Himalayan Glaciers, Peak Water and India's Economic Dependence: Climate Risks, Black Carbon and Resilience

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Recent Developments:

New Report on Himalayan Economic Dependence:

- A new report titled **"A Resilient Himalaya: Protecting a Region at Risk and Securing Future Prosperity"** has highlighted the growing economic significance of Himalayan ecosystems for India.
- The report was prepared by **Systemiq** in partnership with the **Integrated Mountain Initiative**, with technical contributions from the **International Centre for Integrated Mountain Development** and the **G.B. Pant National Institute of Himalayan Environment**.
- The report estimates that **?64.8 lakh crore, equivalent to 21.5% of India's FY24 GDP, is dependent on the Himalayas**, primarily through economic activities linked to Himalayan water.
- This figure does not represent the GDP that would be directly lost because of glacier melting; instead, it measures the economic activity whose functioning is connected to Himalayan water resources.

Accelerating Glacier Loss:

- The **HindKush Himalaya** is experiencing rapid cryospheric change, with ICIMOD reporting that glacier ice loss accelerated substantially during the 2010s compared with the previous decade.
- ICIMOD's 2026 assessments further indicate that the rate of glacier ice loss across the region has approximately doubled since 2000, highlighting an accelerating rather than static trend.

Economic Significance of the Himalayas:

Measuring India's Himalayan Dependence:

- The report calculates Himalayan-linked economic activity through three interconnected layers:
- **Direct:** Economic output generated within Himalayan states and regions.
- **Indirect:** Agricultural production, manufacturing, hydropower and services dependent on Himalayan-fed rivers and groundwater recharge, excluding rain-fed production.
- **Induced:** Supply-chain and income-spending effects generated by Himalayan-dependent economic activities.
- Therefore, the Himalayan economy extends far beyond mountain states because downstream regions also depend upon the water, energy and ecological services originating in the mountains.

Why Himalayan Water Matters:

- The Himalayas function as a major **natural water-storage system**, storing precipitation as snow and ice and gradually releasing meltwater into river systems.
- The **Indus, Ganga and Brahmaputra** river systems receive substantial water from the Himalayan cryosphere and support agriculture, settlements, industries and hydropower across downstream regions.

- Himalayan water is particularly important during dry periods because glacier and snowmelt can maintain river flows when rainfall is limited.
- Consequently, glacier retreat can create both short-term increases in meltwater and longer-term uncertainty over water availability.

Understanding Peak Water:

Meaning of Peak Water:

- **Peak Water** refers to the stage at which glacier-derived water contribution to rivers reaches its maximum because accelerated melting temporarily increases runoff.
- After this point, continued glacier shrinkage reduces the amount of stored ice available for melting, causing long-term glacier-fed river flows to decline.
- Most HindKush Himalayan river basins are expected to approach **Peak Water around the middle of the 21st century**, although the timing varies across individual basins.

Projected Glacier Loss:

- Under current high-emission trajectories, the HindKush Himalaya could lose **up to 80% of its present glacier volume by 2100**.
- ICIMOD has also projected declining snow cover, increasing permafrost degradation and greater variability in water availability as the cryosphere changes.
- These changes could affect both mountain communities and large downstream populations that depend upon Himalayan river systems.

The Himalayas as a Disaster Hotspot:

High Disaster Exposure:

- Himalayan states and Union Territories cover around **18% of India's geographical area but have experienced about 35% of major disasters** over the assessed historical period.
- The region's young and tectonically active geology, steep slopes, seismicity, intense rainfall and fragile ecosystems increase its vulnerability to multiple hazards.
- Major risks include **landslides, flash floods, cloudbursts, avalanches, earthquakes, glacial lake outburst floods and land subsidence**.

Cascading Economic Effects:

- Himalayan disasters can simultaneously affect **food security, water security, infrastructure, supply chains and livelihoods**.
- Repeated disasters can increase displacement and reconstruction requirements while diverting public expenditure away from long-term resilience and development.
- Climate change can therefore generate a **compound risk**, in which environmental degradation increases economic vulnerability and economic disruption reduces the capacity to adapt.

Black Carbon and Glacier Melting:

What is Black Carbon?

- **Black carbon** is a fine particulate pollutant produced mainly through the incomplete combustion of fossil fuels, biomass and other carbon-based fuels.
- When deposited on snow and ice, black carbon reduces surface reflectivity, allowing the surface to absorb more solar radiation.
- This **snow-darkening effect** increases local heating and can accelerate the melting of snow and glaciers.

Himalayan Impact:

- The new report estimates that roughly **one-third of Himalayan glacier melt is associated with South Asian black carbon**.
- Industry, particularly **brick kilns**, is identified as a major contributor to anthropogenic black carbon deposition across the region.
- The report estimates that industrial sources contribute around **32–42% of South Asian anthropogenic black carbon deposition** in the Himalayan region.
- Reducing black carbon therefore offers a relatively immediate mitigation opportunity because it can simultaneously improve **air quality and cryospheric stability**.

Brick Kilns as a Policy Lever:

Zigzag Kiln Technology:

- **Zigzag kiln technology** improves combustion efficiency and can substantially reduce particulate and black carbon emissions compared with traditional brick kilns.
- The report indicates that the technology can reduce black carbon and particulate emissions by roughly **70%** while lowering fuel consumption by around **20–30%**.
- Adoption, however, remains uneven across India, creating scope for targeted technological and financial interventions.

Beyond Brick Kilns:

- Black carbon control cannot depend exclusively on brick kilns because emissions also arise from **cookstoves, transport, industries and crop-residue burning**.
- Effective intervention requires an **airshed-based approach**, where emission sources across interconnected regions are addressed collectively rather than through isolated city-level measures.
- This approach can generate co-benefits for **public health, climate mitigation, agricultural productivity and glacier conservation**.

Broader Climate and Ecological Risks:

Cryosphere–Water–Ecosystem Linkages:

- Himalayan glacier and snow loss affects more than water supply because the **cryosphere is closely connected with ecosystems, biodiversity, agriculture and human settlements**.
- Permafrost degradation can destabilise mountain slopes and infrastructure, while changing snow patterns can alter the timing and availability of water.
- ICIMOD has warned that rapid cryospheric changes are increasing the likelihood of interacting slow- and fast-onset hazards, including **erosion, sedimentation, landslides and glacial lake outburst floods**.

Transboundary Dimension:

- The HindKush Himalaya extends across several countries, while its major river systems cross national boundaries.
- Glacier monitoring, hydrological data, disaster forecasting and early-warning systems therefore require **regional cooperation**.
- Cross-border coordination is particularly important because hazards originating in high-altitude areas can affect densely populated downstream regions across national borders.

Way Forward:

Building a Resilient Himalayan Economy:

- Treat Himalayan ecosystems as **critical national infrastructure** because their services support water, food, energy and economic security far beyond mountain states.
- Strengthen **glacier monitoring, glacial-lake surveillance, early-warning systems and climate-resilient infrastructure** in vulnerable mountain districts.
- Expand **nature-based solutions**, watershed restoration, spring rejuvenation and sustainable land-use planning to improve water retention and reduce disaster risks.
- Promote climate-resilient agriculture, efficient irrigation and diversified mountain livelihoods to reduce dependence on increasingly uncertain water regimes.
- Accelerate **black carbon reduction** through cleaner brick kilns, improved household energy, cleaner transport and better management of crop residues.
- Adopt an **airshed-level pollution strategy** because atmospheric pollutants travel across administrative boundaries.
- Strengthen India's cooperation with **HindKush Himalayan countries** on scientific monitoring, hydrological data sharing, disaster preparedness and climate adaptation.
- Ensure that Himalayan development projects follow **carrying-capacity assessments, cumulative impact assessments and disaster-risk-sensitive planning** rather than focusing only on individual projects.

Value Addition for UPSC:

- **Third Pole:** The HindKush Himalaya is often described as the **Third Pole** because it contains one of the world's largest concentrations of snow and ice outside the polar regions.
- **Peak Water:** The stage at which glacier-derived river discharge reaches its maximum before declining as glacier storage diminishes.
- **Cryosphere:** The part of the Earth system consisting of frozen water, including glaciers, snow, ice sheets, sea ice and permafrost.
- **Black Carbon:** A short-lived climate pollutant produced mainly through incomplete combustion that strongly absorbs solar radiation.
- **Snow Darkening Effect:** Reduction in snow reflectivity caused by deposited particles such as black carbon, resulting in greater absorption of solar energy.
- **Key Data:** Himalayan-linked economic activity is estimated at **21.5% of India's FY24 GDP**, while the HindKush Himalaya could lose **up to 80% of its present glacier volume by 2100** under current trajectories.

Conclusion:

- The Himalayas are simultaneously a **water tower, ecological regulator and economic foundation** for India.
- Accelerating glacier loss and the approaching Peak Water transition create long-term risks for water security, agriculture, energy and disaster resilience.
- While global warming requires international mitigation, reducing **black carbon and other short-lived pollutants** offers India an immediate opportunity to protect air quality while slowing additional pressure on Himalayan glaciers.
- A combination of climate mitigation, ecosystem restoration, scientific monitoring, resilient infrastructure and regional cooperation is therefore essential for securing the Himalayan economy.