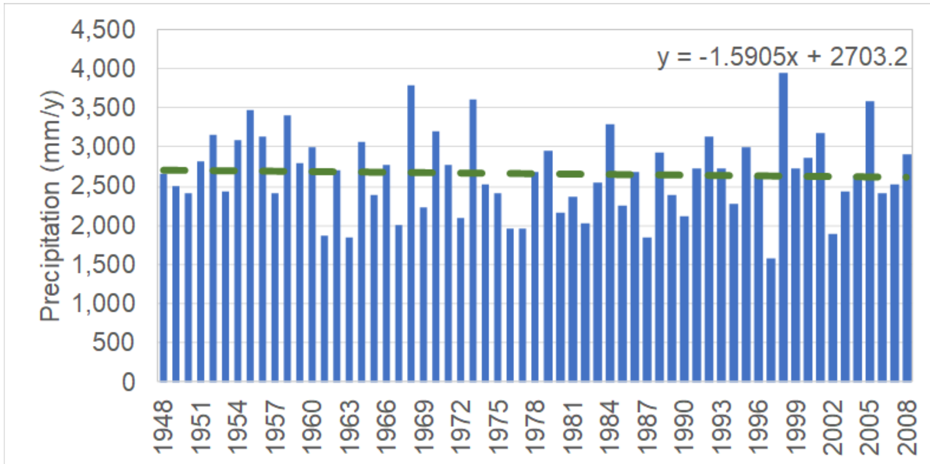


Cimanuk showing Transportation Infrastructure

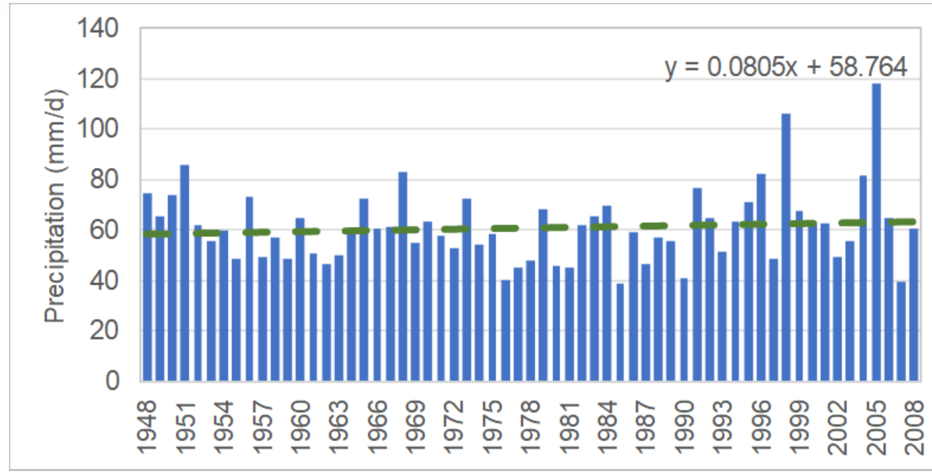


Analysis of Historical Climate: Annual and Extremes

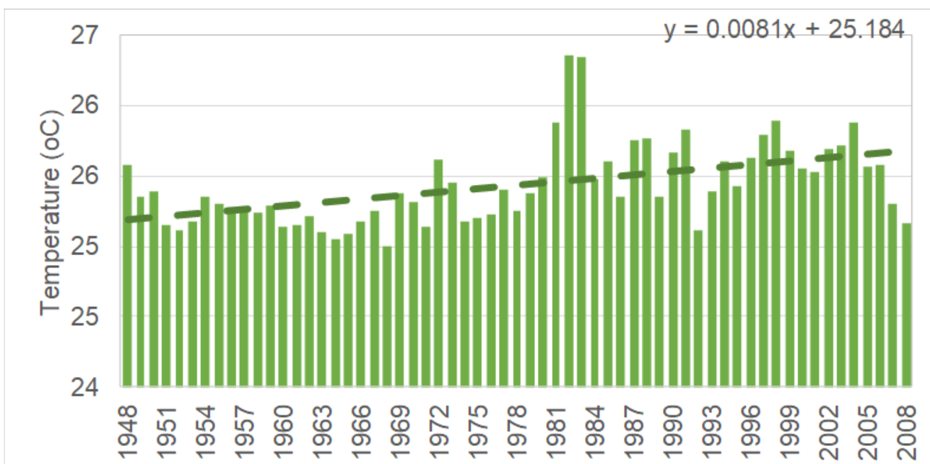
Annual sum of precipitation with trend line.



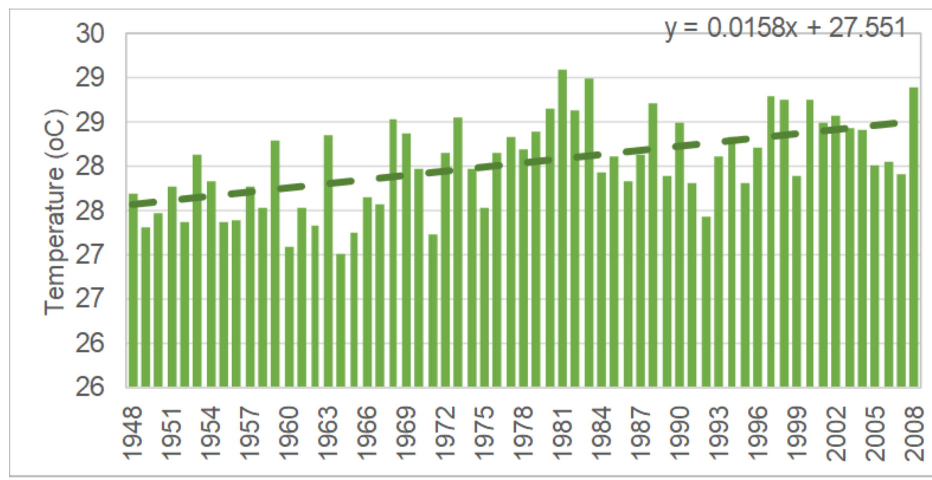
Annual Maximum precipitation at 99% with trend line



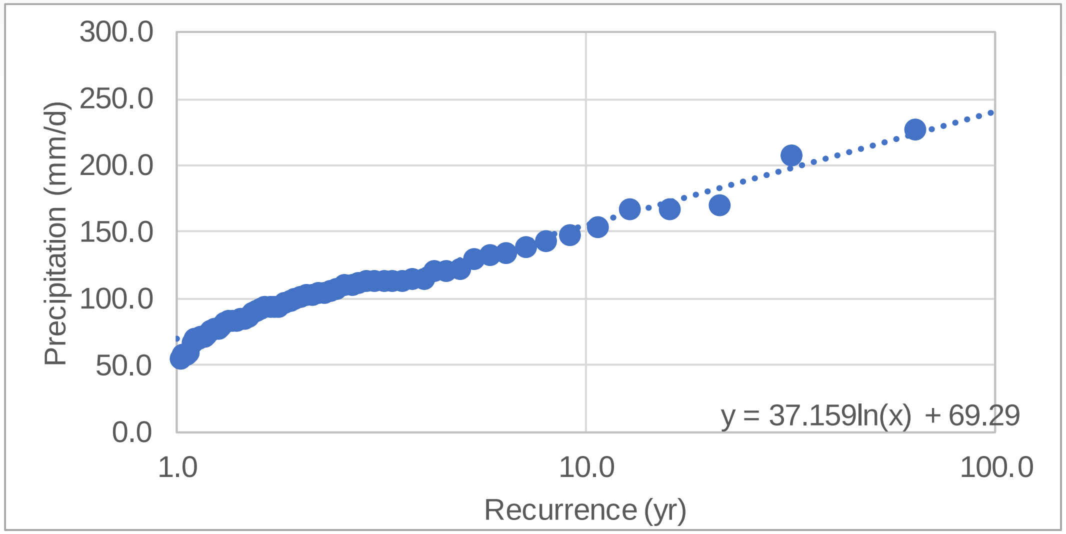
Annul average temperature with trend line.

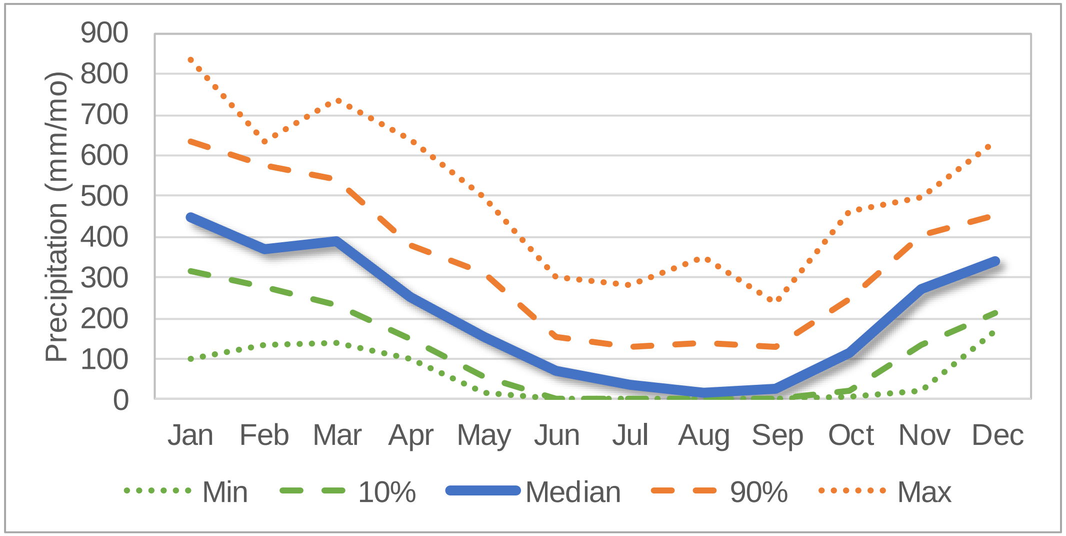


Hottest day per year and trend line.



Analysis of Historical Climate: Design Rainfall Events

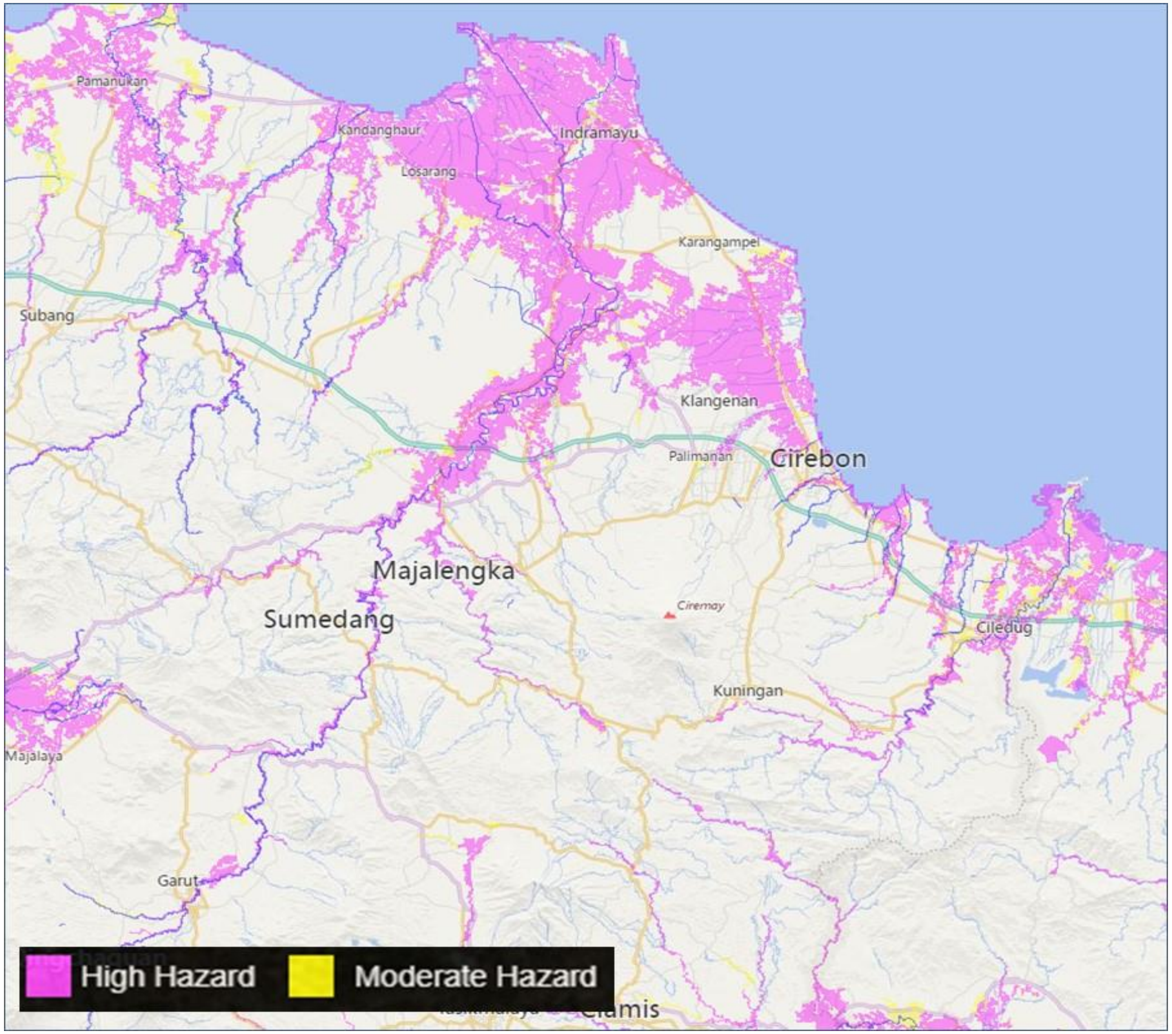




Australian Aid

ADB

Analysis of Historical Climate: Reconstruction of Historical Flood Events

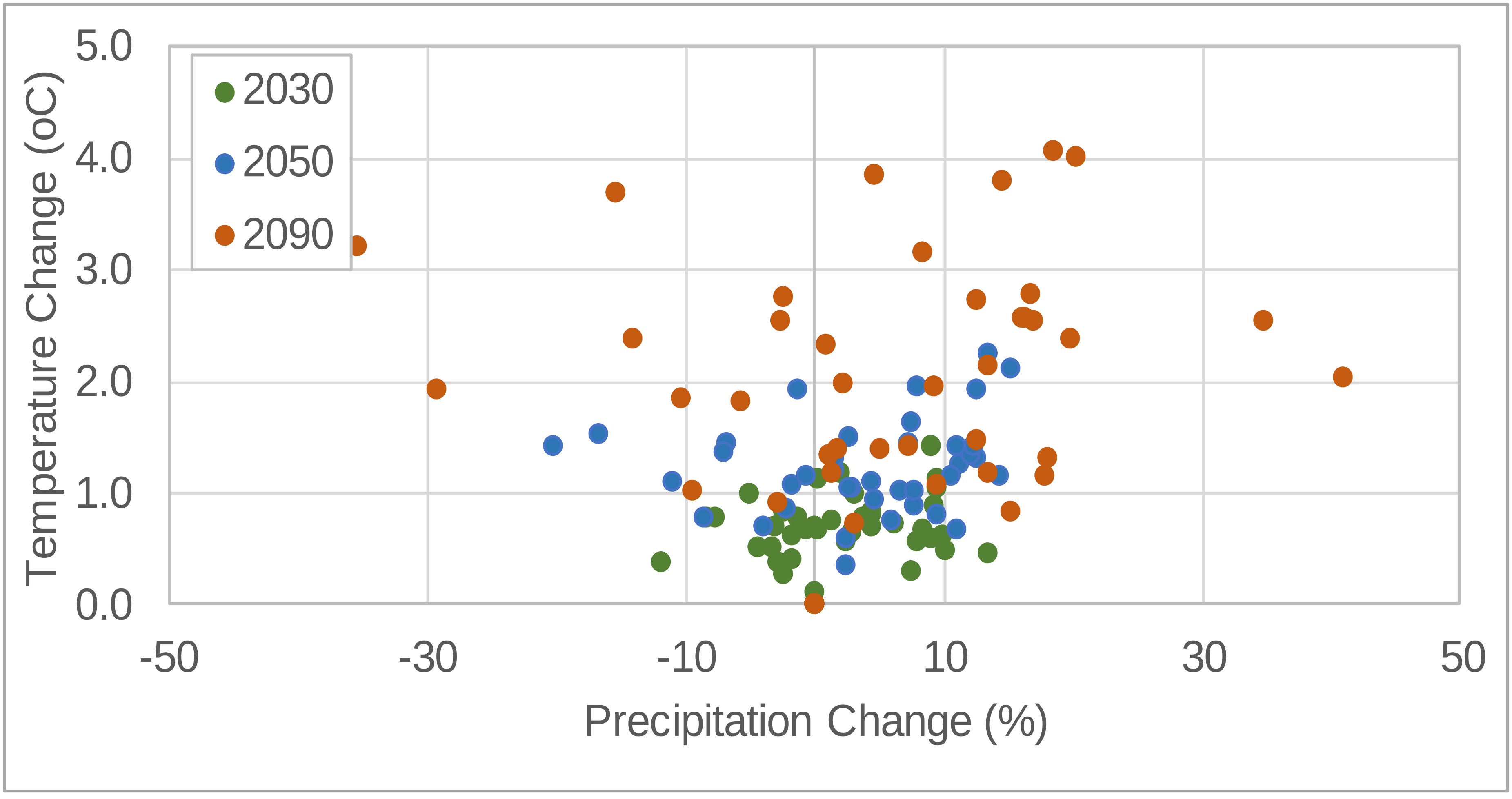


Australian Aid

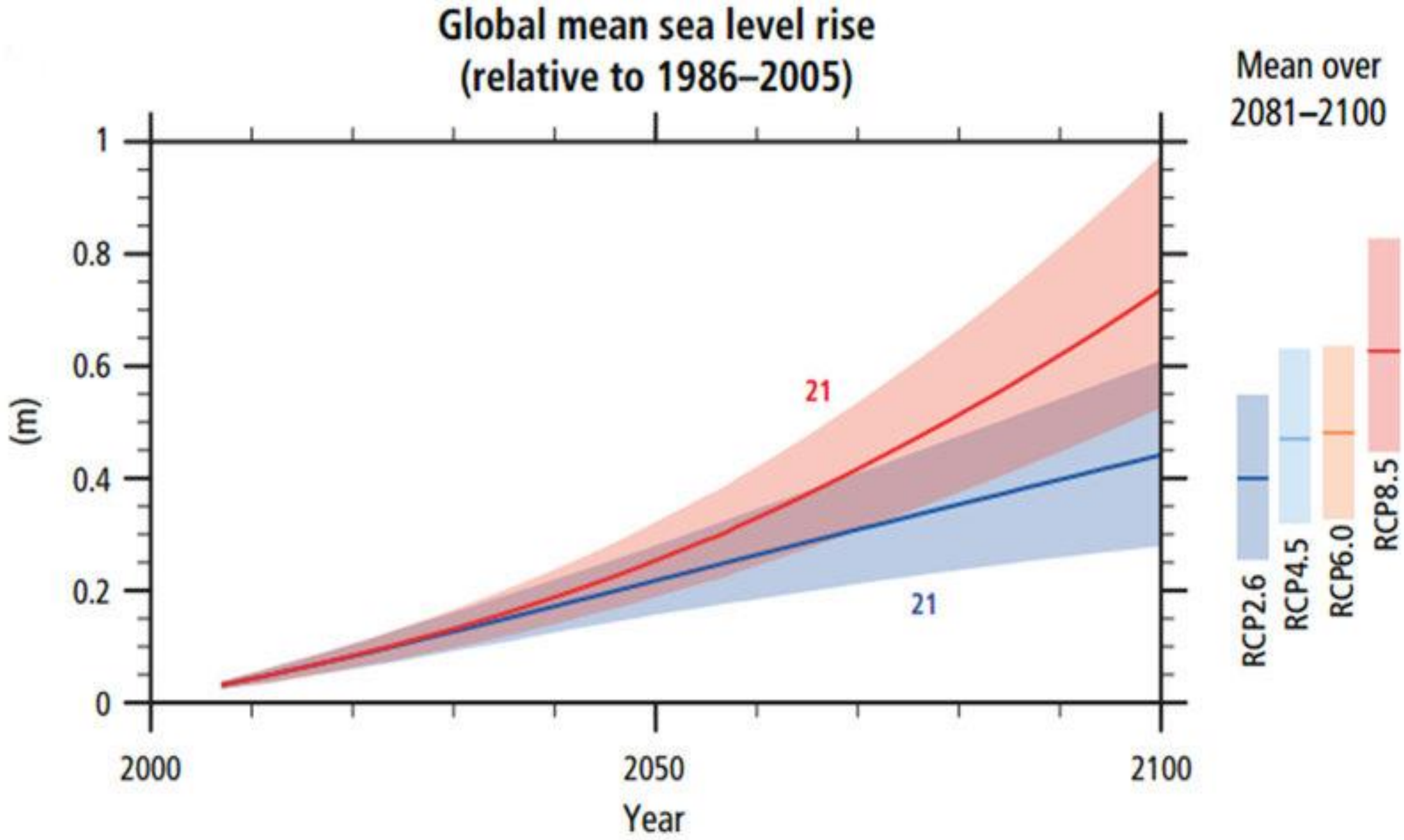
ADB

Source:

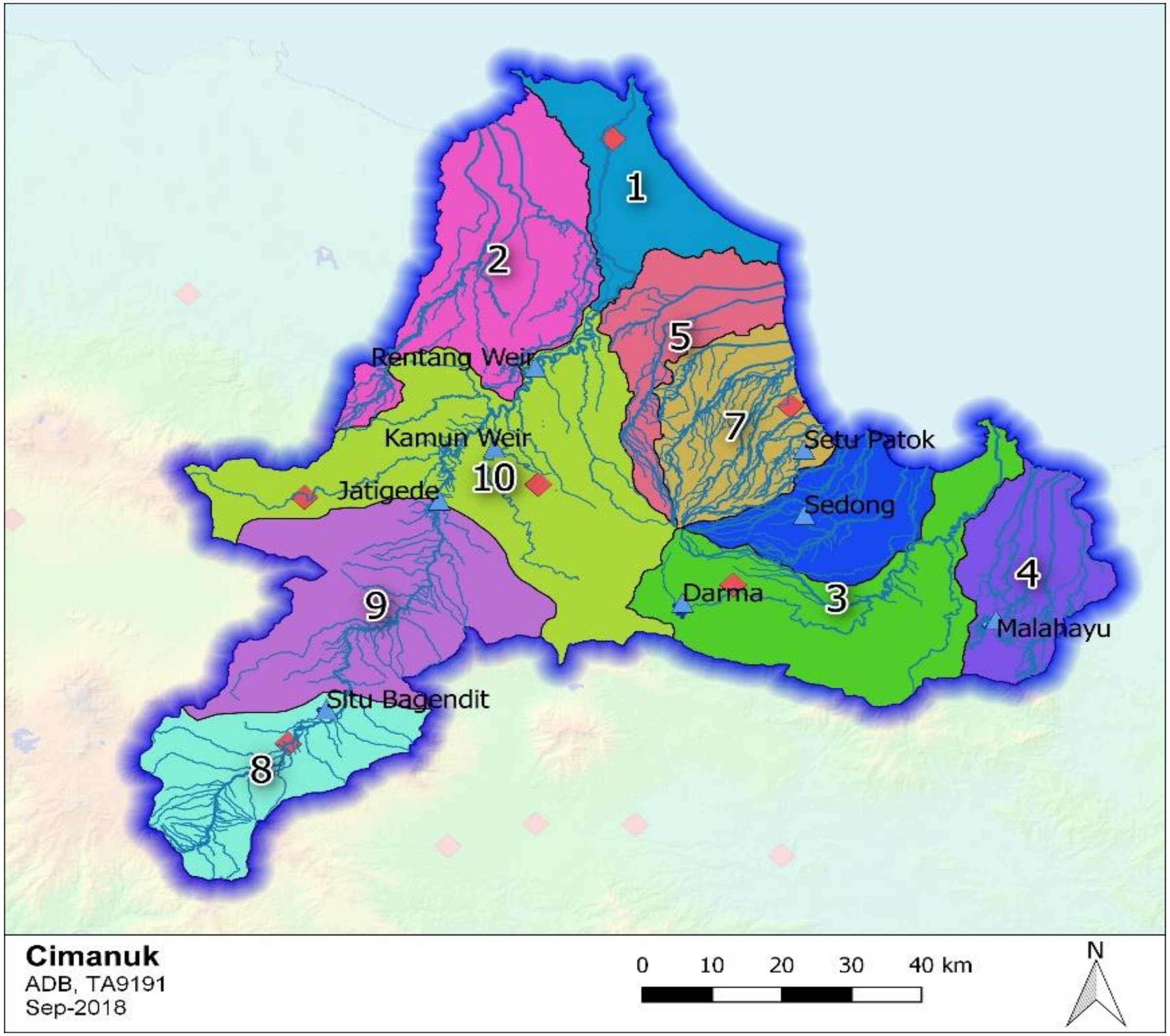
Projected Climate: Use of Model Ensemble



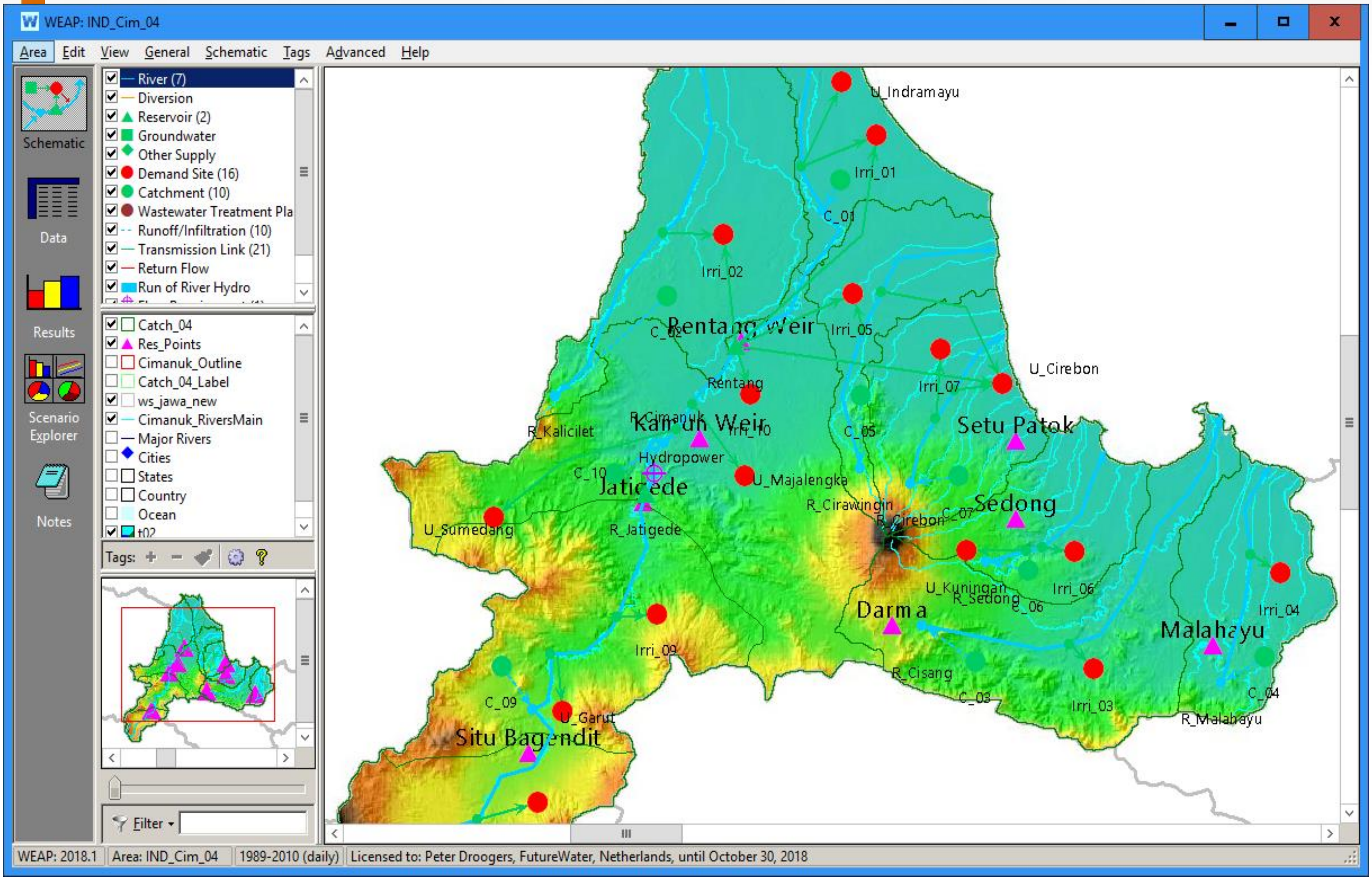
Projected Climate: Sea Level Rise



Hydrologic Simulation Model (WEAP) Indicating Sub-Basins

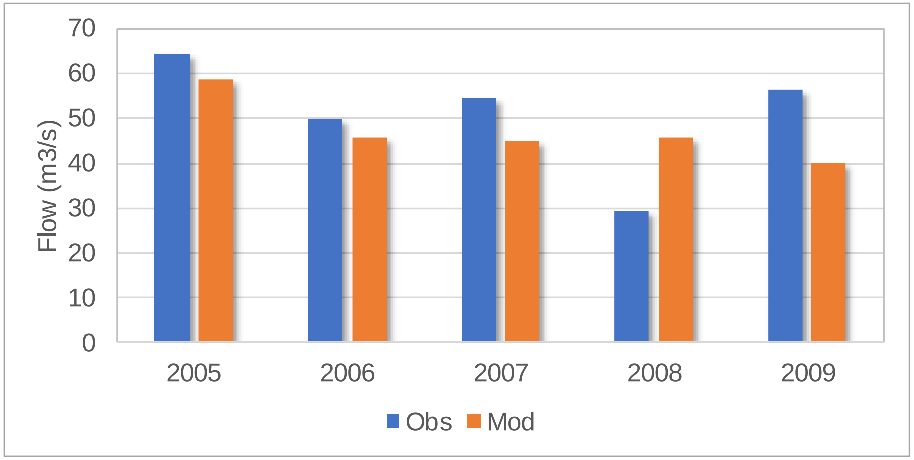


Hydrologic Simulation Model (WEAP) screenshot

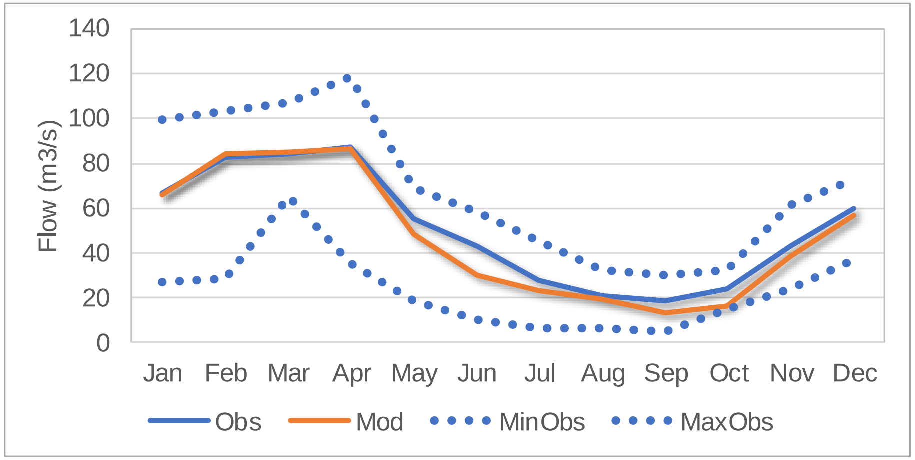


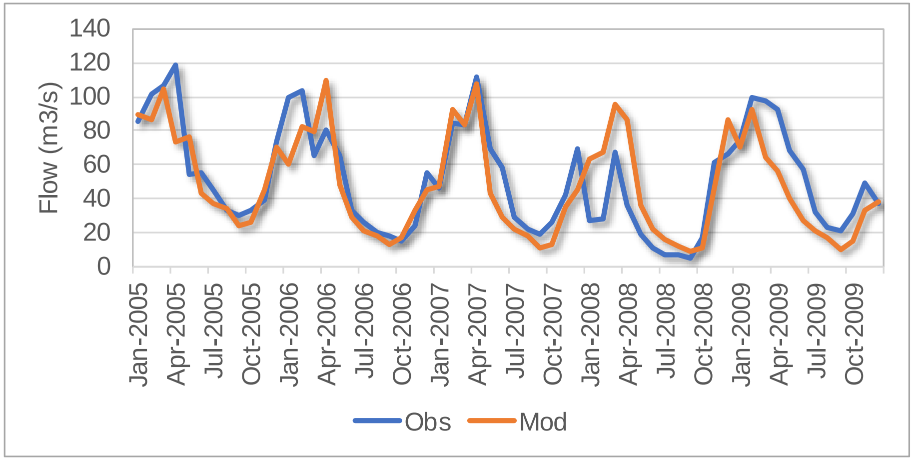
Hydrologic Simulation Model (WEAP) Model Performance

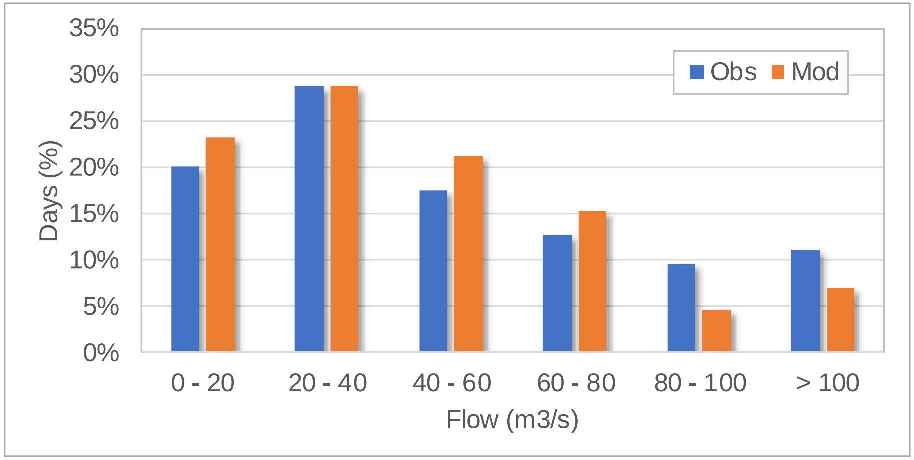
Observed and modeled mean annual flows, Wado station



Observed and modeled mean monthly flows, Wado station

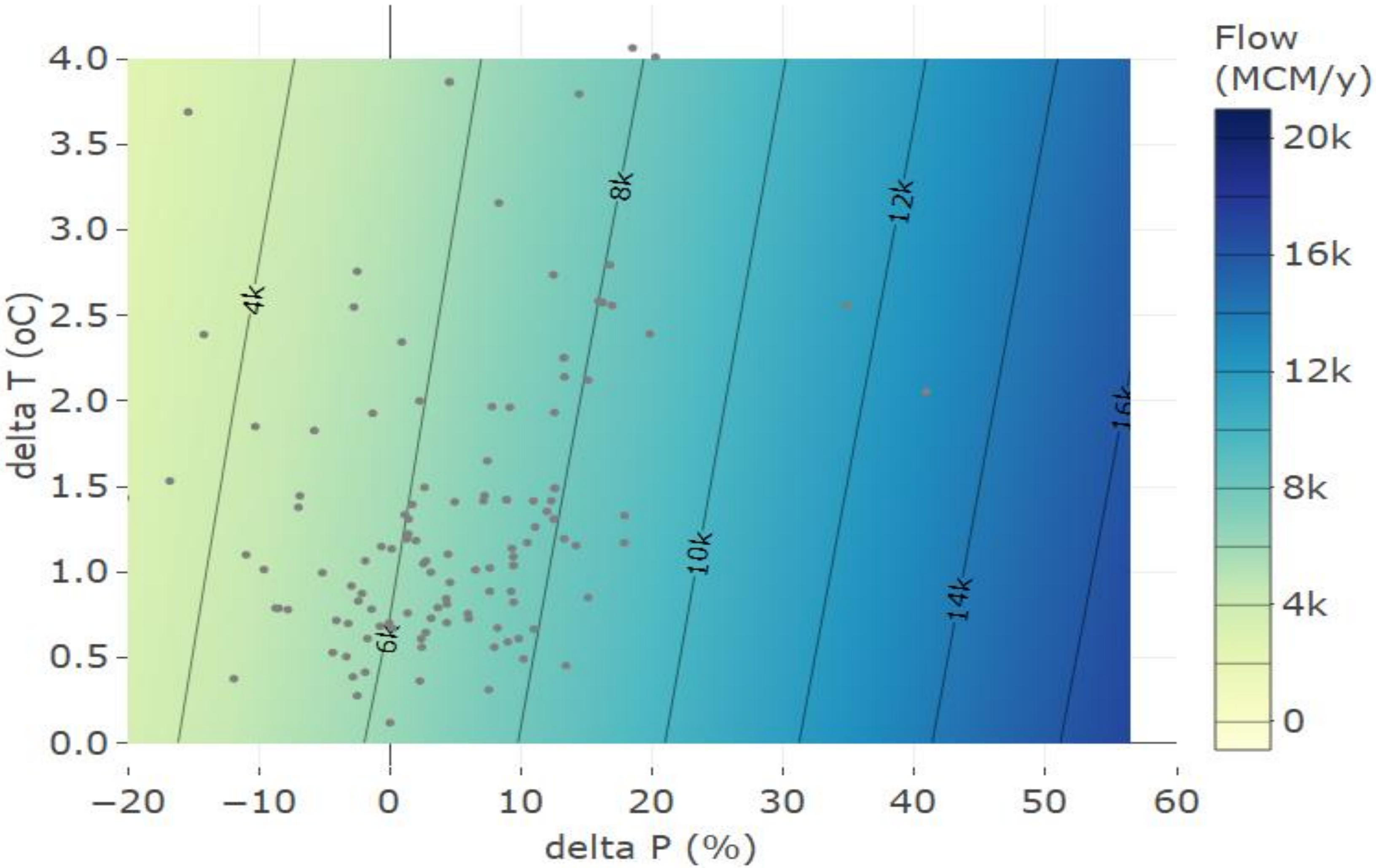




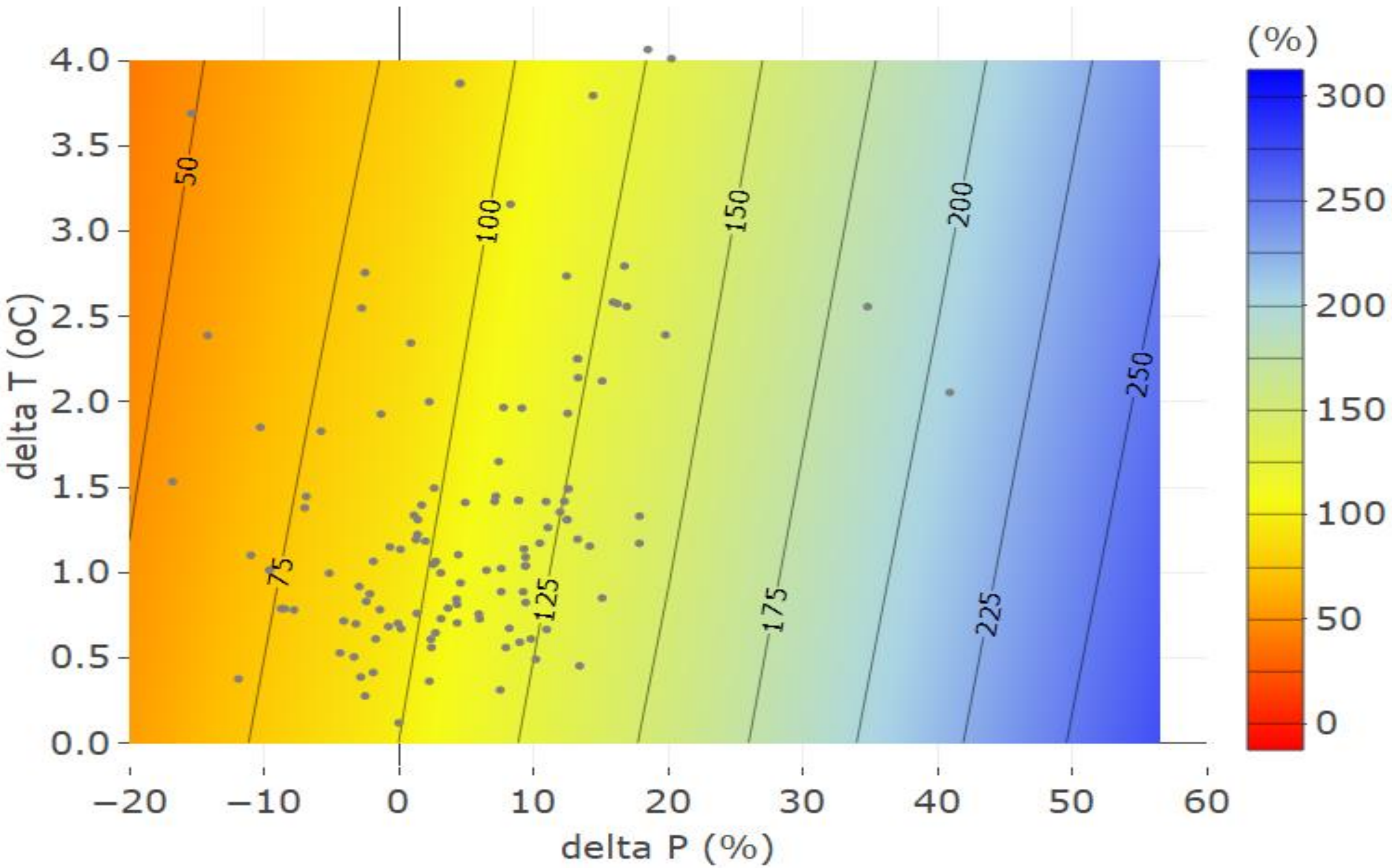


Observed and modeled distribution of daily flows 2005-2009

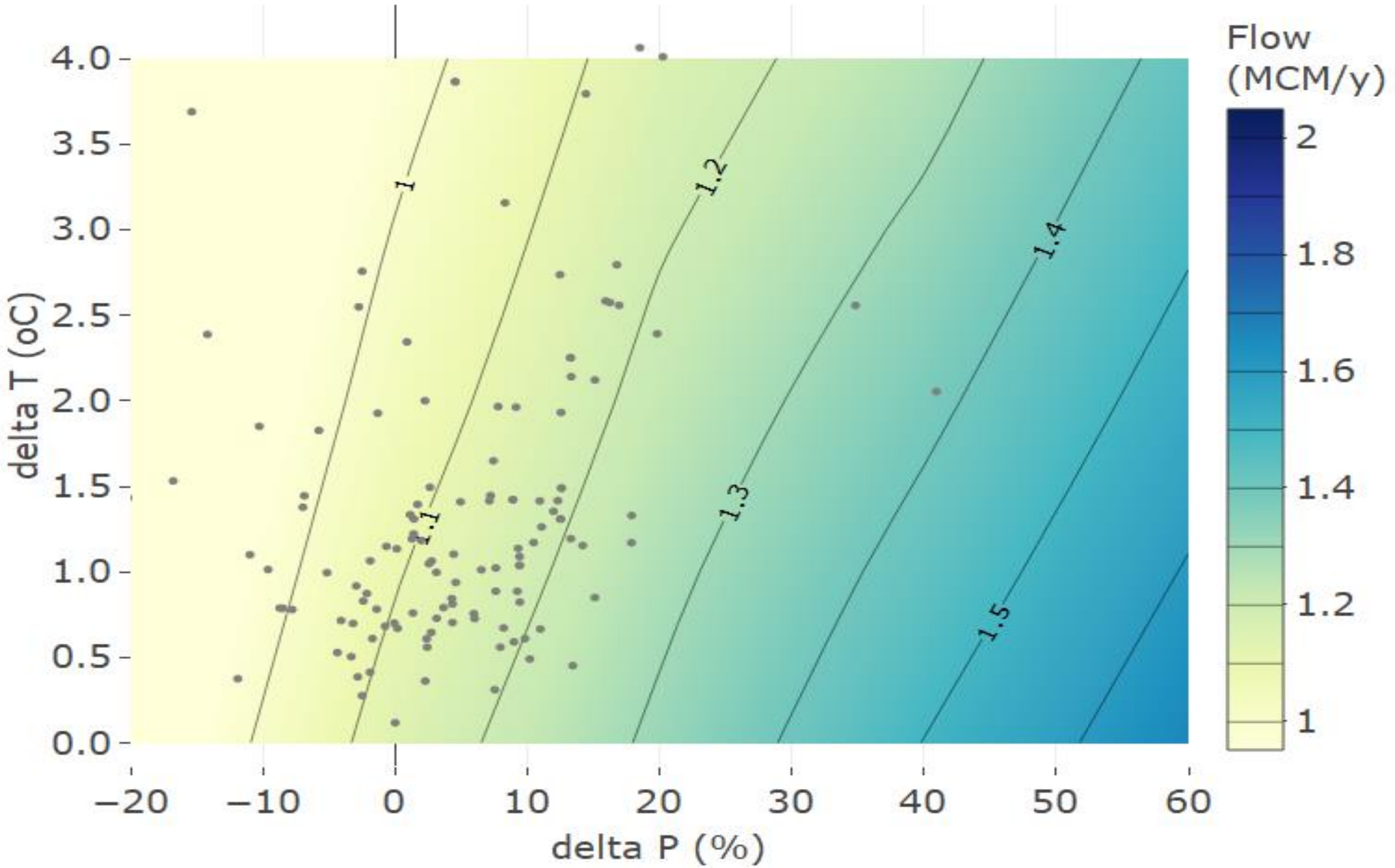
Simulation Results - Combined Impact of Changes in Precipitation and Temperature on Annual Average Cimanuk Discharge (MCM/yr)



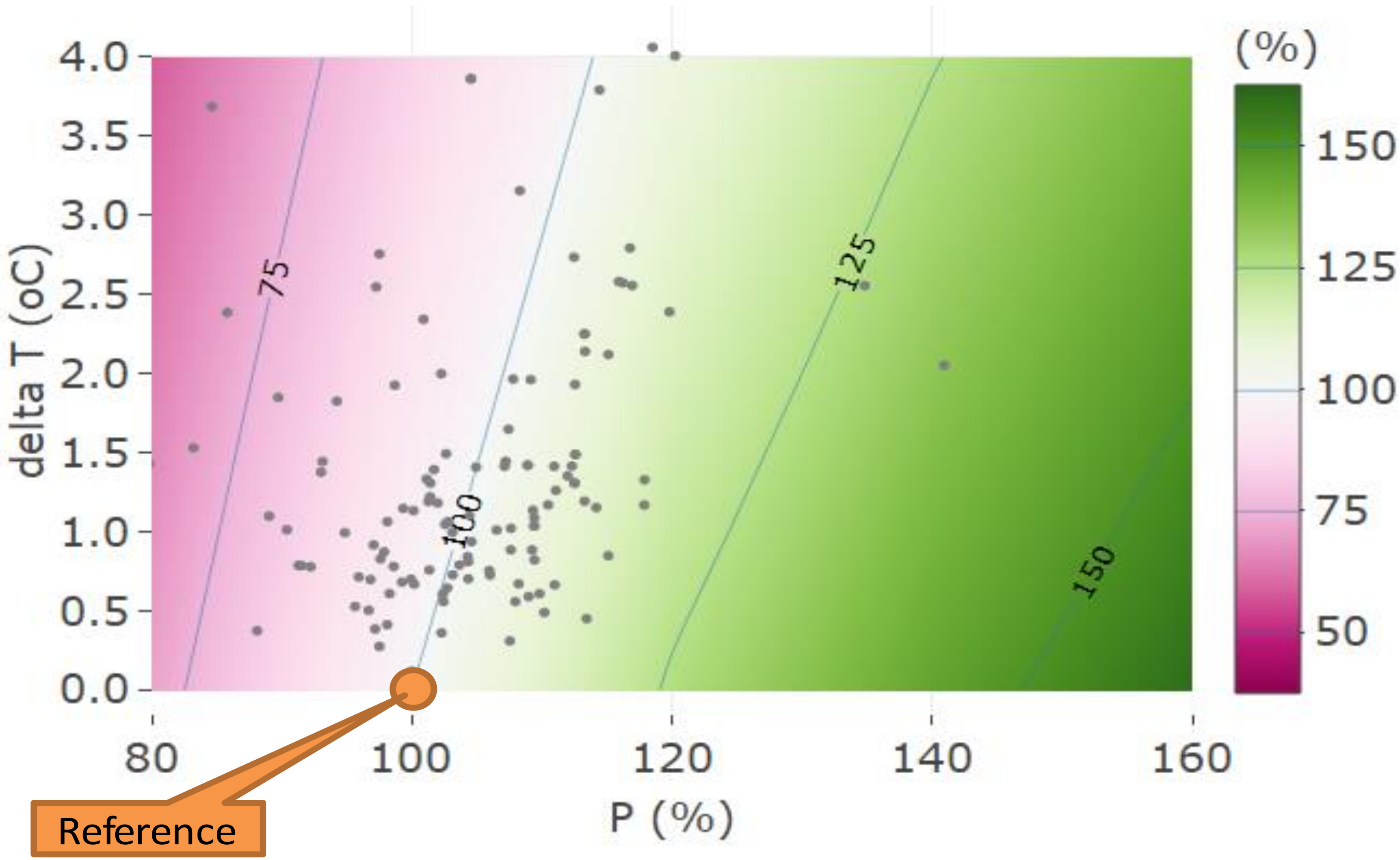
Simulation Results - Combined Impact of Changes in Precipitation and Temperature on Annual Average Cimanuk Discharge in Relative Terms (% of baseline)



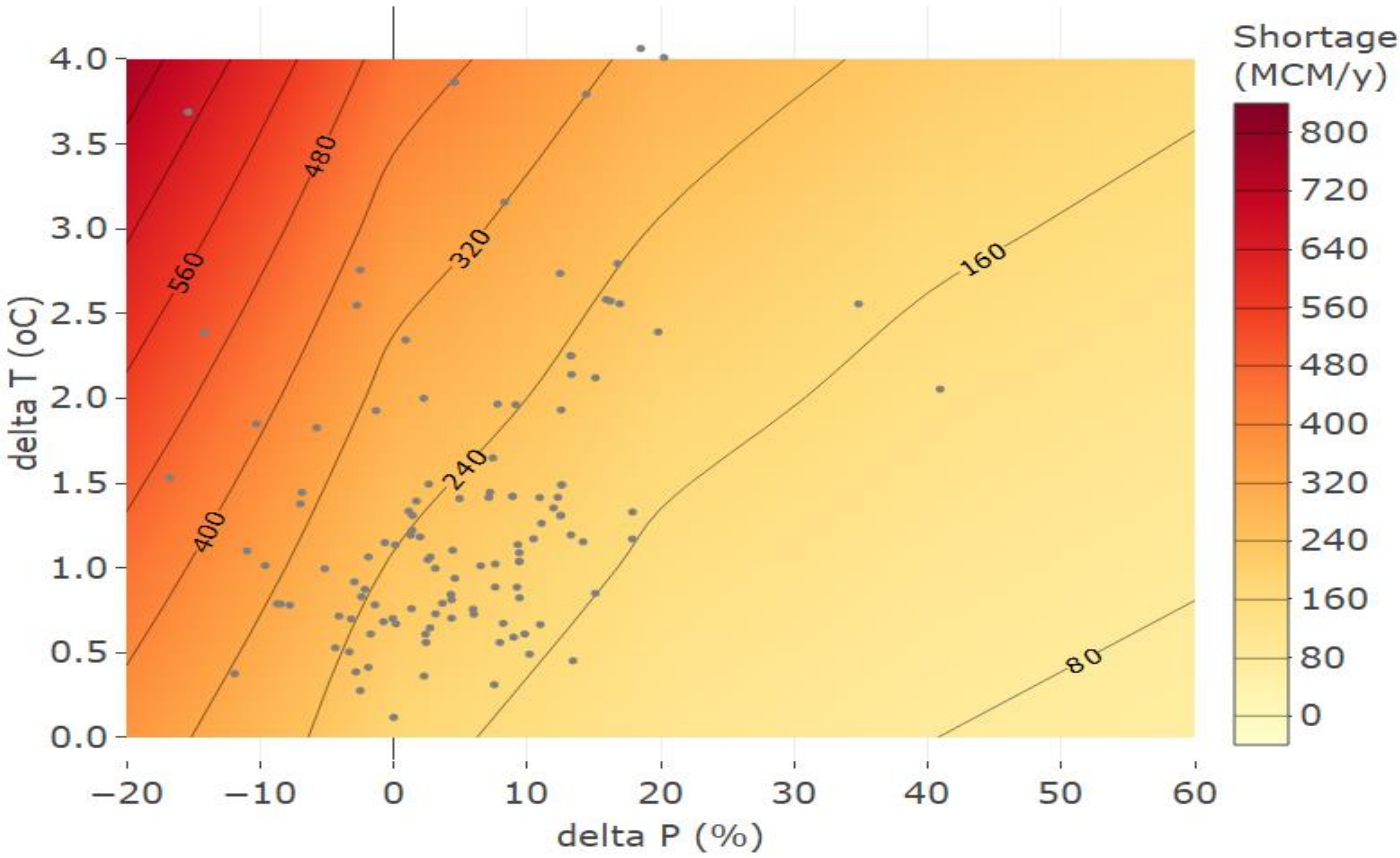
Simulation Results - Combined Impact of Changes in Precipitation and Temperature on Low (5%) Flows at Rentang (MCM/yr)



Simulation Results - Combined Impact of Changes in Precipitation and Temperature on Low (5%) Flows at Rentang relative to Baseline



Simulation Results - Combined Impact of Changes in Precipitation and Temperature on Basin-Wide Water Shortage (unmet demand), 20-year average



Simulation Results - Discrete Impacts of Changes in Precipitation and Temperature on Annual Average Cimanuk Discharge (MCM/yr; %)

DT ºC	Q (MCM)	DQ %	DP %	Q (MCM)	DQ %
0	6,273	0%	-20%	3,456	-45%
+1	5,900	-5.9%	-	6,273	0%
+2	5,543	-11.6%	+20%	9,805	+56%
+3	5,201	-17.1%	+40%	13,719	+119%
+4	4,875	-22.3%	+60%	17,814	+184%

Simulated Adaptation Strategies

The following four strategies were selected from a much wider range of potential adaptation options and evaluated using WEAP simulation:

1. Increase surface water storage – construct additional 1,000 MCM
2. Watershed management – introduce protection measures including terracing and levelling
3. Change in regulations – reduce priority of delivery to irrigation systems (relative to domestic demand)
4. Planning – reduce paddy cultivated area by 10%

Simulated Adaptation Strategies – Results

Percentages represent changes in unmet demand, all sites, relative to Baseline

	Dry	Wet	Avg
	All Sectors		
00_Base	0%	0%	0%
01_Reservoir	-74%	-33%	-73%
02_CatchProtection	-23%	-54%	-47%
03_Priority	0%	0%	0%
04_LessPaddy	-8%	-51%	-12%
	Irrigation		
00_Base	0%	0%	0%
01_Reservoir	-74%	-32%	-72%
02_CatchProtection	-23%	-54%	-47%
03_Priority	+2%	+0%	+2%
04_LessPaddy	-8%	-51%	-12%
	Domestic		
00_Base	0%	0%	0%
01_Reservoir	-98%	-100%	-100%
02_CatchProtection	-28%	-100%	-47%
03_Priority	-100%	-100%	-100%
04_LessPaddy	-8%	-100%	-10%

Recommendations for use of climate risk management in future planning/design cycles

(to be completed)