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How resilient are river basins of Asian Himalayas?

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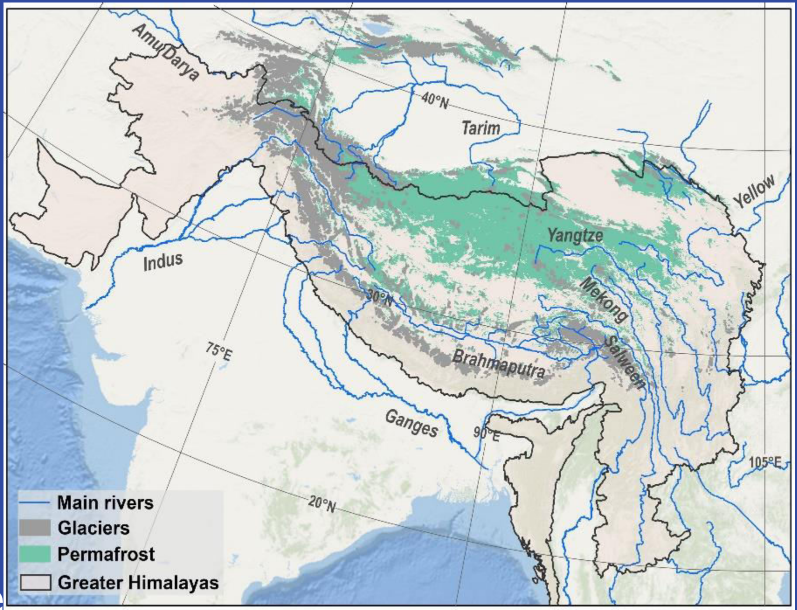
WORLD WATER CONGRESS
Water for All
Harmony between Humans and Nature

第18届
世界水资源大会
水与万物：
人与自然和谐共生

Waterways of river basins in Asian Himalaya

- Reliant on snow/glacial meltwater for irrigation of multi-cropping system in monsoon (Jun-Aug)
- Snow/glacier melts modulate river flows and groundwater recharge
- >60% of irrigation water withdrawals are from snow/glacier melts, contribute 11% water to the crop production alone
- Post-monsoon (dry) season experiences the lowest observed precipitation and river discharge, determines water availability for agriculture, and other sectors in the basins



Kattel et al. 2023 WIREs Water

How resilient are river basins of Asian Himalaya?

A Culturally & Spiritually Intact System

- Have a divine power, any negative human action can anger god
- E.g., Hot water springs, "*tato pani*" in the Nepali and Sikkim Himalayas have healing powers as their source is thought to be protected by goddesses

A Naturally Functioning Biophysical System

- Regulates the global climatic system together with carbon, nitrogen, and phosphorus cycling.
- Flushes pollutants, transports chemicals, and generates ecosystem goods and services for more than one billion people

A Human-Intervened System

- Basin society is at alert, when the Himalayan river system faces a transition to a threshold crossing due to increased perturbation
- Is a complex socio-ecological and hydrological system, thought to be capable of self-organizing after changes, through learning and adaptation

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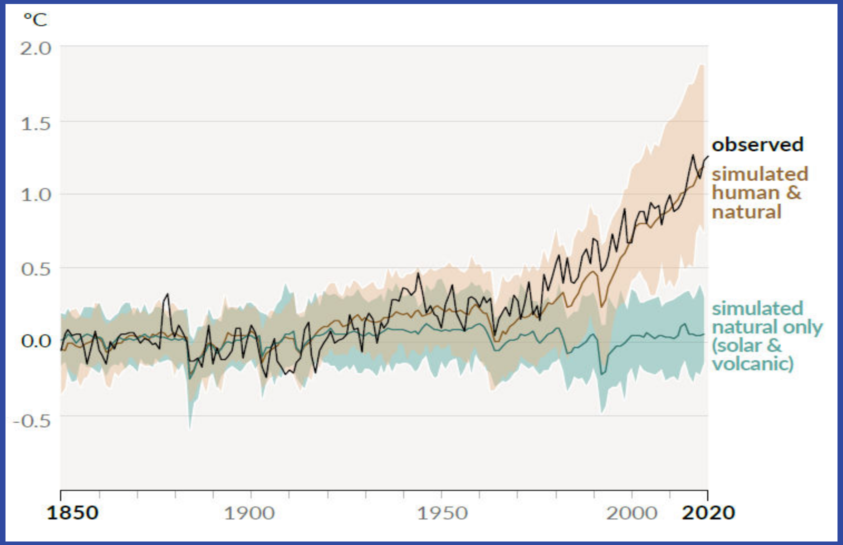
Climate warming affects resilience of river basins in Asian Himalaya

GLOBAL MEAN TEMPERATURE

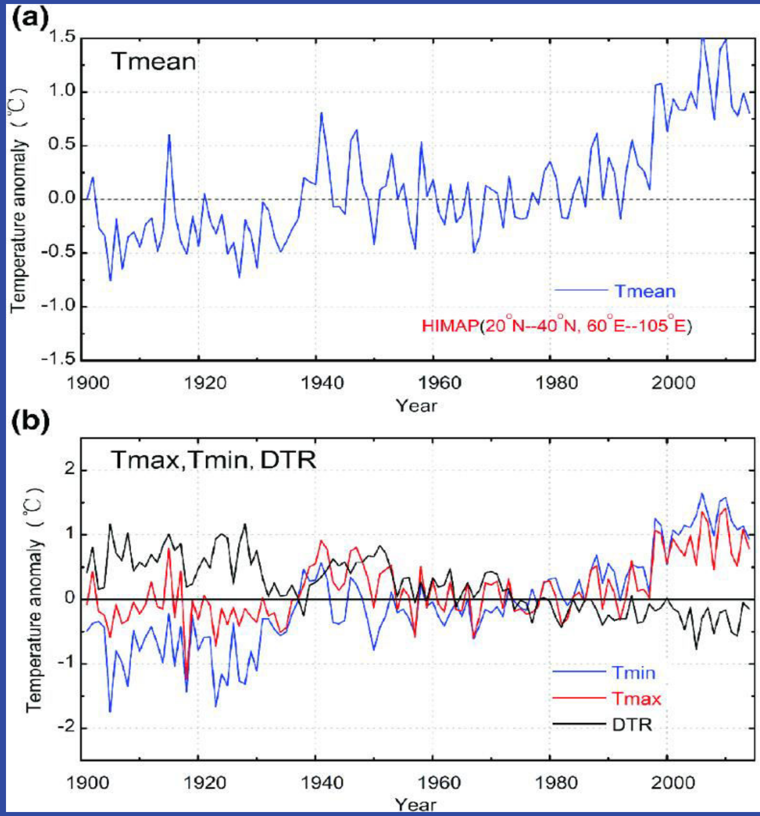


Change in global surface temp (annual average) as

- **observed** and
- simulated using **human &** **natural** and **only natural** factors (both 1850-2020)

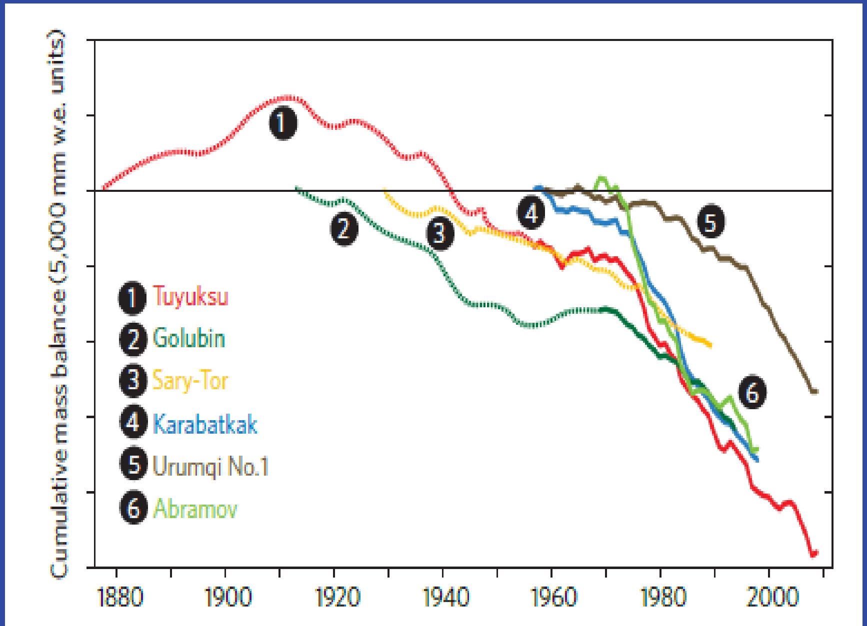
IPCC, 2021

HIMALYAN MEAN TEMPERATURE

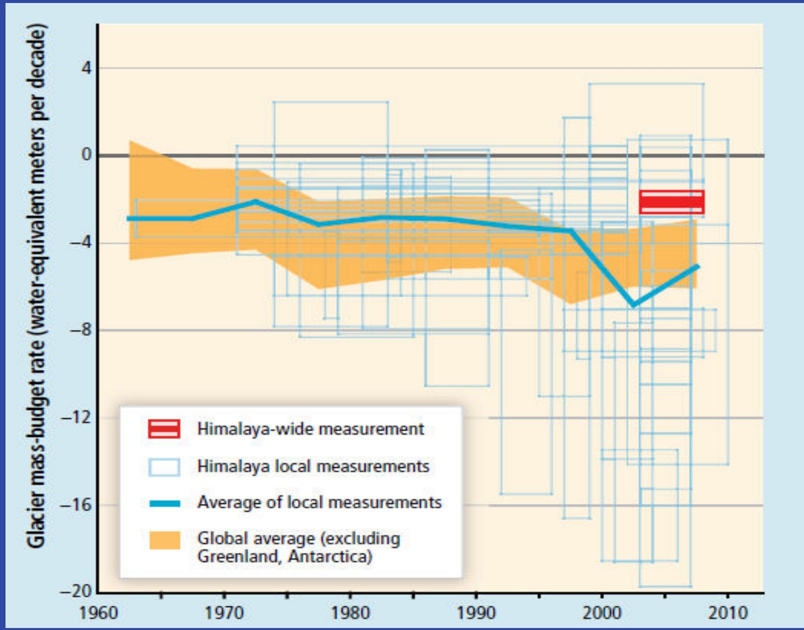


Krishna et al. 2019 The Hindukush Himalaya Assessment

Shrinking glaciers affect resilience of river basins in Himalaya



- Cumulative mass balance of glaciers in west China (past 30-40 years). Since 1920s cumulative mass balance has declined



- Projected glacier mass changes in Bhutan, China, India, Nepal, and Pakistan for 2006–2100 are: 2% gain and 29% loss by 2035 (GCM)

Sorge et al. 2012 Nature Climate

Jiménez Cisneros, B.E. et al. 2014 IPCC Report

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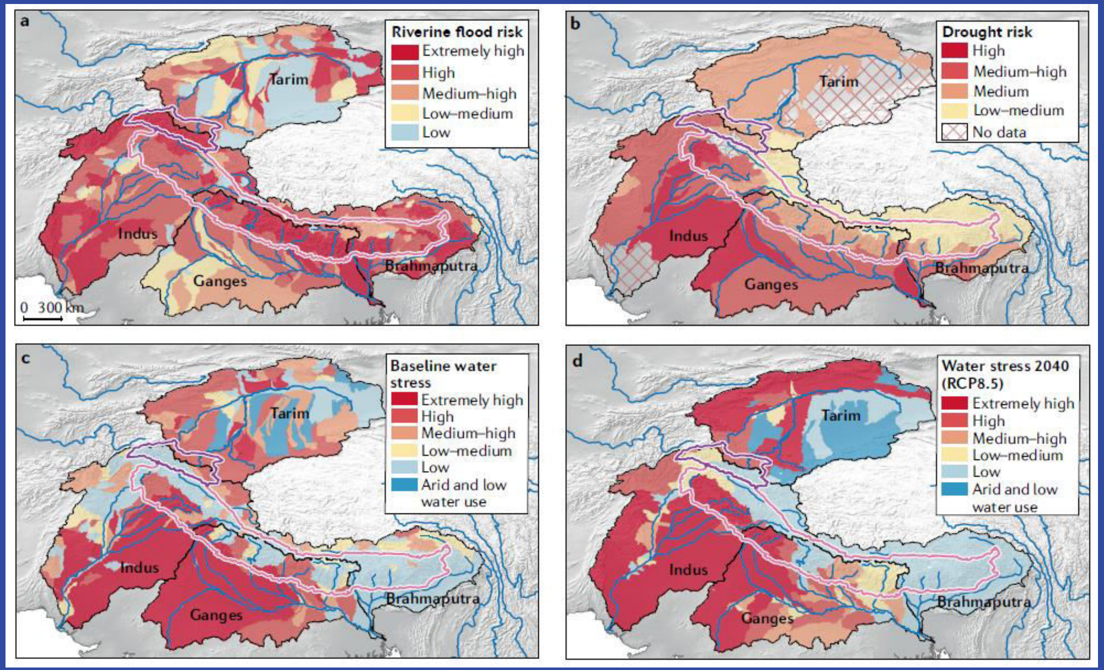
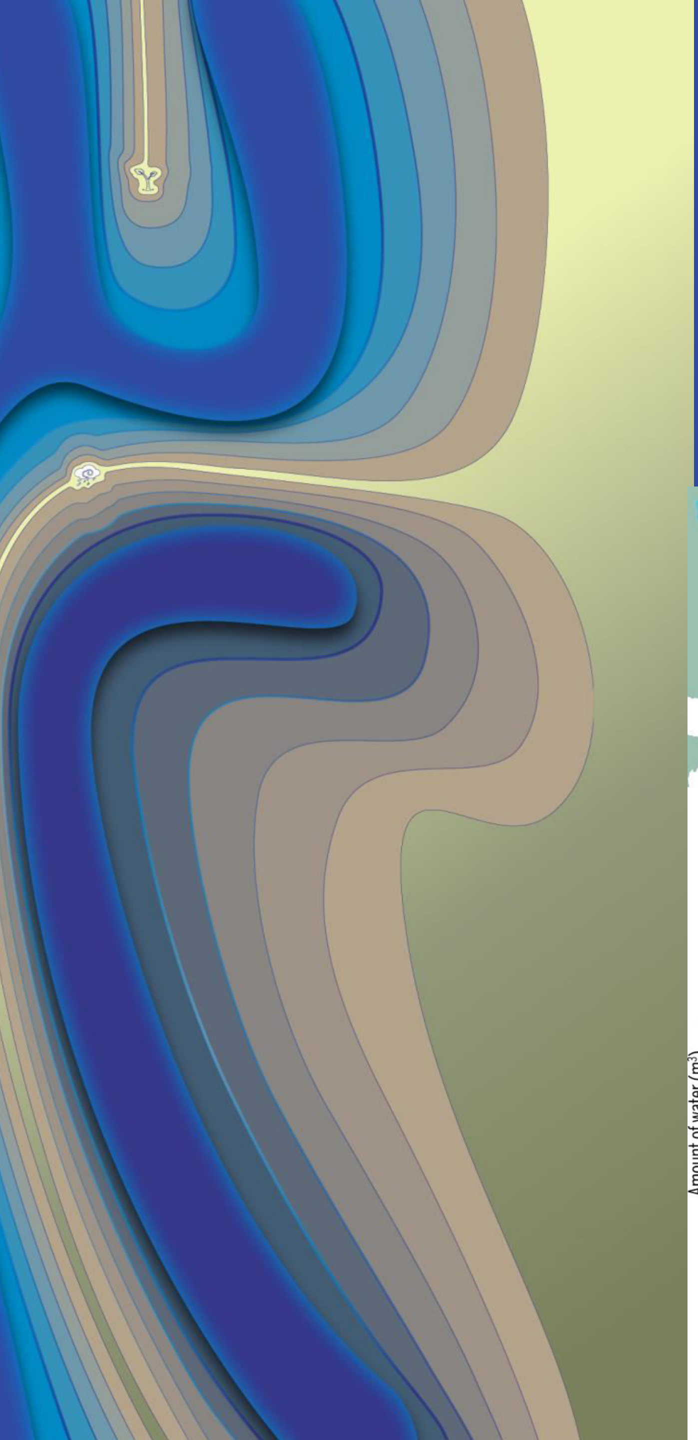
Climatic variability increases water stress & affects resilience of river basins in Himalaya



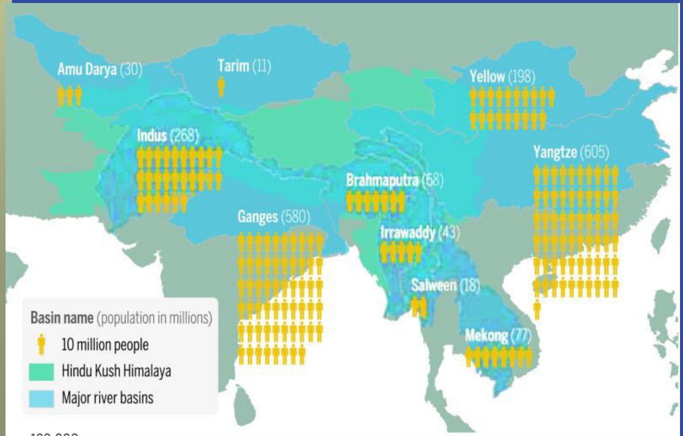
Nie et al. 2021 Nature Reviews Earth & Environment

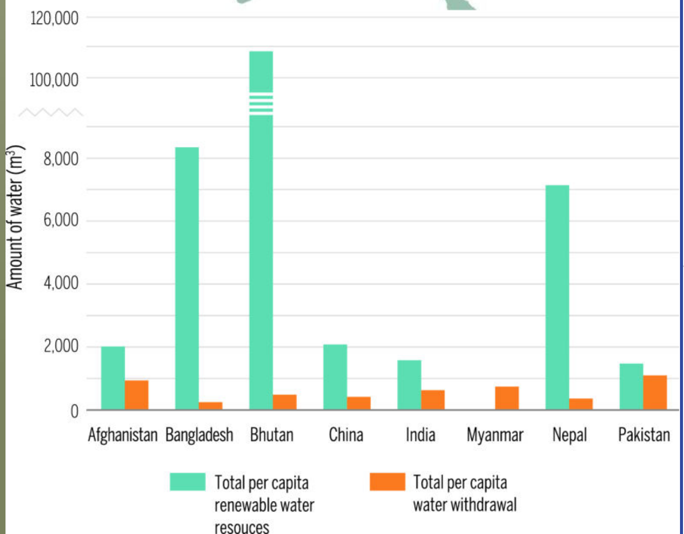
Increased hydrological variability:

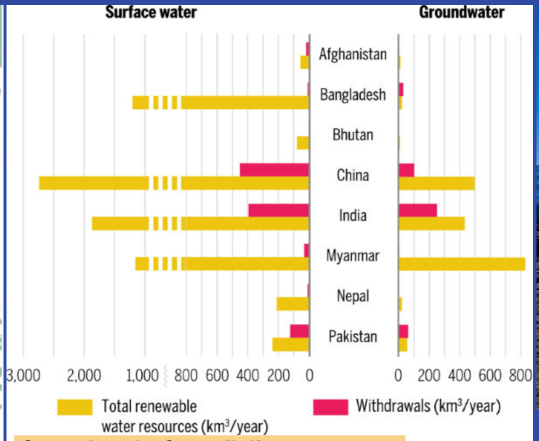
- **Increases flood risk (an average annual impact)' a greater proportion of population to be impacted**
- **Increases drought risk- more people suffer from water shortages in drought prone area**
- **Baseline water stress- a vast region in Asia experience water below baseline**
- **Representative concentration pathway (RCP) 8.5 scenario model predicts increased water stress by 2040 in the region**

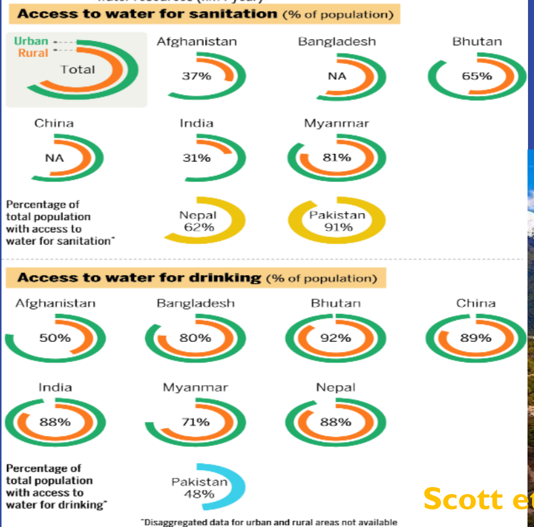


Urbanization increases water withdrawals & affects resilience of river basins in Himalaya



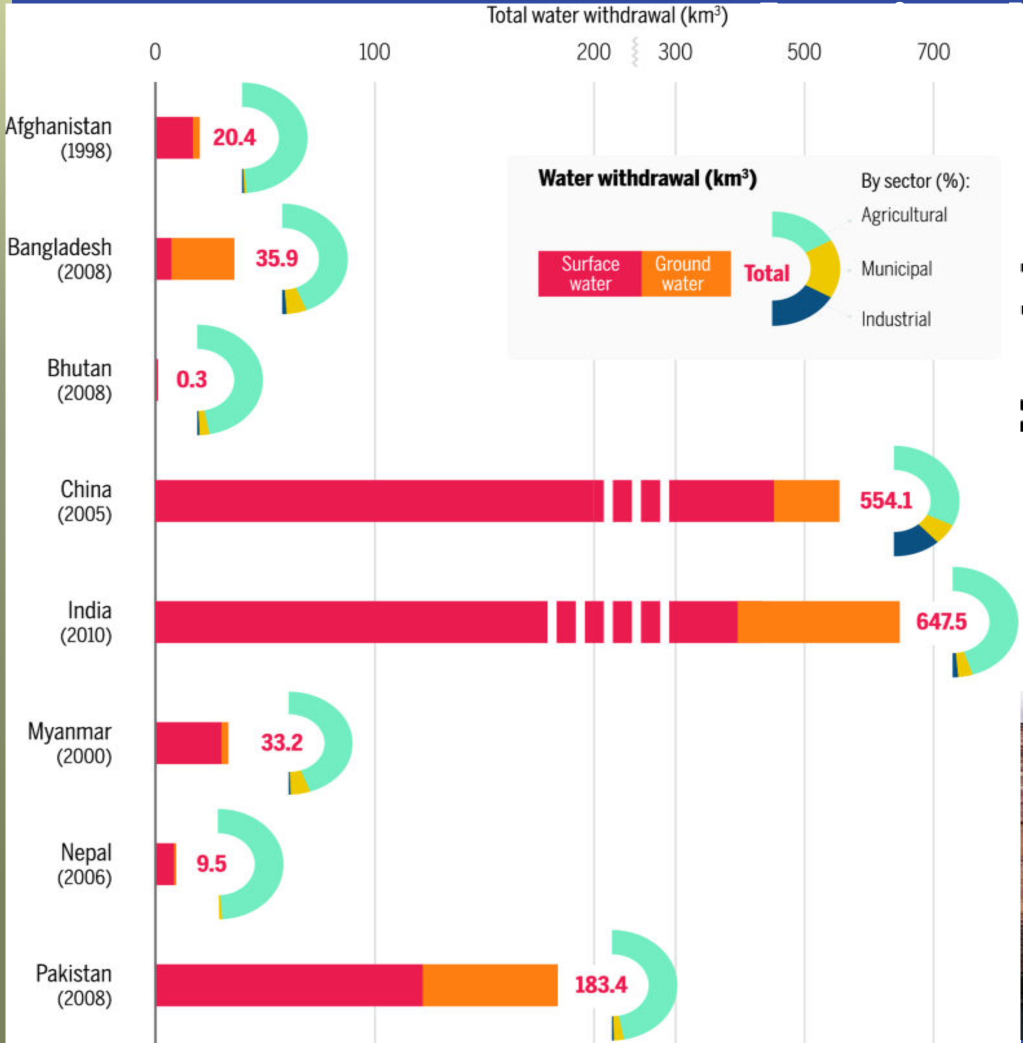


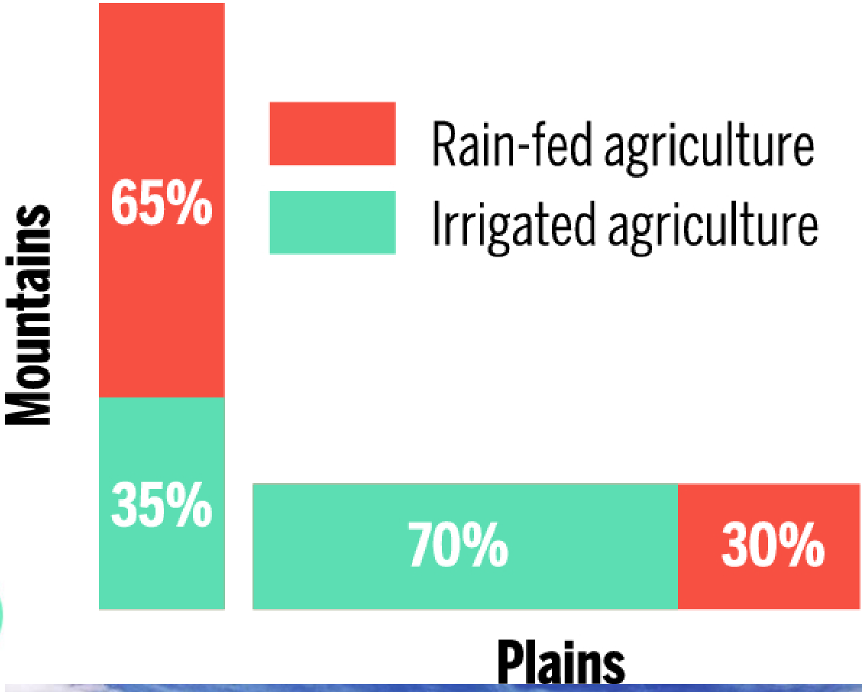




Scott et al. 2019 Water in the Hindu-Kush Himalaya

Irrigation increases water withdrawals & affects resilience of river basins in Himalaya





Scott et al. 2019 Water in the Hindu-Kush Himalaya

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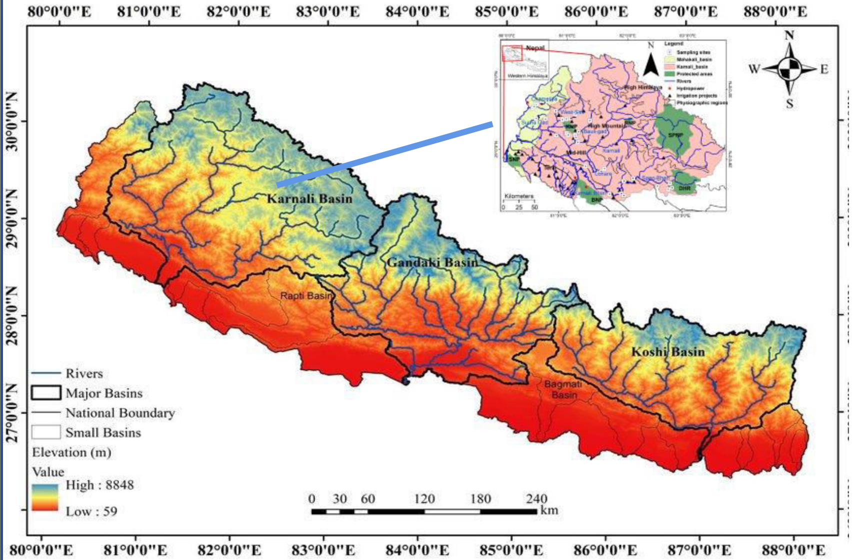
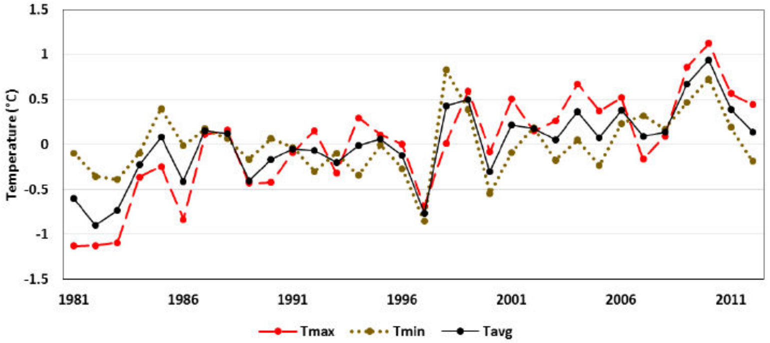
Aquatic biodiversity response to water stress & resilience of river basins in Asian Himalaya

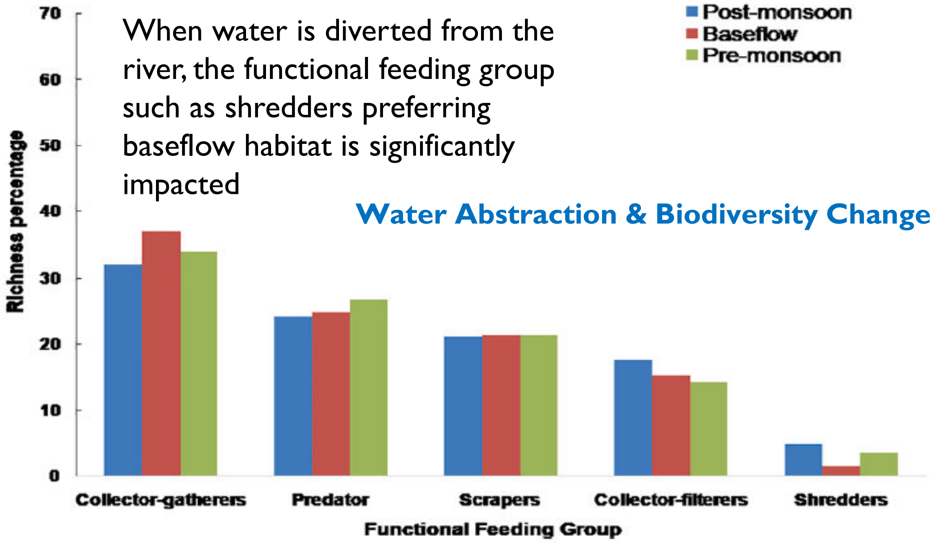


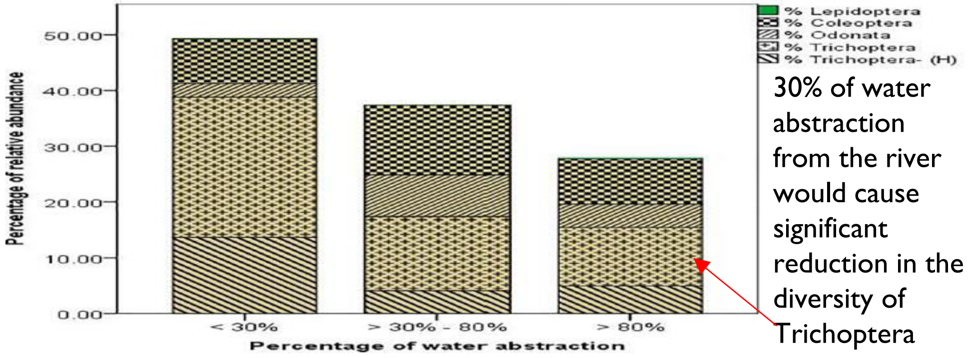


Karnali River Basin, Nepal Temperature Change (Max, Min, Mean)

When water is diverted from the river, the functional feeding group such as shredders preferring baseflow habitat is significantly impacted

Water Abstraction & Biodiversity Change





30% of water abstraction from the river would cause significant reduction in the diversity of Trichoptera

Ram Devi Tachamo Shah 2020 Ecological Indicators

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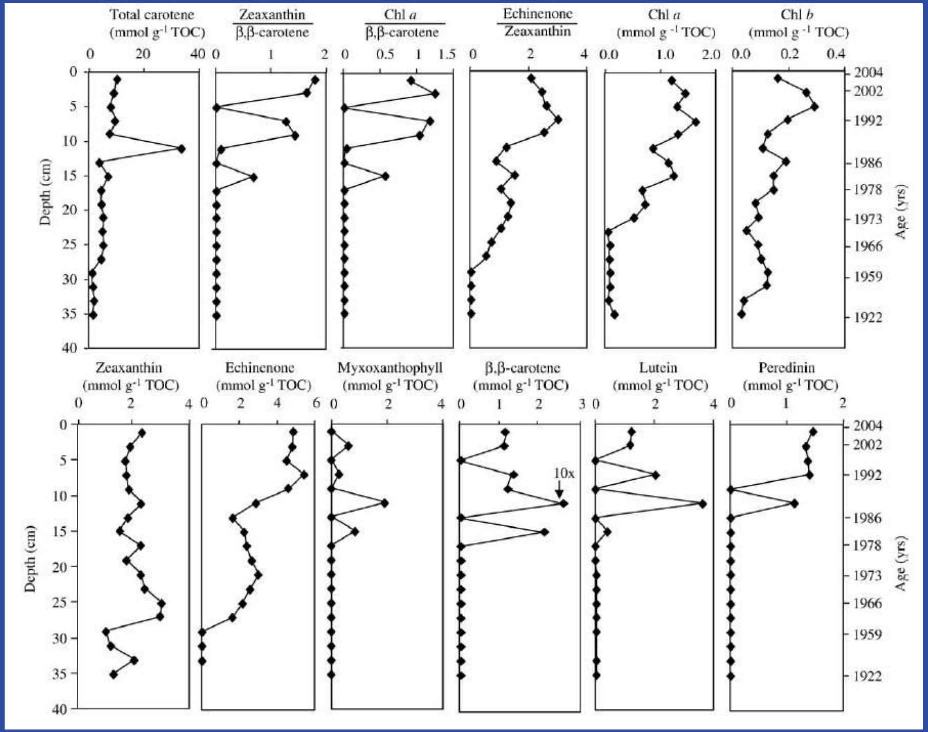
Multi-proxy response to climatic & environmental impacts & resilience of lake basin in Asian Himalaya



Choudhari et al. 2009 STOTEN

- **Response to changes in organic matter/biomass from Lake Sattal in Kumaun Himalayas, India**
- **Phytoplankton pigment (carotene, Chl-a, Chl-b, β-carotene, zeaxanthin, echinenone, myxoxanthophyll, lutein, & peredinin), and their ratios (zeaxanthin/β, β-carotene, Chl a/β, β-carotene, echinenone/zeaxanthin) show strong shift in lake environment**

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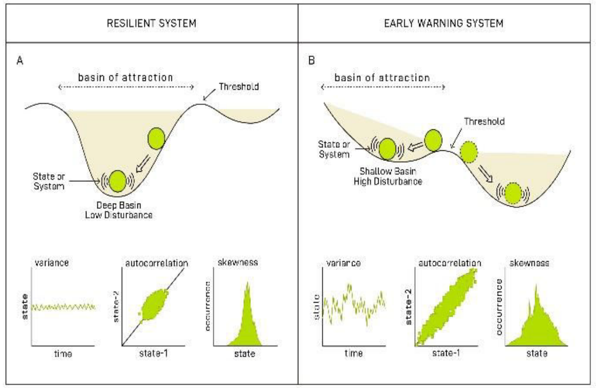
Resilience management: detecting critical thresholds & early warning system (EWS)

- **Understanding basins of attraction & threshold crossing is significant**
- **Resilient system, a stable landscape domain, often returns to original state following perturbation, rather than flipping into a new regime**
- **Peaks separating valleys - unstable thresholds between two or more alternative states**
- **Perturbations shape the stability domains, and thresholds leading to regime shifts**
- **Flickering of the system before a critical transition-indicated by variance, skewness, and autocorrelation of time series data- is EWS**



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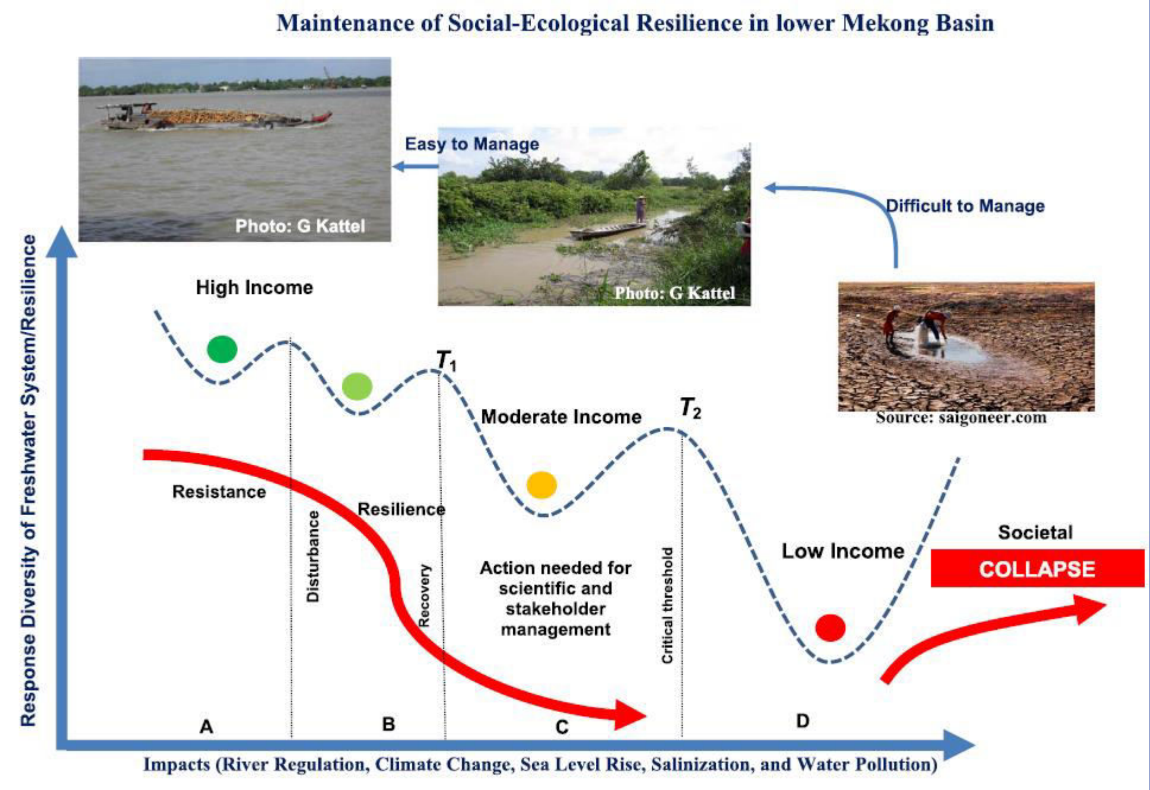
Resilience management: Social-ecological system



Kattel 2020 Environmental Research Communications

A. Identify the response diversity prior to the impacts, as this generates high value (resilient) ecosystem goods and services (green ball)

B. If the waterways (system) shows degrading that means is less resilient (light green ball) due to disturbance (thick downward red arrow), assess the system's self-recovery capacity prior to (T_1)

C. If the system (yellow ball) crosses T_1, take an action for water conservation and increase awareness among scientists and stakeholders

D. If the system crosses T_2, it becomes disastrous (red ball) due to the collapse of ecosystem services, so that avoid this to happen or be prepared to adapt

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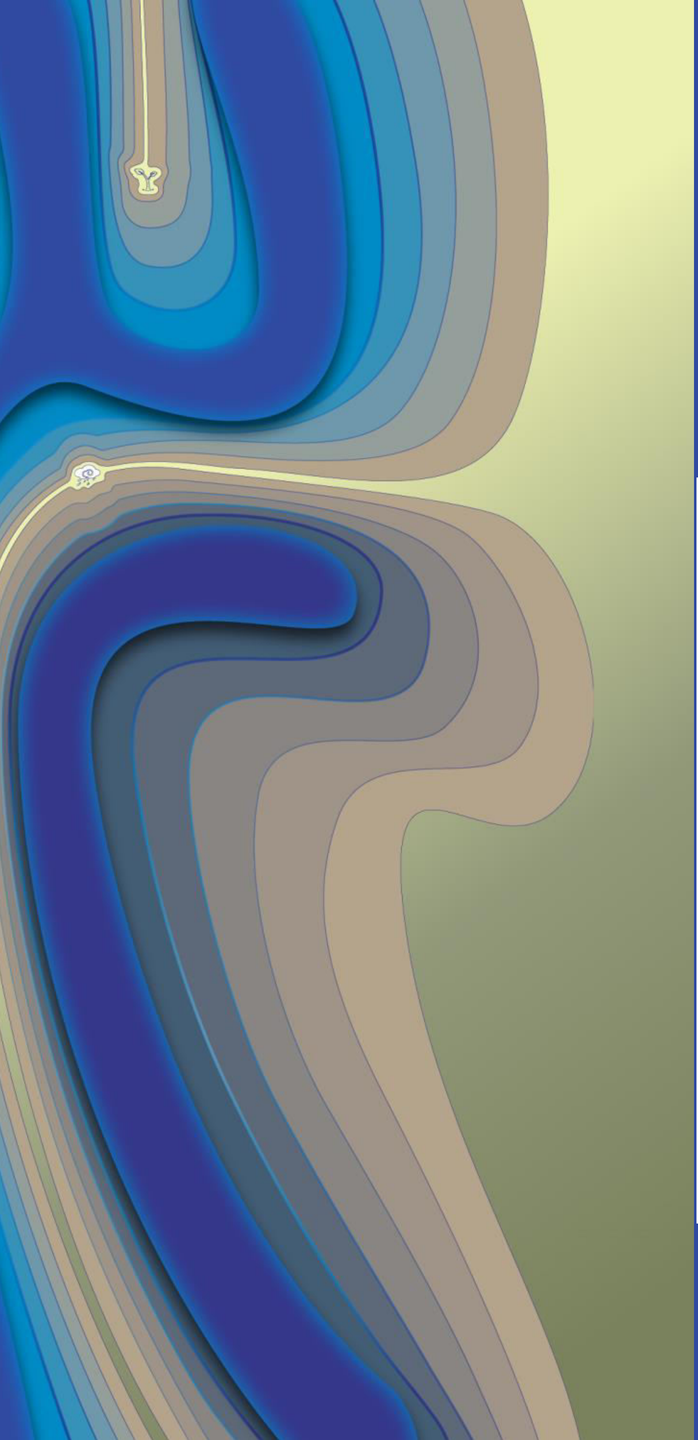
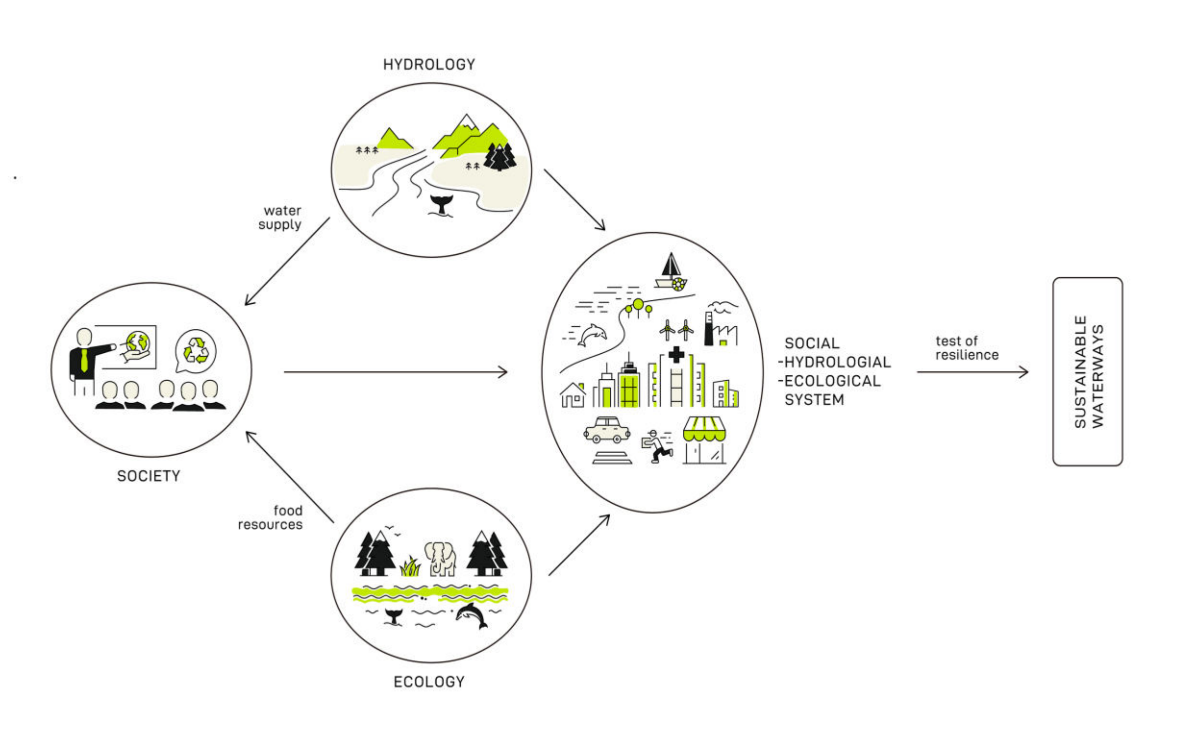


Resilience management: Integration of social-ecological & hydrological system



Current Irrigation

- In arid northwestern states of Punjab and Haryana, thirsty rice and wheat are now the dominant crops,
- Wells are the main source of irrigation water. The water table is sinking up to three meters a year.

Irrigation Water Demand Overtime

1980

2019

- To prevent famine Indian Govt purchases grains and offers farmers free electricity for groundwater pumps
- Return to traditional climate-adapted grains in northwest, and grow rice instead in northeastern and southern India

Integration of social-ecological & hydrological system

- promotes coordinated development of waterways in river basins
- maximizes economic and social welfare & development in an equitable manner without compromising sustainability of vital ecosystems

Kattel et al. 2023 WIREs Water

Conclusions

- Unprecedented rise in temperature in Asian river basins has enhanced rates of glacial-snow melt/permafrost thaw and seasonal variability of flows
- Population growth has intensified the use of water resources for hydropower generation, agriculture, and industries to meet demands of water, food, and energy
- Transboundary communities have become increasingly vulnerable to extreme water insecurity due to reduction in water quantity and quality
- Framing linkages among biodiversity, ecosystem function, and ecosystem services; early warning system of ecosystem; application of geoinformatics, remote sensing & AI; and smart water technologies, is significant
- More importantly, the integration of social–ecological-hydrological system resilience enhances sustainability and economic and social welfares of the people in the region