A Seminar for CCSD students

AIT, Pathumthani, Thailand | 08 February 2024

Integrating top-down and bottom-up approaches for climate adaptation: Concept and application

Mukand S. Babel
Water Engineering and Management (WEM)
Centre for Water and Climate Adaptation (CWCA)
Asian Institute of Technology (AIT)

QUOTES…

While we cannot accurately predict the course of climate change in the coming decades, the risks we run if we don't change our course are enormous.

Prudent risk management does not equate uncertainty with inaction.

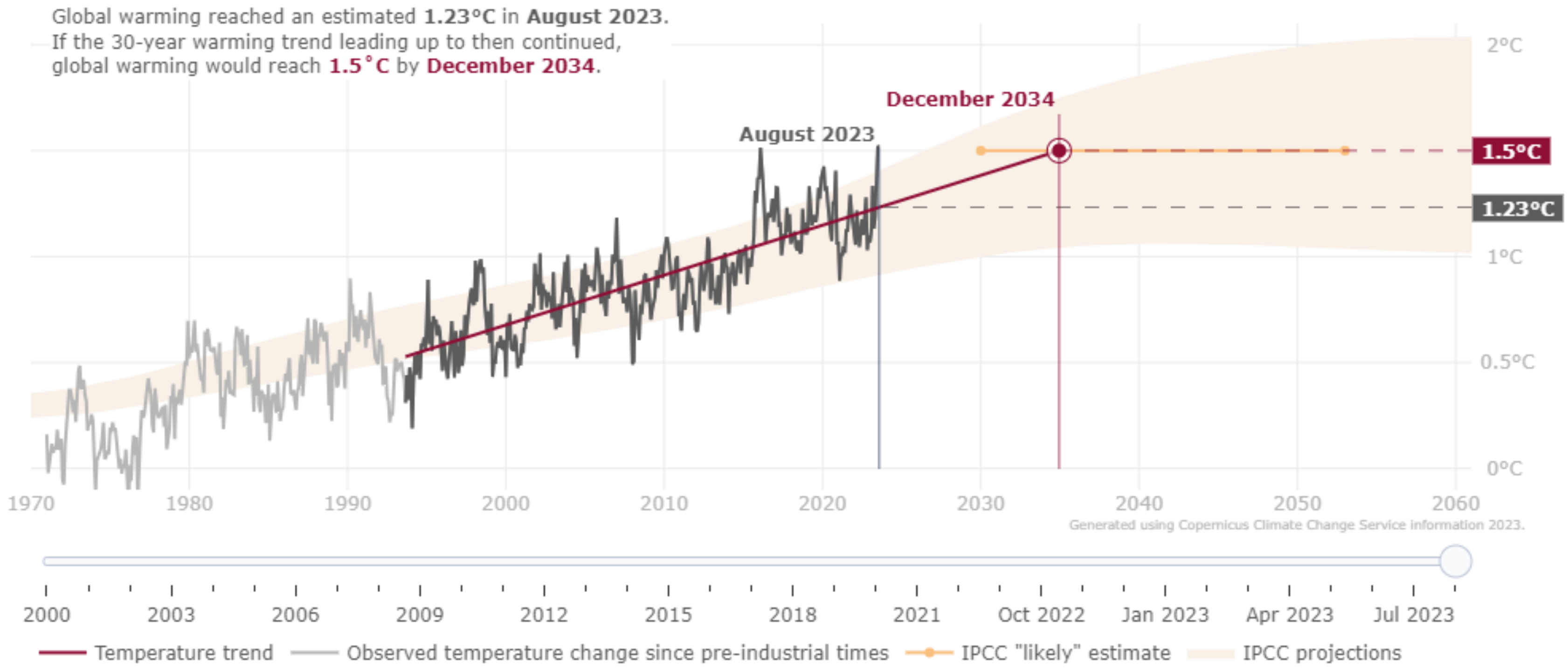
Steven Chu, Nobel Laureate in Physics (1977); Former US Energy Secretary

PRESENTATION OUTLINE

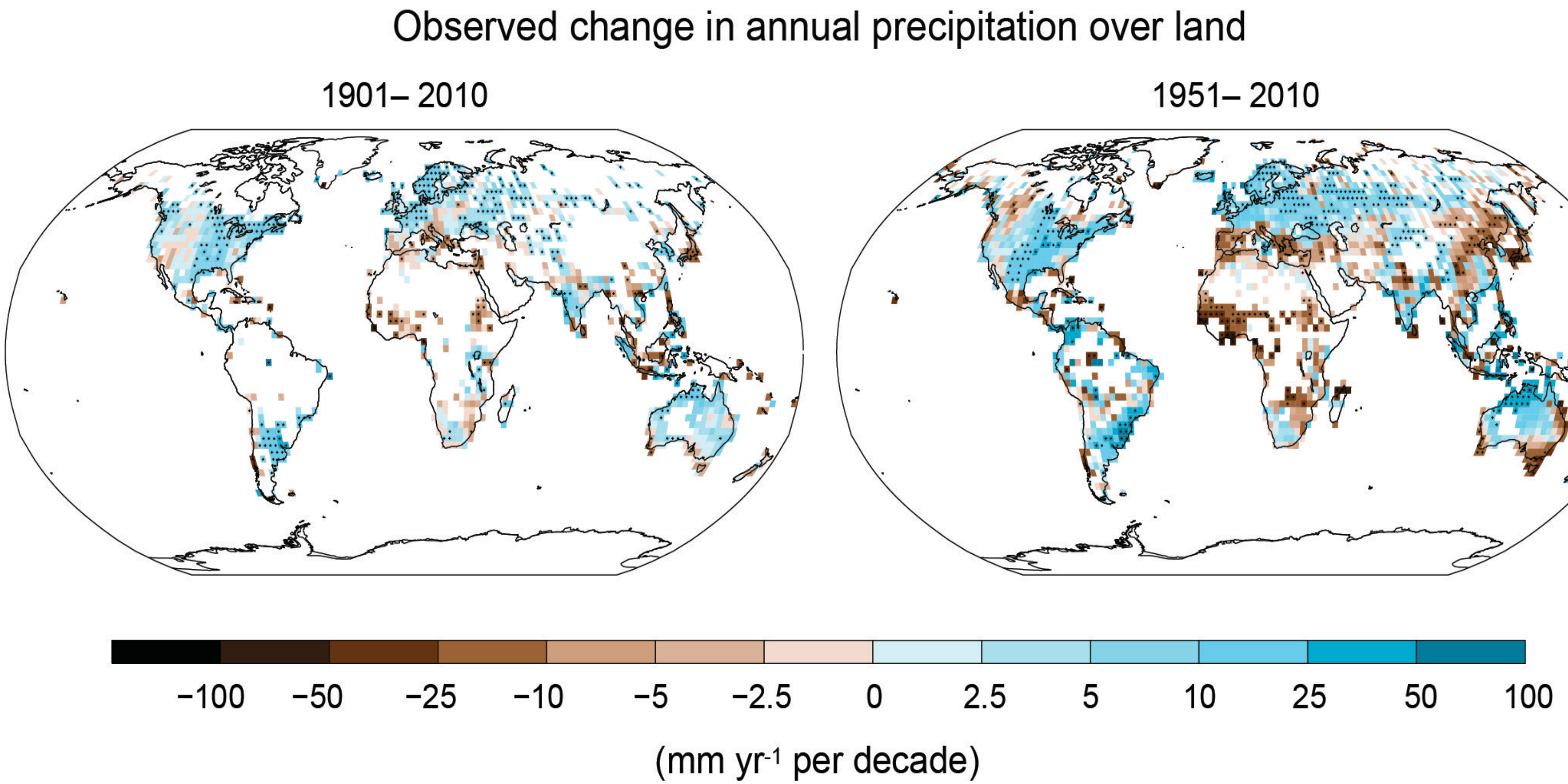
- Setting the scene
  - Climate change and risk
- Vulnerability assessment
  - Top-down and bottom-up
- CRIDA approach
- CRIDA applications
  - Municipal water supply in Bangkok, Thailand
  - Lower Bhavani irrigation project in Tamil Nadu, India
- Way forward…

TEMPERATURE

How close are we to reaching a global warming of 1.5˚C?



PRECIPITATION



(AR5, IPCC 2015)

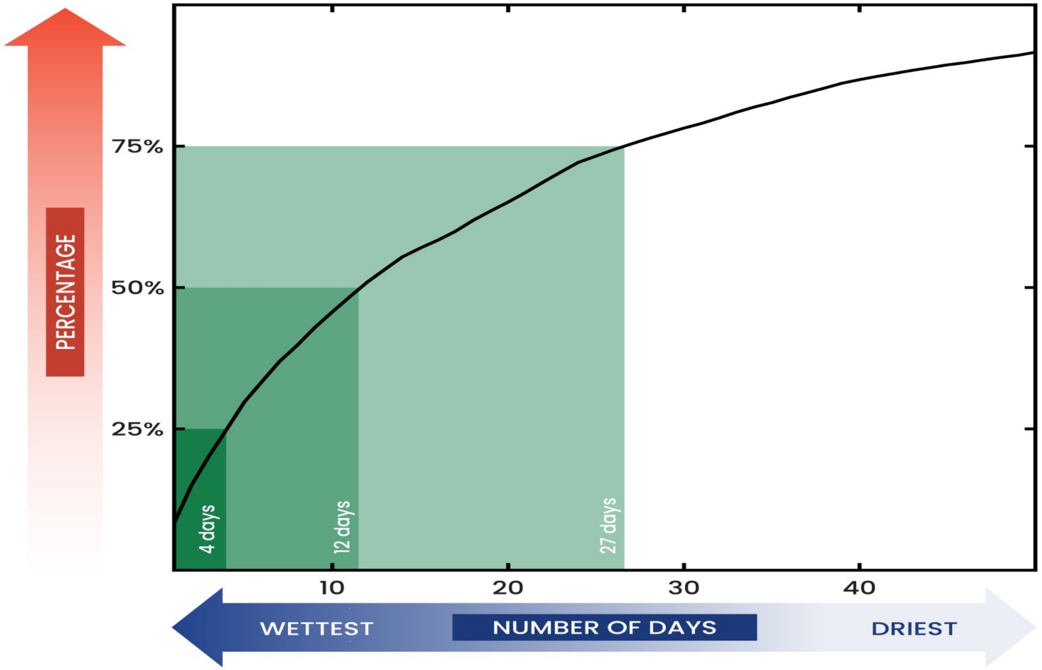
Rate of change of precipitation since 1951 has accelerated than previous period

PRECIPITATION

Half of the world's annual precipitation falls in **just 12 days**

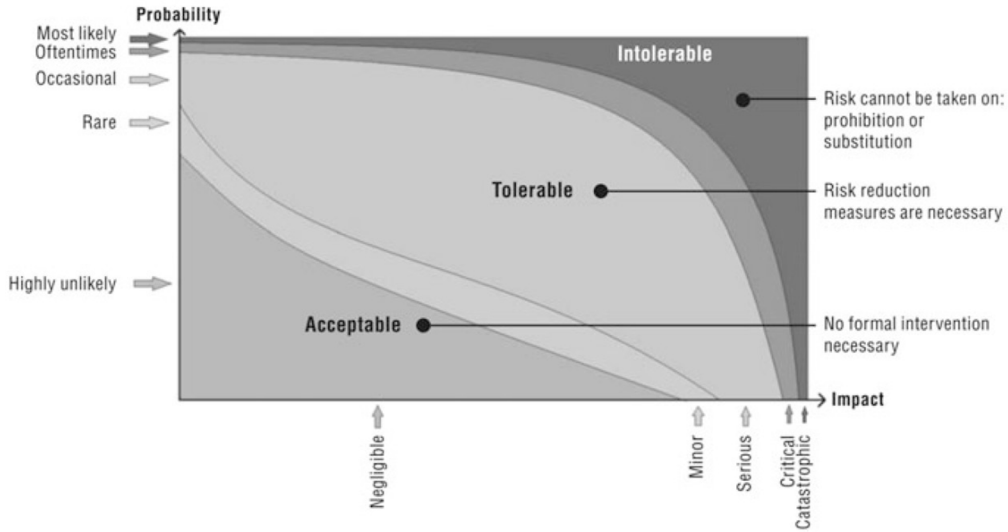
Climate change likely to make global precipitation more uneven

- Analysis of rainfall measured at stations across the globe (1999-2014): the median time it took for 50% of a year’s precipitation to fall was just 12 days
- In a high GHG emission scenario: half of precipitation increase occurs in the wettest 6 days each year

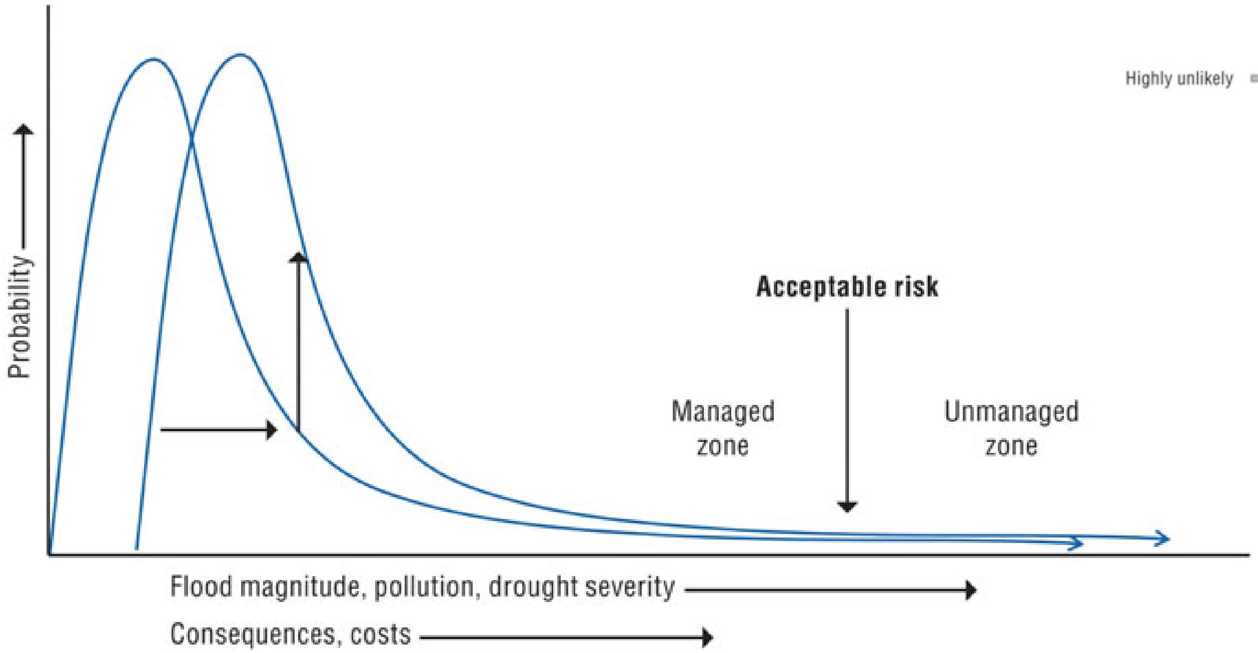


Pendergrass and Knutti (2018)

ACCEPTABLE LEVEL OF CLIMATE AND WATER RISK



Tortajada & Fernandez (2018)



Prosser (2012)

VULNERABILITY

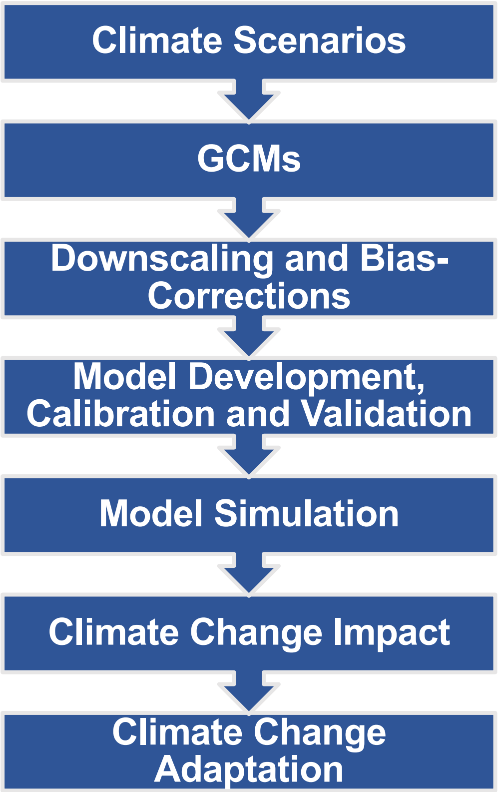
The propensity or predisposition to be adversely affected.

Vulnerability encompasses a variety of concepts and elements, including sensitivity or susceptibility to harm and lack of capacity to cope and adapt

- Component of risk, but also an important focus independently
- Improves understanding of the differential impacts of climate change on people of different gender, race, wealth, social status and other attributes.
- Provides an important link between climate adaptation and disaster risk reduction

CLIMATE VULNERABILITY ASSESSMENT

Top-down (*Predict-then-act*) approach and its uncertainty



Limitation of scenario selection

Are the scenarios capable of representing the future climate?

Limitation in GCM selection

Inability of GCMs to represent basin level climate

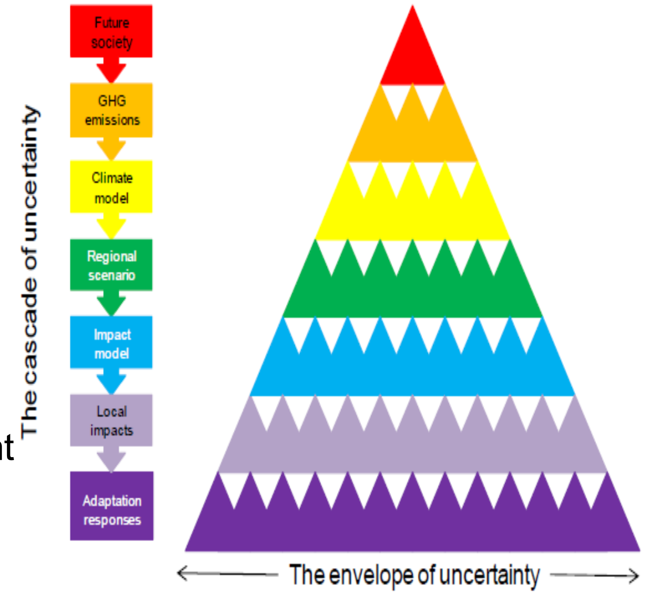
Limitation in downscaling and bias-correction

Which method is most suitable, since every method gives different results!

Limitation in model development and simulation

Selection of different methods for representation of different processes

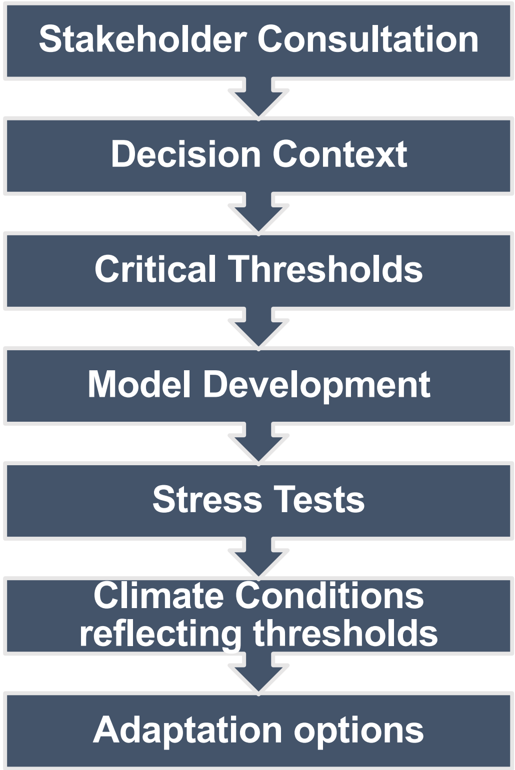
How accurate should the performance of the model be?



(Wilby and Dessai, 2010)

Uncertainty occurs at every stage! Error gets augmented at every step

CLIMATE VULNERABILITY ASSESSMENT



Bottom-up approach

- Involvement of stakeholders in understanding the vulnerability of the existing infrastructure or system
- Decisions are not solely based on model outputs
- Different bottom-up approaches
  - Decision Scaling
  - Eco-Engineering Decision Scaling (EEDS)
  - Climate Risk-Informed Decision Analysis (CRIDA)

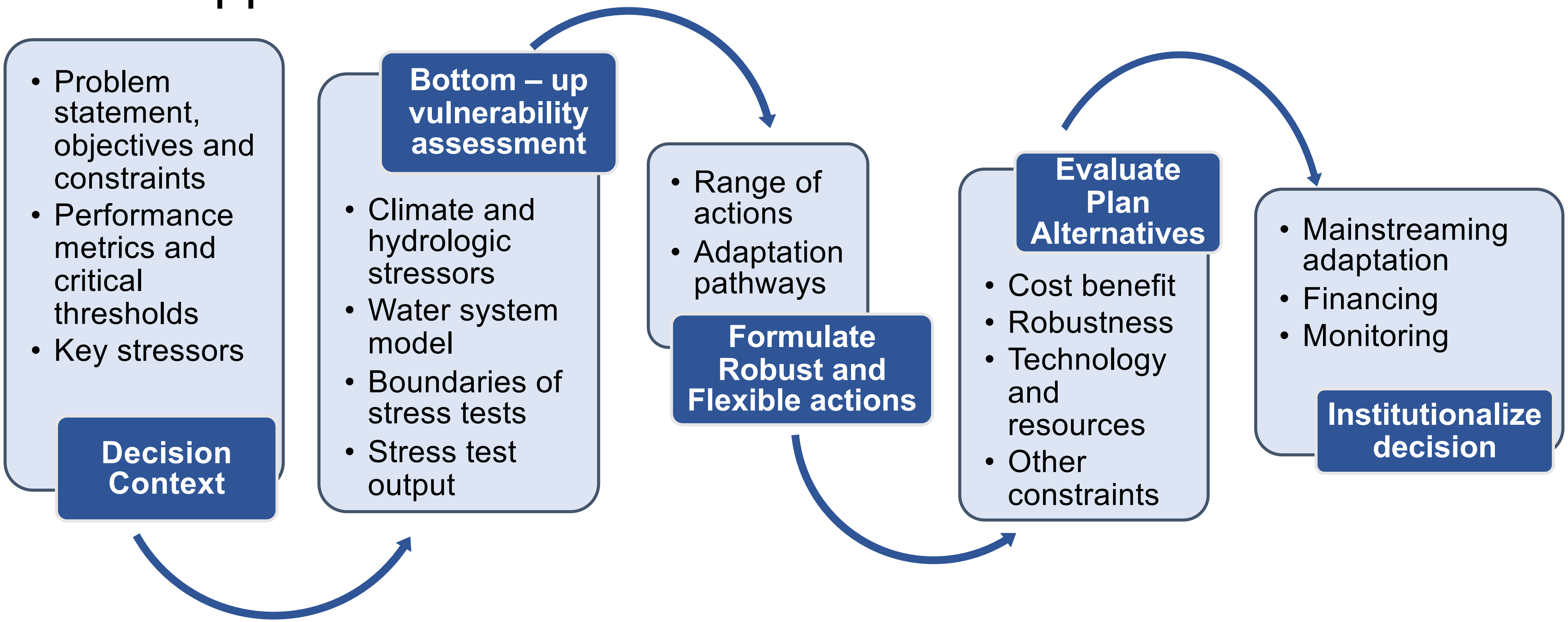
CLIMATE RISK INFORMED DECISION ANALYSIS (CRIDA)

WHAT?	**Adaptive planning, "decision-centric" approach**
WHY?	**Uncertainty in investments and future planning**
WHO?	**Decision makers, water managers, all stakeholders…**
HOW?	**A series of steps for assessing, planning & decision making**
WHERE?	**Any water resources project**
WHEN?	**Any point during or before lifetime of WR project**

"CRIDA provides a collaborative process for risk-informed decision making - effectively assessing, managing, and communicating risks to stakeholders and decision makers, including successfully avoided risks and residual risks that cannot be avoided, quantified, or isolated"

Mendoza et al. (2018)

CRIDA approach



STEP 1. DECISION CONTEXT

1.1 Problem statement – Constructive, include constraints

Constructive	Unconstructive
In the dry season, water shortages affect our crop yields	The irrigation system is inefficient
The site has a growing economy and population, but there is an energy shortage	We need hydropower dams
We see increasing frequencies of flooding and worsening impacts from flooding	We need more flood control levies because of climate change

STEP 1. DECISION CONTEXT

1.2 Set planning objectives

- Related to the problems and opportunities
- Inform, define and prioritize performance metrics
- Limited to one or two core targets
- Provide information on
  - Desired effect (quantified, if possible)
  - Subject of the objective
  - Location of the effect
  - Timing of the effect, and
  - Duration of the effect

STEP 1. DECISION CONTEXT

1.3 Define performance metrics

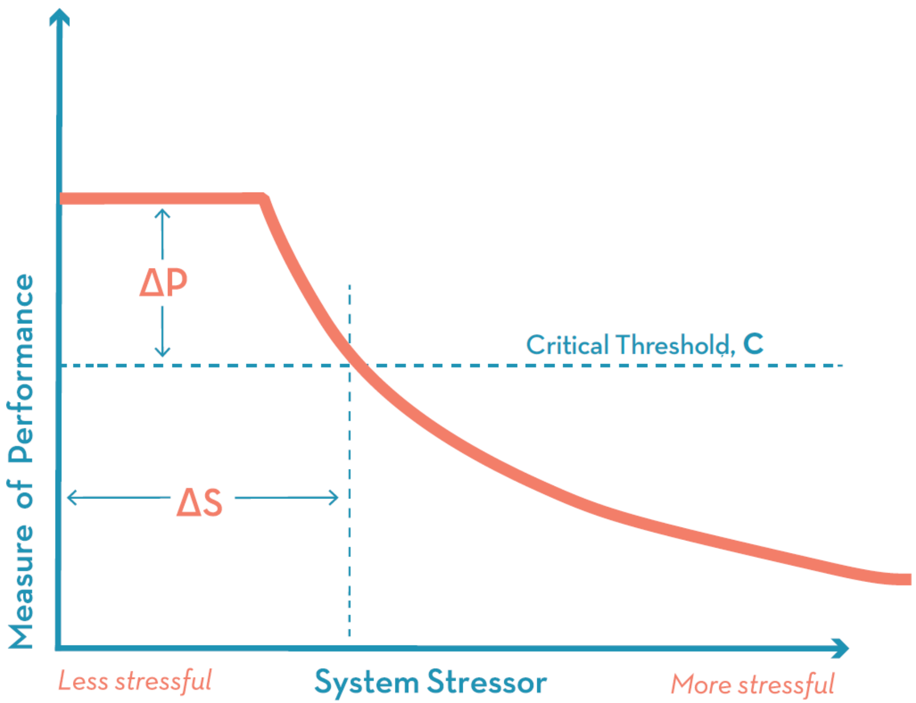
Topic of interest	External driver	Design variables to improve performance	Potential performance metrics
Water supply	Variability, persistence and averages of the hydrologic input variables, target demand, upstream abstractions, Temperature	Storage volume Target yield Demand management	Tied to benefits to relevant sectors in energy, agriculture, industry, and municipal use that benefit from water supply
Flood risk reduction	Intensity, duration, frequency, and spatial extent of rainfall events; permeability of catchment; antecedent moisture; operations; value and location of property and human settlements	Levee height Floodplain area Flood routing bypass Detention volume Management of risk Runoff coefficient	Based on losses to productivity, property, and lives (probability function for expected losses); or based on an area flooded or a specific level of loss or impact (e.g., a design flood)

STEP 1. DECISION CONTEXT

Topic of interest	External driver	Design variables to improve performance	Potential performance metrics
Coastal risk reduction	Sea level rise, storm surge, and frequency of events; value and location of property and human settlements	Dune height and width Sea wall dimensions Wetland area Management of risk	Same as flood risk reduction
Ecology	Flow regime, environmental water quality, dam operations, nutrient composition, sediment transport	Floodplain area Indicators of hydraulic alteration Habitat connectivity	Often based on species indicators, habitat quality, different flow regimes, species abundance, fishery productivity, reproductive success, floodplain connectivity, divergence from flow regime reference

STEP 1. DECISION CONTEXT

1.4 Performance thresholds



Threshold - Level of chronic unacceptable performance

Impact (P) from unacceptable performance - Difference between the performance under expected climate states and the critical threshold defined

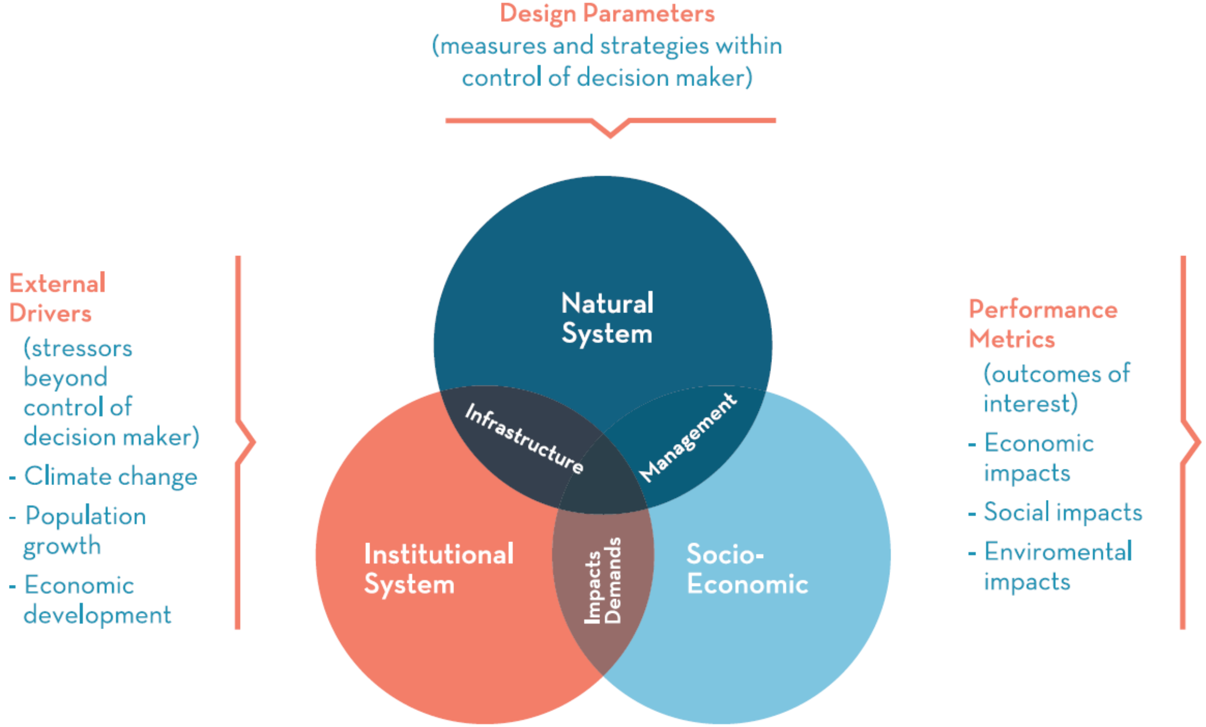
STEP 1. DECISION CONTEXT

1.5 Drivers of change

Water resources system type	Key hydrologic statistic
Rainfall dependent water supply system	Variability of flow or rainfall Persistence (or auto-correlation) of low flows or rainfall
Glacial dominated water supply system	Persistence of high mean temperatures
Flood risk reduction system	Maximum annual peak flow
Coastal risk reduction	Mean sea level
Ecological	All the above

STEP 2. BOTTOM-UP VULNERABILITY ASSESSMENT

2.1 Water Resources System Model

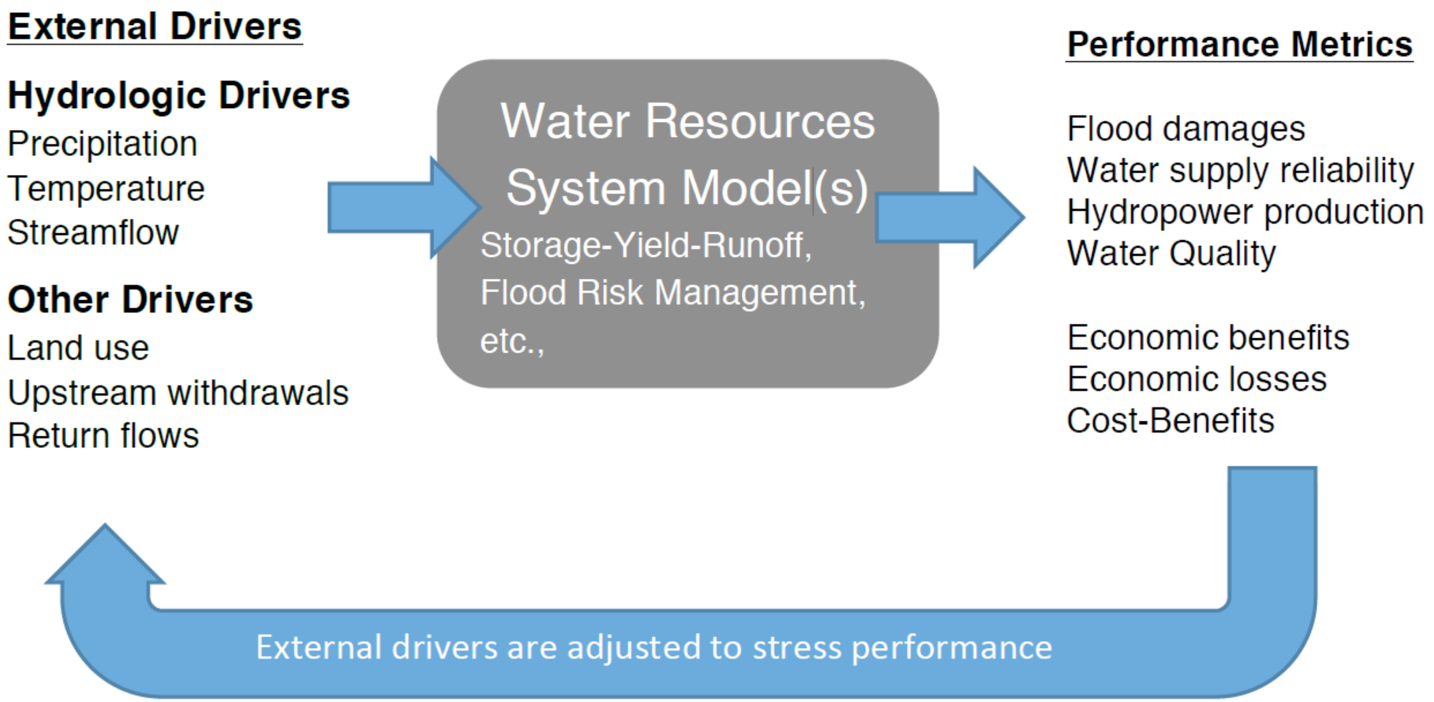


Connect external drivers to measures of performance

- Variables
  - Technical
  - Social
  - Economic
  - Natural system

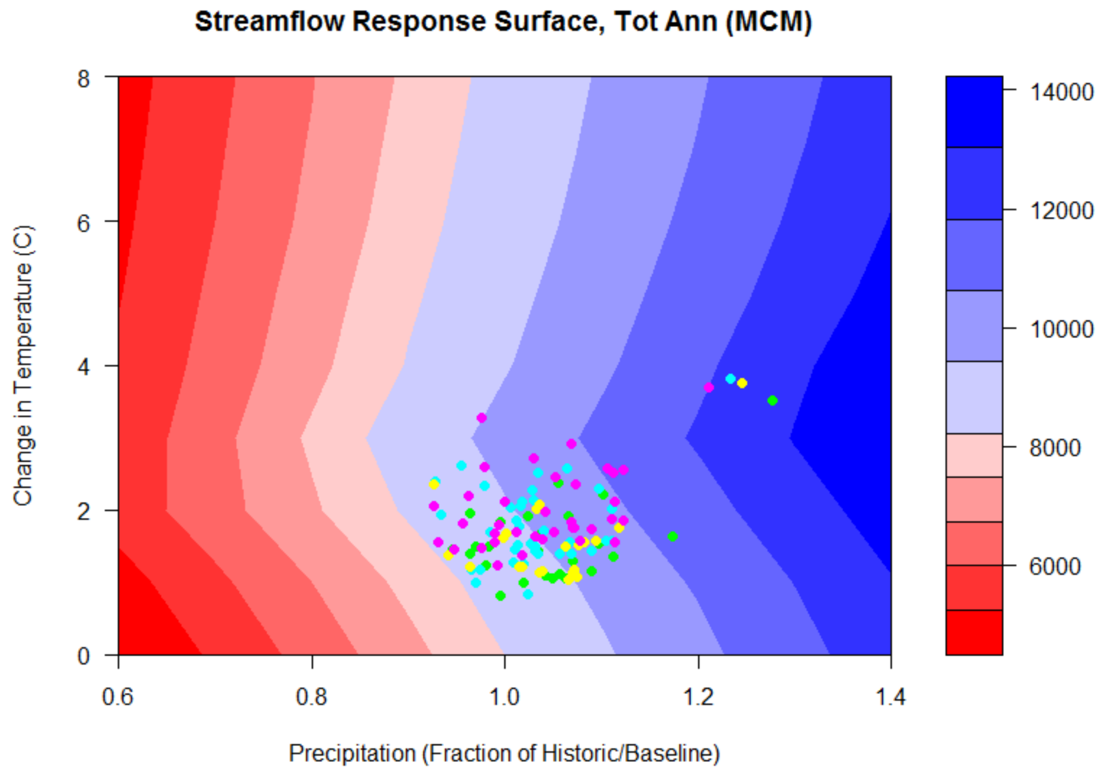
STEP 2. BOTTOM-UP VULNERABILITY ASSESSMENT

2.2 Stress test



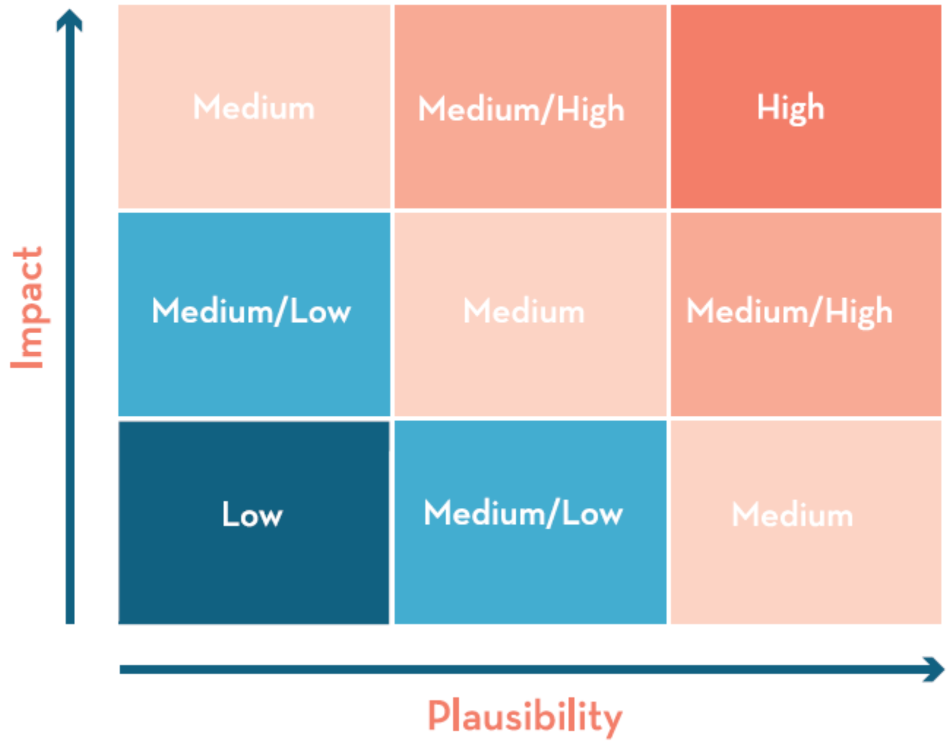
STEP 2. BOTTOM-UP VULNERABILITY ASSESSMENT

2.2 Stress test



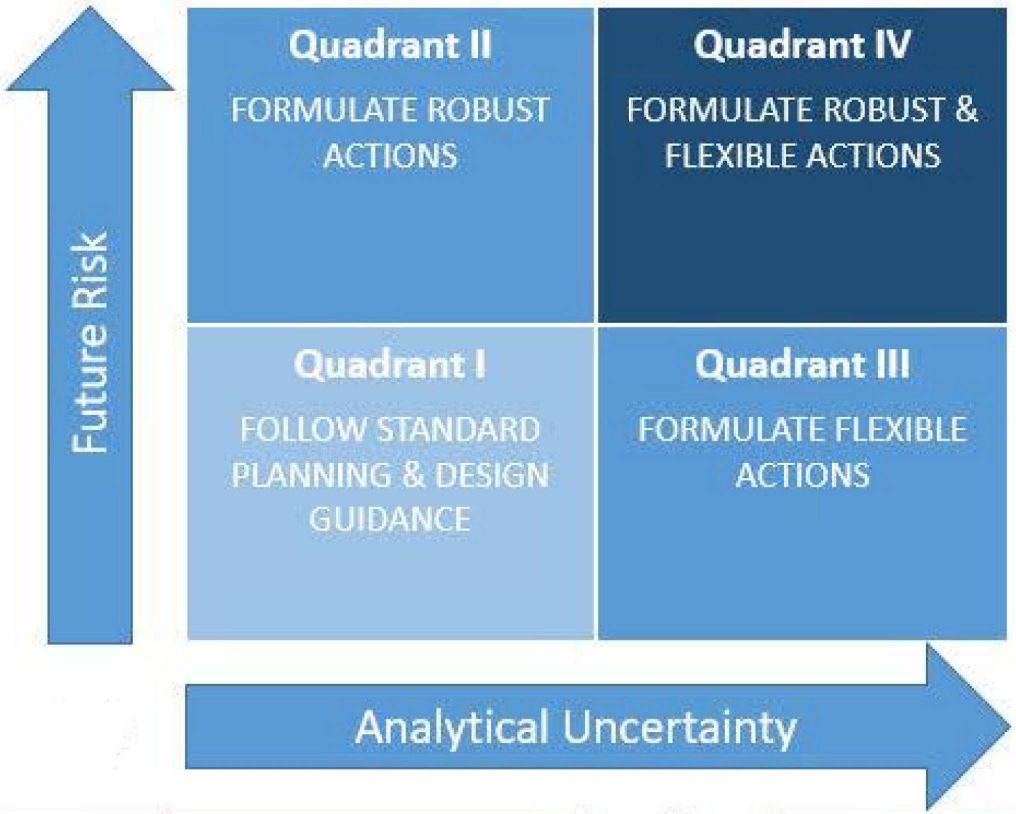
STEP 2. BOTTOM-UP VULNERABILITY ASSESSMENT

2.3 Risk matrix



STEP 3. FORMULATING ALTERNATIVE PLANS

3.1 Level of Concern Analysis



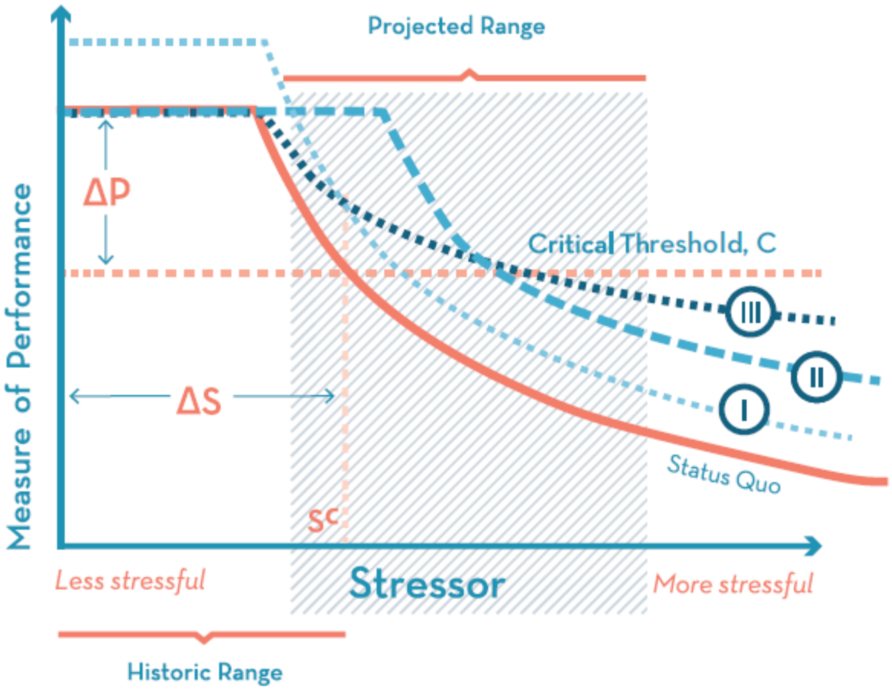
STEP 3. FORMULATING ALTERNATIVE PLANS

3.2 Diverse course of action

- Rank groups of futures and formulate actions to reduce the impact of each cluster
- Formulate actions that reduce risk across multiple steps or stages of a project
- Develop robust actions ranked by efficacy and cost
- Consider completeness—other necessary actions or investments that are needed beyond the “core” solution
- Propose actions that must comply with regulations and/or be socially acceptable.

STEP 3. FORMULATING ALTERNATIVE PLANS

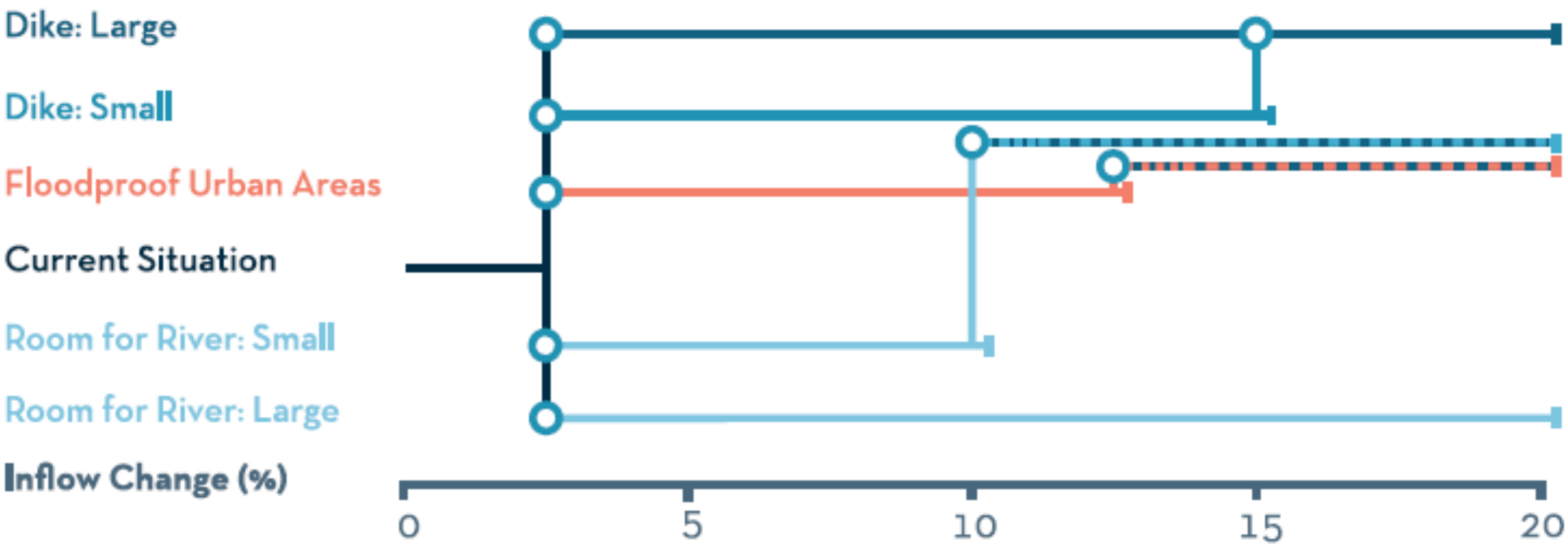
3.3 Evaluate robustness using stress test



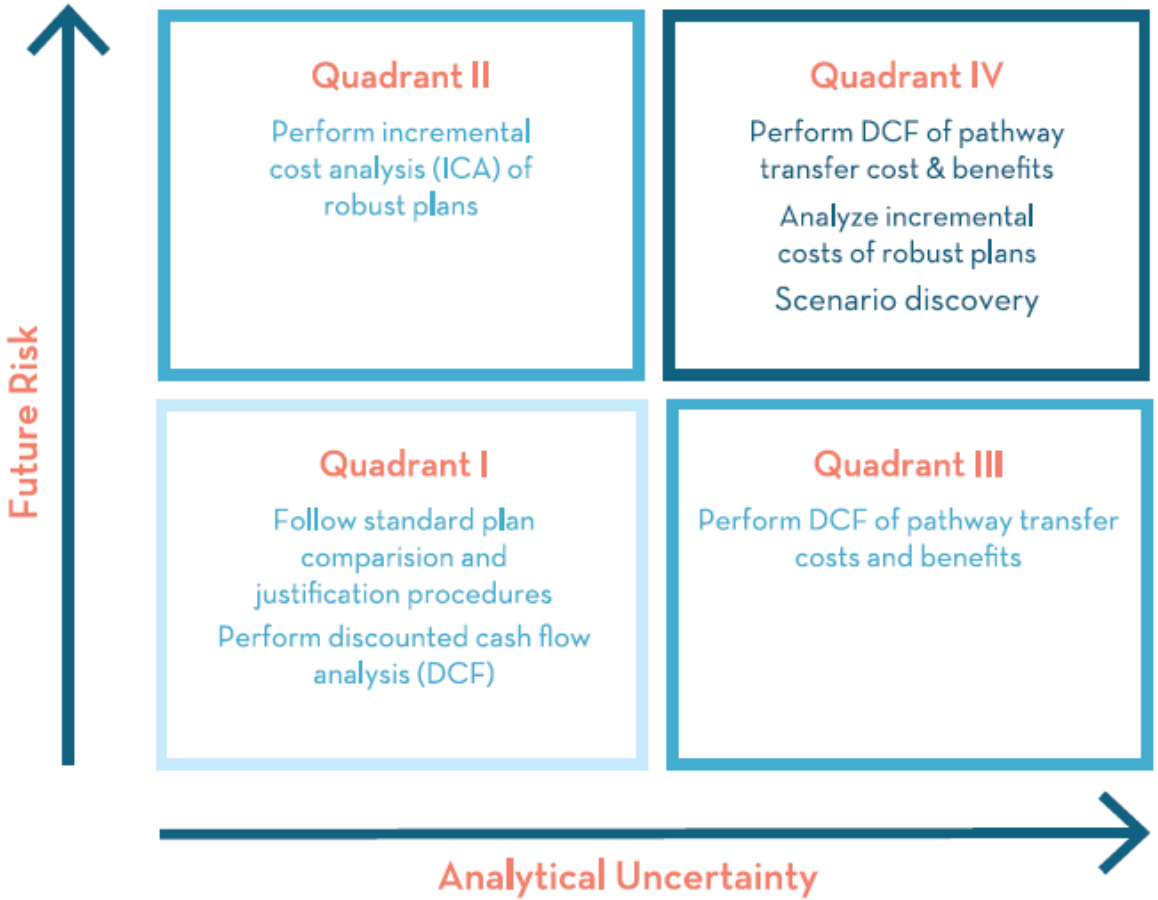
How performance reliability or resilience is improved over the status quo if risk reducing measures were to be implemented.

STEP 3. FORMULATING ALTERNATIVE PLANS

3.4 Developing adaptation pathways

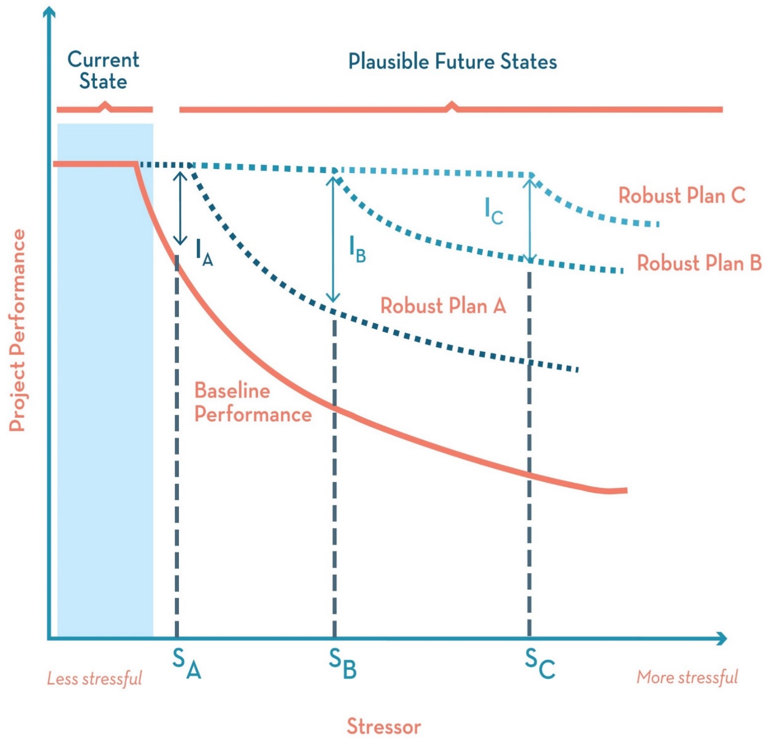


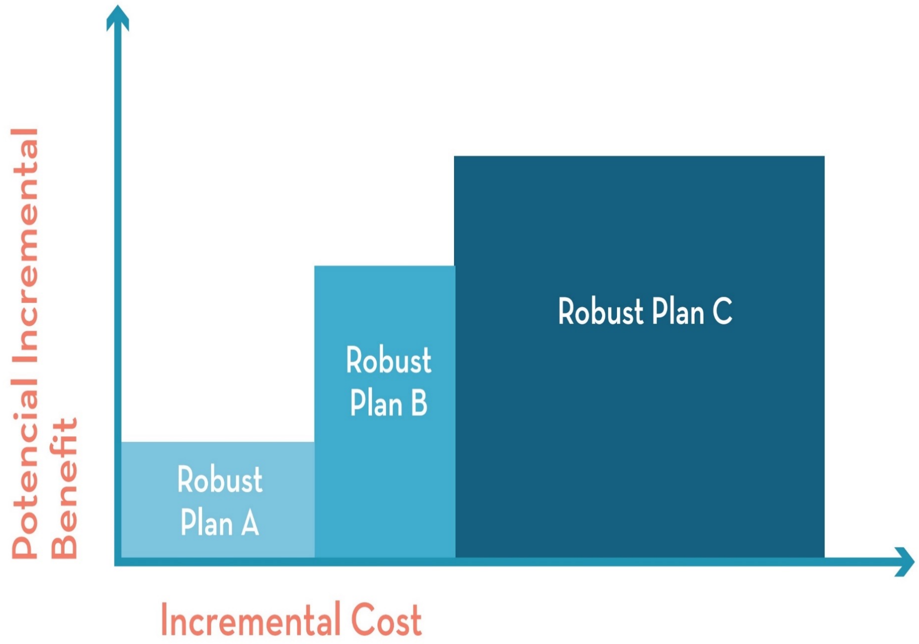
STEP 4. COMPARING AND RECOMMENDING PLANS



STEP 4. COMPARING AND RECOMMENDING PLANS

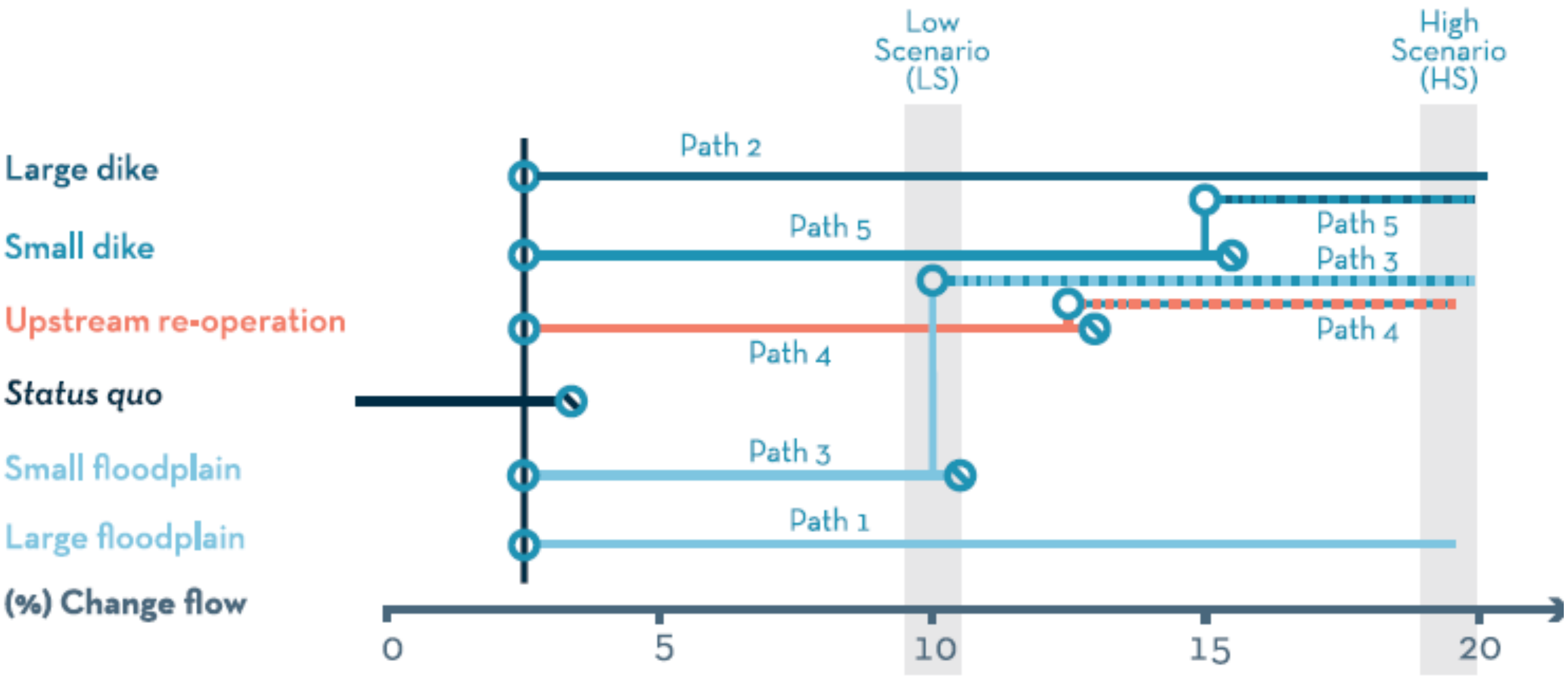
4.1 Incremental Cost Analysis





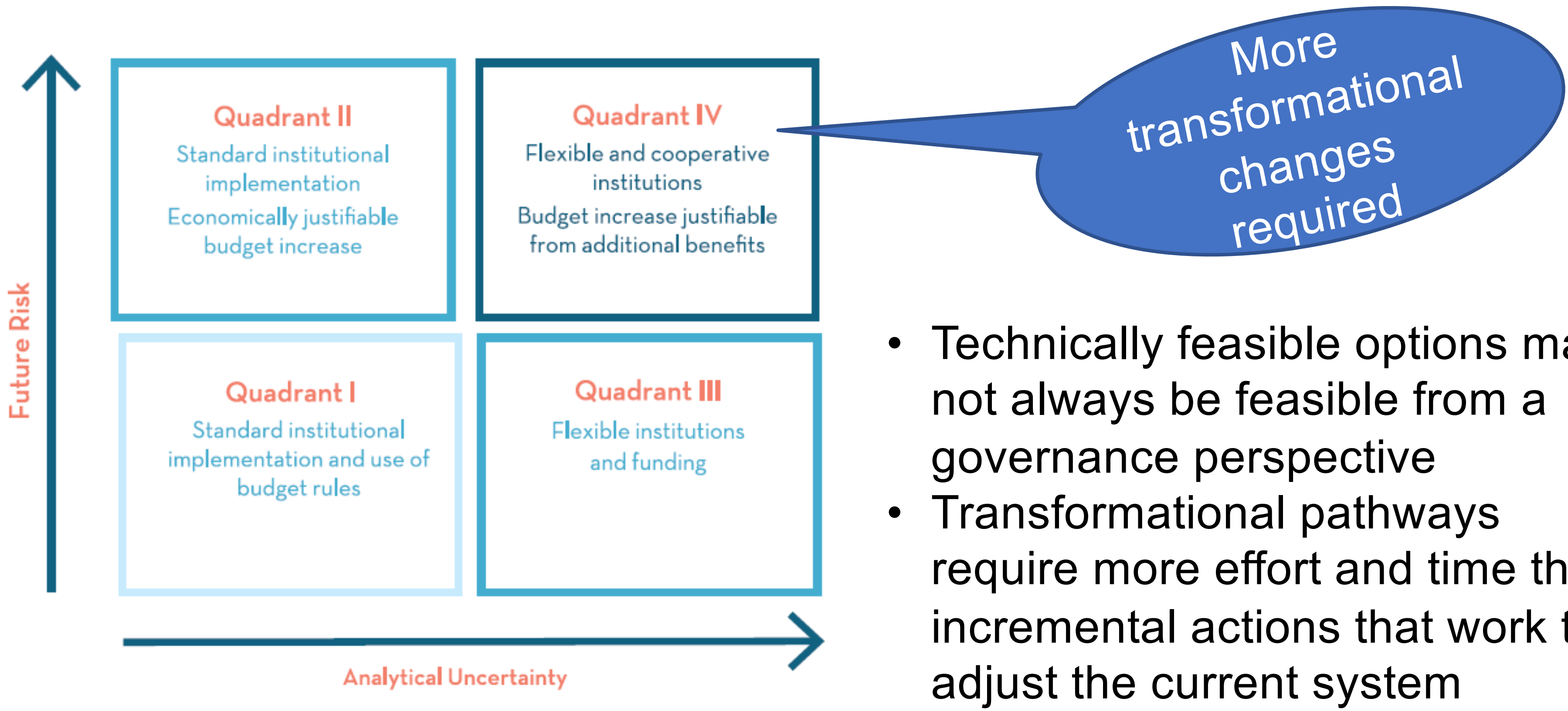
STEP 4. COMPARING AND RECOMMENDING PLANS

4.2 Adaptation pathways map



STEP 5. INSTITUTIONALIZING THE DECISIONS

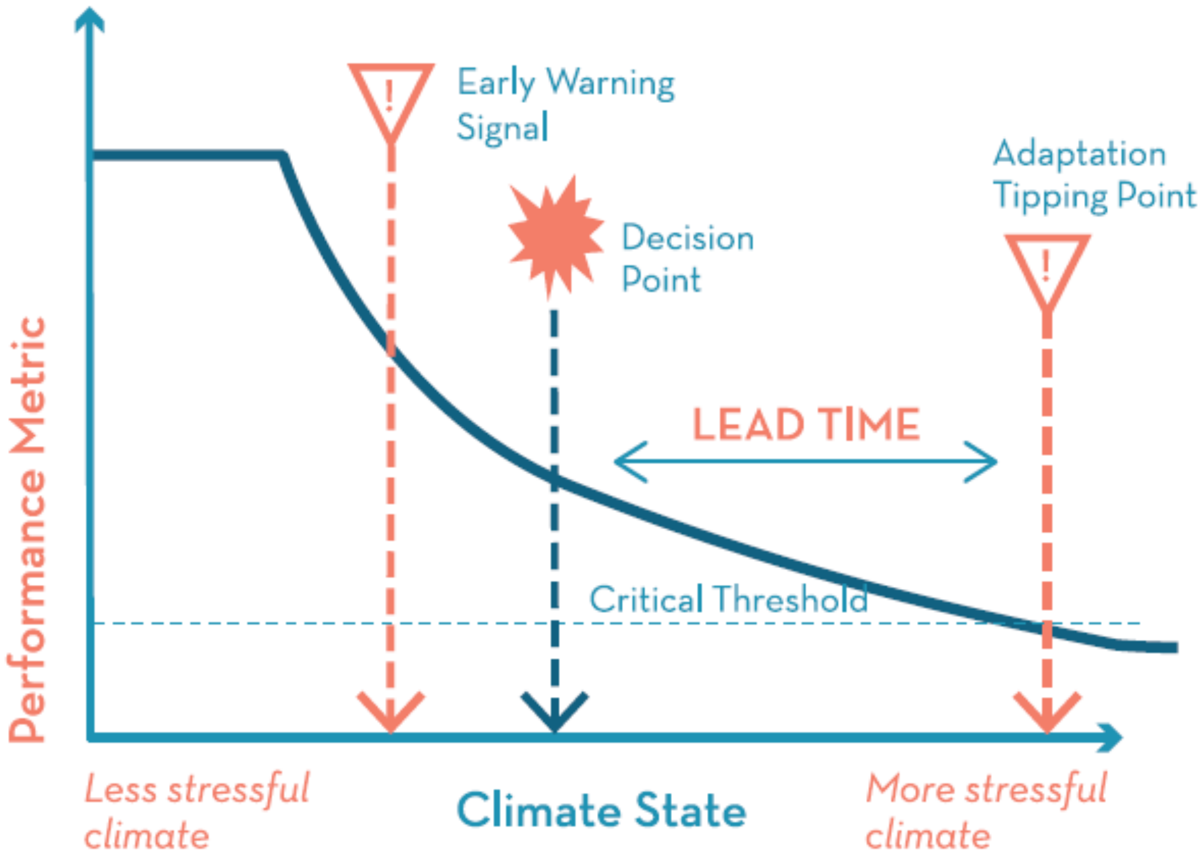
5.1 Institutional Decision Rules



- Technically feasible options may not always be feasible from a governance perspective
- Transformational pathways require more effort and time than incremental actions that work to adjust the current system

STEP 5. INSTITUTIONALIZING THE DECISIONS

5.2 Monitoring and Evaluation



Case Study

Climate Change Adaptation in Municipal Water Supply of Bangkok, Thailand

Rachel Koh, **Mukand Babel**, Victor Shinde and Guillermo Mendoza

Climate Risk Management 35 (2022) 100406

Contents lists available at ScienceDirect

Climate Risk Management

journal homepage: www.elsevier.com/locate/crm

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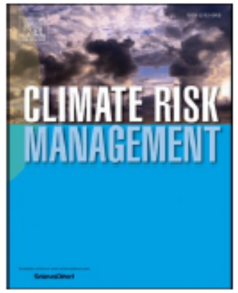
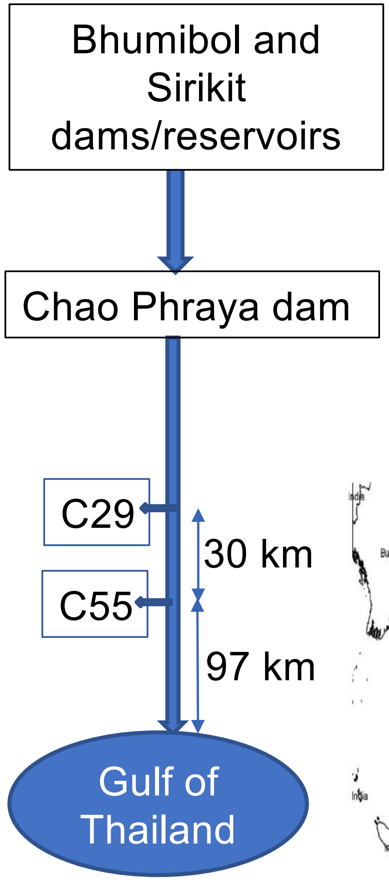


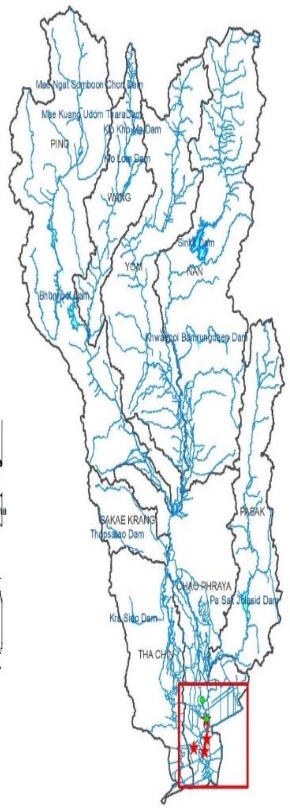
Towards climate resilient municipal water supply in Bangkok: A collaborative risk informed analysis

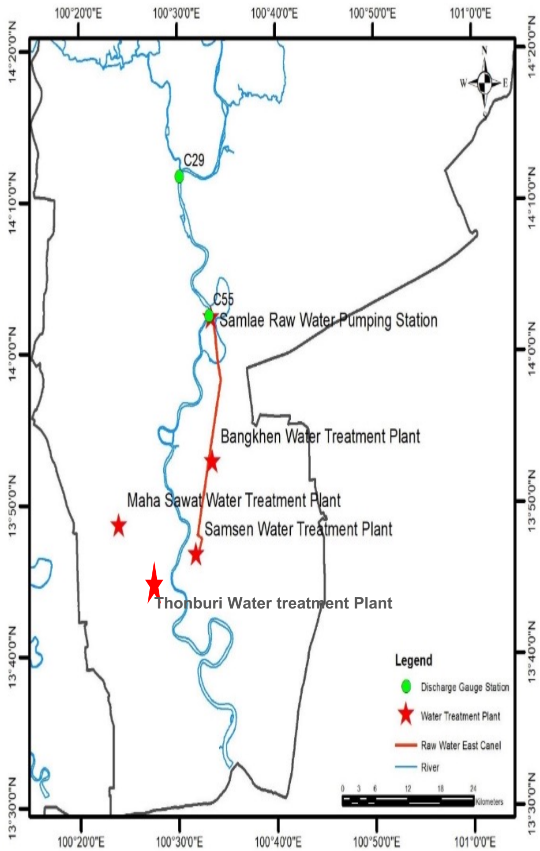
Rachel Koh [a,b], Mukand S. Babel [b,*], Victor R. Shinde [b,c], Guillermo Mendoza [d]

[a] *Pillar of Engineering Systems and Design, Singapore University of Technology and Design, 8 Somapah Rd, Singapore 487372, Singapore*
[b] *Water Engineering and Management, Asian Institute of Technology, P.O. Box 4, Klong Luang, Pathum Thani 12120, Thailand*
[c] *National Institute of Urban Affairs, New Delhi, India*
[d] *United States Army Corps of Engineers Institute for Water Resources, Washington, United States*

STUDY AREA: MUNICIPAL WATER SUPPLY OF BANGKOK, THAILAND





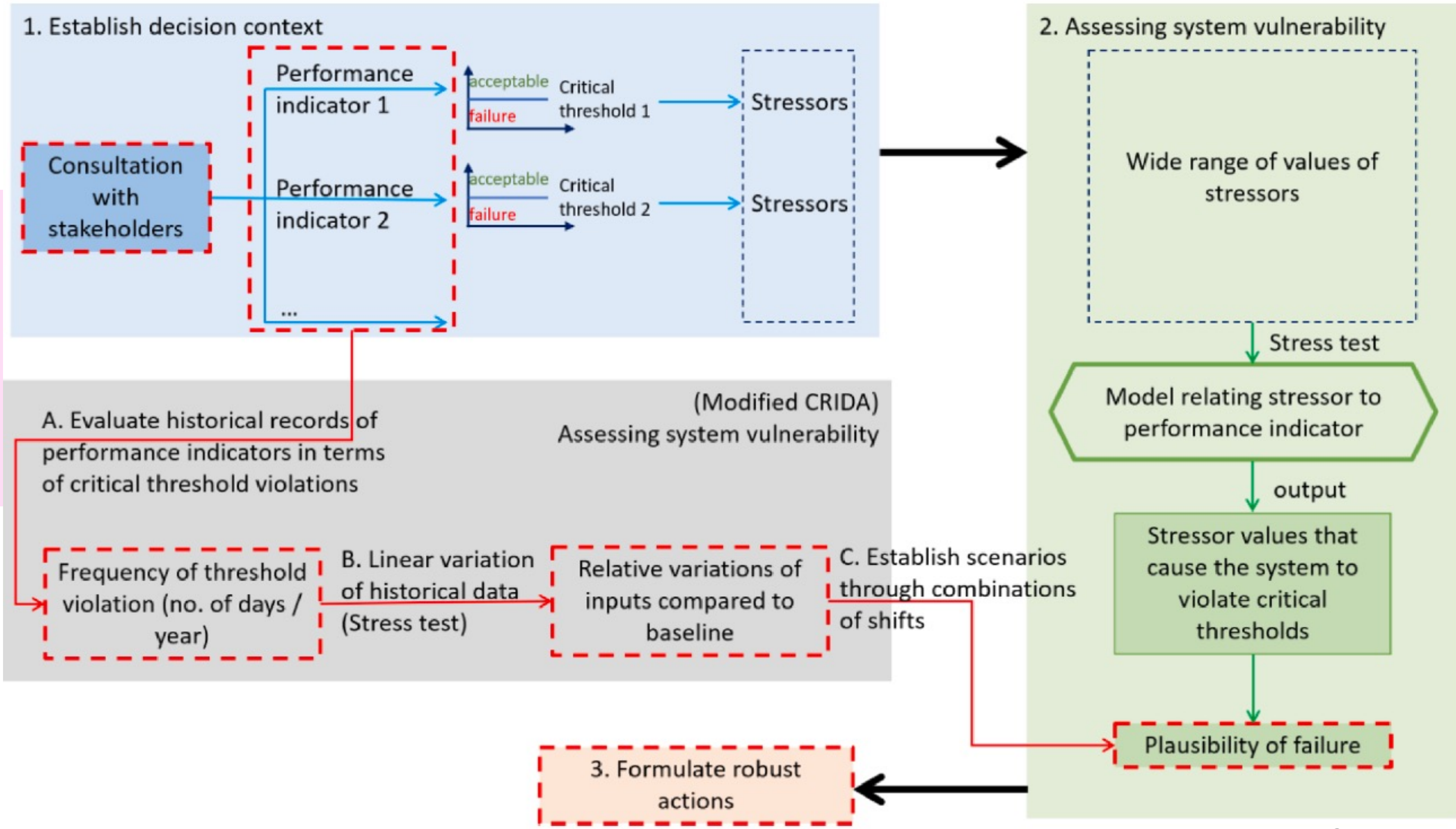


Metropolitan Waterworks Authority (MWA)

- Service area: 2,470 km2
- Bangkok, Nonthaburi and Samut Prakan
- WTP: Bangkhen, Mahaswat, Samsen and Thonburi
- 913 DMAs
- Population served: 8.3 million
- Connections: 2.5 million
- Water production: 2,075 MCM/year
- 14 Pumping stations

METHODOLOGY: MODIFIED CRIDA

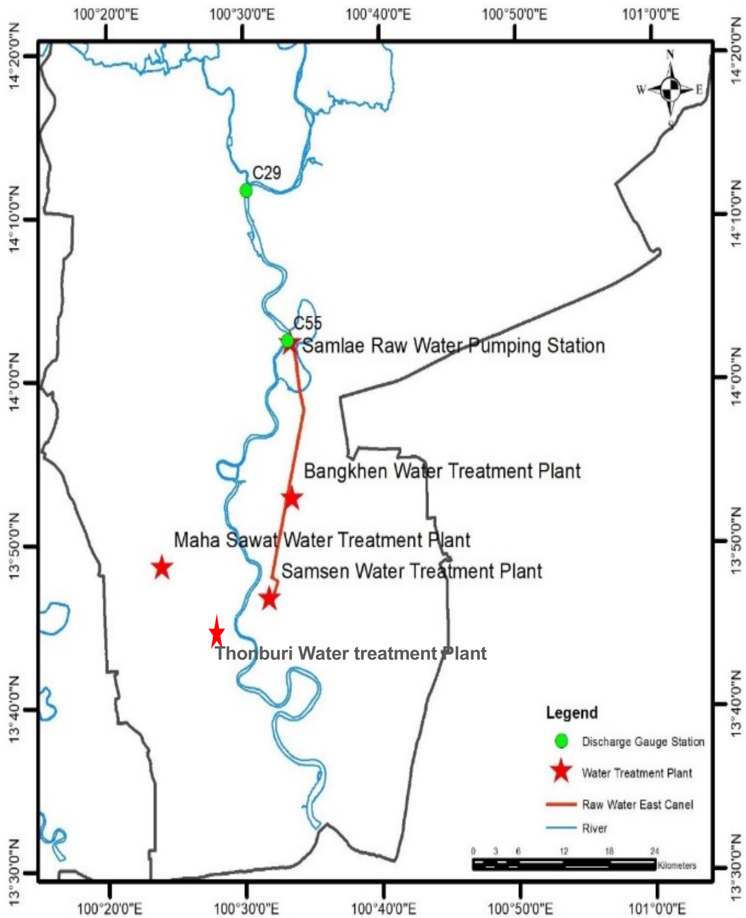
- The blue box, green box, and orange box detail the first three steps of CRIDA, respectively.
- The modified methodology steps are outlined with red dotted lines and follow the red arrows.



RESULTS I: ESTABLISHING THE DECISION CONTEXT

Results of stakeholder (MWA) consultation

- Flow at C29
  - **< 80 m^3/s:** Salinity caused by saltwater intrusion from the Gulf of Thailand
- Salinity at C55 (Samlae pumping station)
  - **> 0.25 g/L**: Reduced plant operations
  - **> 0.50 g/L:** Critical plant operation plans
- Turbidity at C55
  - **>200 NTU:** Increased cost and duration of water processing

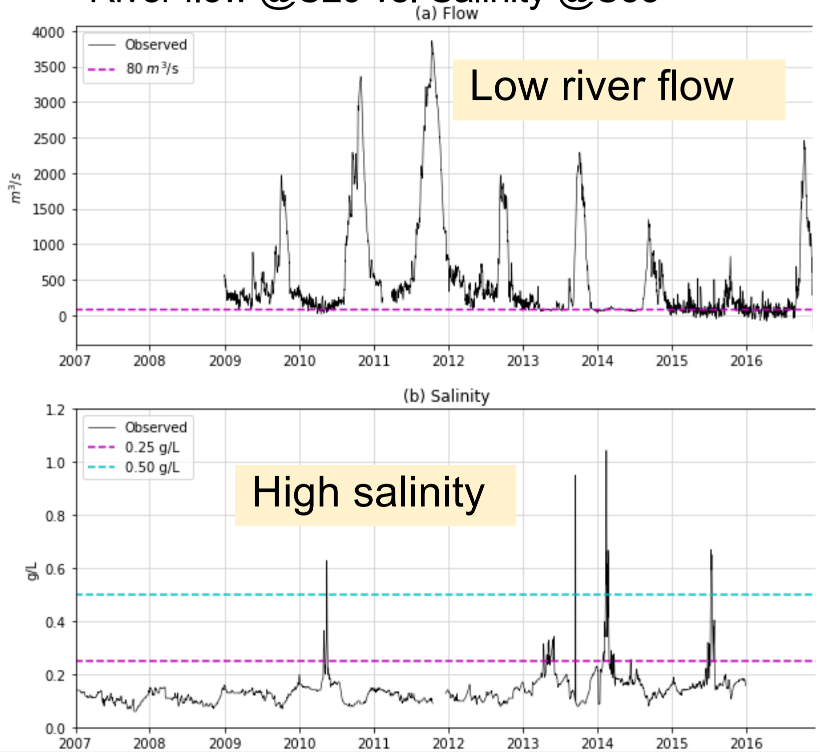


RESULTS II: HISTORICAL SYSTEM PERFORMANCE

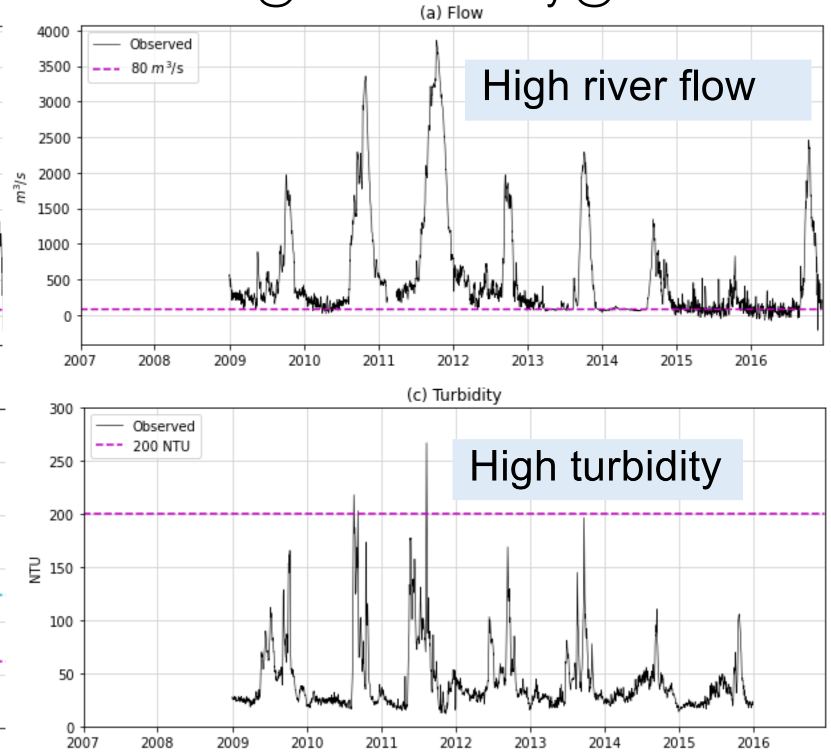
Defined thresholds:

- River flow at C29 < 80m^3/s
- Salinity at C55 > 0.25 g/L
- Salinity at C55 > 0.50 g/L
- Turbidity at C55 > 200 NTU

River flow @C29 vs. Salinity @C55



River flow @C29 vs. Turbidity @C55

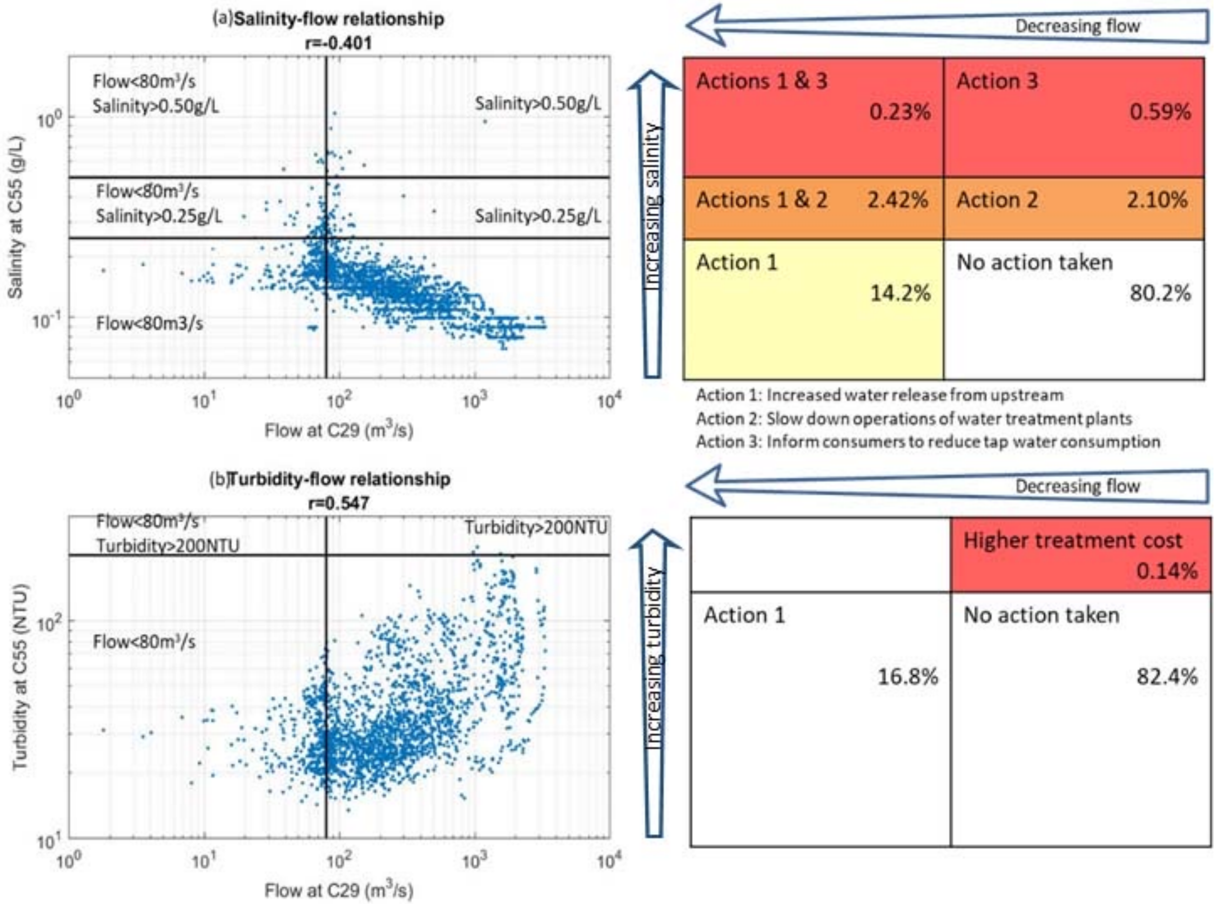


River flows are an indication of potential failure, actual failures are defined by salinity and turbidity measured at the intake point

RESULTS II: HISTORICAL SYSTEM PERFORMANCE

Observed data analyzed for 2009-2010, 2012-2015

- Salinity-flow failure zones
  - Left of action matrix: Low flow rates less likely to counter high salinity from saltwater intrusion
  - Right of action matrix: Higher flow rates may not be able to counter high salinity during high tides in Gulf of Thailand
- Turbidity-flow
  - High flows bring in more sediments, causing higher turbidity levels



RESULTS III: STRESS TEST

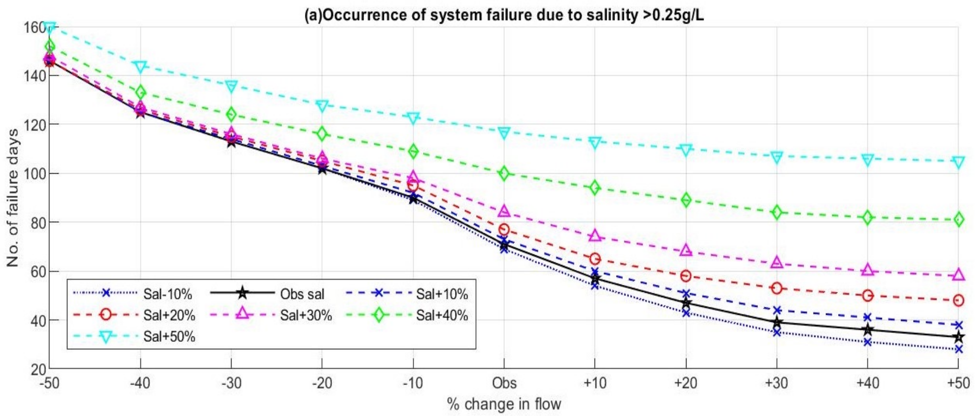
(a) Worst annual performance identified for each threshold

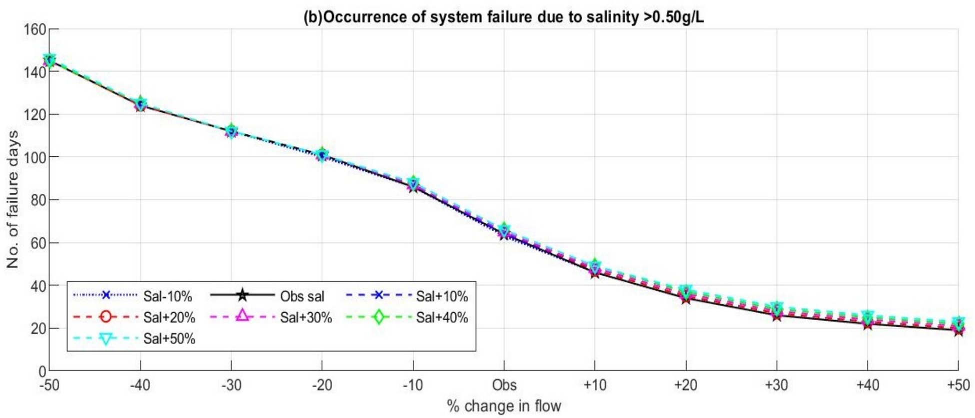
(b) System stressed by varying entire range of observed data until worst performance exceeded

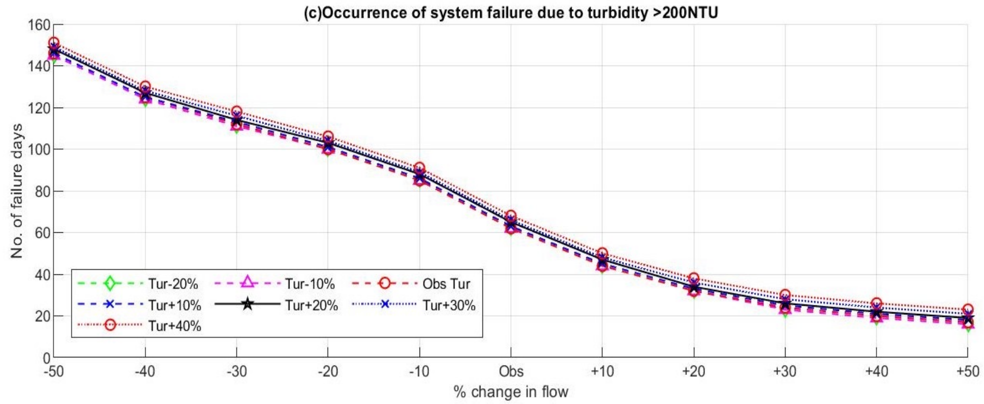
Critical Thresholds	(a) No. of failure days in a year							
	2009	2010	2011	2012	2013	2014	2015	Average
Flow <80 m3/s	1	24	-	1	74	134	136	62
Salinity >0.25 g/l	0	14	-	0	31	28	22	19
Salinity >0.5 g/l	0	2	-	0	1	8	6	3
Turbidity >200NTU	0	3	4	0	0	0	0	1

Critical Thresholds	(b) Variation in parameter values (% change)								
	-30	-20	-10	0	+10	+20	+30	+40	+50
Flow <80 m3/s	112	100	85	62	44	32	24	20	17
Salinity >0.25 g/l	7	10	14	19	24	35	45	69	96
Salinity >0.5 g/l	1	2	3	3	4	5	5	7	8
Turbidity >200NTU	0	0	0	1	2	3	5	7	7

RESULTS III: STRESS TEST







- With current salinity, even if the flow is increased by 50%, there will still be ~35 days of failure
- If salinity increases (0.375 g/L) in future due to sea level rise, even when the flow is increased to 50%, there will still be ~100 days of failure
- The system will still fail for ~18 days when turbidity comes down by 20% and flow increases by 50%

CONCLUSIONS

- Complex system at risk where Bangkok water supply is dependent on:
  - River flow available, salinity and sediment
- The combined effects of SLR and LS is expected to increase the salinity, which cannot be reduced even with an increase (50%) in river flow
- Adaptation solutions that can be further explored include:
  - For salinity: (a) Seawater desalination, (b) shifting of the raw water intake upstream, (c) inter-basin transfer.
  - For turbidity: Enhanced soil conservation efforts upstream watersheds, and tighter policies and enforcement to prevent chemical discharges
- Hydrological modeling of upstream watersheds to project river flows and a coupled hydrodynamic-AD model downstream under climate change
  - Will help capture the complex dynamics of river flow, salinity and sediment.

Case Study II

Climate Change Vulnerability Assessment in Agriculture in Lower Bhavani Irrigation Project, India

Ambili G K, **Mukand Babel**, Venkataramana Sridhar and Geethalakshmi Vellingiri

Climate Services 30 (2023) 100358

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Original research article

A novel approach to vulnerability assessment for adaptation planning in agriculture: An application to the Lower Bhavani Irrigation Project, India

Ambili G. Kamalamma[a,b], Mukand S. Babel[a,*], Venkataramana Sridhar[c], Geethalakshmi Vellingiri[d,*]

[a] *Water Engineering and Management, Asian Institute of Technology (AIT), Thailand*
[b] *Centre for Water Resources Development and Management (CWRDM), Kerala, India*
[c] *Department of Biological Systems Engineering, Virginia Tech, Blacksburg, VA 24061, USA*
[d] *Tamil Nadu Agricultural University (TNAU), Tamil Nadu, India*

HIGHLIGHTS

- Climate Risk Informed Decision Analysis (CRIDA) applied for vulnerability assessment in agricultural sector for the first time.
- Adaptation strategies need to be focused on demand management options.
- Paddy yield is at low risk and supply–demand ratio is at high risk to change in climate stressors.
- CRIDA application suggests the need for both robust and flexible adaptation plans.

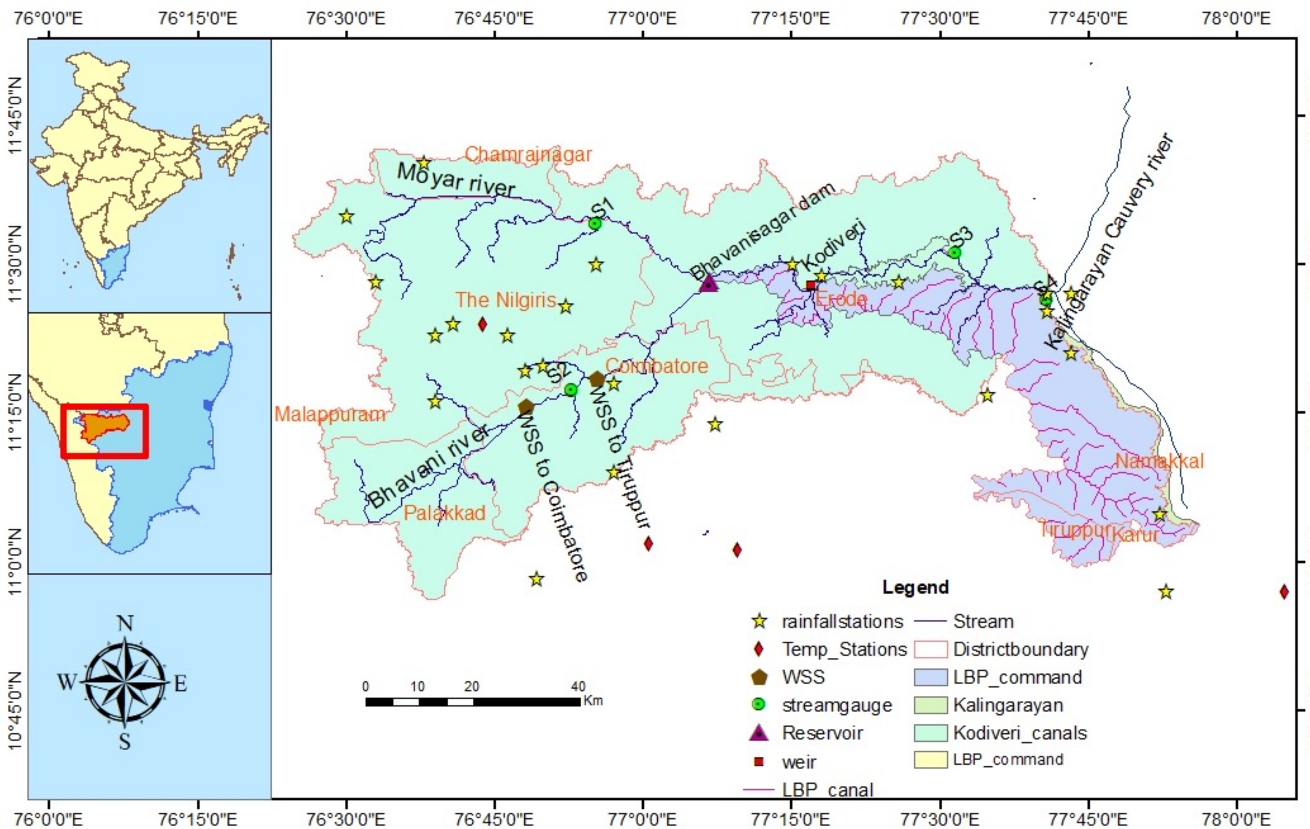
ARTICLE INFO

Keywords:
Vulnerability assessment
Adaptation planning
CRIDA
Stress testing
Lower Bhavani Irrigation Project

ABSTRACT

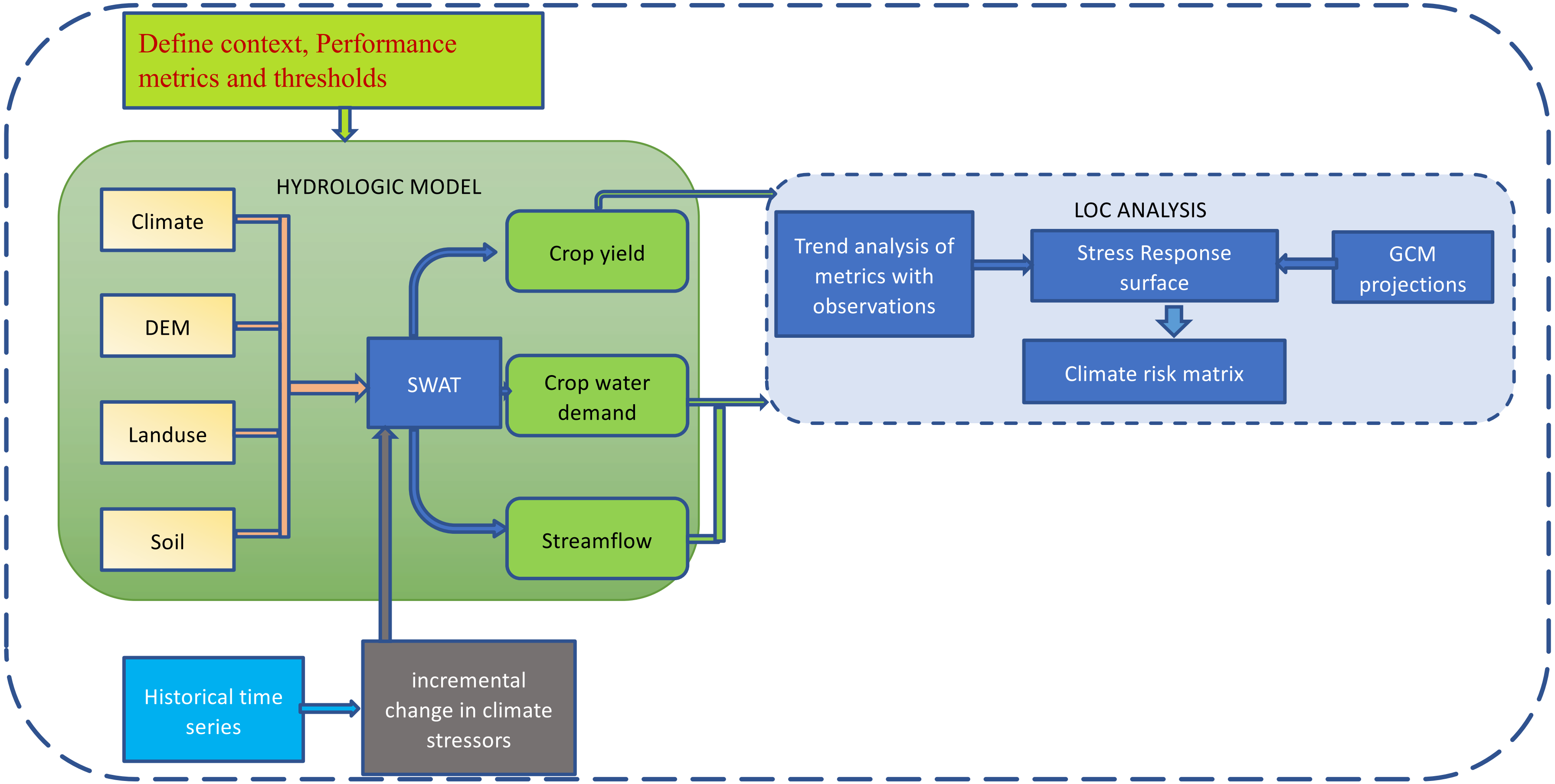
The global discourse on climate change adaptation in various sectors has largely taken a top-down approach. However, impact analysis based on top-down approach with uncertainties at every stage of the process may lead to poor adaptation responses and hence there is a need for an alternative to this conventional approach. This study aims to implement a bottom-up, risk-based approach to vulnerability assessment in the agriculture sector, by adapting the Climate Risk Informed Decision Analysis (CRIDA) approach. This paper explains the risks that climate variability and change pose to the agricultural system, with Lower Bhavani Irrigation Project in the South

BHAVANI RIVER BASIN AND LOWER BHAVANI IRRIGATION PROJECT



Land-use	%area in basin	% area in LBP
Built-up	0.2	1
Forest	39.6	
Plantation/ Orchard	15.0	
Rice	8.7	**71**
Sugarcane	5.0	8
Groundnut	3.3	5
Maize	3.2	0.5
Sorghum	3.3	0.2
Banana	3.3	0.1
Mixed	3.5	2.6
Scrub/Degraded forest	2.6	
Grassland	1.5	
Current fallow	4.7	8
Scrub land	4.8	5
Water bodies	1.4	0.1

METHODOLOGY



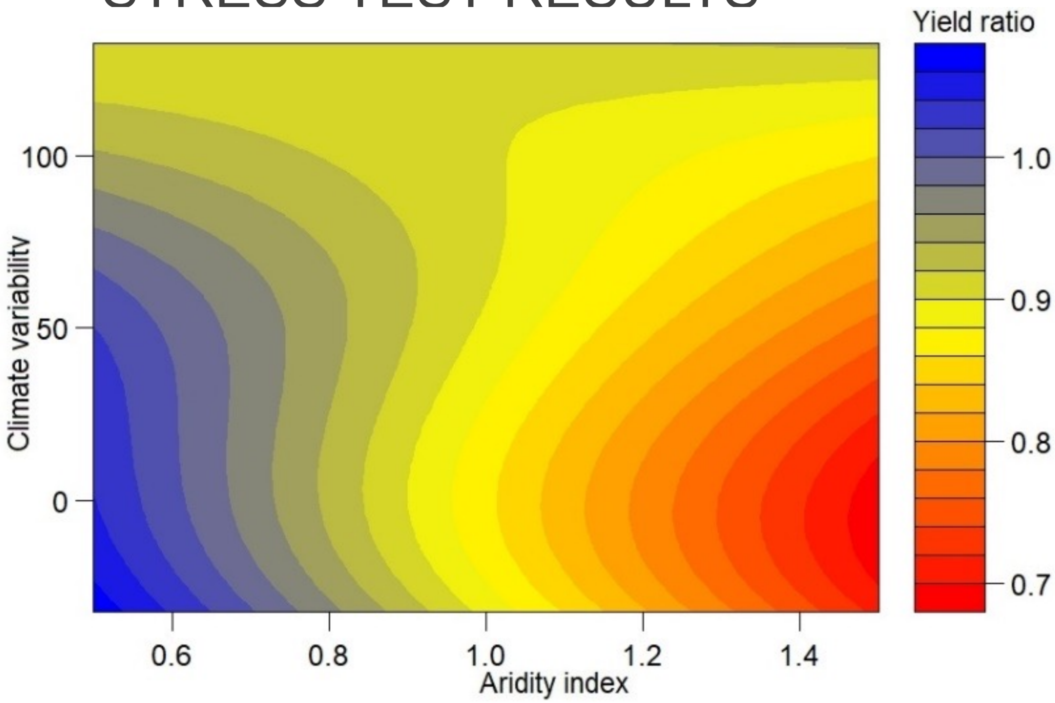
CRIDA DECISION CONTEXT

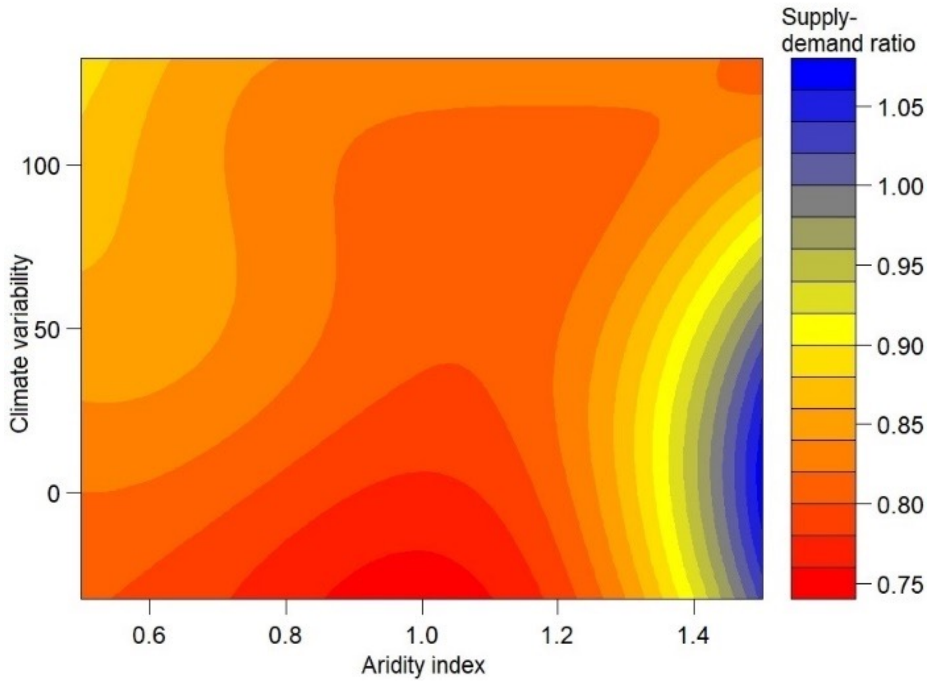
	Agriculture Department, Farmers	Irrigation Department
Performance objective	• To maintain the crop yields to long-term normal yield	• To improve supply-demand ratio
Decision variable	• Target yield	• Supply management
Performance metric	• Yield/Normal yield (4t/ha)	• Supply-Demand ratio
Threshold	• 1	• 1

Climate stressors

- Aridity index (P/PET)
- Climate variability

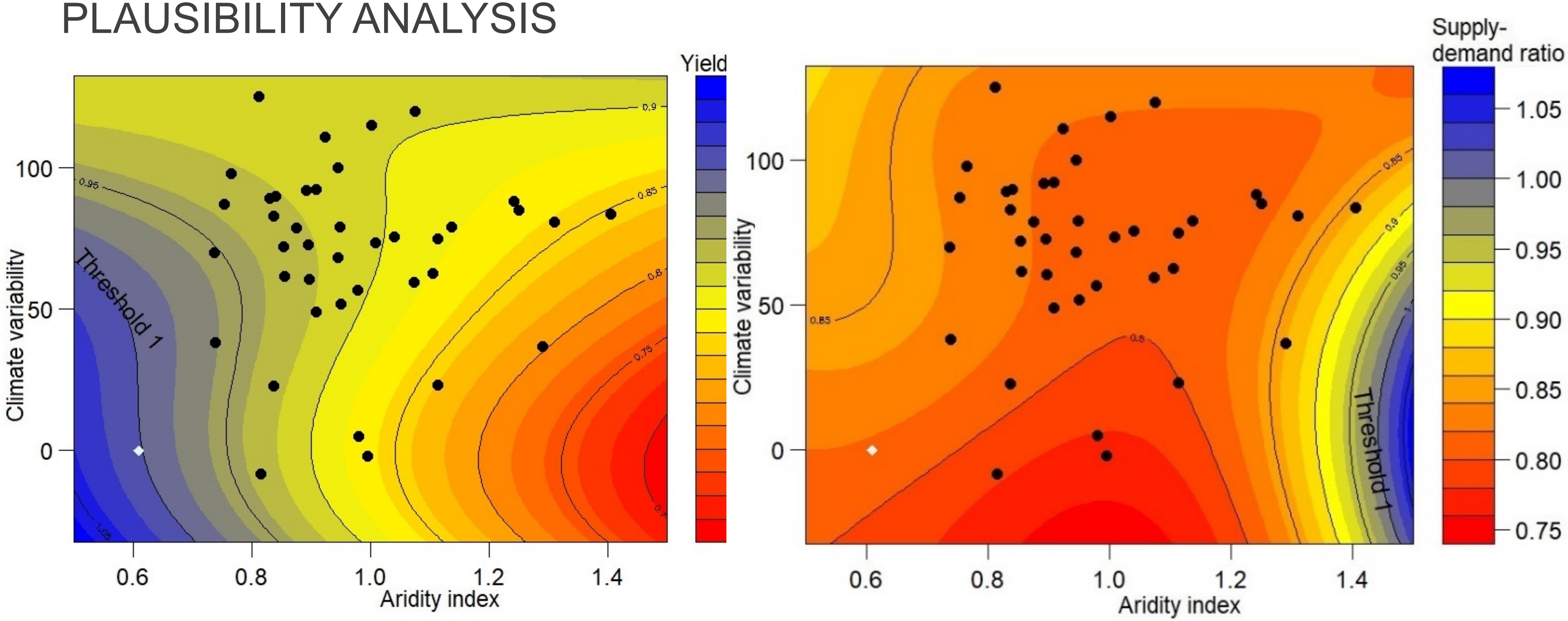
STRESS TEST RESULTS





- At low aridity index, yield is more sensitive to climate change than to variability, but when AI is high, the system becomes responsive to both climate change as well as variability.
- When AI>1.1, an inflection point is reached at where positive changes in climate variability will increase the yield and negative changes in climate variability will decrease the yield.
- System failure in yield at high aridity index and low variability and failure in supply-demand gap at low aridity index and all ranges of climate variability

PLAUSIBILITY ANALYSIS



Future conditions are very much plausible to lead to system failure

RISK MATRIX

		Plausibility (No. of RCM projections)		
		<20	20-30	>30
Impact (Yield ratio or Supply demand ratio)	<0.8	Medium	High	Critical
	0.8-0.9	Low	Medium	High
	>0.9	Low	Low	Medium

- Supply-demand ratio: High risk due to climate change and variability
- Yield – Low risk

CONCLUSIONS

- At lower AI, the yield is more sensitive to climate change whereas at high AI, both yield and supply-demand ratio is sensitive to both climate change and variability.
- Paddy yield in the irrigation project is at low risk to climate change and variability, but the system is at high risk due to the mismatch of supply and demand
- Both robust as well as flexible adaptation actions are needed to reduce the risk

WAY FORWARD…

- Evaluation of adaptation measures
  - Carbon neutrality – Mitigation potential
  - Cost benefit analysis – Societal and environmental costs and benefits
  - Adaptation pathways
- Institutionalizing adaptation
  - Implementation
  - Monitoring and evaluation – robust and flexible
- Subjective to past and present challenges
  - Room for new and emerging challenges
  - Other socio-economic stressors imposing challenges to urban water management
- Applying CRIDA for entire urban water cycle
- Big-data and AI technology for vulnerability assessment
- …

“Be the change you want to see in the world”

-Mahatma Gandhi

“The Earth provides enough to satisfy every man’s needs, but not every man’s greed”

- Mahatma Gandhi

Thank you very much

Mukand S Babel
Asian Institute of Technology
msbabel@ait.asia
msbabel@gmail.com

Professor, Water Engineering and Management
Director, Centre for Water and Climate Adaptation (CWCA)
Chair, Climate Technology Center and Networks (CTCN) SC at AIT

Director, Executive Board, IWRA (2016-18)
Board Member, Asia Water Council (AWC)

Expertise: Hydrologic and Water Resources Modeling; IWRM; Hydrologic Extreme Events; Water Resources and Socio-economic Development; Groundwater Management; Water Supply and Sanitation; Climate Impacts and Resilience; Water-Energy-Food Nexus

International Award: 2018 Japan Society of Hydrology and Water Resources award
International Recognition: 2021 Reuters Hot List of 1,000 top climate scientists; 2019 top 2% scientists in the world for research impact; 2021, 2022 and 2023 top 2% scientists in the world by Elsevier BV and Stanford University
Experience: 40 years of teaching, research and consulting
Geographical coverage: South and Southeast Asia

Metrics	Scopus	Google scholar
Articles	194	312
h-index (*i*10-index)	44	54 (134)
Citations	5722	9571