The value of stakeholder elicited information in models of coupled human-water systems

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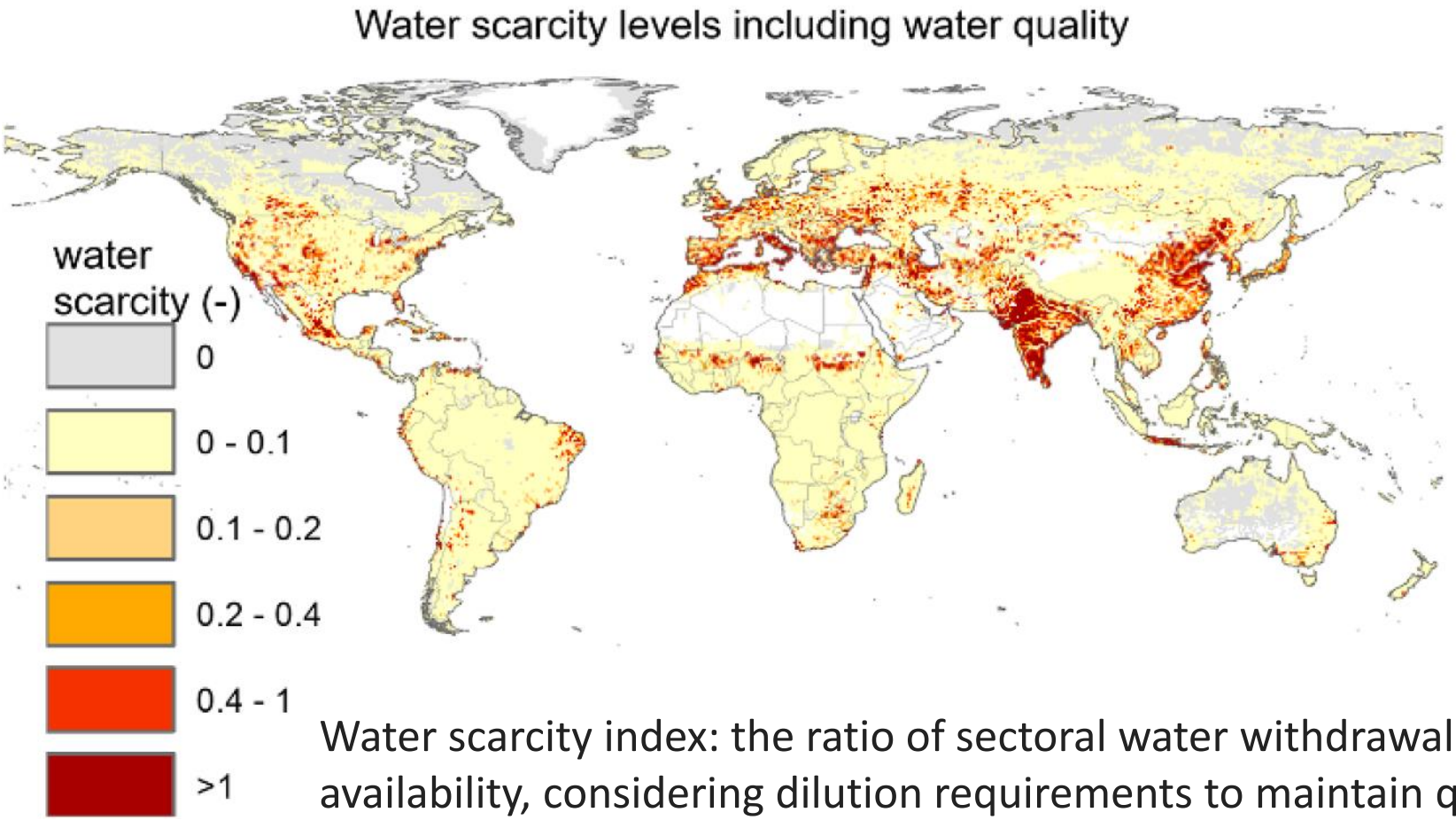
Session on Water-Energy-Food Nexus: Towards future research and strategies
Theme 2 – A Systems Analysis Approach for Complex Global Problems

The world faces severe water scarcity challenges

Water scarcity driven by water quantity and water quality issues for 2000–2010



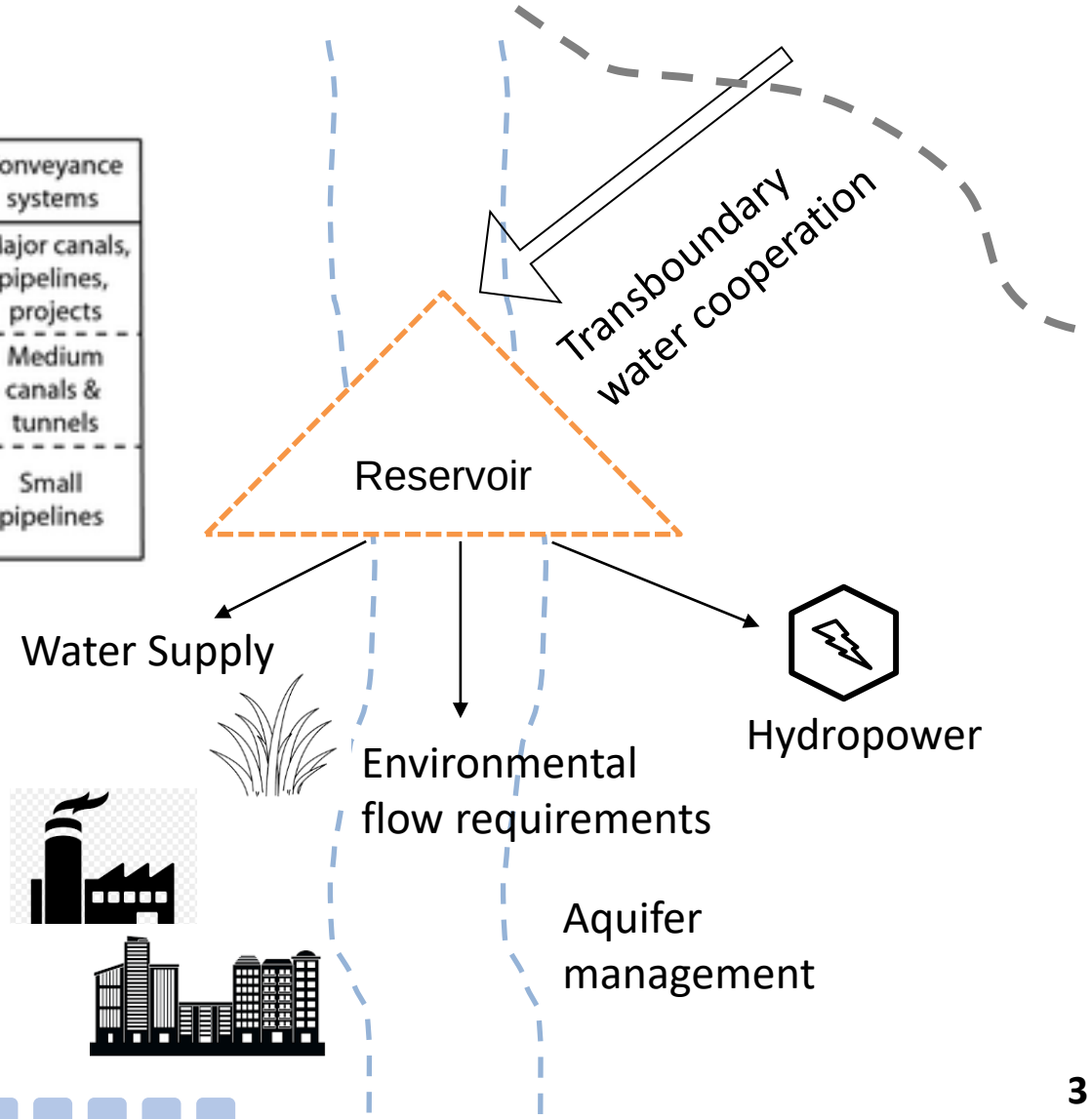
Water scarcity index: the ratio of sectoral water withdrawals to water availability, considering dilution requirements to maintain quality thresholds.

van Vliet et. al., *Environ. Res. Lett.,* 2021

Water infrastructure is crucial to maintain water security

Water infrastructure elements by type and scale

	Dams & Hydropower	Water supply	Wastewater, sanitation, WQ	Stormwater systems	Irrigation & drainage	River works	Conveyance systems
Large scale	Large dams and hydro systems	Large city systems	Large natural systems	Large city systems	Large systems	Large river navigation works	Major canals, pipelines, projects
Medium scale	Medium dams and hydro systems	Medium city systems	Medium city systems	Medium city systems	Farm irrigation	Medium stream systems	Medium canals & tunnels
Small scale	Small dams and micro-hydro	Communities, sites & households	Communities, sites & households	Site drainage	Site irrigation	Small stream stabilization	Small pipelines



Grigg, *International Journal of Water Resources Development*, 2019

The Nagarjuna Sagar reservoir on the Krishna river

Nagarjuna Sagar Dam was the earliest in a series of large infrastructure projects.

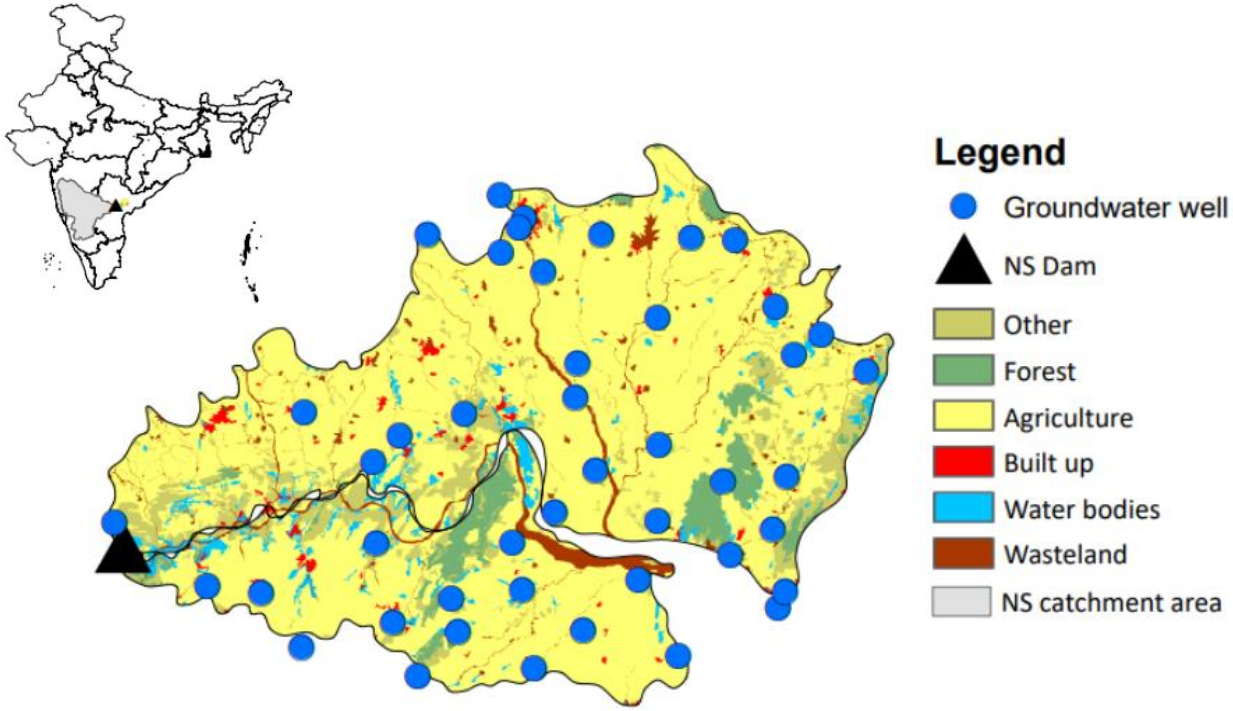
- Rural urban conflicts
- Upstream downstream conflicts
- Water-food-energy conflicts

As Nagarjuna Sagar reservoir dries up and power outut falls, Telangana's water woes worsen

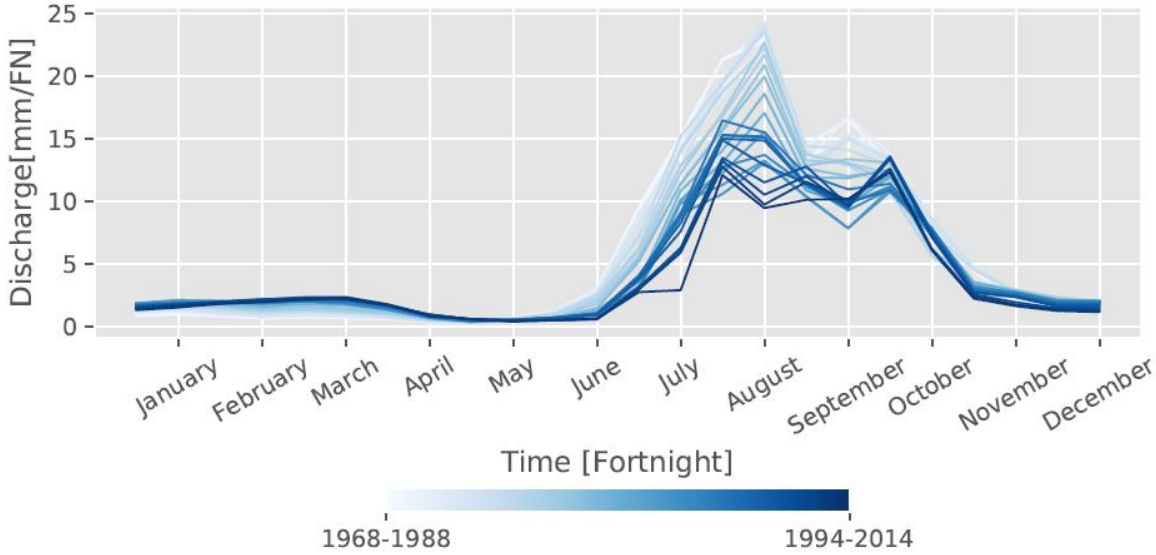
In the zero sum game played by the riparian States along the Krishna, Nagarjuna Sagar stands much reduced from the lofty vision behind its birth...

Source: https://www.newindianexpress.com/states/telangana/2017/may/14/as-nagarjuna-sagar-reservoir-dries-up-and-power-outut-falls-telanganas-water-woes-worsen-1604651.html

Nagarjuna Sagar has been facing gradual reductions in water availability



Inflows to NS



The NS reservoir, its catchment area, and command area within Krishna basin.
Command area is dominated by agriculture.
Farmers conjunctively use reservoir water and groundwater.
Location of observations wells in blue.

Source: Irrigation and CAD Department, Telangana

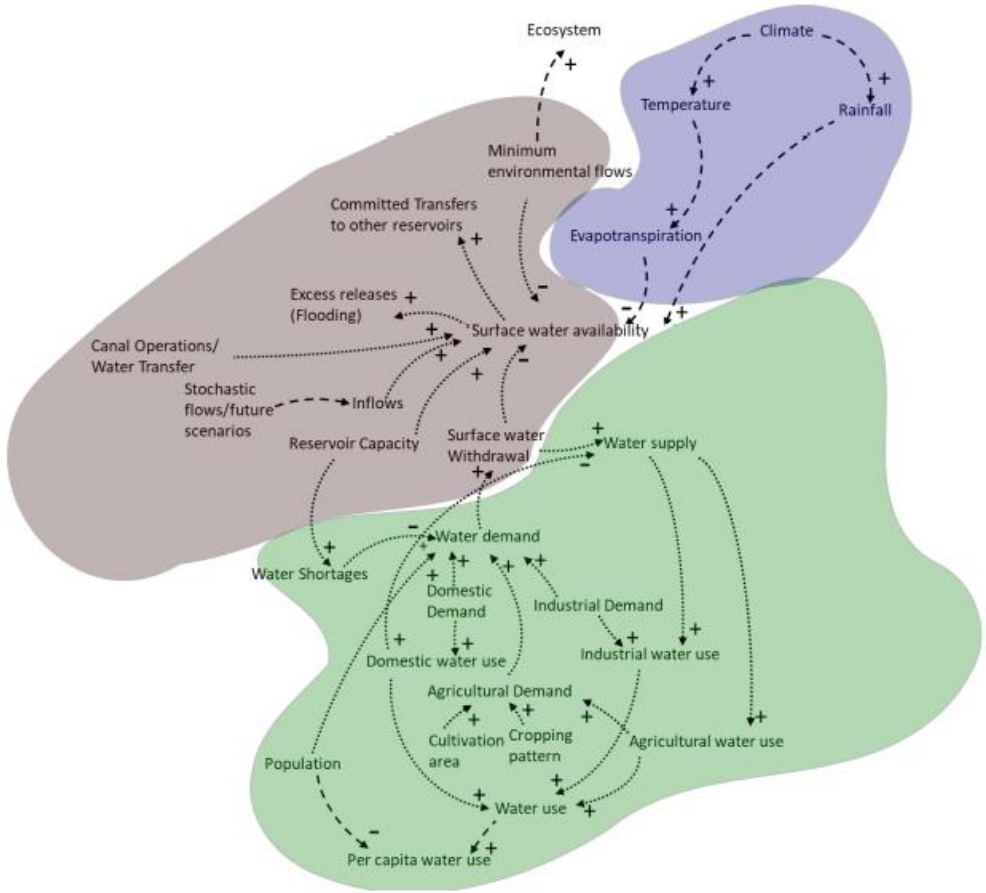
Methods: interview based coupled human-water models

1. Preliminary conceptualization of the system based on natural processes and assuming a rational decision maker
2. Identify stakeholders, conduct semi-structured interviews
3. Develop alternative system models
4. Validate using historical data
5. Simulate future conditions

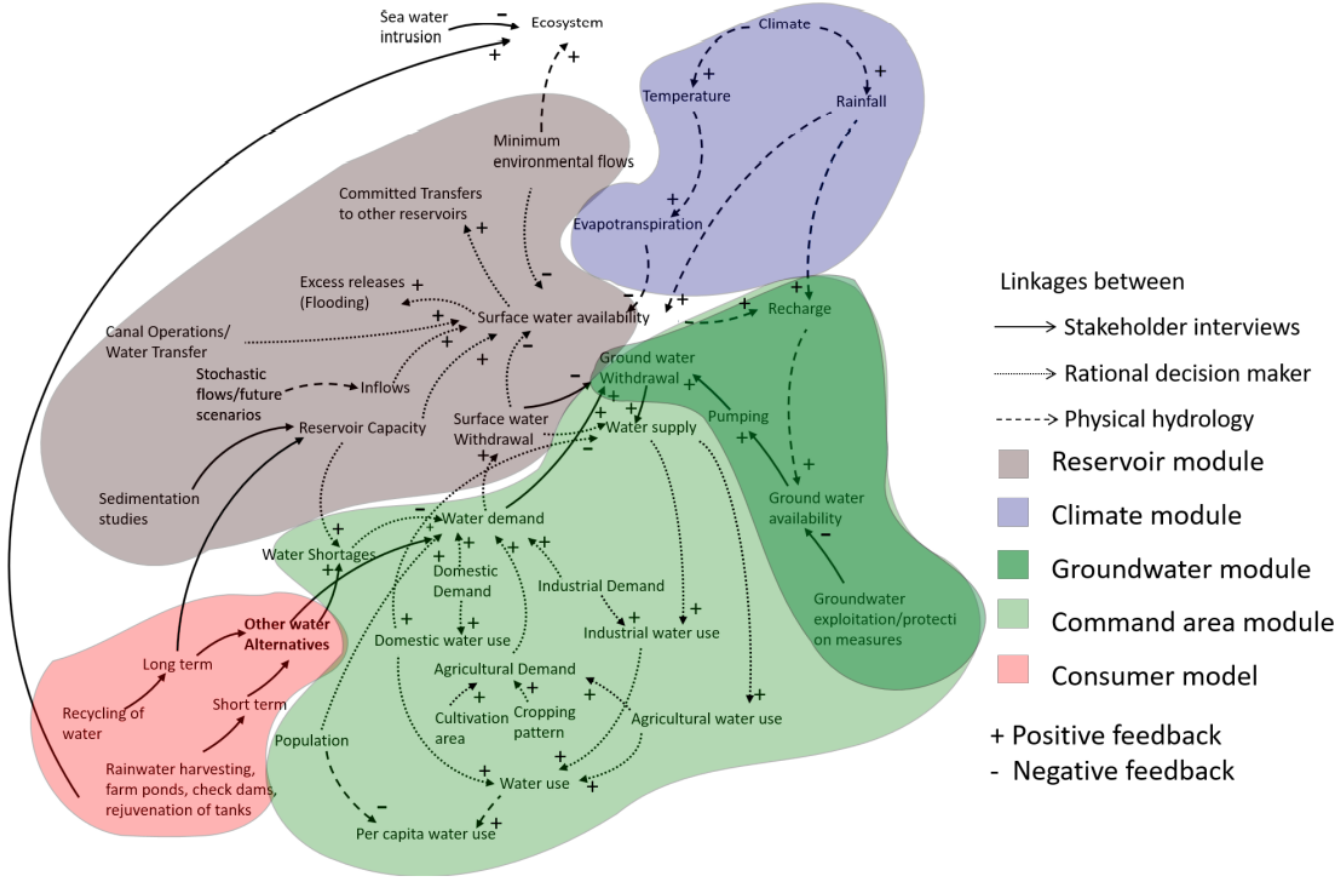
Group 1 (Decision makers)	Group 2 (Water Users)	Group 3 (Environmental Groups)
NWDA	Aranya Agricultural Alternatives	EPTRI
Irrigation and CAD department	Farmer Training center	Hyderabad Greens
Nagarjuna Sagar dam division	Center for sustainable agriculture	Centre for Environmental concerns
Krishna River Management Board	Uppal Industries Association	Prakriti Environment Society
Godavari River Management Board	Other farmers on phone	WASSAN: works with watershed management
Irrigation-Nagarjuna Sagar Project		
CWC		
HMWSSB		

Causal loop diagrams developed with and w/o stakeholder inputs

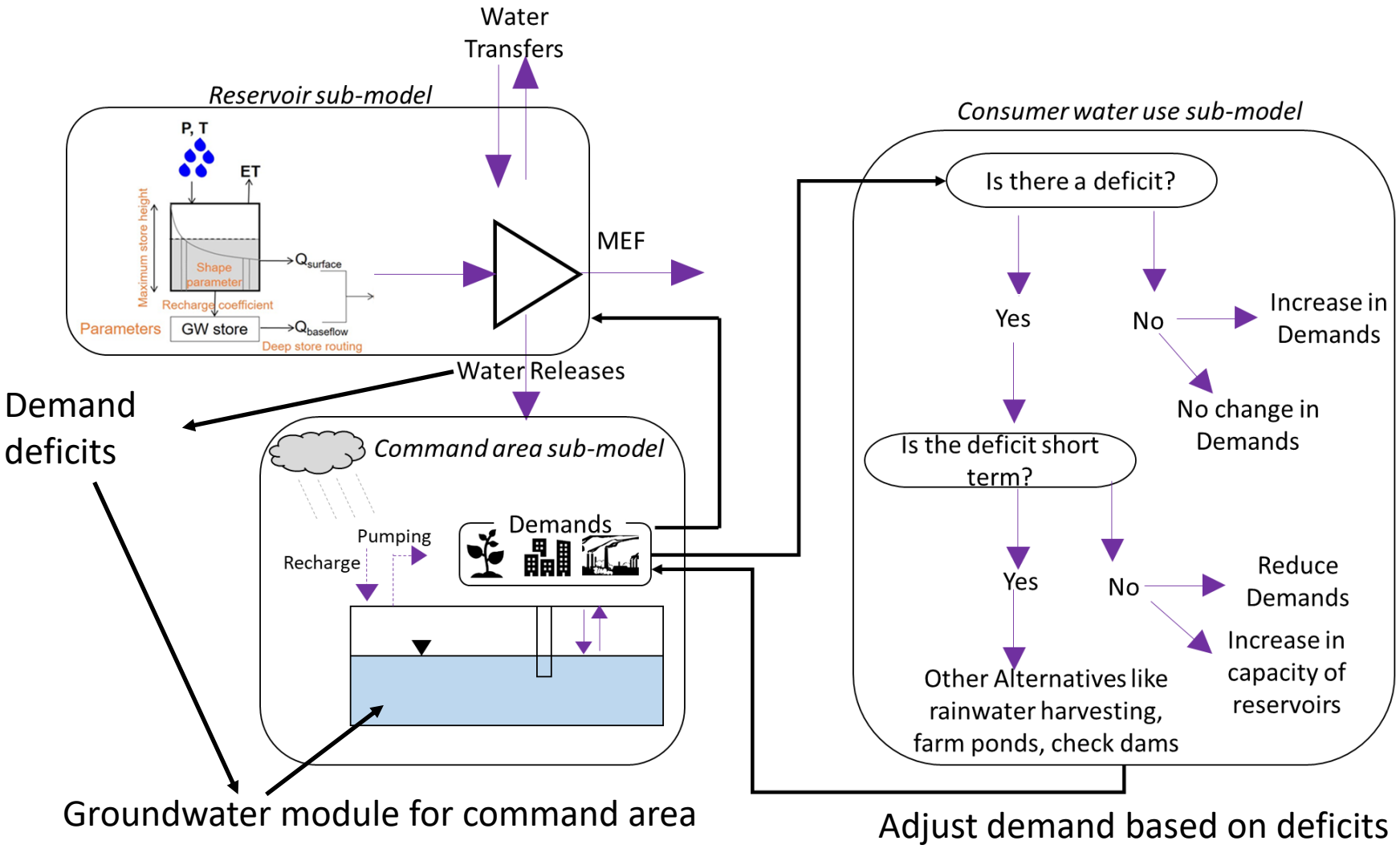
Preliminary conceptualization w/o stakeholder inputs



Alternative conceptualization with stakeholder inputs



Model structures derived from CLDs



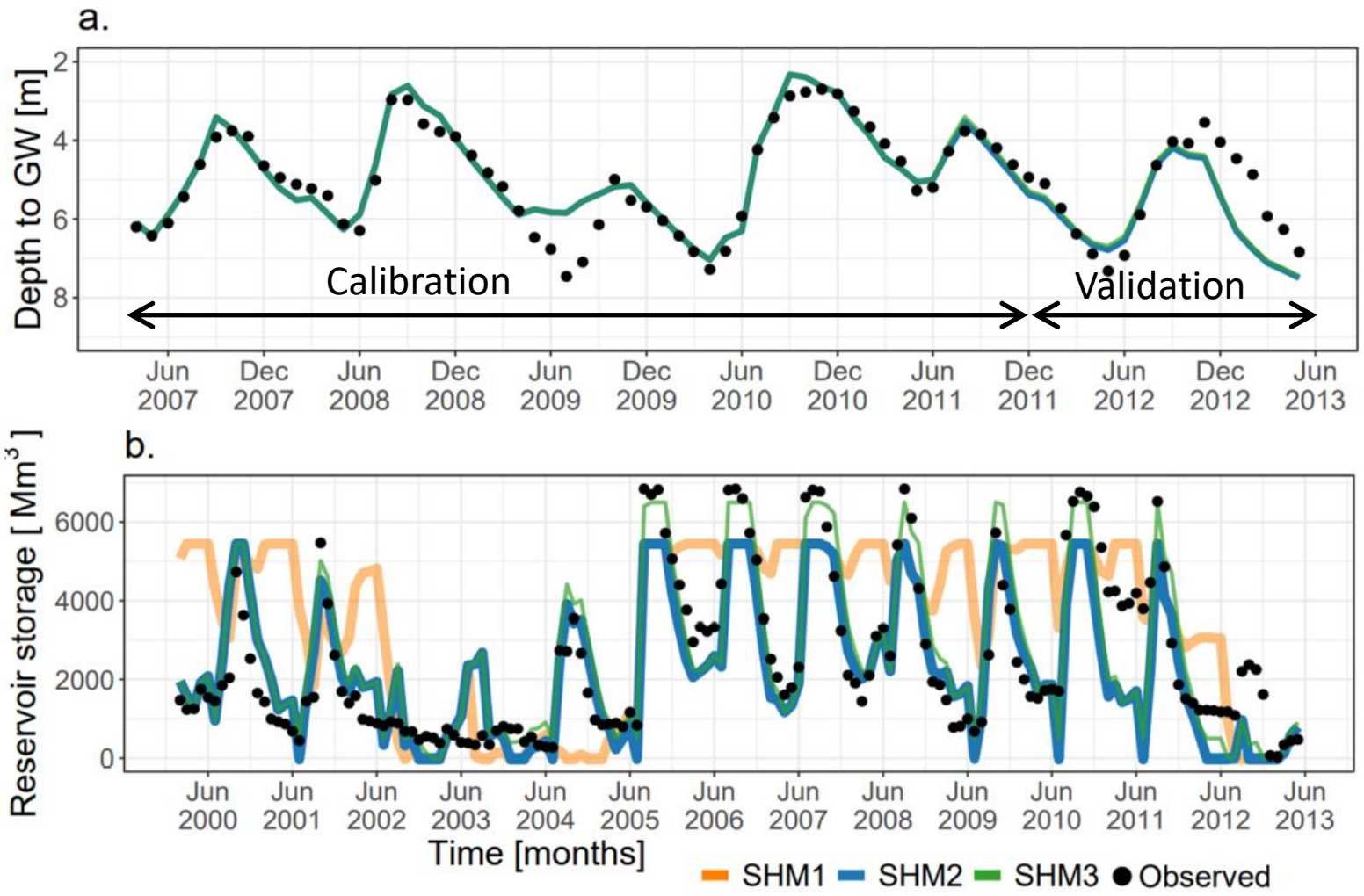
Three models were developed based on these CLDs

SHM1: basic model using natural hydrology and priority based reservoir release rules

SHM2: added conjunctive use of surface water and groundwater in command area

SHM3: farmers adapt to deficits, conjunctive use of surface water and groundwater included

Model validation: simulating depth to GW in command area and reservoir water storage



Calibration/ validation NSE
SHM2 – 0.84/ 0.76
SHM3 – 0.85/ 0.76

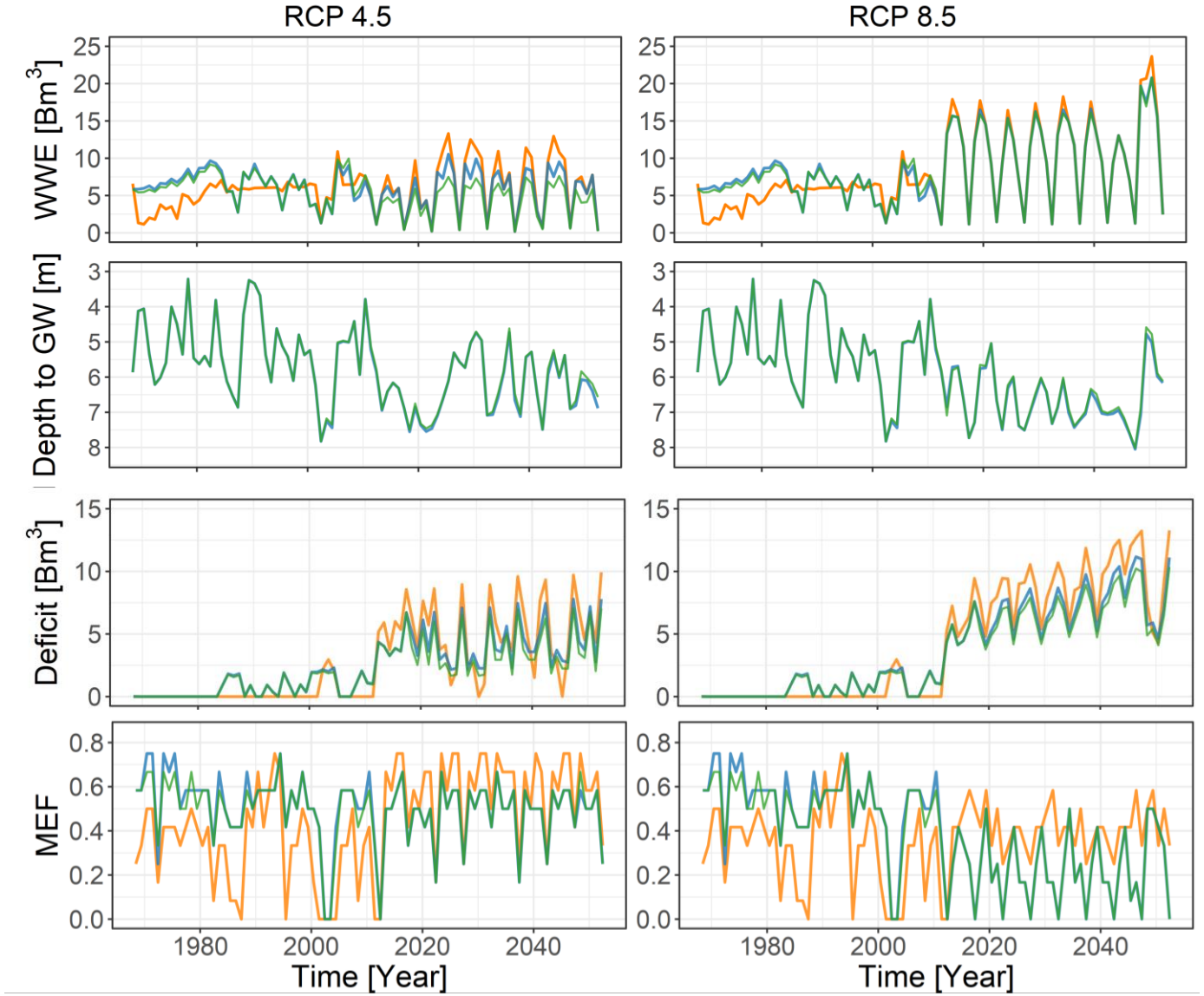
Correlation coefficient between observed and simulated storage
SHM1 - 0.57
SHM2 - 0.85
SHM3 - 0.87

Two alternative scenarios to represent future climatic and socioeconomic conditions

	Climate related processes	**Reservoir related processes**		**Command area related processes**	**Consumer water use related processes**
	Climate forcing	Whether MEF included	Proposed water transfers to and from the NS reservoir	Change in demands with time	Rules related to update of demands based on previous deficits
Historical (1968-2013)	Historical	No	No inter-basin transfers	Cropping pattern and irrigated area changed based on observations	Demands are reduced following Eq. A3-A4.
Sustainability Scenario 1 (2014-2050)	RCP 4.5 with SSP1	Yes, and prioritized over demand releases	No inter-basin transfers	Cropping pattern similar to historical, increase in command area by 2% every decade	Demand reductions are twice that prescribed by Eq. A3-A4.
Business as usual Scenario 2 (2014-2050)	RCP 8.5 with SSP3	No	Transfer based on proposed strategy by NWDA (2021)	More water intensive crops, increase in command area by 5% every decade	Demand reductions are half of that prescribed by Eq. A3-A4

Climate uncertainty: projections from a globally available downscaled product using 5 GCMs
Socioeconomic uncertainty: Sustainability scenario (S1), business-as-usual scenario (S2)
Total number of futures: 10

Projected conditions of the reservoir performance and command area



Volume of water withdrawn above freshwater boundary, ideal value: 0

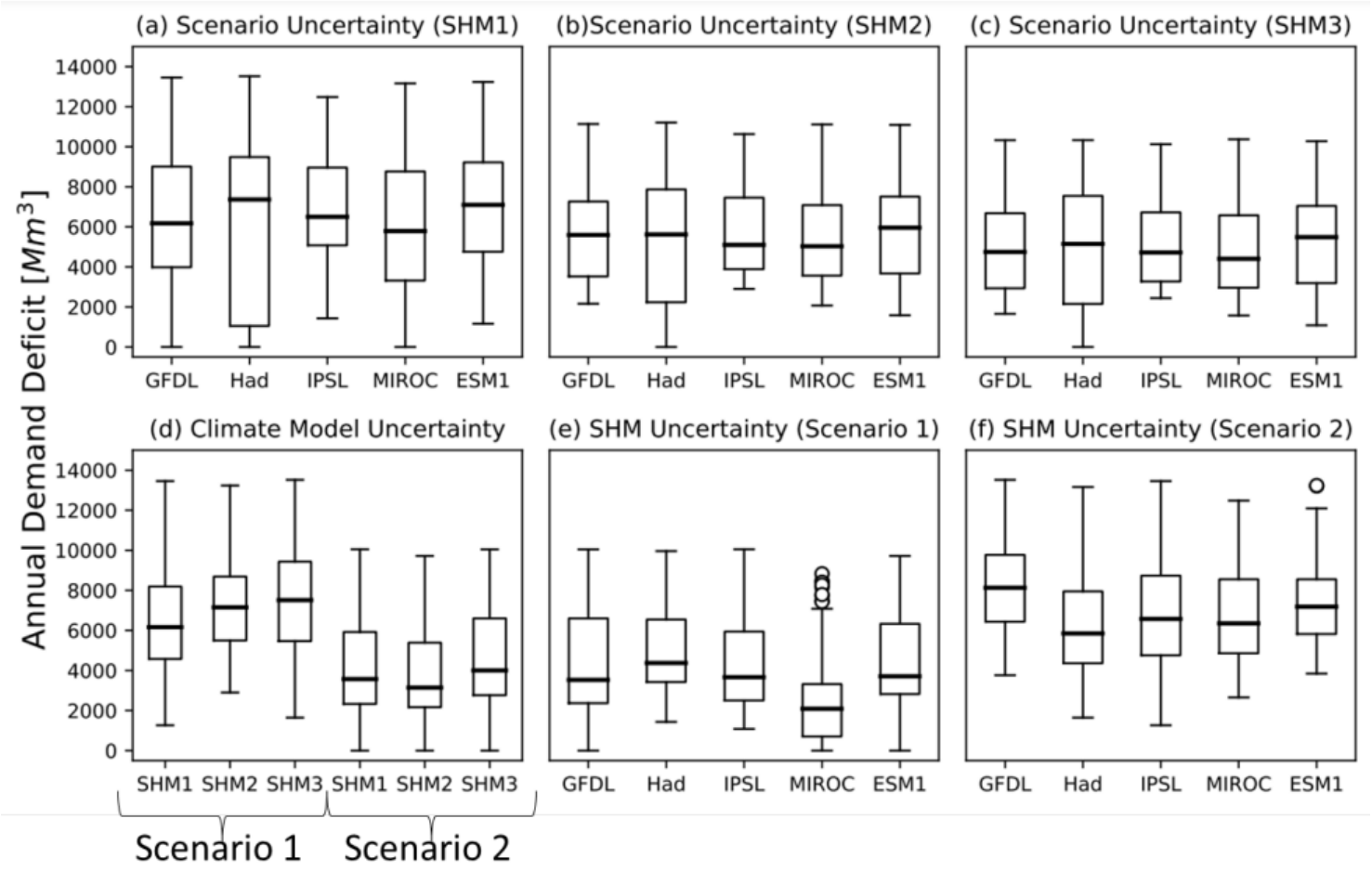
Depth to groundwater in the command area

Total unmet water demands, Ideal value: 0

% of time minimum environmental flow (MEF) limits are met
Ideal value: 1

SHM1
SHM2
SHM3

Lack of knowledge about the system model can severely limit our ability to plan for such large projects



Uncertainty from lack of knowledge about the system model is comparable to that stemming from future climate projections