Managing climate induced disasters and natural resources in the Himalaya

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Why the Indian Himalayan Region (IHR) is vital for Climate Change (CC) ?


9,575 glaciers

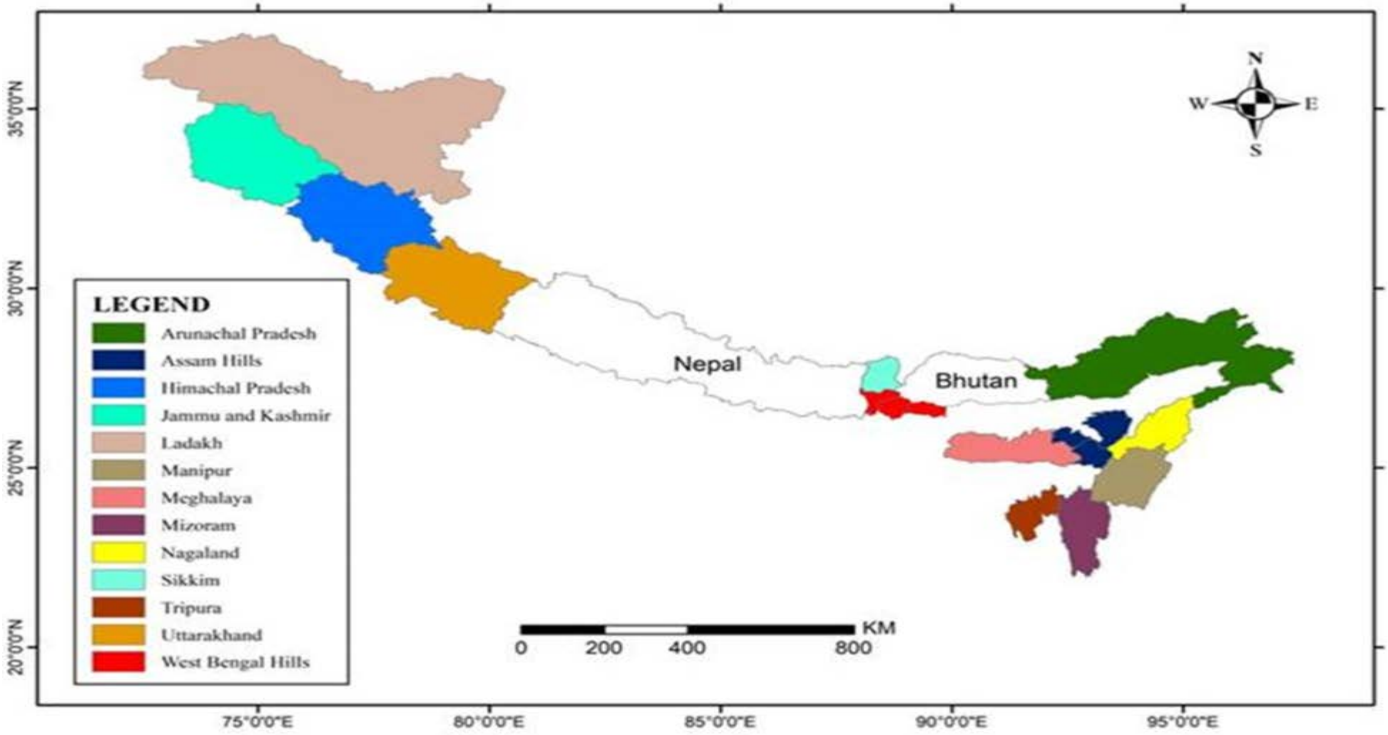

19 major rivers


10,000 species of plants
(3,160 are endemic)

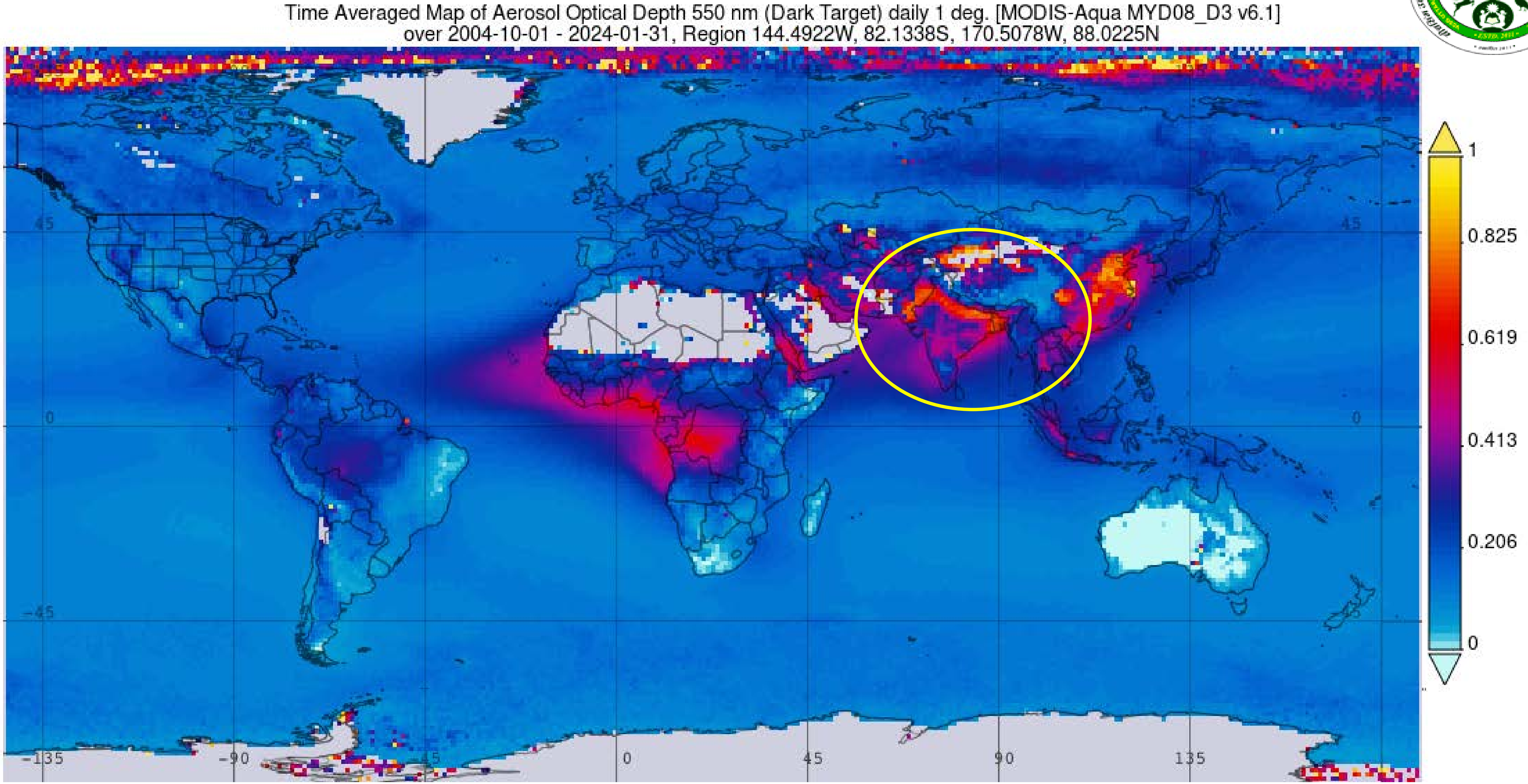

30,377 *Faunal* species


3,04,68,612 human population


171 Tribes



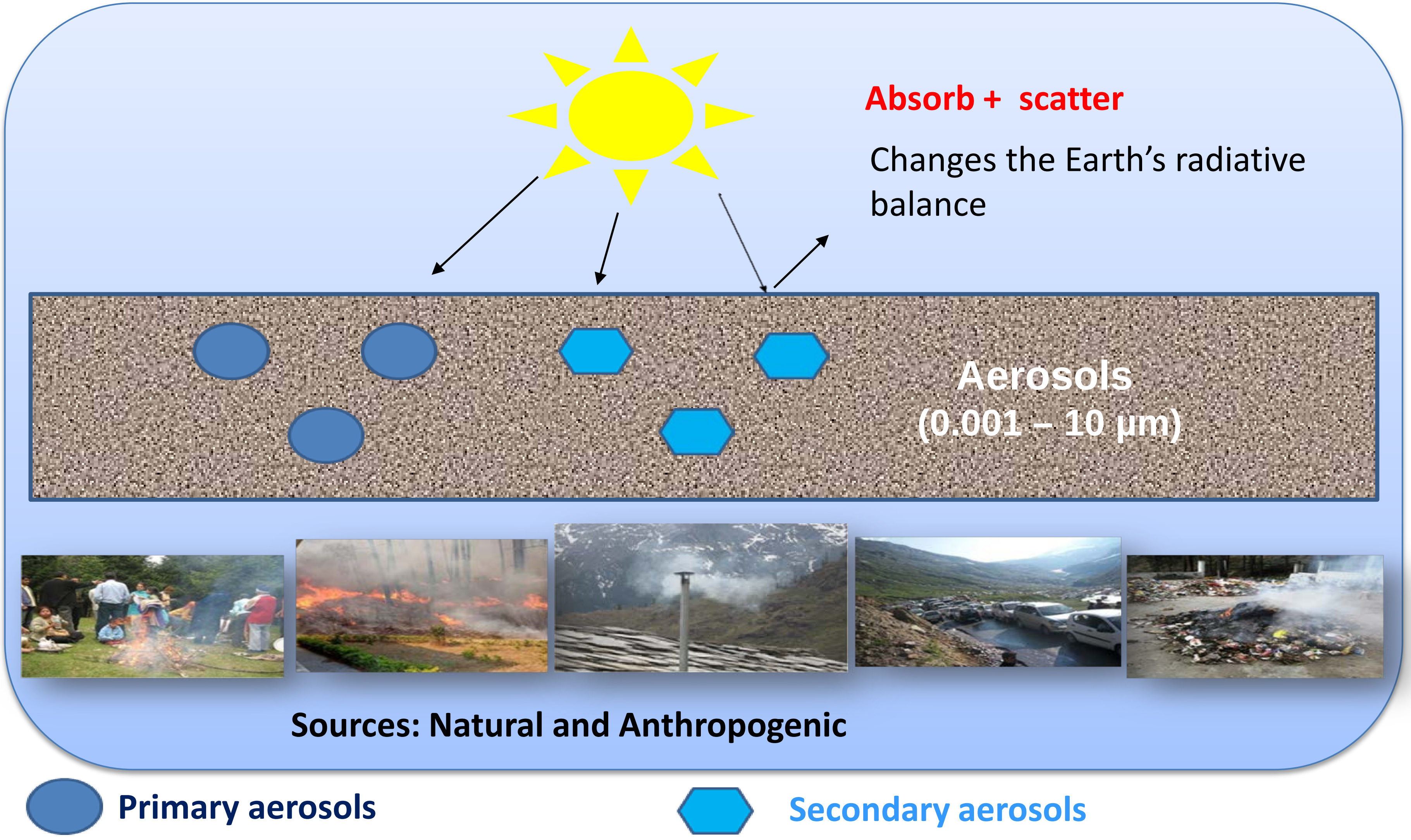
Global map of AOD from MODIS



Source: https://giovanni.gsfc.nasa.gov/

Aerosols and climate

Aerosols: solid + gaseous + liquid particles suspended in air



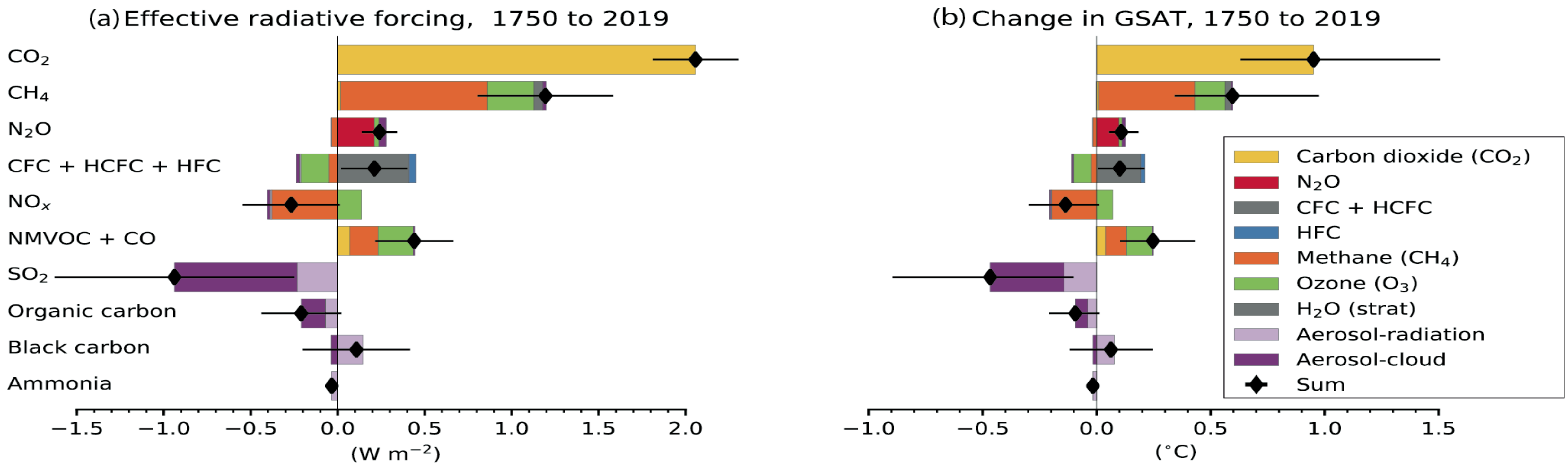
- Cause warming or cooling

  Black carbon
  – Warm

  Sulfates
  – **cool**

- Shifting of crops, orchards and vegetation to higher altitude
- Changes in precipitation intensity and patterns
- Temperature rise, global warming, climate change

Contributions of Anthropogenic Emissions to ERF and GSAT Change (1750–2019)



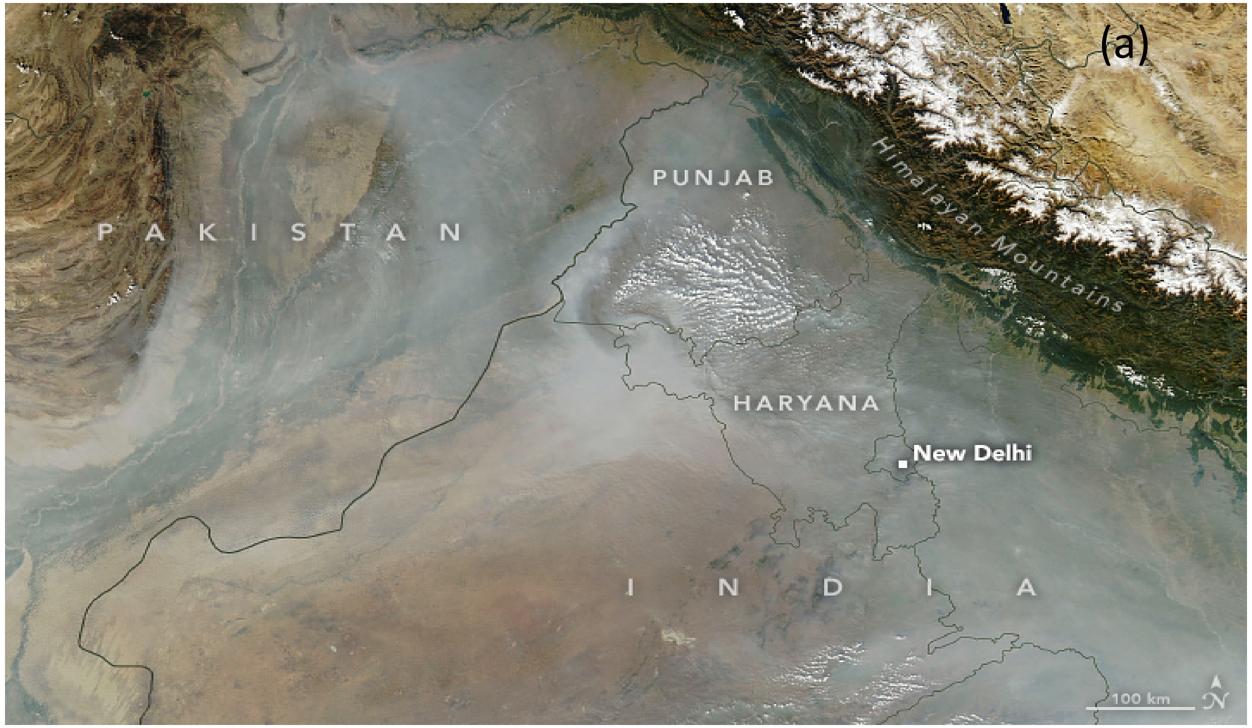
Error bars indicate 5–95% Uncertainty.

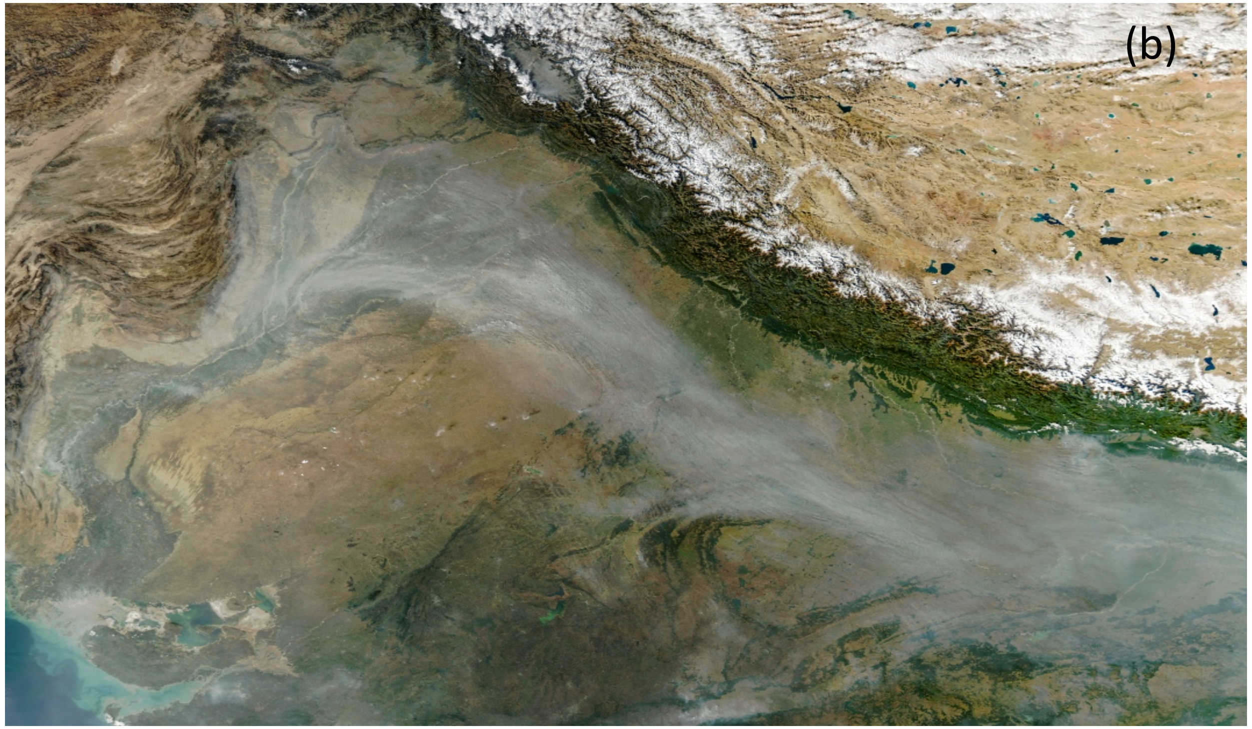
•Contribution of major anthropogenic emissions to: (a) Effective Radiative Forcing (ERF), and (b) Global Mean Surface Air Temperature (GSAT) changed during 1750–2019, based on CMIP6 multi-model simulations.

•Aerosol effects include aerosol–radiation interactions (ERFari) and aerosol–cloud interactions (ERFaci), while GSAT changes are derived from historical ERF time series using an impulse response climate model .

After Thornhill et al., 2021b; IPCC AR6.

Satellite Evidence of Regional Haze and Crop Residue Burning over Northern India



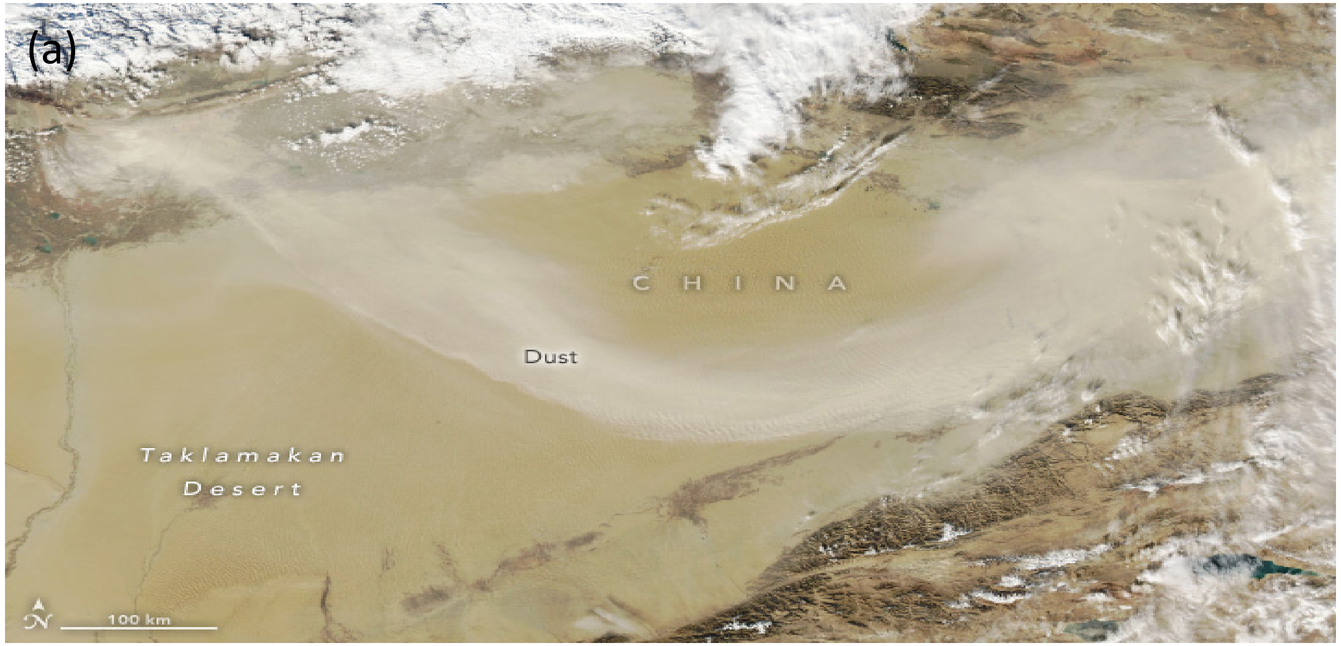


•Satellite imagery showing regional aerosol loading over the Indo-Gangetic Plain and adjacent Himalayan region: Dense haze covering northern India on 20 November 2023 (left panel),

•Smoke generated by widespread post-harvest crop residue (stubble) burning over northwestern India on 11 November 2025, illustrating large-scale aerosol transport across northern India.

Source: *NASA Earth Observatory, prepared by Michala Garrison and Wanmei Liang, using MODIS data from NASA EOSDIS LANCE & GIBS/Worldview.*

Satellite Observations of Dust Storms over the Taklamakan affecting the Himalaya



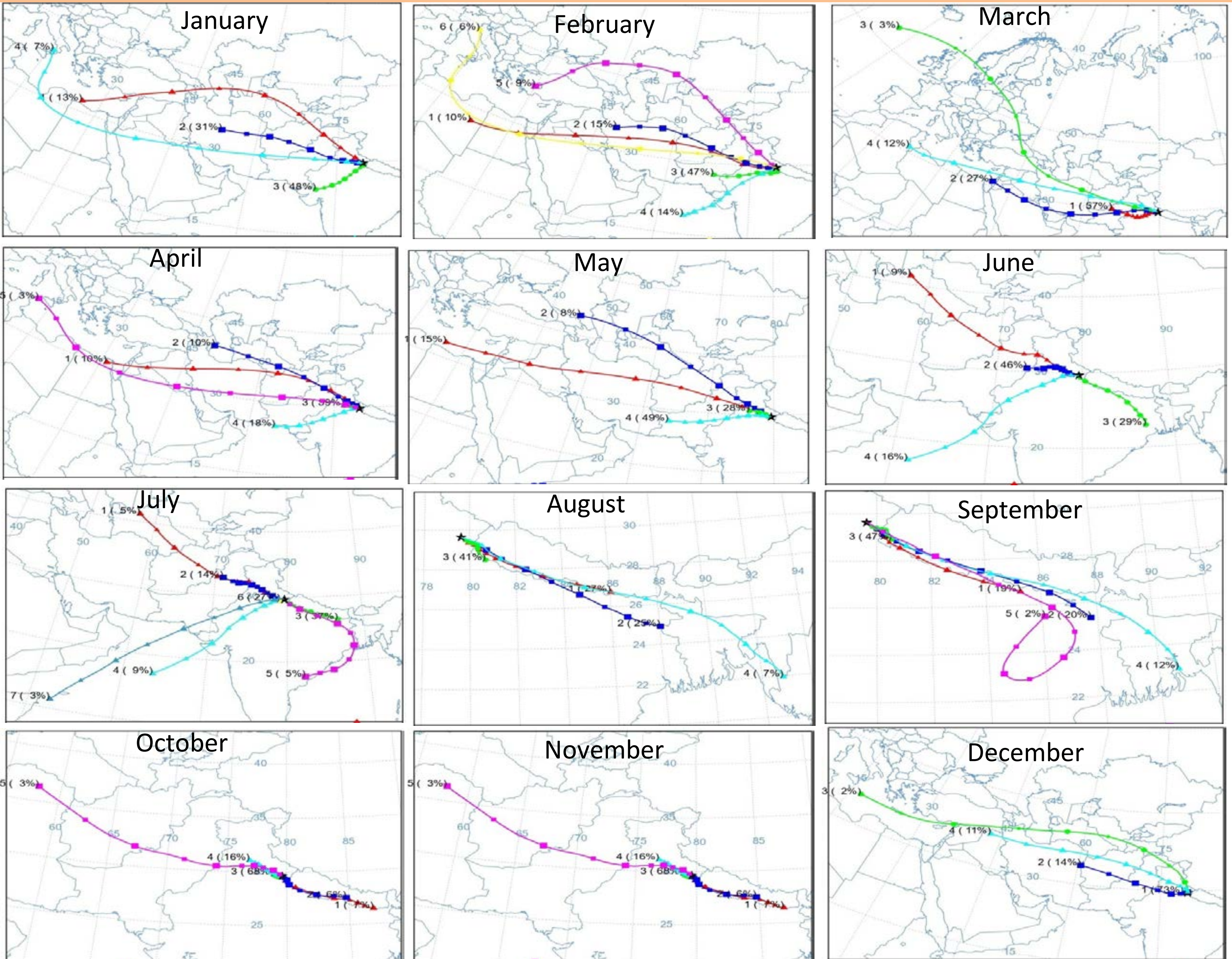
Satellite images showing dust storm activity over the Tarim Basin, northwestern China.

•A large dust wall over the Taklamakan Desert on 11 November 2023.

•Widespread dust transport across the Tarim Basin on 1 September 2025.

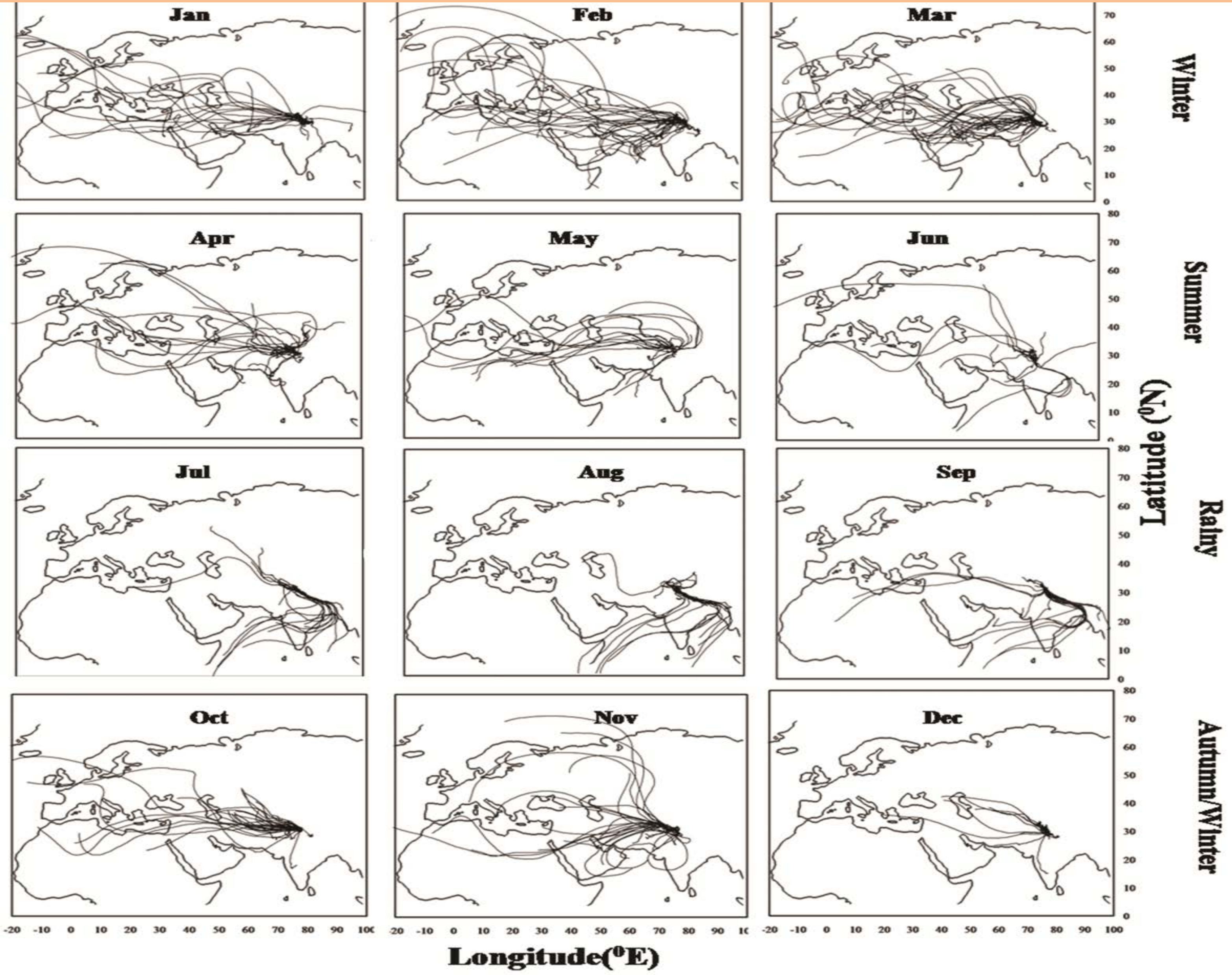
Source: NASA Earth Observatory, prepared by Michala Garrison and Wanmei Liang data from NASA EOSDIS LANCE, GIBS/Worldview, and JPSS .

Back trajectories over Katarmal (Uttarakhand) during the year



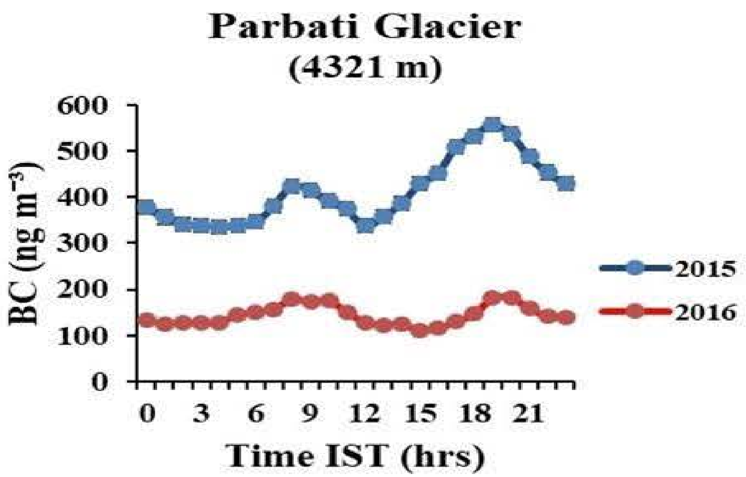
- Air mass backward trajectory during winter and autumn months is from the west of the experimental sites
- During winter months highest percentage of air mass originated from the Pakistan & Iran area
- In the month of June and July some amounts of air mass also trajected from the Arabian Sea
- In the monsoon and post-monsoon season, the air mass trajectories originated from the eastern part of the experimental site.

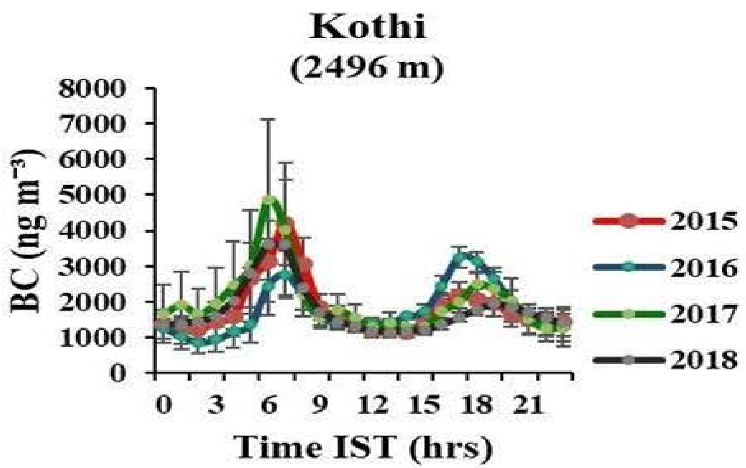
Back trajectories over Mohal (Himachal Pradesh) During the year

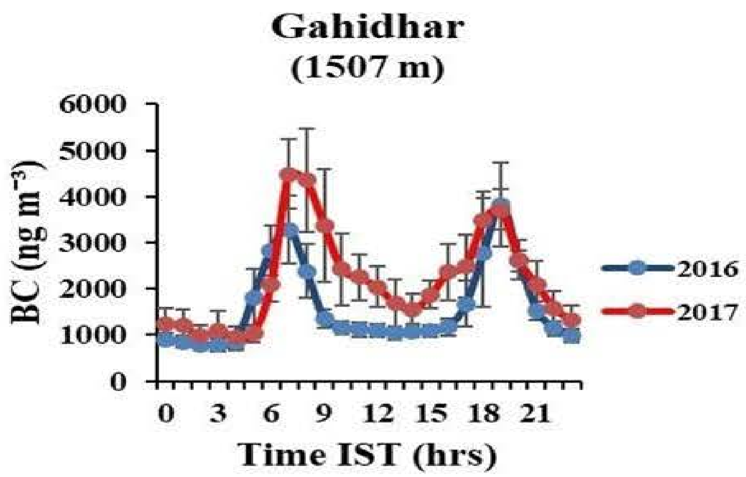


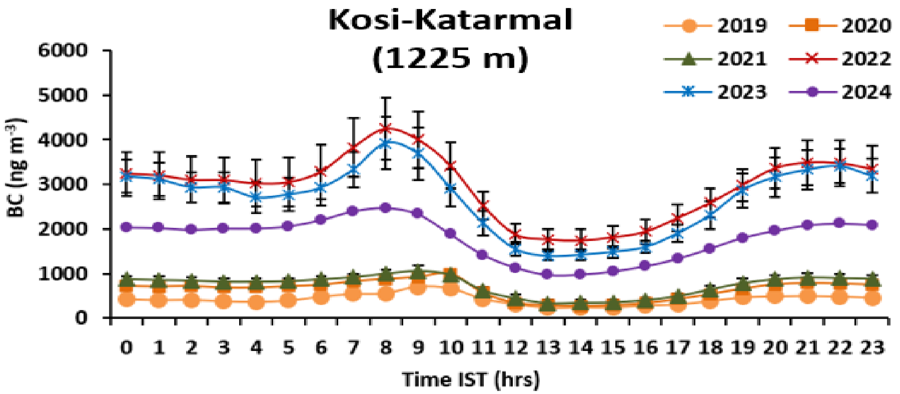
- Air mass movement during winter and autumn months is from west of the experimental site.
- During summer, it is from north-west and south west and in rainy it is from south east or south-west.
- During rainy season, the air mass movement of trajectories originates over the Arabian and Bay of Bengal
- Marine air mass was relatively clean compared to the continental air

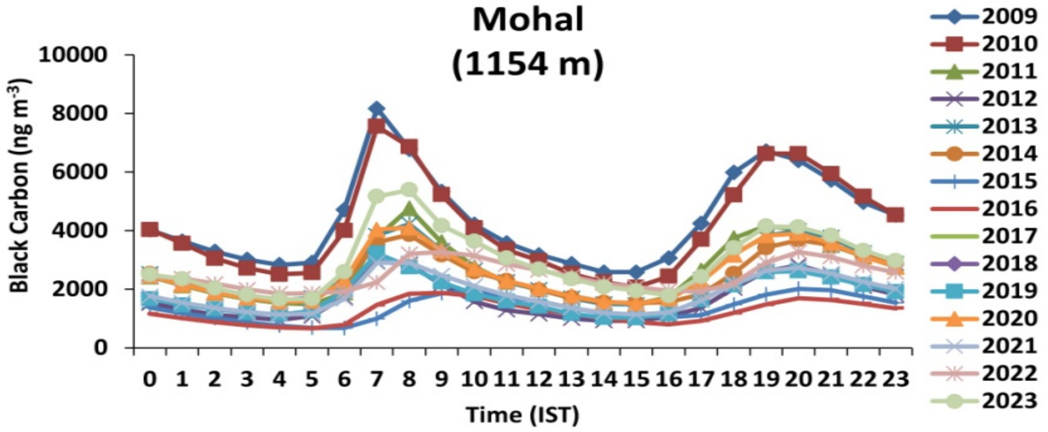
Black carbon- Foothills to Glaciers in the Himalaya











Average BC (in ng m^{-3})

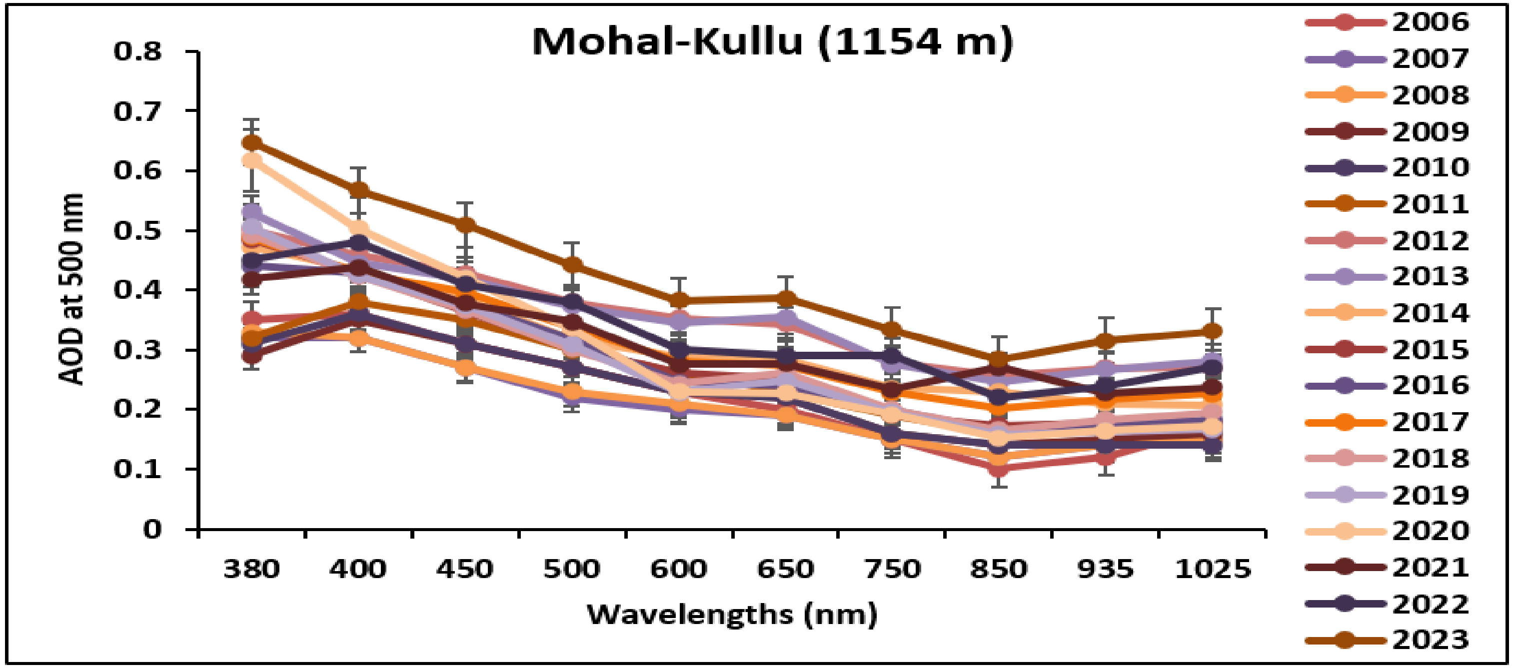
Parbati Glacier: 278 ± 145, Kothi: 1875 ± 958, Gahidhar: 1810 ± 540, Kosi-Katarmal: 1538 ± 411, Mohal: 2424 ± 317

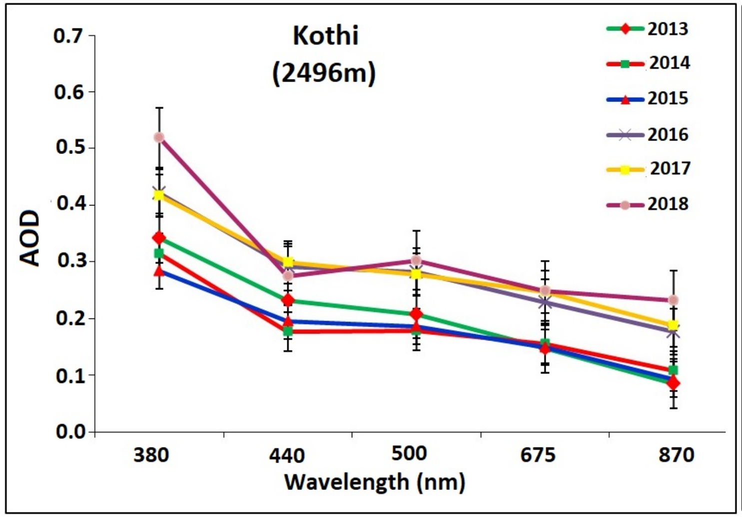
AOD variation in different altitudinal gradients

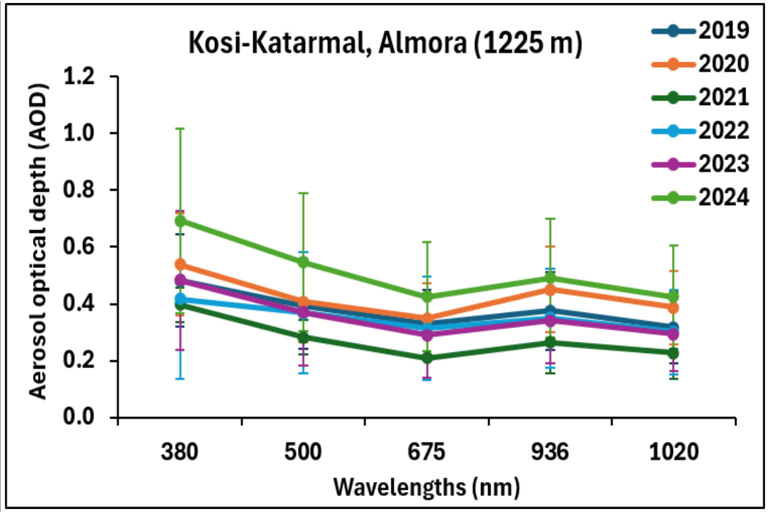
AOD values at shorter wavelengths are higher indicating increase in anthropogenic activities.

Average AOD_{500nm} were observed in the range of:

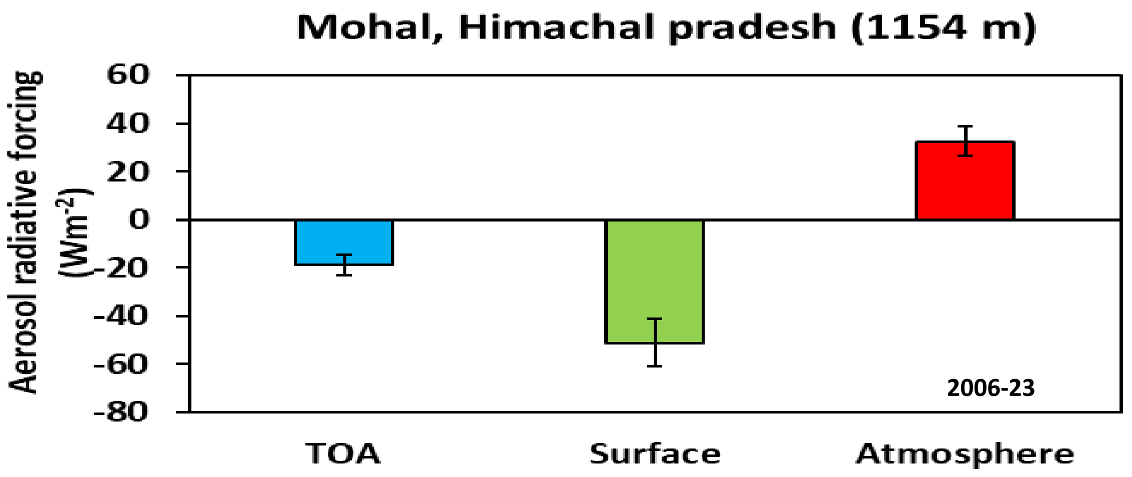
- At Kothi, 0.18 - 0.30 from 2013 to 2018.
- At Mohal, AOD_{500nm} has increased from 0.27 to 0.44 and by 57.4% from 2006 to 2023.
- At Kosi-Katarmal, Almora, daily AOD $_{500nm}$ ranged 0.03 - 2.43 from 2019 to 2024.

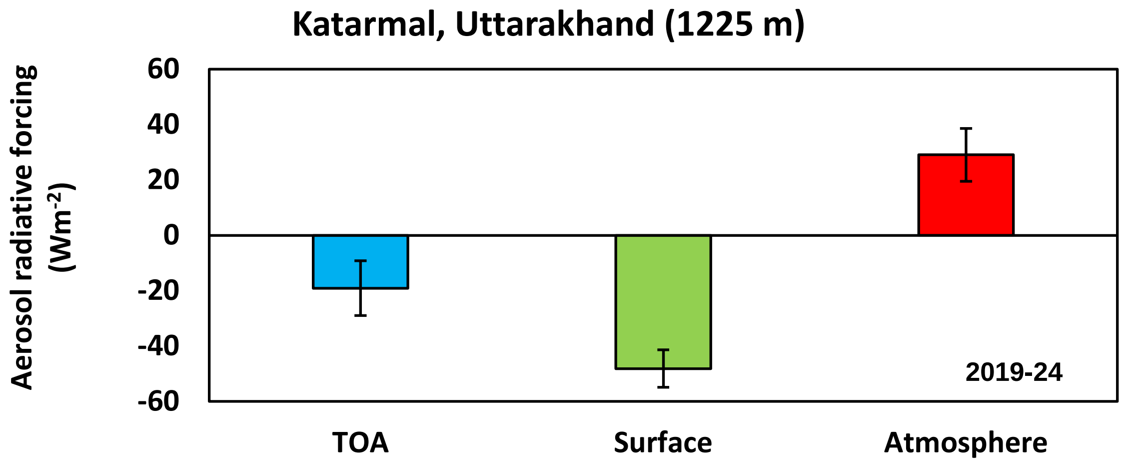




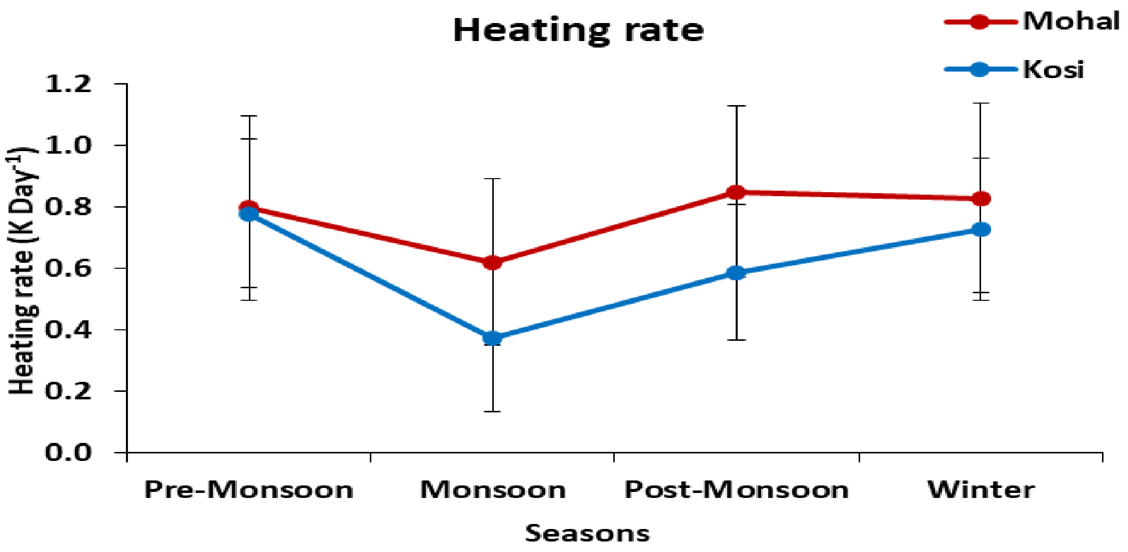


Aerosol radiative forcing & heating rate





- Katarmal: Mean shortwave ARF = −19.1 ± 9.9 W m^{-2} (TOA), −48.1 ± 6.8 W m^{-2} (Surface), and +29.1 ± 9.5 W m^{-2} (Atmosphere); HR = 0.8 ± 0.3 K day^{-1}.
- Mohal: Mean shortwave ARF = −18.7 ± 4.3 W m^{-2} (TOA), −51.1 ± 9.7 W m^{-2} (Surface), and +32.4 ± 6.2 W m^{-2} (Atmosphere); HR = 0.9 ± 0.2 K day^{-1}.



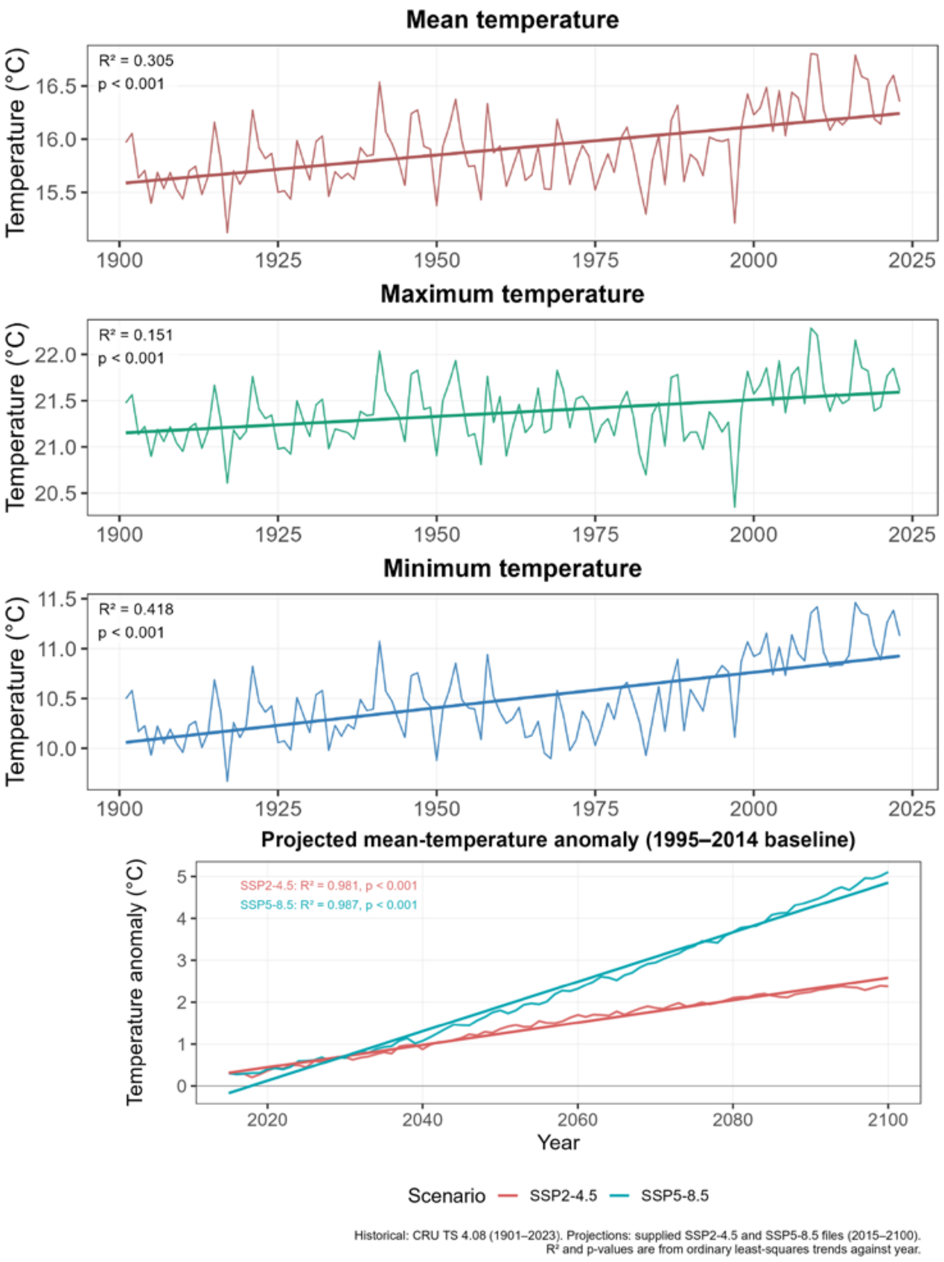
Changing climate in the Himalayan Region: Current status

- **The Himalayan region has experienced significant warming, with a mean annual temperature increase of 0.105 °C decade^{-1} during 1901–2021.**

- **Maximum and minimum temperatures increased at rates of 0.079 °C decade^{-1} and 0.180 °C decade^{-1}, respectively.**

- **Projected surface warming in the Himalaya exceeds the global and South Asian averages.**

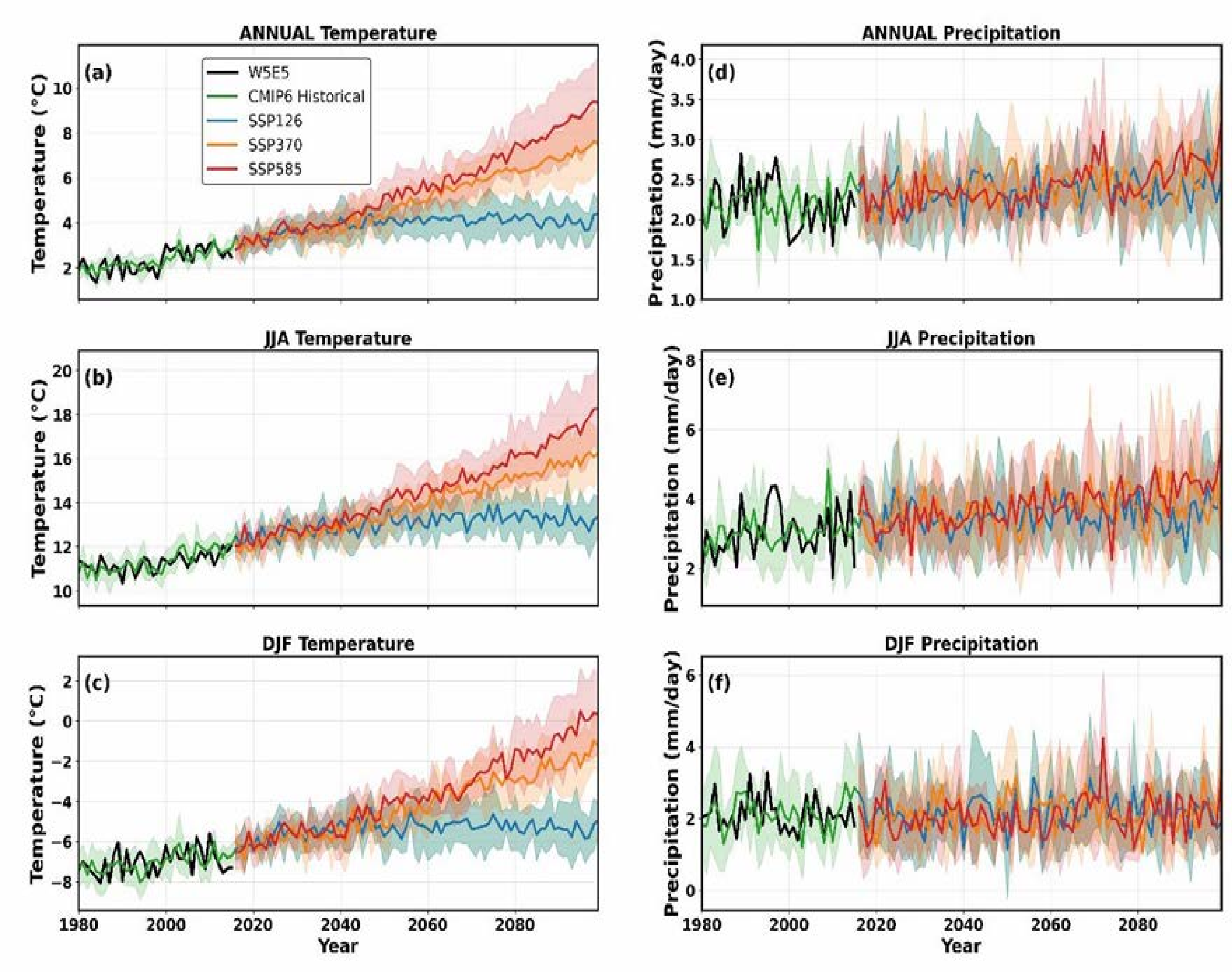
- **Projected warming is approximately 2.5 ± 1.5°C under RCP4.5 and 5.5 ± 1.5°C under RCP8.5 by the end of the 21st century.**



Data source: Climate Research Unit TS v. 4.06

Data source: https://www.ipcc-data.org/sim/gcm_monthly/AR5/

Projected temperature and precipitation changes in the Western Himalaya from CMIP6 multi-model ensembles

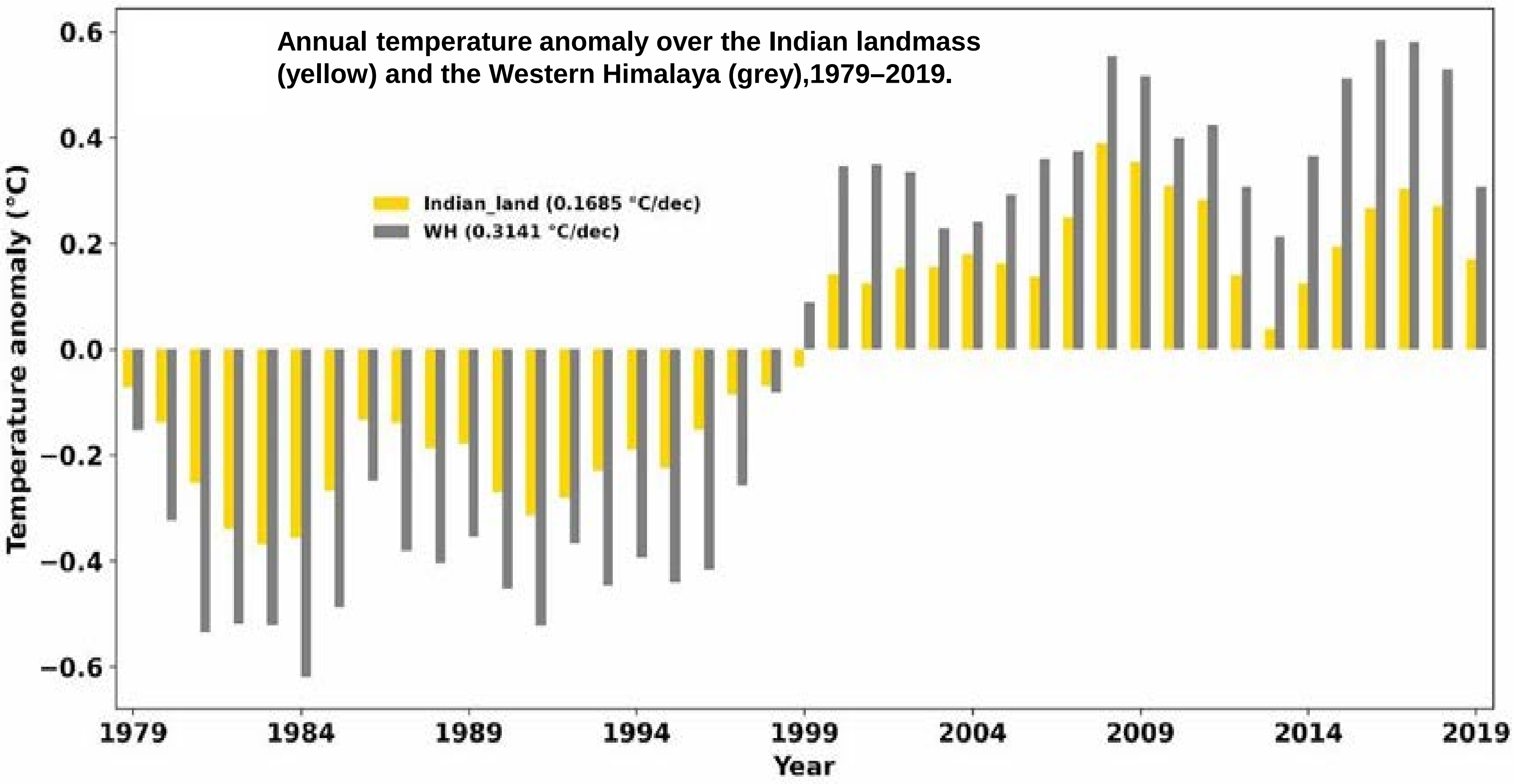


- **Winter warming** is stronger than annual warming, reaching **+6.42 ± 2.74°C** under SSP5–8.5.
- **Summer temperatures** may rise up to **+6.20 ± 2.45°C** under high-emission scenario.
- **Summer precipitation** generally increases, with the largest rise (**+1.90 mm day^{-1}**) under **SSP5–8.5**.
- **Warmer conditions and increased precipitation are expected to accelerate glacier mass loss and alter regional hydrology, respectively.**

After Umakant et al. 2026. *Environ. Res: Climate, 5*(3), 035022. https://doi.org/10.1088/2752-5295/ae7749

Annual temperature anomaly

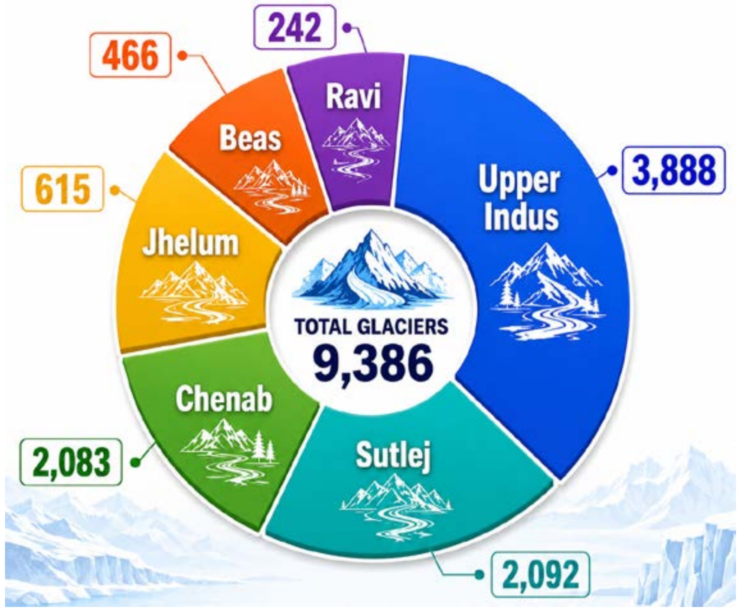
- The Western Himalaya warmed at a rate of 0.31°C decade^{-1} during 1979–2019, nearly twice the Indian average (0.16°C decade^{-1}) and higher than the Himalayan average (0.24°C decade^{-1}).
- Future warming is projected to reach 3.5–6°C by 2100 under SSP3–7.0.

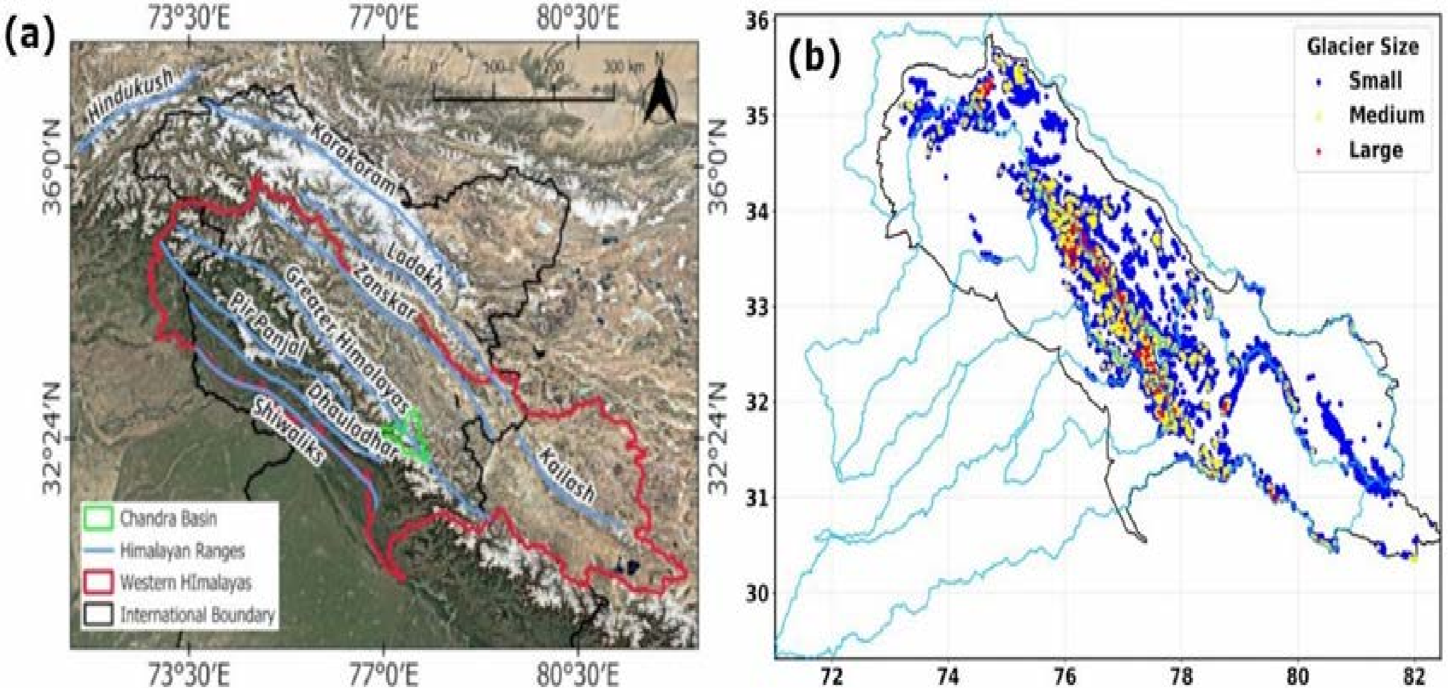


After Umakant et al. 2026. *Environ. Res: Climate, 5*(3), 035022. https://doi.org/10.1088/2752-5295/ae7749

Topography and glacier distribution in the Western Himalaya

- **Upper Indus** contains **highest number of glaciers (3,888)**, dominated by small glaciers.
- **Sutlej (2,092)** and **Chenab (2,083)** have the second and third highest glacier counts.
- **Ravi** has **fewest glaciers (242)** among six basins.
- **Small glaciers (<2 km²)** reasonably dominate glacier numbers across all basins.
- **Large glaciers (>10 km²)** are relatively rare, with highest count in **Chenab (38)** followed by **Upper Indus (34)**.





Topography and glacier distribution in the Western Himalaya : **(a)** Regional topography showing the Western Himalaya & Chandra Basin. **(b)** Glacier size distribution (<2, 2–10, and >10 km²

- **Glacier meltwater is projected to peak at about +2°C** global warming.
- Beyond **+2°C**, meltwater production declines due to rapid glacier mass loss.
- At **+4°C**, total **Western Himalayan glacier meltwater flux decreases by 65.4 ± 10.7%**.

After Umakant et al. 2026. *Environ. Res: Climate, 5*(3), 035022. https://doi.org/10.1088/2752-5295/ae7749

Five groups disasters based on origin of the cause

Water and climate related disasters
- Flood
- Cyclone
- Tornadoes
- Hailstorm
- Cloudburst
- Heat waves & cold wave
- Snow avalanches & GLOFs
- Drought
- Sea erosion
- Thunder and lightning
- Tsunami (not in HPC list)

Geologically related Disasters
- Landslides and mudflows
- Earthquakes
- Dam failures / dam burst
- Mine fires

Chemical, industrial and nuclear
- Chemical and industrial disasters
- Nuclear disasters

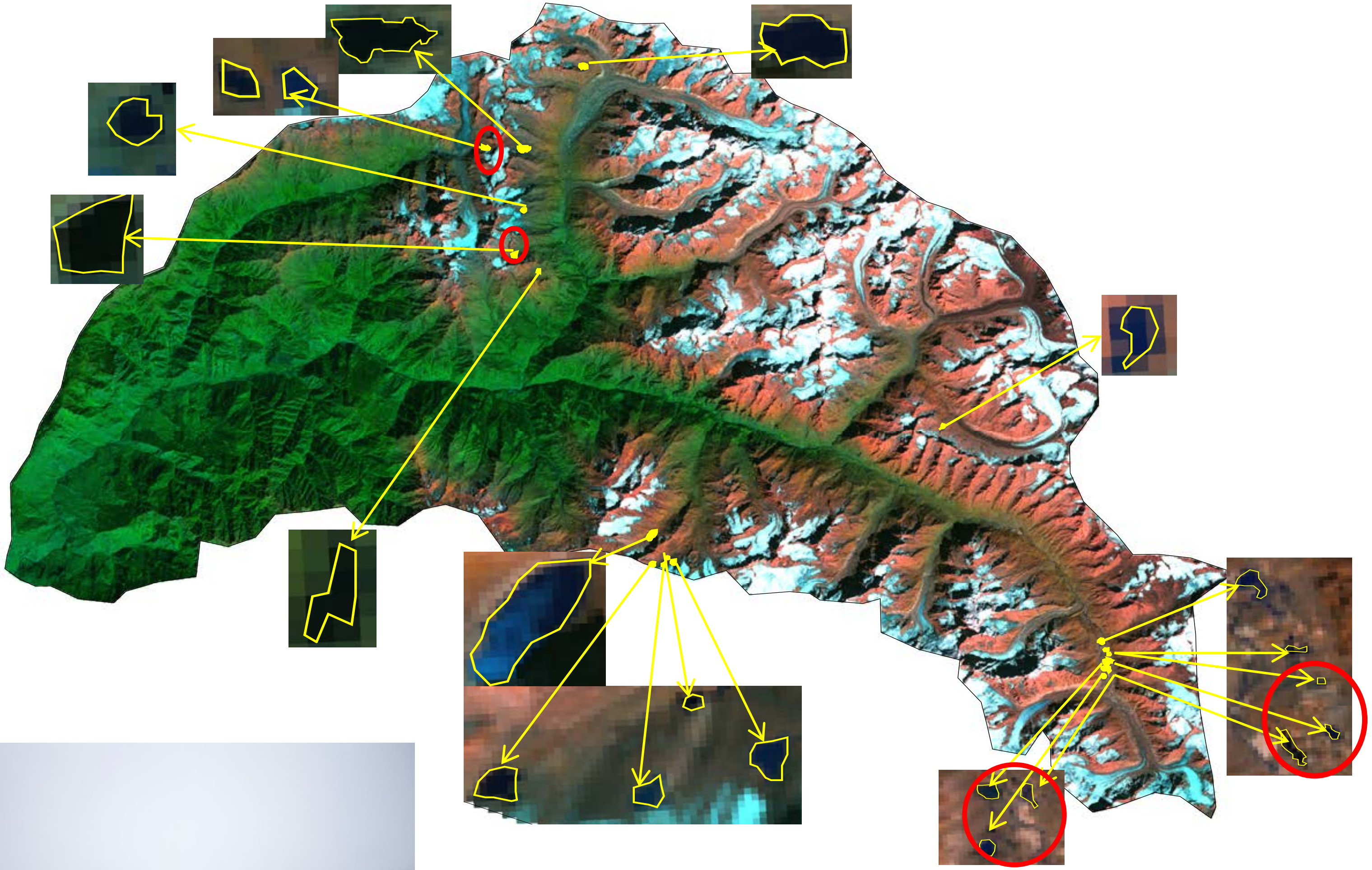
Accidental disasters
- Forest fire
- Urban fires
- Mine flooding
- Oil spill
- Major building collapse
- Serial bomb blast
- Festivals related disasters
- Electrical disasters & Fires
- Air, Road & Rail Accidents
- Boat Capsizing
- Village Fire

Biologically related disasters
- Biological disasters & epidemics
- Pest attacks
- Cattle epidemics
- Food poisoning

Prominent in IHR
- GLOFs & Snow avalanches
- Flood / flash floods
- Cloudbursts
- Landslides

Source: Indian Meteorological Department, New Delhi

GLOFs-Impact on Glaciers: A case of Parbati Glacier, H.P.

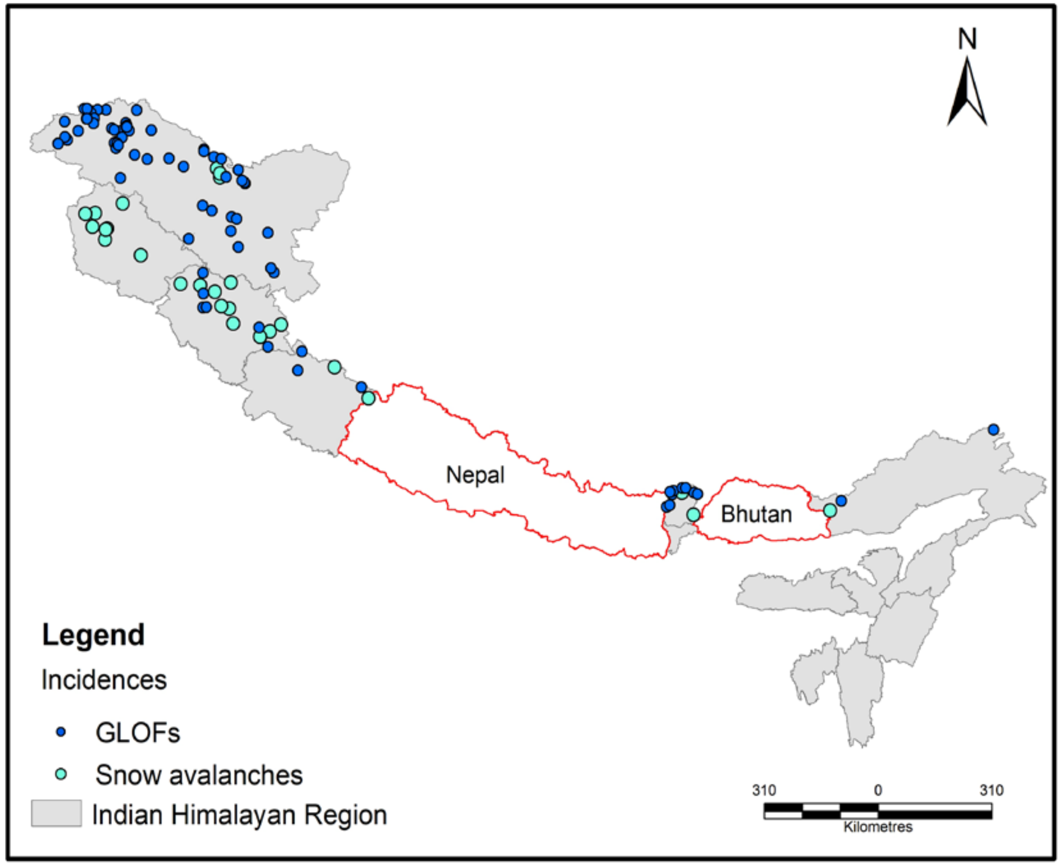


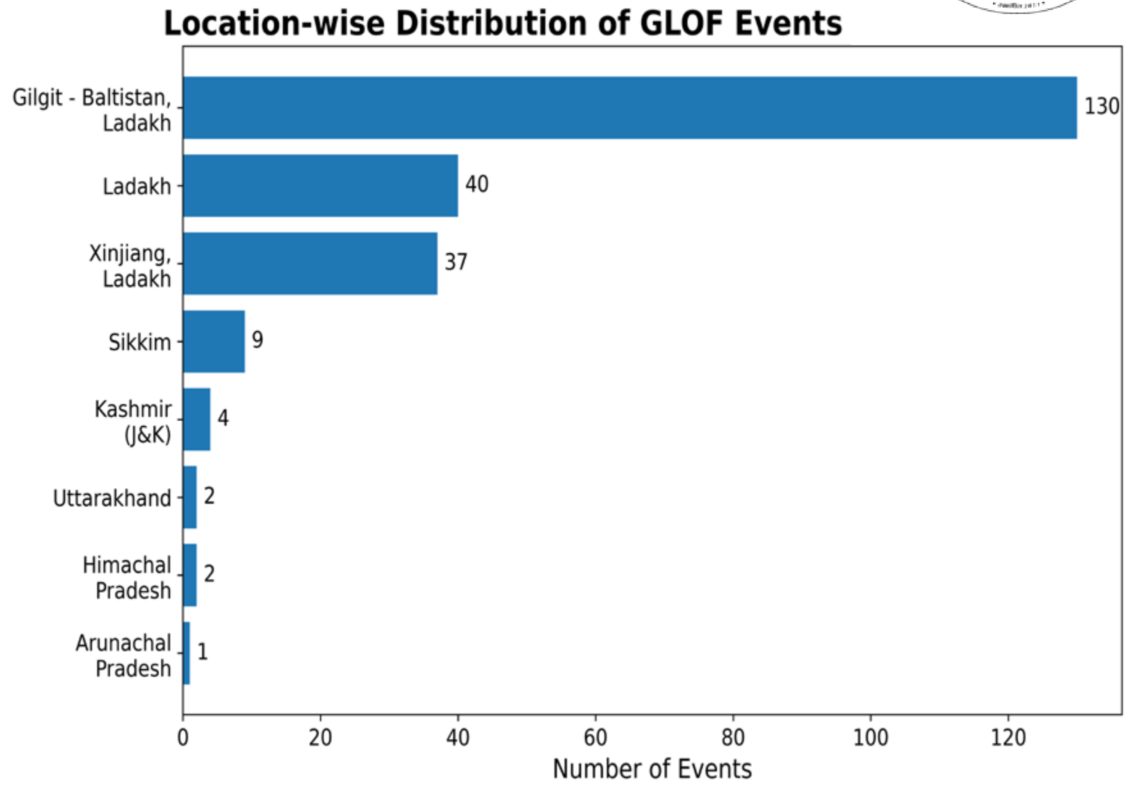
- Red circled indicate Glacial lakes identified in 2016.
- Twenty glacial lakes were mapped, covering a total area of 0.468 km²
- The glacier area declined from 439.83 km² (1970) to 328.40 km² (2016).
- The glacier snout retreated by 19.4 ± 1.35 m.
- Average retreat rate: 0.36 m $year^{-1}$.
- Black carbon concentration ranged from 0.14 ± 0.01 to 0.41 ± 0.02 μg m^{-3}.
- Fossil-fuel emissions contributed 81–87%, whereas biomass burning 13–19%.

Snow Avalanches & GLOF Incidences (1533 – 2023) in the IHR

Snow Avalanches Events

Location	Year
Deo-Tibba	1972
Himanchal Pradesh (HP)	1973
Lippa(HP)	1975
Lahual and Spiti (HP)	1978
Lahaul Valley (HP)	1979
Kilba, Kinnaur (HP)	1984
Udaipur, Lahual (HP)	1992
Keylong, Lahual (HP)	1996
Uri-Sector	1997
Banihal, Jammu and Kashmir	1998
Kinnaur (HP)	2002
Jammu and Kashmir	2005
Bharatpur, Lahaul (HP)	2008
Siachen Glacier	2016
Gurez Sector	2017
Pithoragarh (Uttarakhand)	2017
Kashmir avalanches	2018
Siachen	2019
Kashmir	2020
Line of Control	2020
Lugnak La avalanche	2020
Siachen	2021
Chamoli (Uttarakhand)	2021
Kameng sector	2022
Nathula, Sikkim	2023
Chika	2023
Chamoli (Uttarakhand)	2023
Gulmarg (Kashmir)	2023
Gulmarg	2024



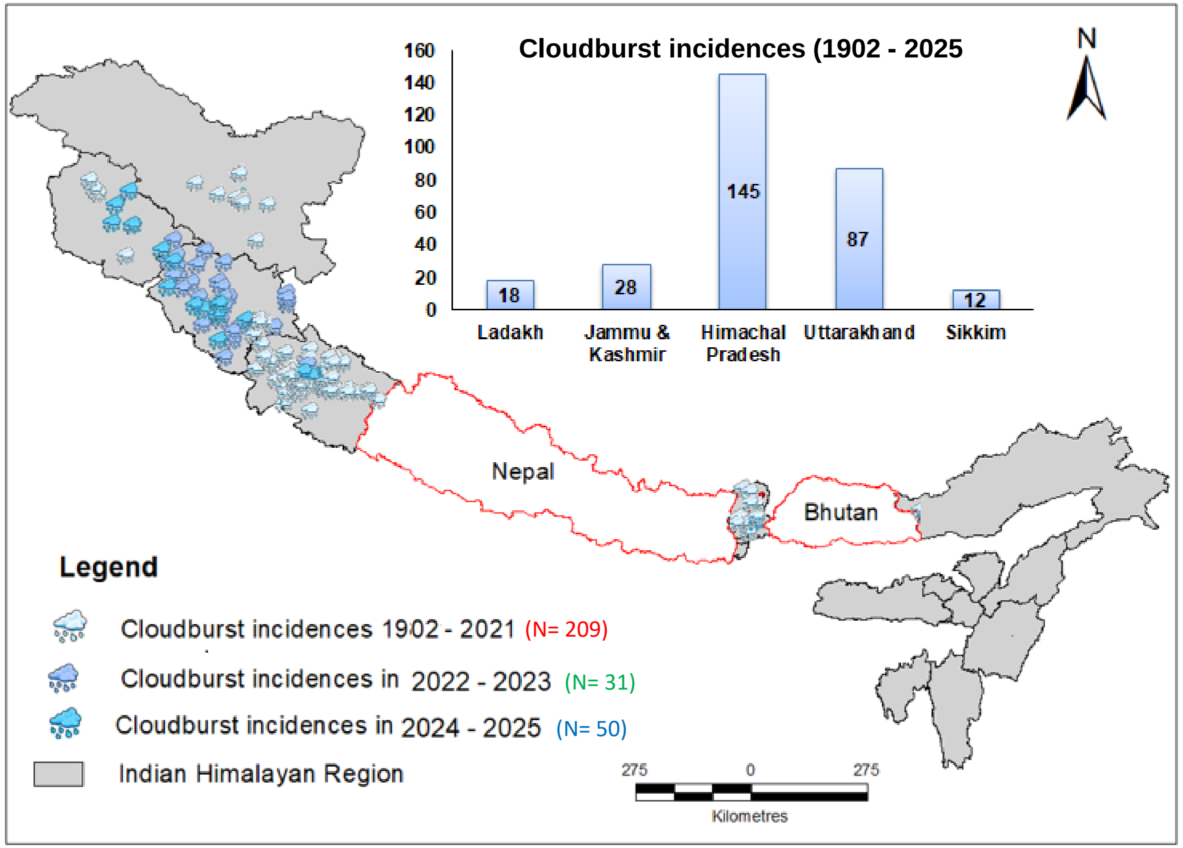


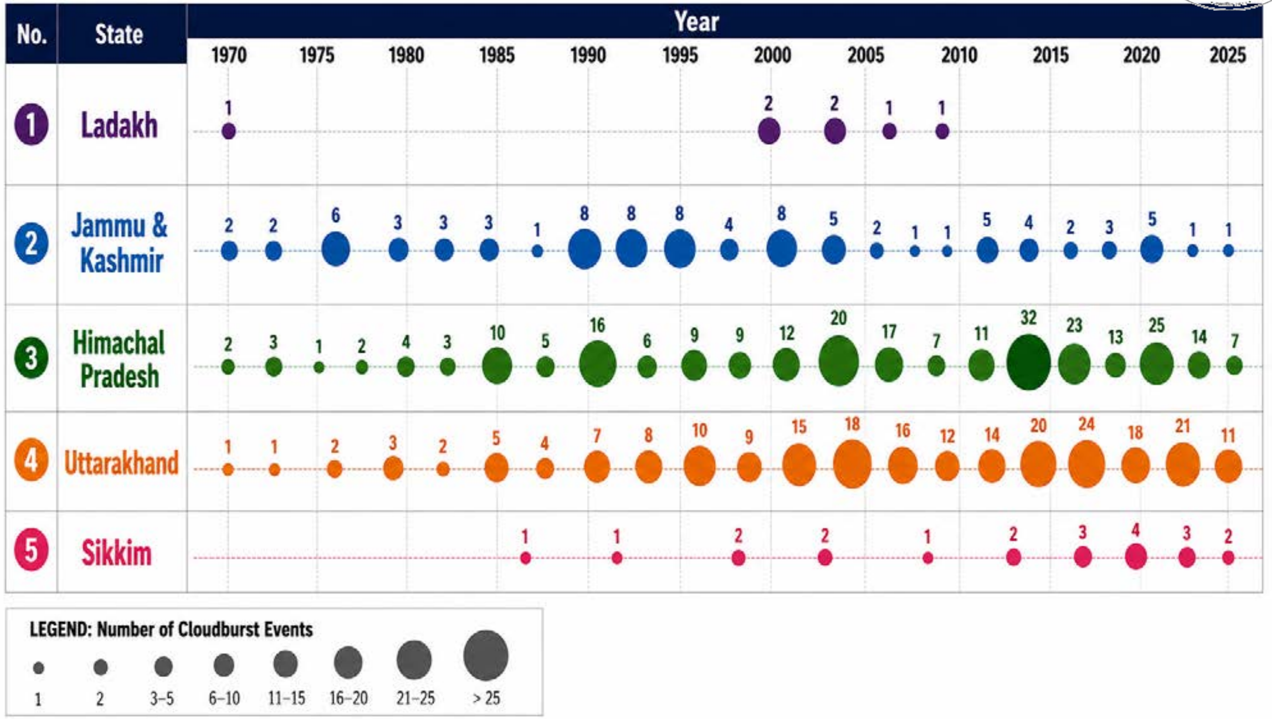
- **Lahaul Valley- 1979 (237 fatalities)**
- **Jammu & Kashmir - 2005 (540 fatalities)**

Snow Avalanches in Kinnaur (H.P)

After Lützow et al. (2023) Earth Syst. Sci. Data, 15, 2983–3000.

Cloudburst events in the Indian Himalayan Region



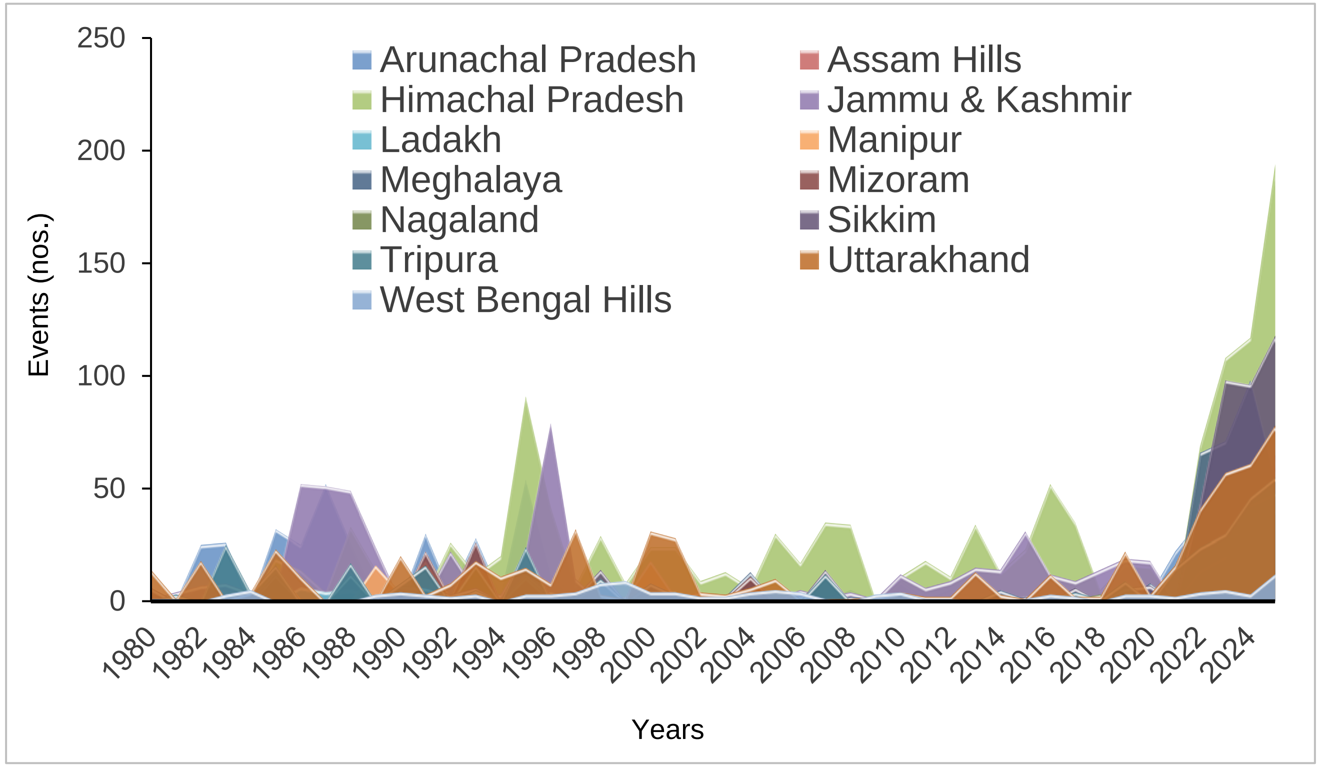


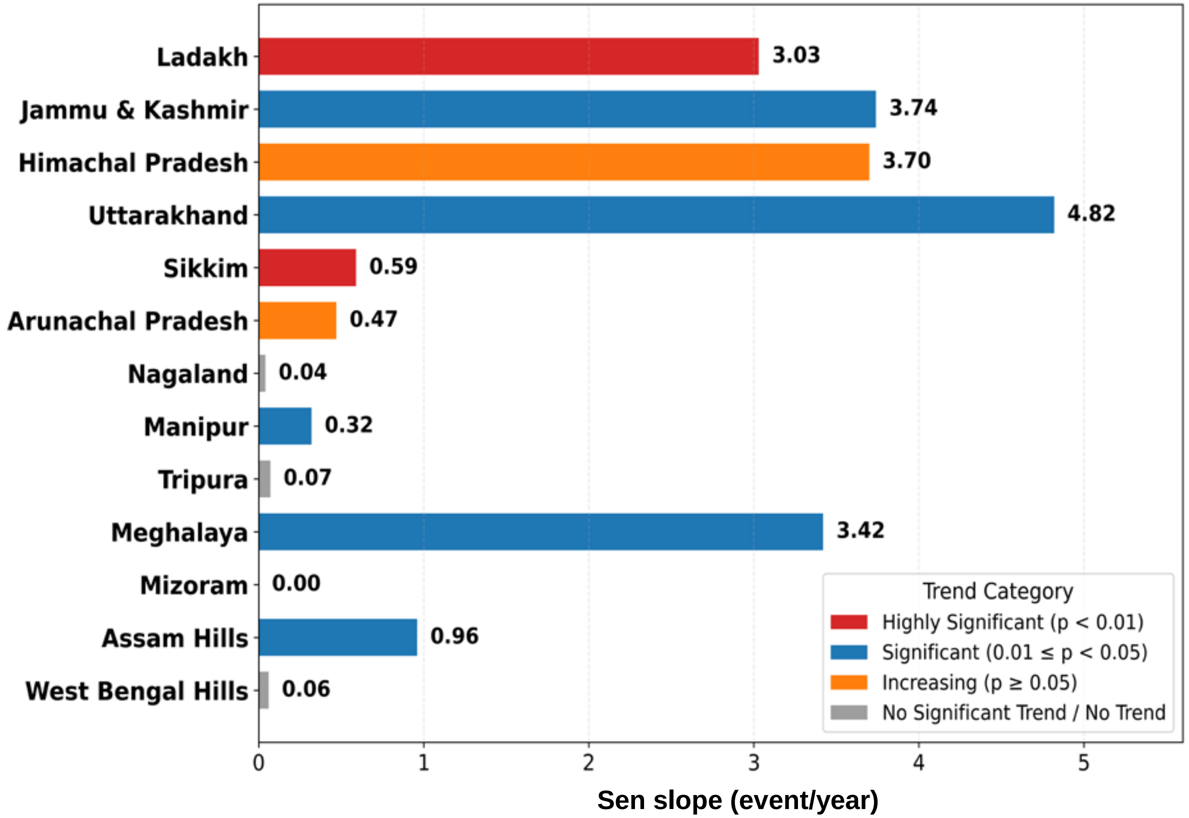

After effects of Chamoli (Raini village) disaster on 7 February 2021

Source: UNDRR's Disaster Loss Database (DisInventar), Dartmouth Flood Observatory (DFO), Emergency Events Database (EM-DAT), NIDM & SDMA web portal; published journals, IMD Disaster Weather Reports (1980 – 2020)

- **A total of 290 cloudburst events** were documented across the Indian Himalayan Region between **1902** and **2025**.
- Nearly **one-fourth of all documented cloudburst events (~28%) occurred after 2021**, highlighting a reasonable increase in recent years.
- Majority of cloudburst events are concentrated in the **Western Himalaya**, particularly **Himachal Pradesh and Uttarakhand**, emphasizing these regions as major hotspots.

Flood & Heavy Rainfall events (1980-2025) in the IHR States

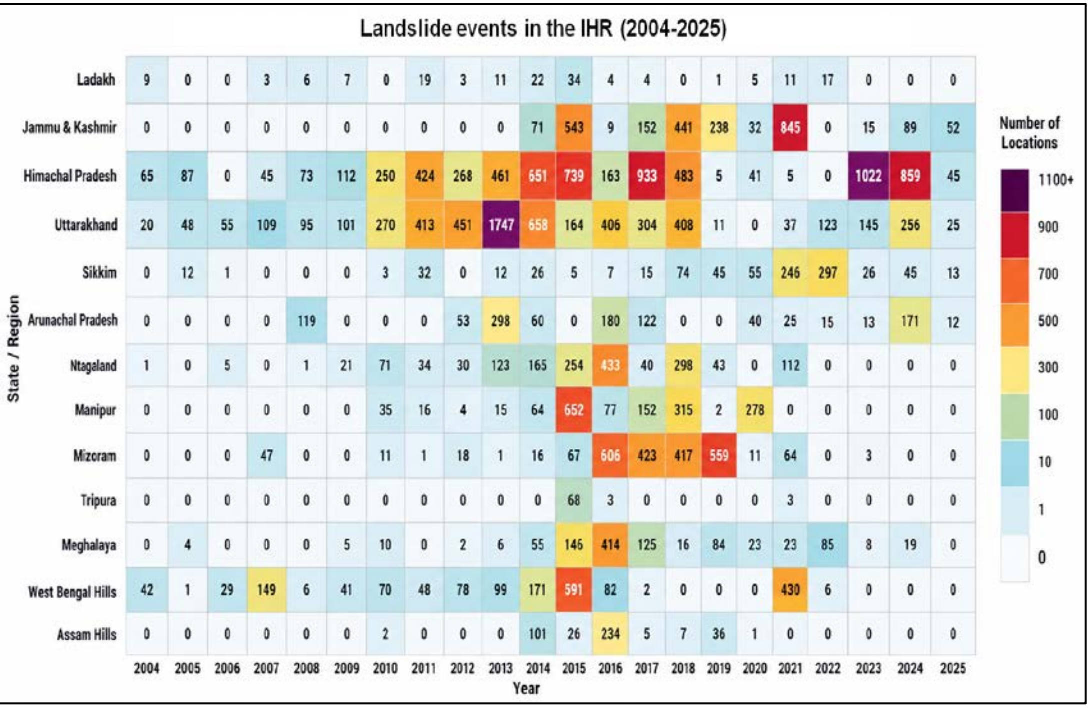


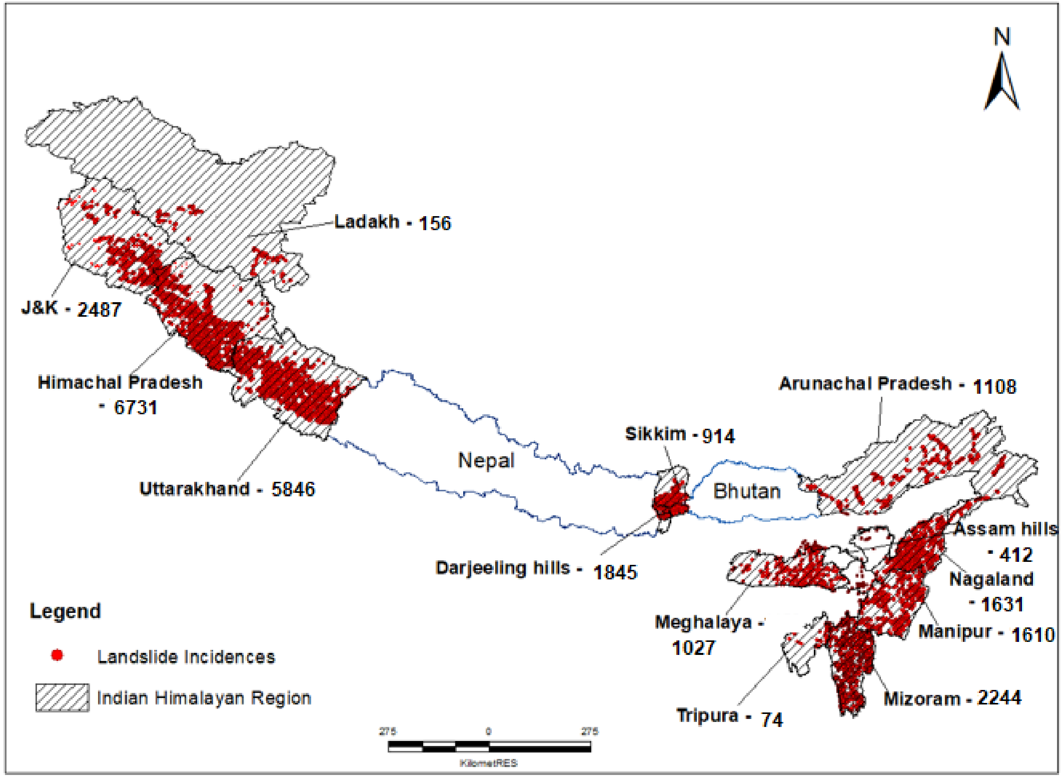


- Noticeable increase after 2000 mainly in Western Himalayan states.
- A sharp acceleration is evident after 2021, with 2023–2025 recording the highest number of events in the entire study period.
- Himachal Pradesh (1252), Uttarakhand (597), and Jammu & Kashmir (626) contribute largest share of recent flood and heavy rainfall events.
- Eastern Himalayan states generally show lower event frequencies, although several exhibit gradual increasing trends.
- Uttarakhand exhibited highest increase (4.82 events/year), followed by Jammu & Kashmir (3.74), Himachal Pradesh (3.70), Meghalaya (3.42), and Ladakh (3.03).
- Ladakh and Sikkim showed highly significant increasing trends, while Assam Hills and Manipur moderate but significant increases.

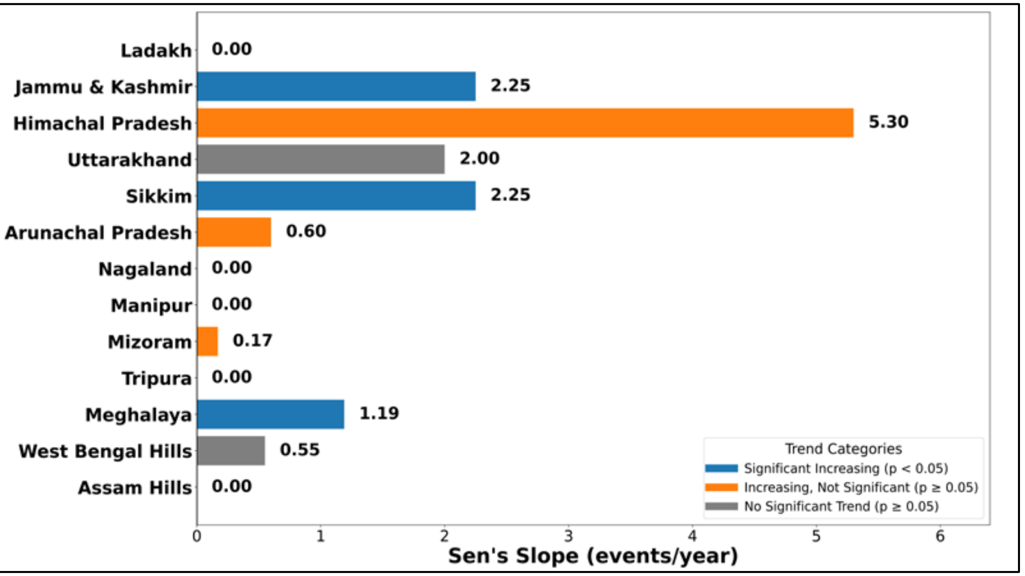
Source: UNDRR's Disaster Loss Database (DisInventar), Dartmouth Flood Observatory (DFO), Emergency Events Database (EM-DAT), NIDM & SDMA web portal; published journals, IMD Disaster Weather Reports (1980 – 2020)

Landslide events in the Indian Himalayan Region





Source: UNDRR's Disaster Loss Database (DisInventar), Dartmouth Flood Observatory (DFO), Emergency Events Database (EM-DAT), NIDM & SDMA web portal; published journals, IMD Disaster Weather Reports (1980 – 2020)



- **Himachal Pradesh** recorded **highest number of events 1,022 in 2023**, followed by **933 (2017)** and **859 (2024)**.
- **Uttarakhand** experienced a major peak of **1,747 events in 2013**, followed by **658 (2014)** and **451 (2012)**.
- **Jammu & Kashmir** showed a sharp spike of **845 events in 2021** and **543 events in 2015**.
- **Manipur (652 events, 2015)** and **Mizoram (606 events, 2016; 559 events, 2019)** also experienced notable landslide outbreaks.
- **Western Himalayan states** consistently recorded higher landslides as compared to Eastern Himalaya.

Tapovan, Chamoli (Uttarakhand)

Other Sectorial impacts of climate change in the IHR

Sector	Current status
Glacier	Glaciers are retreating : ➢ Brahmaputra basins (− 20.2 ± 19.7 m/a) ➢ Ganga basin (− 15.5 ± 14.4 m/a) ➢ Indus basin (−12.7 ± 13.2 m/a) ➢ Karakoram region (−1.37 ± 22.8 m/a)
Water resource	➢ Spatial and temporal shift in rainfall: drying of springs / perennial spring flow becomes seasonal ➢ Glacier mass loss is likely to affect hydrological behaviour of most of the Himalayan rivers that potentially affect downstream water cycle
Forest	➢ Increased precipitation and temperature—an upward shift in all forest types except sub-tropical conifer forests
Biodiversity	➢ Affect some MAPs in arctic and alpine regions due to more warming in arctic and alpine (e,g. snow lotus (*Saussurea laniceps*) in Tibetan mountains) ➢ Plants migrate upward ➢ Blooming earlier ➢ Habitat threat for fauna 73% of the Himalayan brown bears (*Ursus arctos isabellinus*) habitat by 2050 ➢ Habitat loss from 13 protected areas (PAs), and 8 of them will become completely uninhabitable by 2050

SPECIAL SECTION:

Climate change impacts on glacier-fed and non-glacier-fed ecosystems of the Indian Himalayan Region: people's perception and adaptive strategies

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[5]CSIR: North-East Institute of Science and Technology, Branch Laboratory, Lamphelpat, Imphal 795 004, India

Other Sectorial impacts of climate change in the IHR

Sector	Current status
Agriculture	➢ Future crop loss may increase at an unprecedented rate and may become difficult to cope up with rising needs of growing population
Tourism	➢ Tourism threats from melting glaciers, biodiversity loss, and extreme events ➢ Mass tourism & carrying capacity issue ➢ Changing climate & increase of aerosol emission ➢ Solid waste problem
Traditional Knowledge System	➢ Comprehensive methodologies for efficient and holistic documentation of TKS for its preservation, protection and management are needed ➢ Out-migration
Health	➢ Effects specifically on vector-, water-, and food-borne infectious diseases, malnutrition, and mental health including a gender health perspective. ➢ Cholera, infective gastroenteritis ➢ Cardio-pulmonary mortality

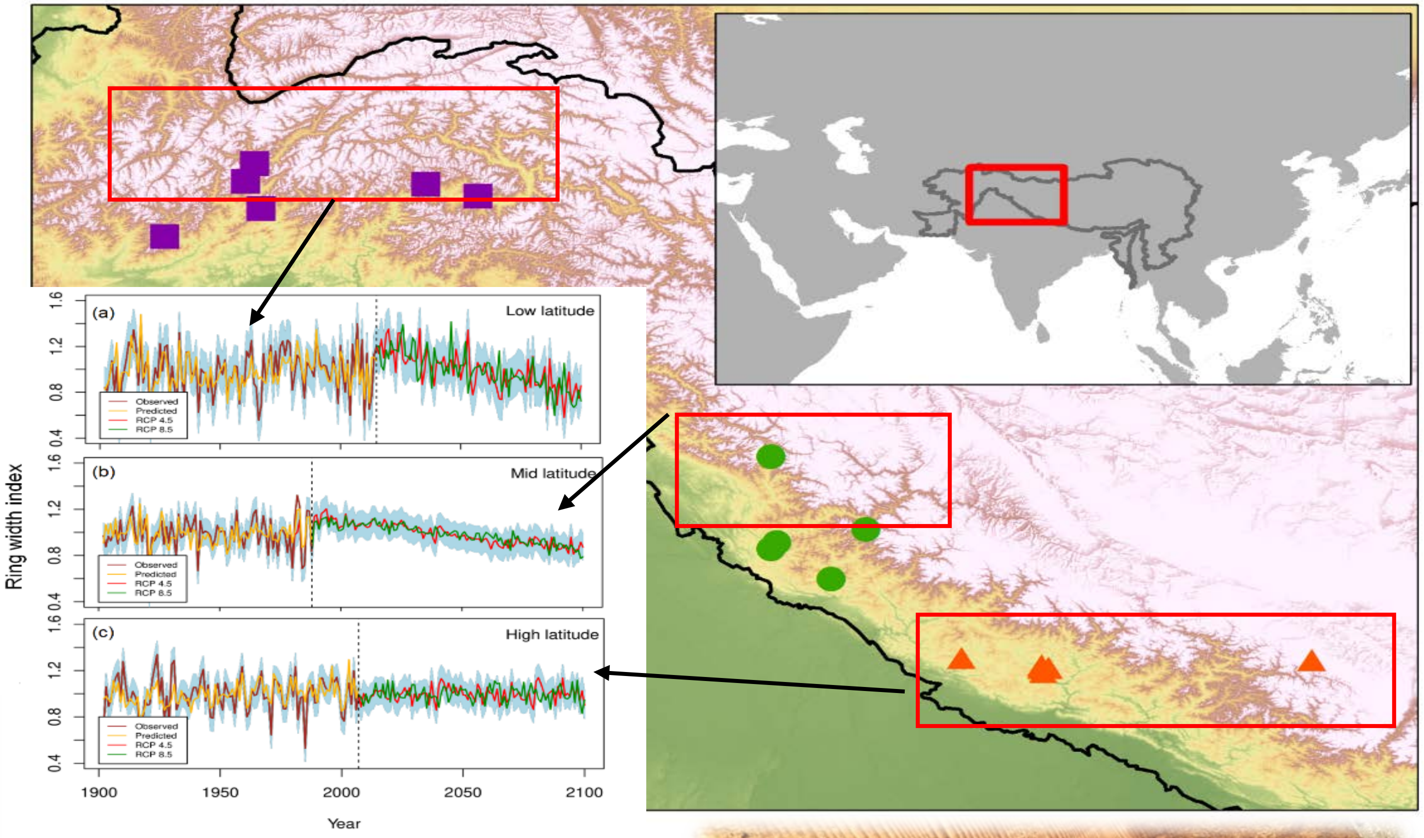


PC: SECURE Himalaya Habitat degradation assessment team, PNIHE

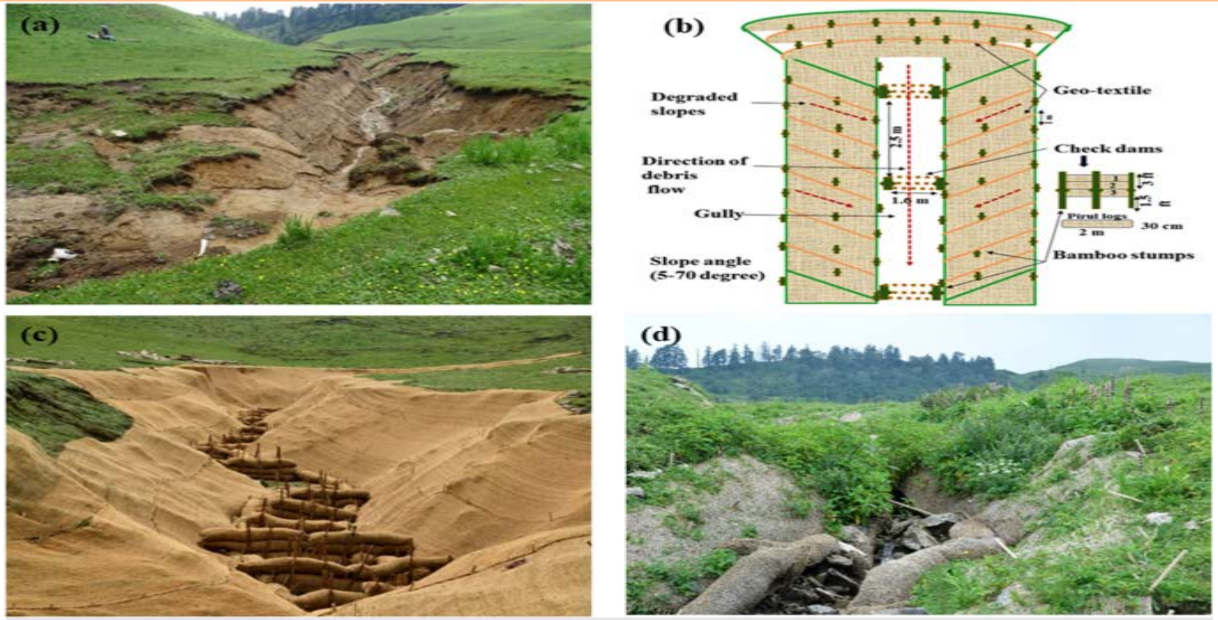
Natural Resources & Management:

Forests- Changing climate & dendrochronology in the IHR

- A tree ring based study of *Cedrus deodara* and climate modelling indicate tree growth is projected to decline by 34% and 38% respectively by the end of the 21st century under RCP 4.5 and RCP 8.5 in low latitude region of the Himalaya.
- Future warming may reduce deodar growth in future of low and mid latitude sites of the Himalaya due to increasing growing season temperature.
- High latitude site may be benefited from glacier expansion in Karakoram region of the Himalaya.



Alpine meadow- Dayara bugyal ecorestoration: mitigation strategies in SECURE Himalaya



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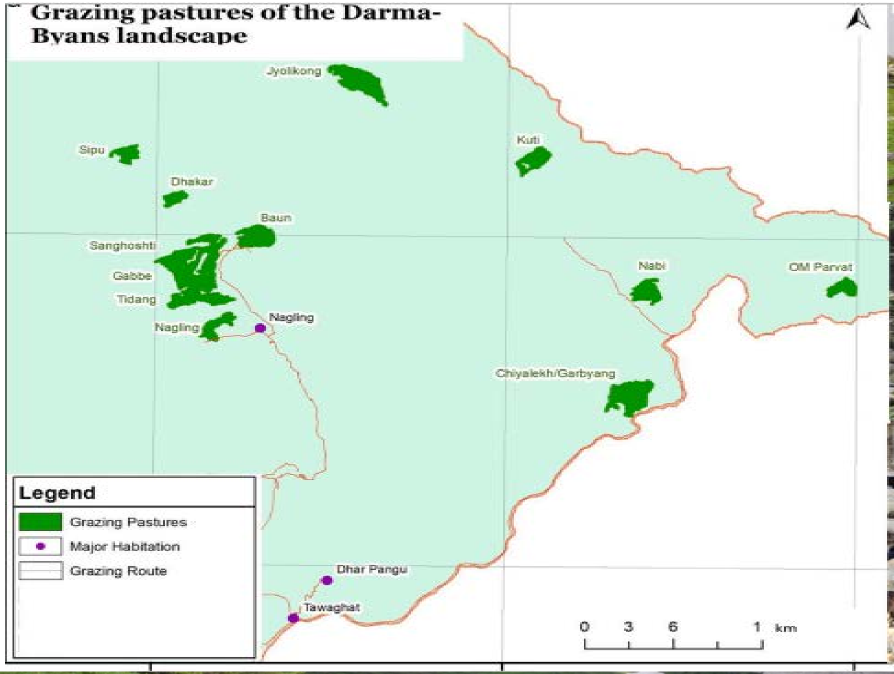
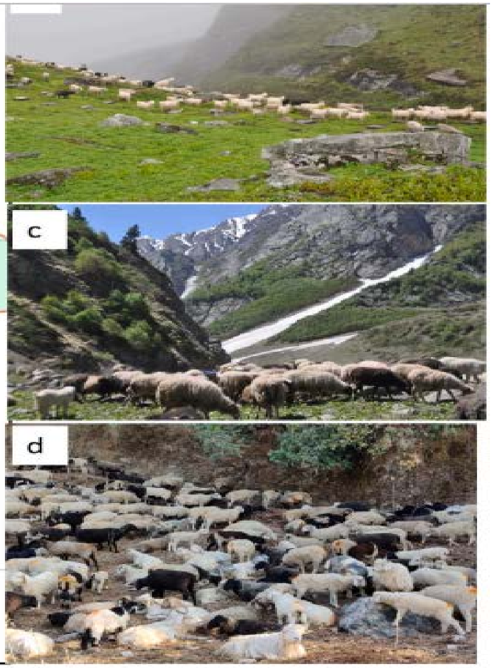
Dayara bugyal restoration model in the alpine and subalpine region of the Central Himalaya: a step toward minimizing the impacts

Jagdish Chandra Kuniyal[1], Priyanka Maiti[1], Sandeep Kumar[2], Anand Kumar[1], Nisha Bisht[1], K. Chandra Sekar[1], Satish Chandra Arya[1], Sumit Rai[1] & Mahesha Nand[1]

- The **ecosystem index score** was evaluated for reference (81.94), treated (64.5) and untreated zones (52.03), increasing profile of these values were found.
- **Improved vegetation profile** in herb density, soil nutrient profile of restored area along with **soil pH (4.96) and water holding capacity (49.85%)** were found. Controlling 169.64 tonne year^{-1} soil erosion from draining.
- Assessment of grazing pattern of 118 migratory Cow Unit (CU) (76 horse/mule and 18 sheep/goat, already controlled), **318 local CU (30 horse/mule and 187 sheep/goat) were calculated and recommended to be controlled.**
- **Tourists' carrying capacity 274 tourists per day within limit.**
- **Manual removal of *Rumex nepalensis*** at the shepherd camping site needed in the area.

Alpine Meadow- Landscape level ecorestoration planning: Darma Byans landscape





- Results showed the natural regeneration of biodiversity in the alpine meadows.
- Decreasing trend in human population (in 15 villages) and livestock population (from 1987 by ~50% of the total population).
- Grazing pressure was below its capacity (20,897 cow units per year).
- Increasing trend in NDVI in the area shows increasing green area.

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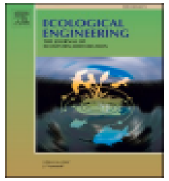

Landscape level ecological assessment and eco-restoration strategies for alpine and sub-alpine regions of the Central Himalaya

Priyanka Maiti [a], Jagdish Chandra Kuniyal [a,*], K. Chandra Sekar [a], K.V. Satish [a], Dalbeer Singh [a], Nisha Bisht [a], Anand Kumar [a], Satish Chandra Arya [a], Mahesha Nand [a], R.C. Sundriyal [b]

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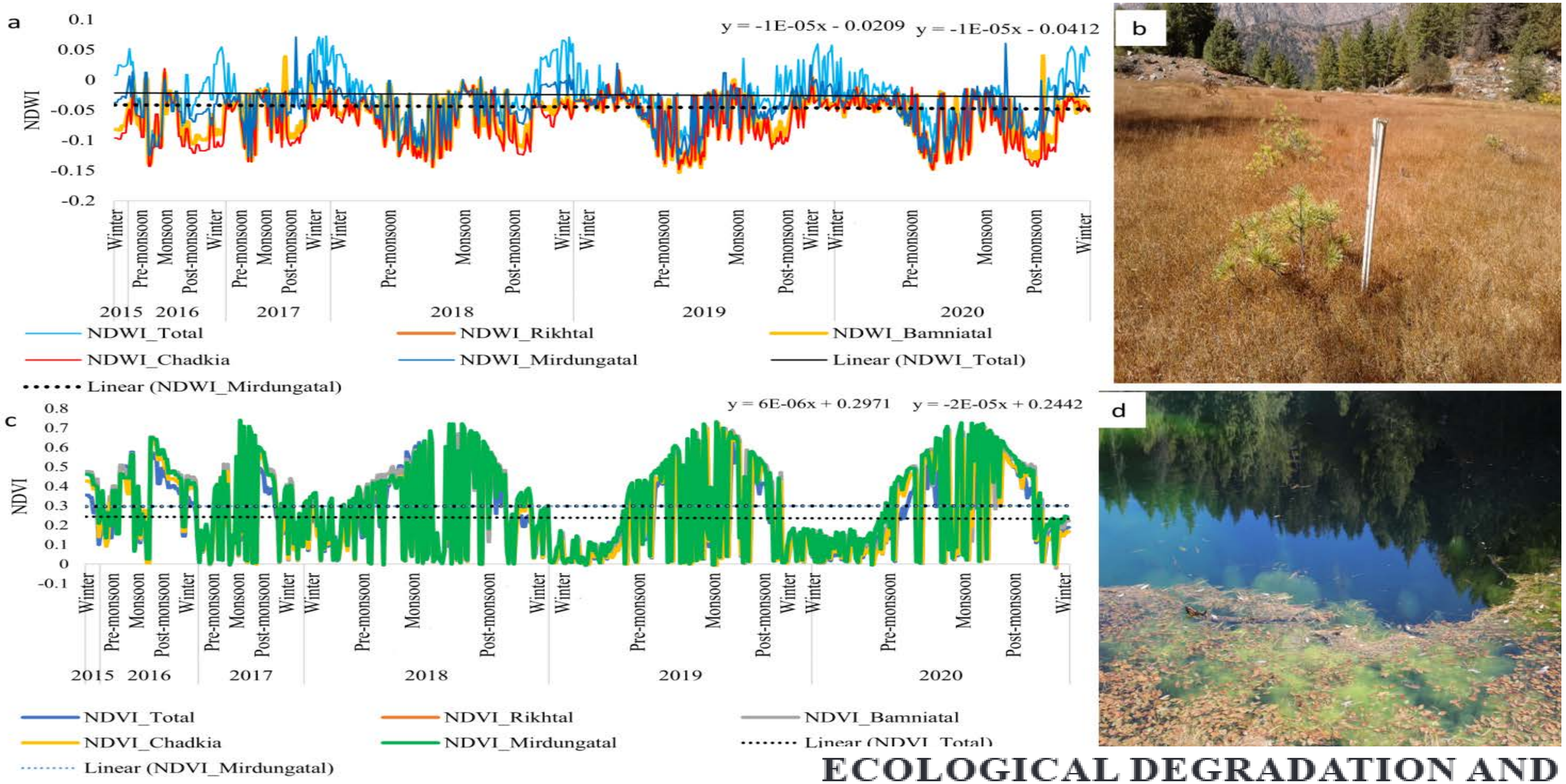
[b] Department of Forestry and Natural Resources, Chauras Campus, HNB Garhwal University, Srinagar (Garhwal), 249169, Uttarakhand, India

Wetland- Water security: Wetland health assessment



- Decreasing trend of Normalized Difference Water Index (NDWI) and increasing trend of Normalized Difference Vegetation Index (NDVI) during last five years (2016-2020).
- Encroachment activities in the down-hill area were assessed as degradation indicators of the area.

ECOLOGICAL DEGRADATION AND ECO-RESTORATION STRATEGIES FOR SATTAL WETLAND AREA OF THE BHAGIRATHI-ECO SENSITIVE ZONE

Priyanka Maiti[1], Jagdish Chandra Kuniyal[1]*, K Chandra Sekar[1], S.C. Arya[1], Nisha Bisht[1], Anand Kumar[1], Mahesha Nand[1] and R.C. Sundriyal[2]

[1]G. B. Pant National Institute of Himalayan Environment, Kosi-Katarmal, Almora, Uttarakhand, India,
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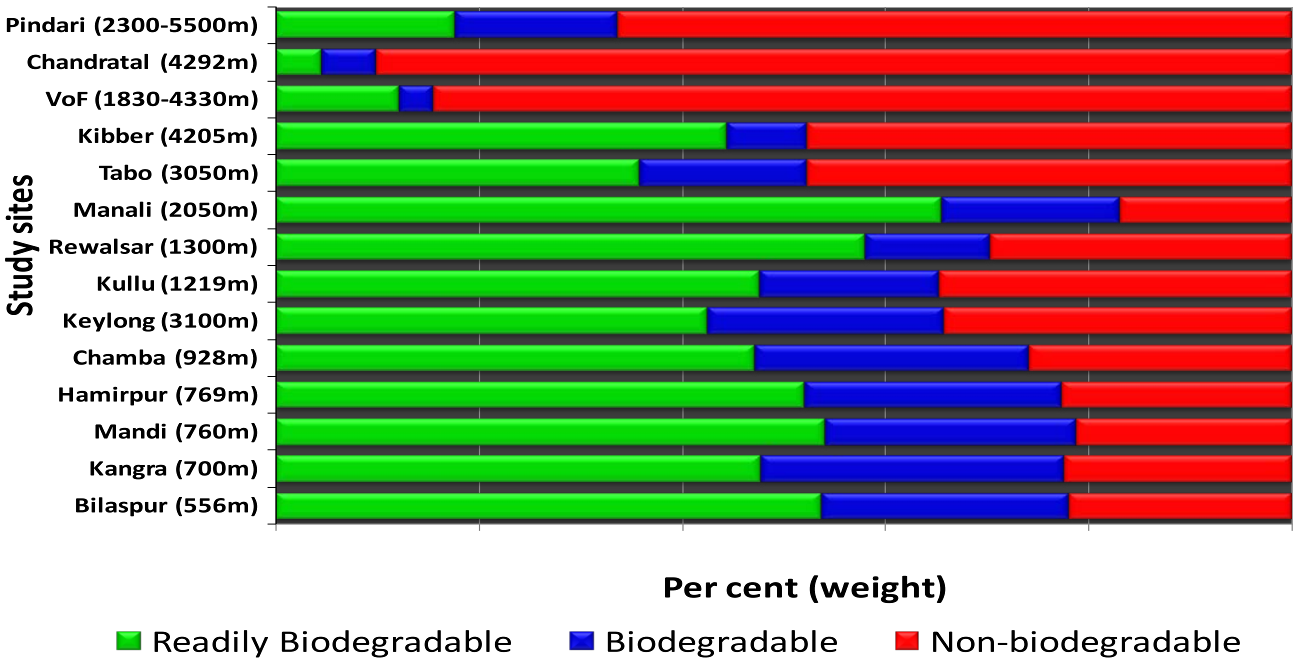
Waste Pollution- Microbial biocomposting: waste to energy



Valley of Flowers and Hemkund Sahib:
~288 g waste generation visitor^{-1} day^{-1} compared with the nation-wide average of 350 g capita^{-1} day^{-1}

Gomukh trek:
~364 g waste generation visitor^{-1} day^{-1}

Kedarkantha trek:
~580 g waste generation /visitor^{-1} day^{-1}

ELSEVIER
Waste Management
Volume 23, Issue 9, 2003, Pages 807-816

Solid waste management in Indian Himalayan tourists' treks: a case study in and around the Valley of Flowers and Hemkund Sahib

Jagdish C Kuniyal, Arun P Jain [1], Ardhendu S Shannigrahi [1]

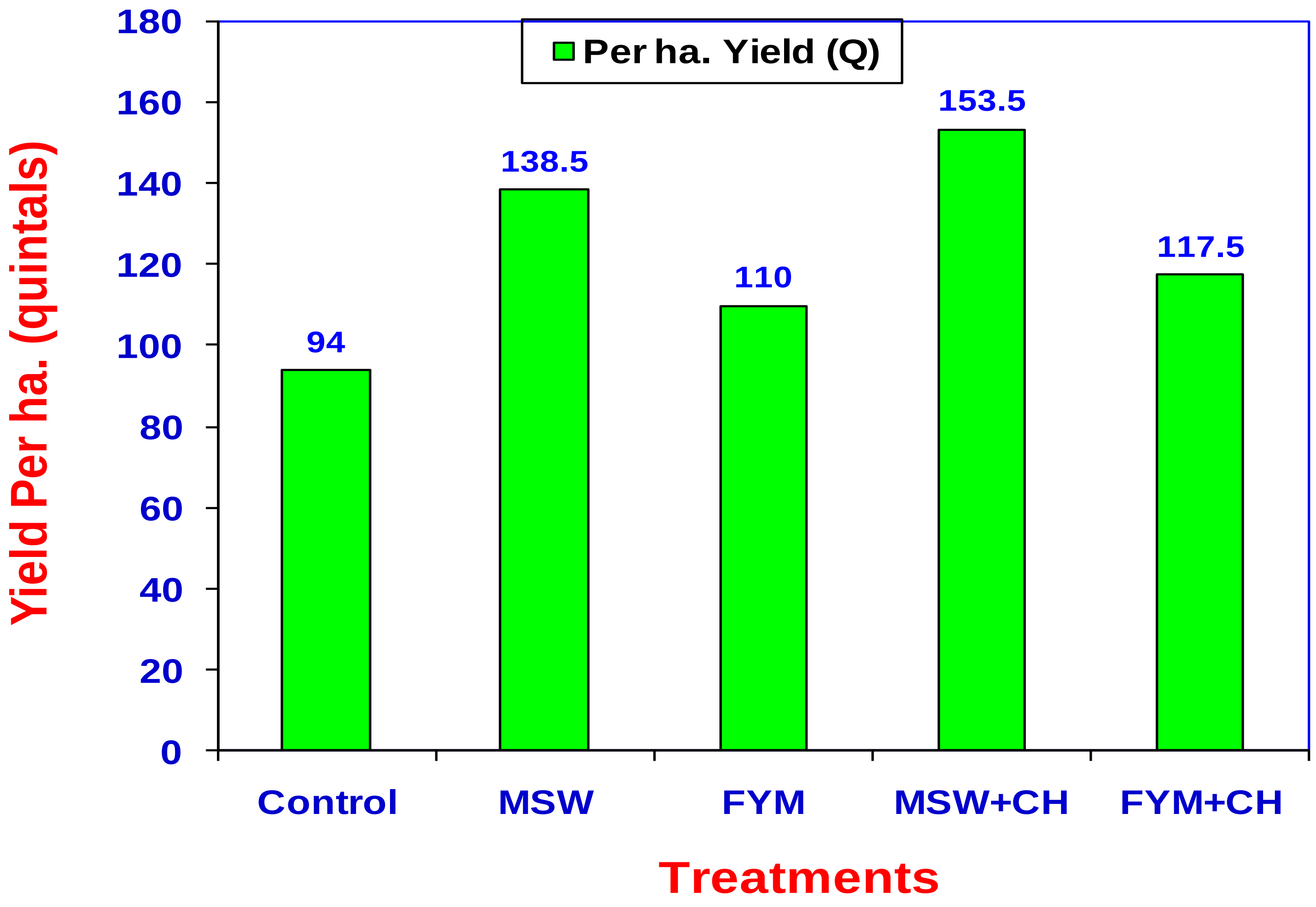
Waste Pollution -Solid waste- Treatment and Products

- Proper segregation from households to municipal levels
- Proper aeration
- Inoculums (compostable material)
- Turning up of waste in an interval of 15 days

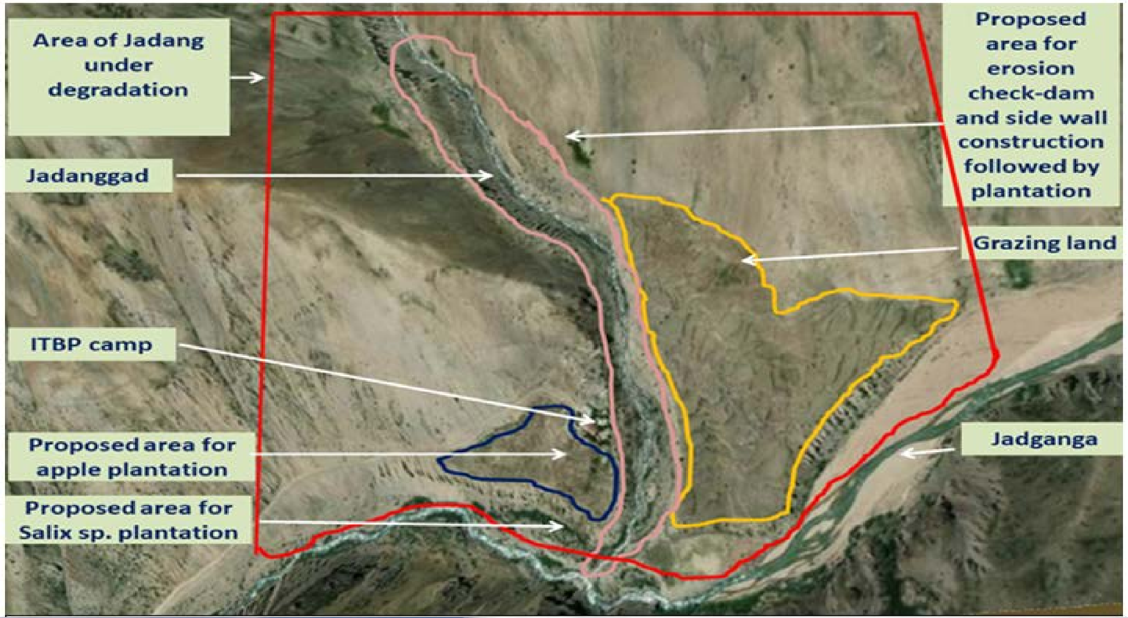
Period of compost formation: 55±5 days (summer) and 65±5 days (winter)

500 kg of wastes produce 1/3rd (167 kg) compost

Biocomposting- Garlic yield after using compost

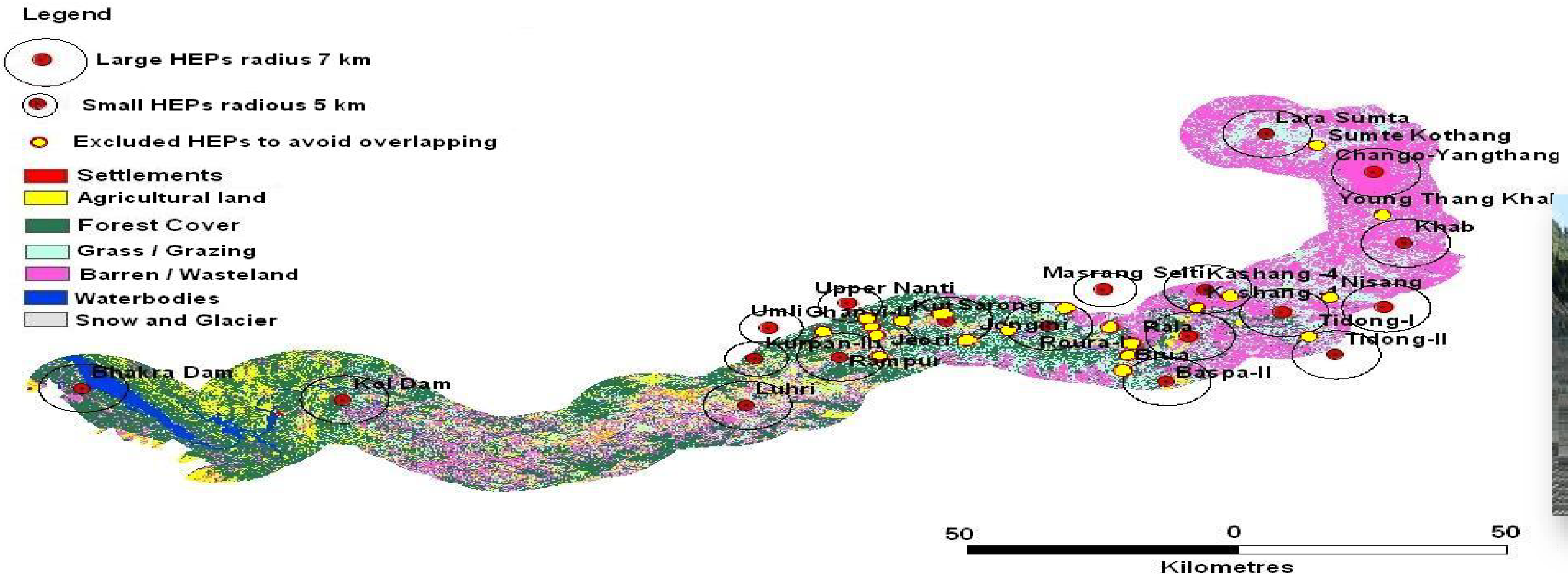


Ecorestoration of Degraded land: Nelang valley Cold desert



- Grazing carrying capacity of the area should be maintained below 8166 CU per year.
- The permits for migratory animals in the Nelang valley need to be gradually reduced and stopped completely within 3-4 years.
- Jadang (3865 m) is under the pressures of grazing as well as intensive soil erosion.
- Construction of stone made check dams, gully plugs and walls are urgently recommended in Jadang gad to stop massive soil erosion followed by renovation of traditional stone-made irrigation system of the area.
- Needs plantation activity of apple and *Thelu* plants.
- Establishment of shepherd night stays near 2-3 km away from the pastures with 3-4 stone made huts is suggested

Energy- SEA of hydroelectric projects & Mitigation strategies



- Only 20 projects out of 38 projects (small & large) could fulfill the criteria of the recommended areal inter-distance

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https://doi.org/10.1007/s11629-017-4653-z

Vulnerability assessment of the Satluj catchment for sustainable development of hydroelectric projects in the northwestern Himalaya

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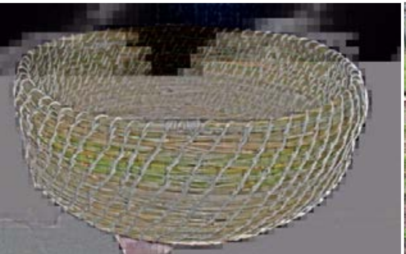
*Corresponding Author

Forest fires & Mitigation Strategies- bio-briquettes & other use of pine needles



Preparing Climate smart communities- Capacity building of stakeholders

State	Programmes	Total	Male	Female
Himachal Pradesh	03	57	18	39
Almora, Uttarakhand	07	223	99	124
Garhwal, Uttarakhand	03	189	80	109
Sikkim	01	36	00	36
Arunachal Pardesh	01	40	23	17
Total	**15**	**545**	**220**	**325**

Natural Hazards
https://doi.org/10.1007/s11069-024-06413-7

ORIGINAL PAPER

Assessment and modelling of hydro-sedimentological flows of the eastern river Dhauliganga, north-western Himalaya, India

Kuldeep Singh Rautela[1,2] · Jagdish Chandra Kuniyal[1] · Manish Kumar Goyal[2] · Nidhi Kanwar[1] · Ajay Singh Bhoj[1]

Received: 28 December 2022 / Accepted: 4 January 2024

Conclusions

- **The Himalayan region has been experiencing significant warming** with projected temperature increases of **3.5–6.0°C by 2100**, accelerating glacier melt and altering regional hydrology.
- **The Western Himalaya** has warmed nearly twice as fast as the Indian average **(0.31 vs. 0.16°C decade^{-1}), with projected warming 3.5–6.0°C by 2100.**
- **Parbati Glacier has undergone substantial degradation** from 439.83 km² (1970) to 328.40 km² (2016) (~25% reduction) and the formation of **20 glacial lakes**, highlighting increasing GLOF susceptibility.
- **Floods and heavy rainfall events have increased markedly since 2000**, with the highest frequency recorded during **2023–2025**. Himachal Pradesh, Jammu & Kashmir, and Uttarakhand account for the largest number of events.
- **Landslides remain one of the most frequent hazards**, with major event concentrations in **Himachal Pradesh, Uttarakhand, and Jammu & Kashmir**, while several the northeastern Himalayan states also experienced localized outbreaks.
- **A total of 290 cloudburst events were documented (1902–2025)**, with **about 28% occurring after 2021**, indicating a pronounced increase in recent years, particularly in the Western Himalaya.
- **Historical records show recurring snow avalanches and GLOFs across the Himalaya**, with notable events concentrated in **Lahaul–Spiti, Kinnaur, Kashmir, Uttarakhand, and Sikkim**.

Way Forward

Landscape specific management options, differentiated for snow-fed and rain-fed contexts, are needed to minimize climate-induced implications and build community resilience.

- **Strengthen Early Warning System**

  Expand networks and hydro-climatic extreme monitoring in both glacier- and rain-fed basins of the mountains, e.g., AWLR / AWS.

- **Regulate Land use Pressure**

  Enforce carrying-capacity limits of tourism or any other activity (Sindh), hydropower siting norms, and viable *jhum*-cultivation alternatives (Ranganadi, Imphal).

- **Build Community Resilience**

  Scale green-skill livelihoods: bee-keeping, agri-eco-tourism with a focus on women's adaptive capacity across the IHR.

- **Mountain Specific Policy**

  Mountain specific policy guidelines are needed to address their location specific problems.

'Adaptive Capacity must Keep Pace' **would help in establishing a balance between**

ecology, economy & people

Acknowledgements

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•Dr. B.P. Bhatt, Hon’ble Vice Chancellor, Veer Chandra Singh Garhwali Uttarakhand University of Horticulture & Forestry,

Bharsar-246 123 for providing me this opportunity.

Organizing Committee of the ANSO-MAS 2026 for continuous follow ups.

Ms. Matt Kimberley for continuous responses & support

Co-Investigators, Project staff & students for providing research inputs.

Stakeholders-local communities, local government, etc. for sharing relevant information.

A view of Pārbati Glacier, Himachal Pradesh