Himalayan Glaciers

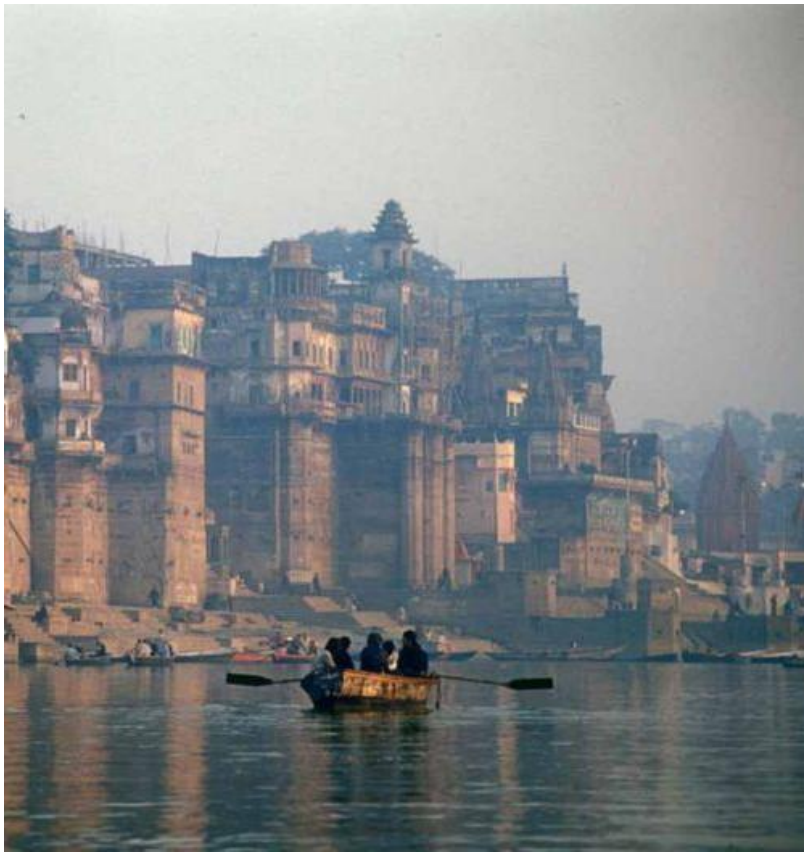
Climate Change, Water Resources, and Water Security

Henry Vaux, Committee Chair

November 1, 2012

Study Context

- Glacial meltwater is commonly thought to significantly contribute to water supply in the region
- There is confusion about how changes in the climate will affect the timing and rates of glacial wastage in different parts of the region
- The purpose of this study was to clarify many of the misunderstandings surrounding the broad topic of glacial retreat and its implications for water resources and water security



Ganges River, Varanasi, Uttar Pradesh, India
Photo Credit: Steve Evans

Charge to the Committee

- How sensitive are the Himalayan glaciers to climate change?
- What are the likely major impacts of climate change on water supplies and flood regimes? What additional observational and modeling resources are needed?
- What management systems are in place to manage climate-induced changes in regional hydrology, and how might they be strengthened?
- What are some of the main vulnerabilities to adjusting to changes in water supply? What are the prospects for increased competition, or improved cooperation, between different downstream water users? What are some of the implications for national security?

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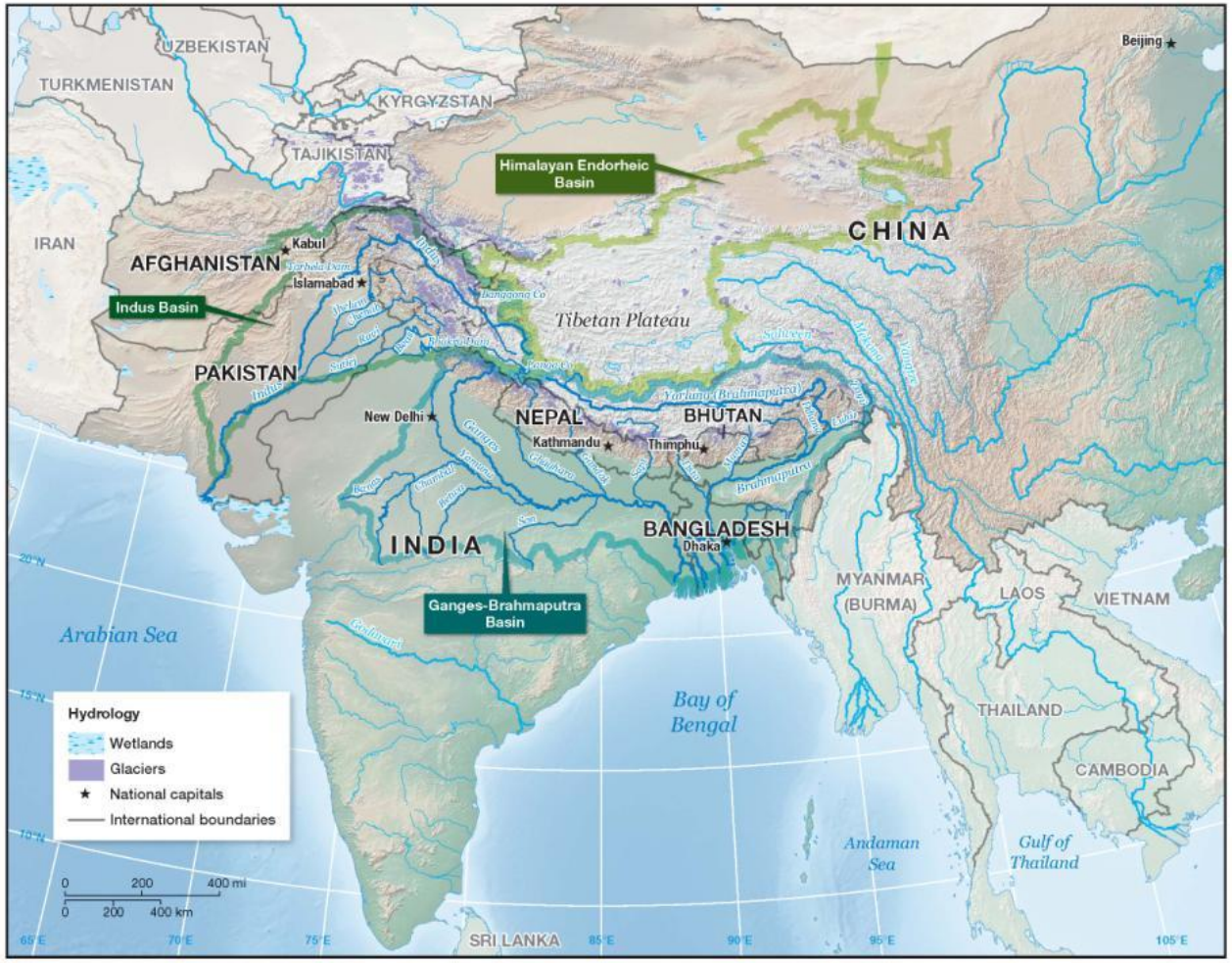
Geographic Scope

The Hindu-Kush Himalayan (HKH) region extends 2,000 km across South Asia and includes all or parts of Afghanistan, Bangladesh, Bhutan, China, India, Nepal, and Pakistan.

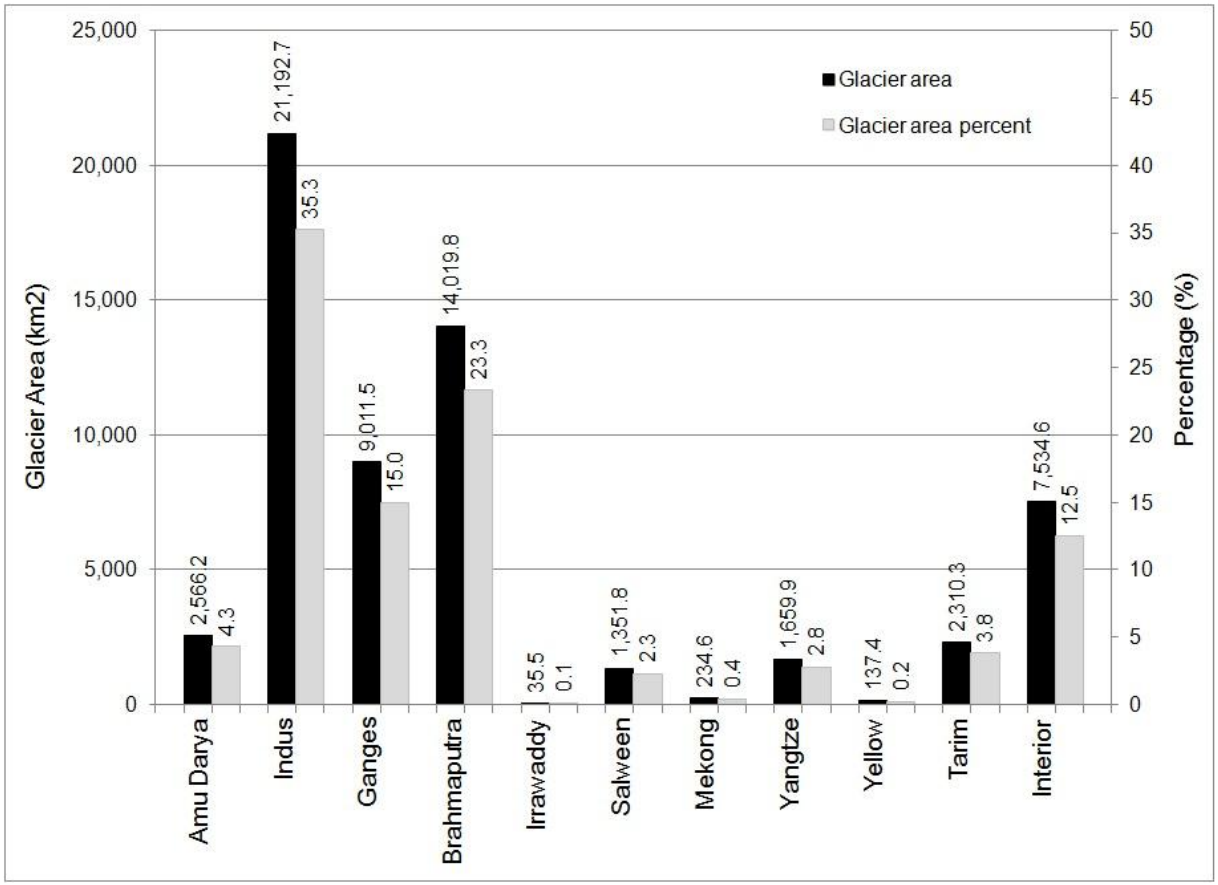
Hydrologic Scope

The rivers of the HKH region provide water for 1.5 billion people.



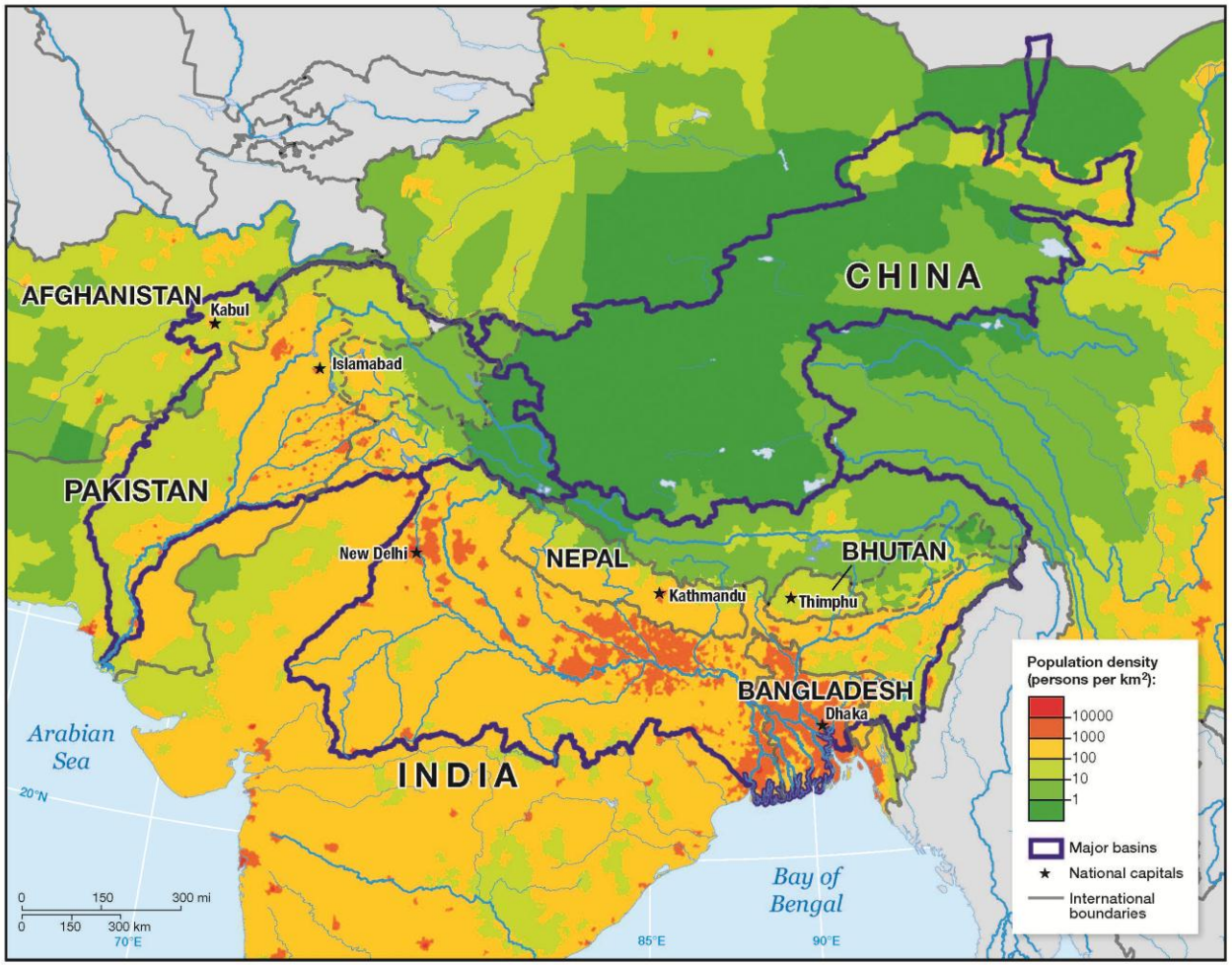
Hydrologic Scope

Only the **Indus**, **Ganges**, **Brahmaputra**, and the **rivers of the Tibetan Plateau** contain more than five percent of the region's glacier area and are most likely to be affected by glacier retreat.

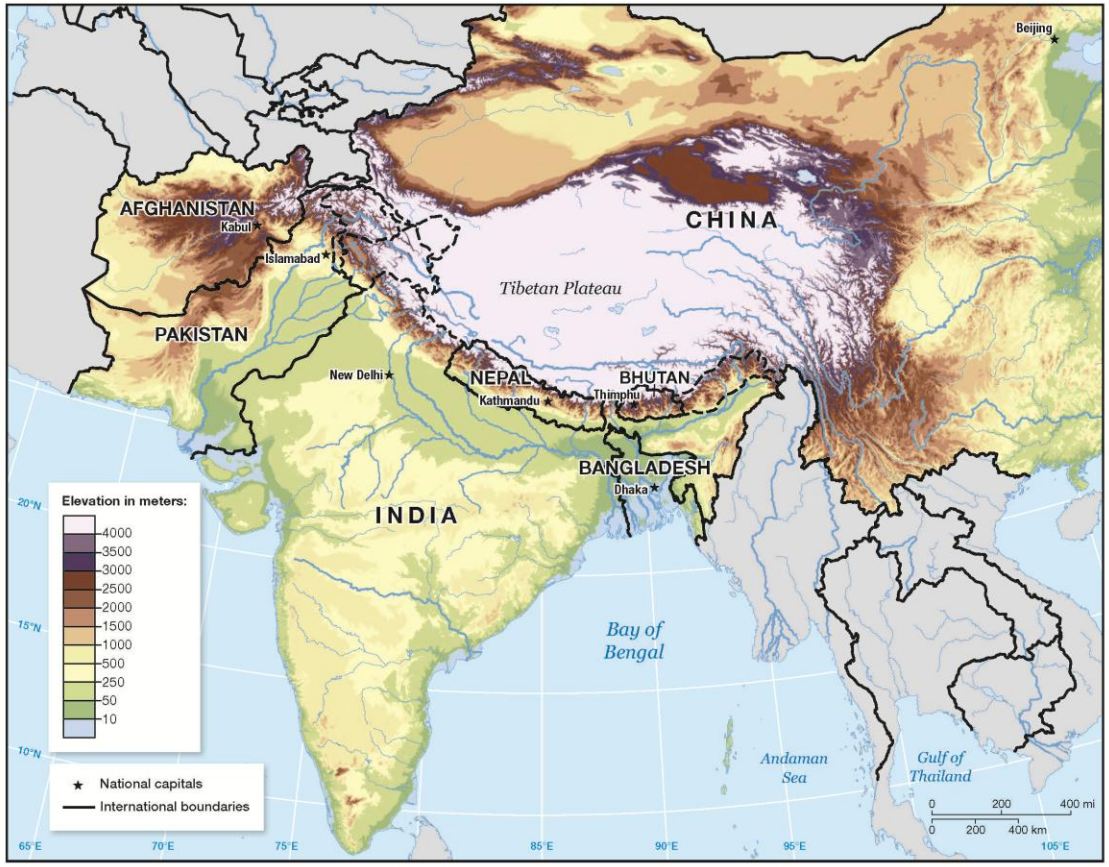


Demographic Scope

The densely populated basins of the **Indus**, **Ganges**, and **Brahmaputra** are most likely to be affected by glacier-related changes in water supply.



A Vast and Varied Region

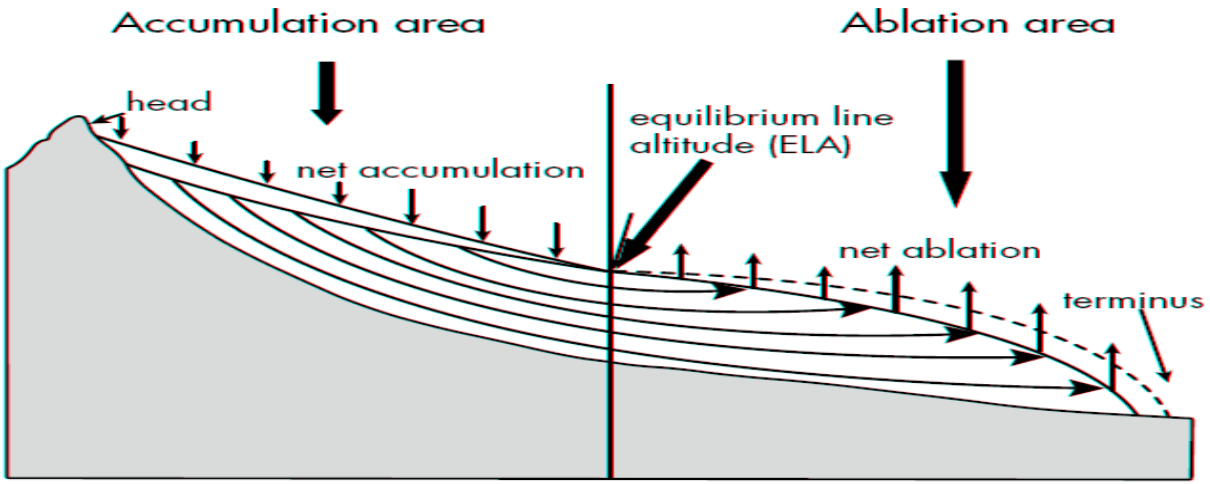


The HKH, rising from its base in the alluvial Indo-Gangetic Plain near sea level to the great heights of the HKH (~8,000 m) in a distance of 100 to 400 km, has a very high climatic gradient across the region. The region's climate ranges from tropical at the base of the foothills to permanent ice and snow at the highest elevations.

The climatic gradient is strong not only across, but also along the arc of the Himalayas. In the west, most precipitation falls as snow in the winter while in the east, precipitation is dominated by the summer monsoon.

GLACIAL RETREAT

Glacier Retreat



GLACIAL MASS BALANCE:

Glacial Retreat Occurs When:

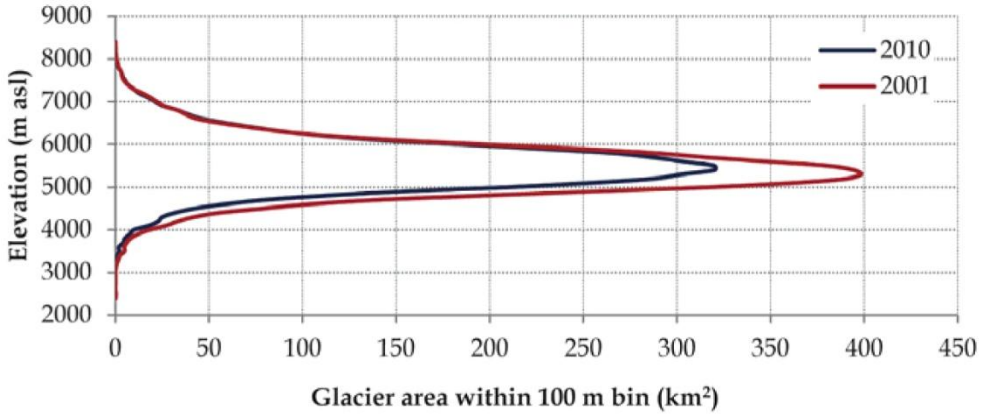
Ablation > Accumulation

Glacier Retreat

- Glaciers in the **eastern** and **central** HKH are **retreating** at accelerated rates.
- The rates of glacier retreat in the HKH region are comparable to other parts of the world.
- Glaciers in the **western** HKH appear to be **more stable**, and perhaps even growing.
- Projected temperature increases will continue to contribute to glacier retreat. Future precipitation changes are less certain, but shifts in the location and intensity of rain and snowfall could affect the rate of glacial retreat.

Measuring Glacier Retreat

- In Nepal, glacial ice ranges from about 3,200 m to 8,500 m in elevation.
- Total glacial area decreased between 2001 and 2010, although the highest amount of glacial ice remained at about 5,400 m in elevation.
- Glacial area decreases as the elevation increases or decreases from 5,400 m.



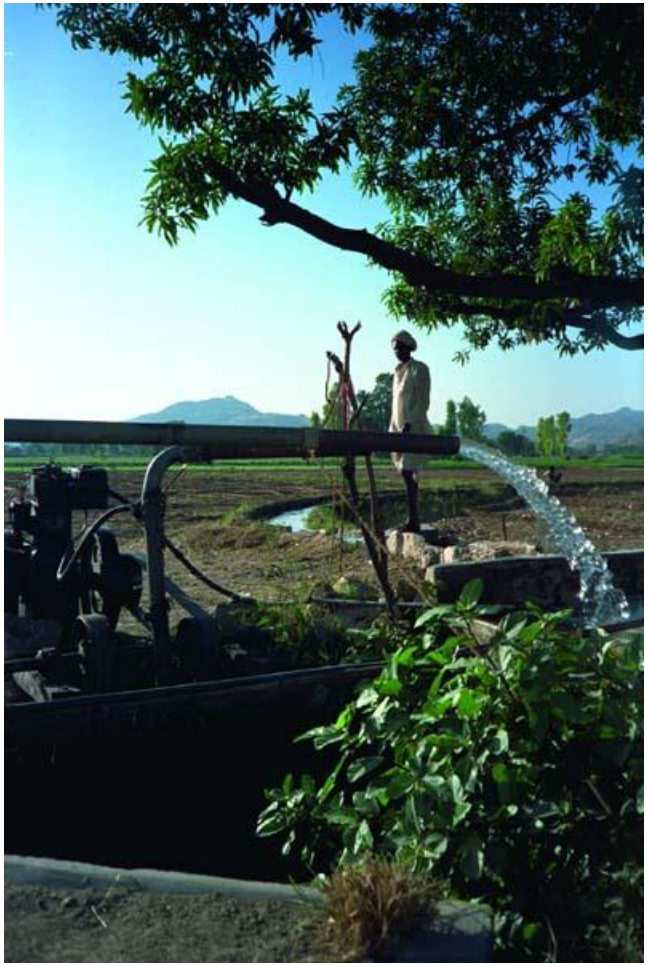
Glacier Area in Nepal as a function of Elevation. Source: Bajracharya et al. (2011).

Glacier Retreat and Water Supply

- The **contribution** of glacial melt to water supply **varies** across the region and is highly seasonal.
- Glacier melt is **more important in the west** and at **higher elevations**
- Glacier meltwater can act as "insurance" during drought and dry seasons
- Retreating glaciers would provide more meltwater in the short term; the loss of glacier "insurance" could become problematic over the longer term
- Changes in the monsoon will probably be more important for water supply at lower, downstream elevations than changes in glacier wastage

Chota Sigri, India.
Photo Credit: Mark Williams.

Groundwater

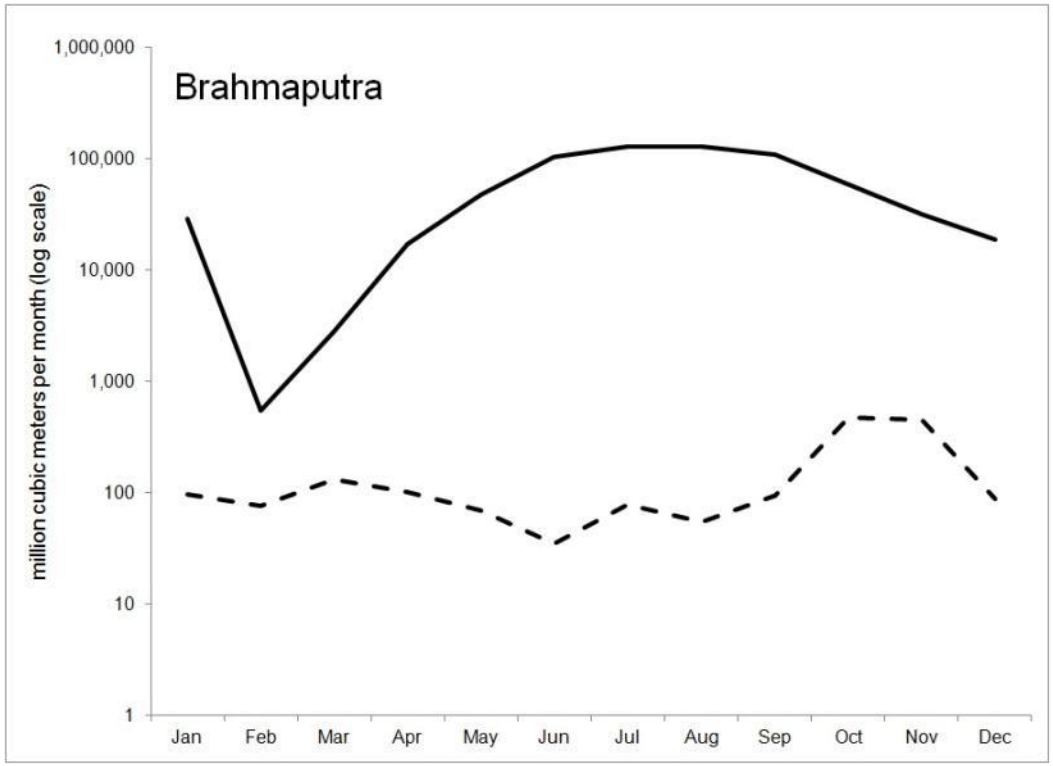


Gujurat, India.
Photo Credit: Food and Agriculture Organization.

- Groundwater is an important supplement to surface water
- Uncertainties about groundwater are even greater than surface water
- Groundwater is already being depleted, with evidence of overdraft in the central Ganges Basin
- Overdraft of groundwater is likely to have an earlier and larger impact on water supplies than foreseeable changes in glacier meltwater

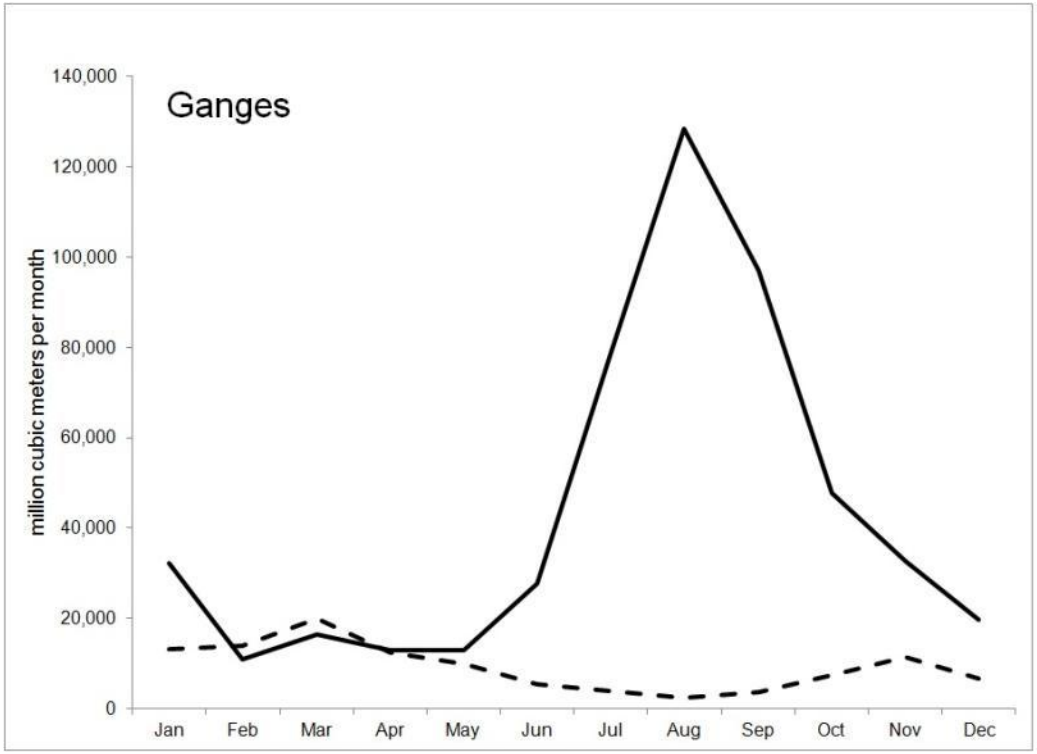
WATER SCARCITY

Water Use and Water Security
Brahmaputra



Natural Run-off: solid line
Blue Water Consumed: dashed line

Water Use and Water Security
Ganges



Natural Run-off: solid line
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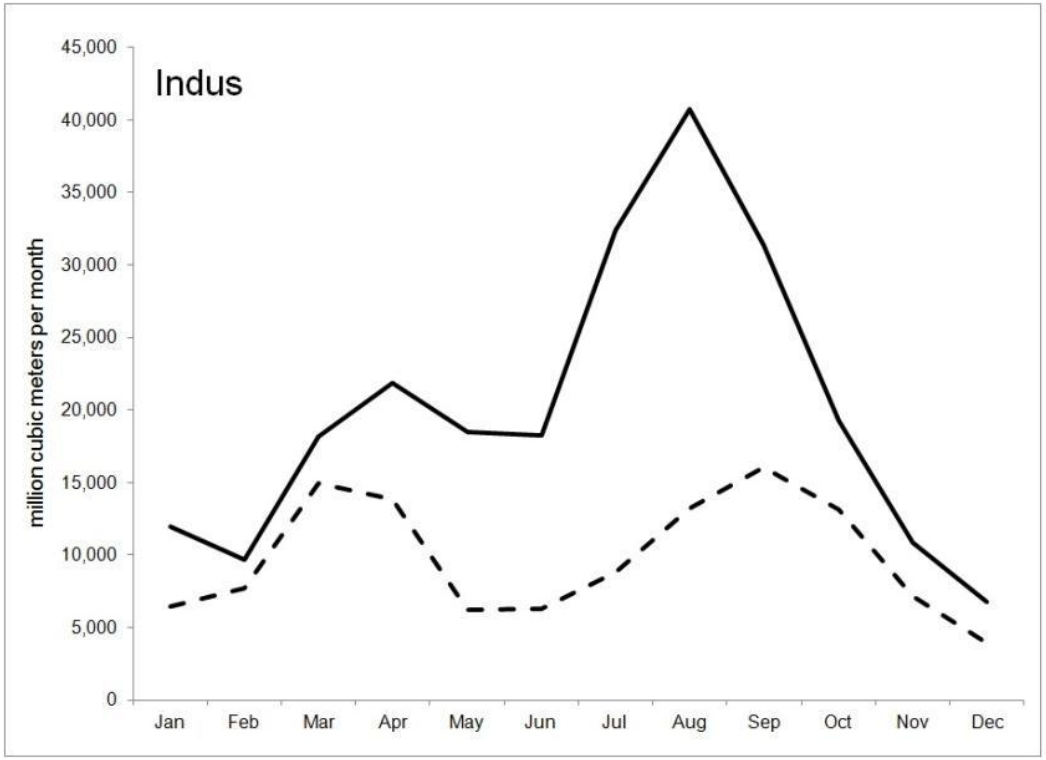
Water Use and Water Security
Indus



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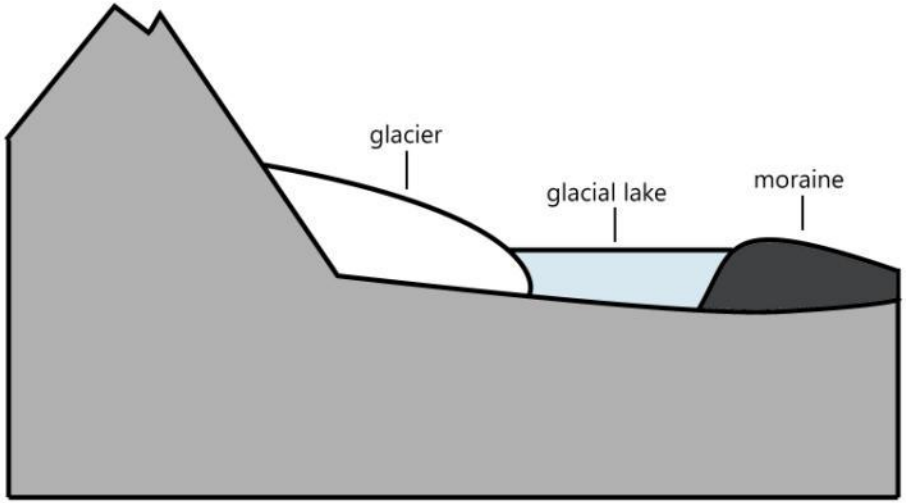
Natural Hazards

- Glacial retreat is unlikely to lead to flows of water large and rapid enough to cause flooding, but the region does face other hazards.
- For upstream populations, GLOFs and LLOFs are the dominant physical hazard risk.
  For downstream populations in the central and eastern Himalayas, floods from changes in monsoon rainfall and cyclones are more likely to be important.



A moraine-dammed glacial lake formed by glacial meltwater. Failure of the confining moraine dam leads to an outburst flood. Outburst floods include both Glacial Lake Outburst Floods (GLOFs) and Landslide Lake Outburst Floods (LLOFs).

Water Use and Water Security

Dhaka, Bangladesh.
Photo Credit: GlobeImages.

- Social changes will have as much impact on water use as environmental factors do on water supply.
- Projected population growth, urbanization, and shifts in dietary patterns and water use are all likely to increase water demand in the region.
- The rural and urban poor will be the most vulnerable to water scarcity.

Water Use and Water Security

- The effectiveness of existing water management institutions indicates how the region will cope with changes in water supply.
- Current political disputes could complicate the process of reaching agreements in resource disputes.

Zangmu Dam, Tibet Autonomous Region, China. Photo Credit: TerraDaily.

- Changes in water resources could play an increasing role in political tensions.

Links between humans and the environment within the context of water security in the HKH region

- Theme 1: There is significant variability in the climate, hydrology, and glacier behavior as well as the demographics and water use patterns.
- Theme 2: Uncertainties exist and will continue to exist in both the physical and social systems.
- Theme 3: To reduce and respond to this uncertainty, there is a need for improved monitoring of both the physical and social systems.
- Theme 4: In the face of uncertainty, the most compelling need is to improve water management and hazards mitigation systems.

Theme 1: Variability

- The retreat rates of Himalayan glaciers vary over time and space, with the rate of retreat being higher in the east than the west.
- The contribution of glacial melt to streamflow varies seasonally and with space, with the contribution being greater in the west than the east.
- Rates of urbanization vary across the region.
- The portion of the population with access to improved water and sanitation varies across the region, and between urban and rural areas.

Langtang, Nepal.
Photo Credit: Mark Williams.

Theme 2: Uncertainty

Kakadhowa village, India.
Photo Credit: Associated Press.

- The impact of future climate change is uncertain but will probably accelerate rates of glacier retreat.
- Existing demographic methods do not allow for projections at sufficient spatial resolution to determine whether certain basins or elevation zones will experience higher rates of population growth.
- In both the physical and social systems, stationarity will no longer apply; the past will not be a good basis for prediction.

Theme 3: Monitoring

- Monitoring on a more extensive and consistent basis is needed.
- Enhanced monitoring is necessary to respond to changing environmental and social conditions.

Guliya ice cap, Tibetan Plateau.
Photo Credit: Lonnie Thompson.

Theme 4: Adaptation

- Existing patterns of water use and water management need improvement.
- Improved implementation of lessons from climate assessments in water policies and programs will be necessary going forward.
- Adaptation approaches need to be flexible enough to respond to changing conditions.
- The capacity of governments and institutions to adapt to climate change will vary across the region.

Stakmovillage, India.
Photo Credit: National Geographic.

Conclusions

- Most glaciers in the HKH region are retreating and the consequences for the region's water supply are nuanced
- At lower elevations, shifts in the location, intensity, and variability of rain and snow will have a greater impact on water supply than changes in glacier retreat rates
- Groundwater depletion and increasing water use will have a greater impact in the short term.
- Key responses
  - Monitor and measure
  - Make existing water management as effective as possible

THANK YOU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