Open GIS, Earth Observation (EO) and Glacial Lake Outburst Floods (GLOFs) in Himachal Himalaya, India

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Content

- Commitment of IGU to Open GIS
- FOSSEE Project of IIT Bombay
- Climate Change and the western Himalaya
- Case Study: Monitoring GLOFs in Himachal Himalaya
- Limitations

International Geographical Union (IGU)

IGU
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The **strategy** of the IGU for 2020-2024

Commitment to contribute to **UN Sustainable Development Goals (SDGs),** the UN Decade of Ocean Science for Sustainable Development, International Decade of Basic Sciences for Sustainable Development (2024-2033), UN Disaster Risk Reduction (DRR), Paris Climate Action and Habitat-III, and ISC Future Earth.

Engagement with, relevant international organizations, especially the **International Science Council (ISC)** including the (**GeoUnions, CODATA**) **UN-GGIM** and the **International Council for Philosophy and Human Sciences (CIPSH)** inter alia.

SUSTAINABLE DEVELOPMENT GOALS

2021 2030 United Nations Decade of Ocean Science for Sustainable Development

UNDRR UN Office for Disaster Risk Reduction

2022 2023 IYBSSD

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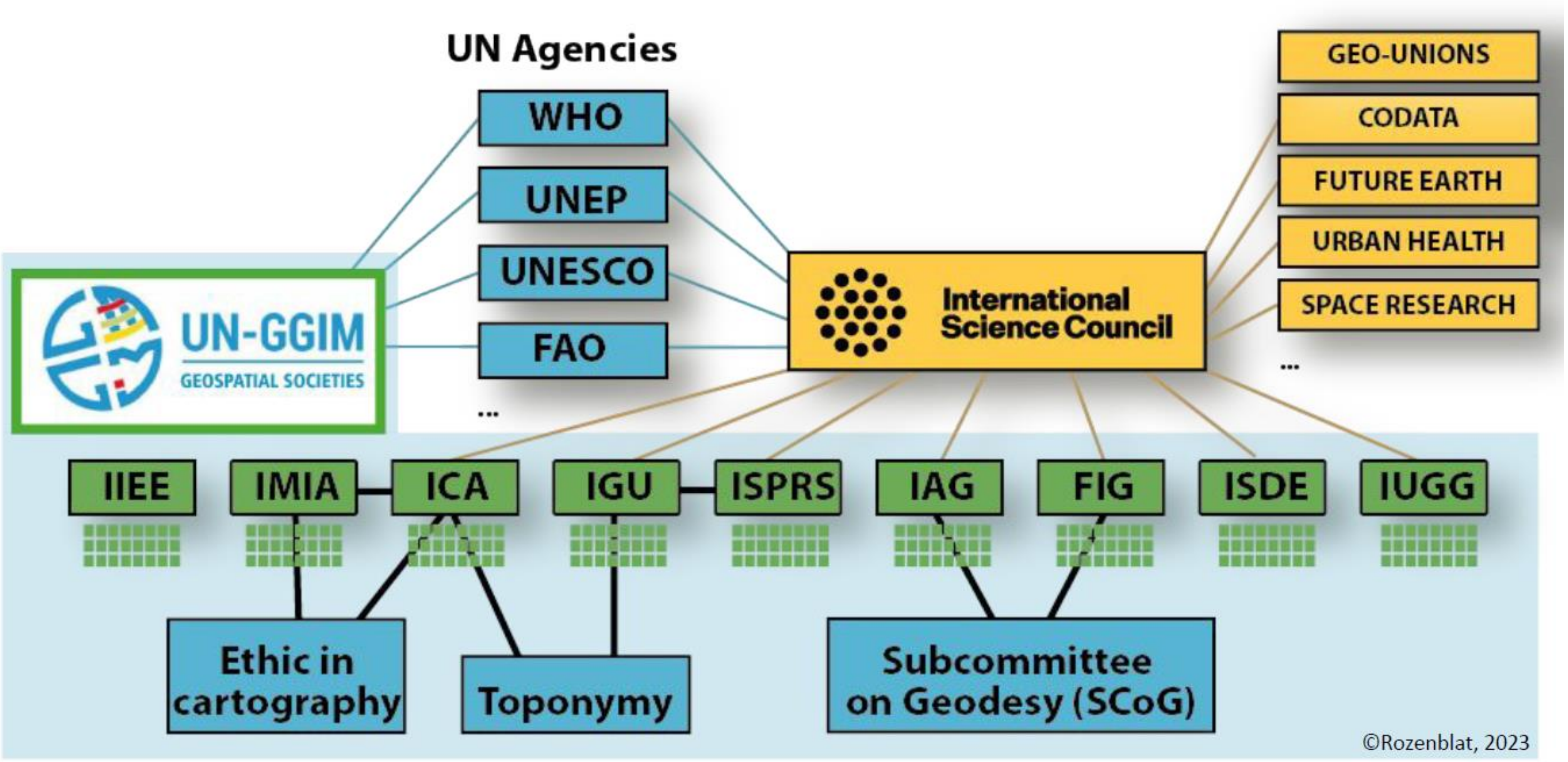
IGU Commissions (46 in Number)

C20.13 Geographical Information Science
Co-chair, Fenzhen Su, Director of State Key Laboratory of Environmental and Resource Information Systems, Institute of Geography and Natural Resources Research, CAS, **China**

Co-chair, Dr Daniel Sui, Chancellor for Research and Innovation, Professor of Geosciences, University of Arkansas, Fayetteville, **USA**
URL: http://igugis.lreis.ac.cn/

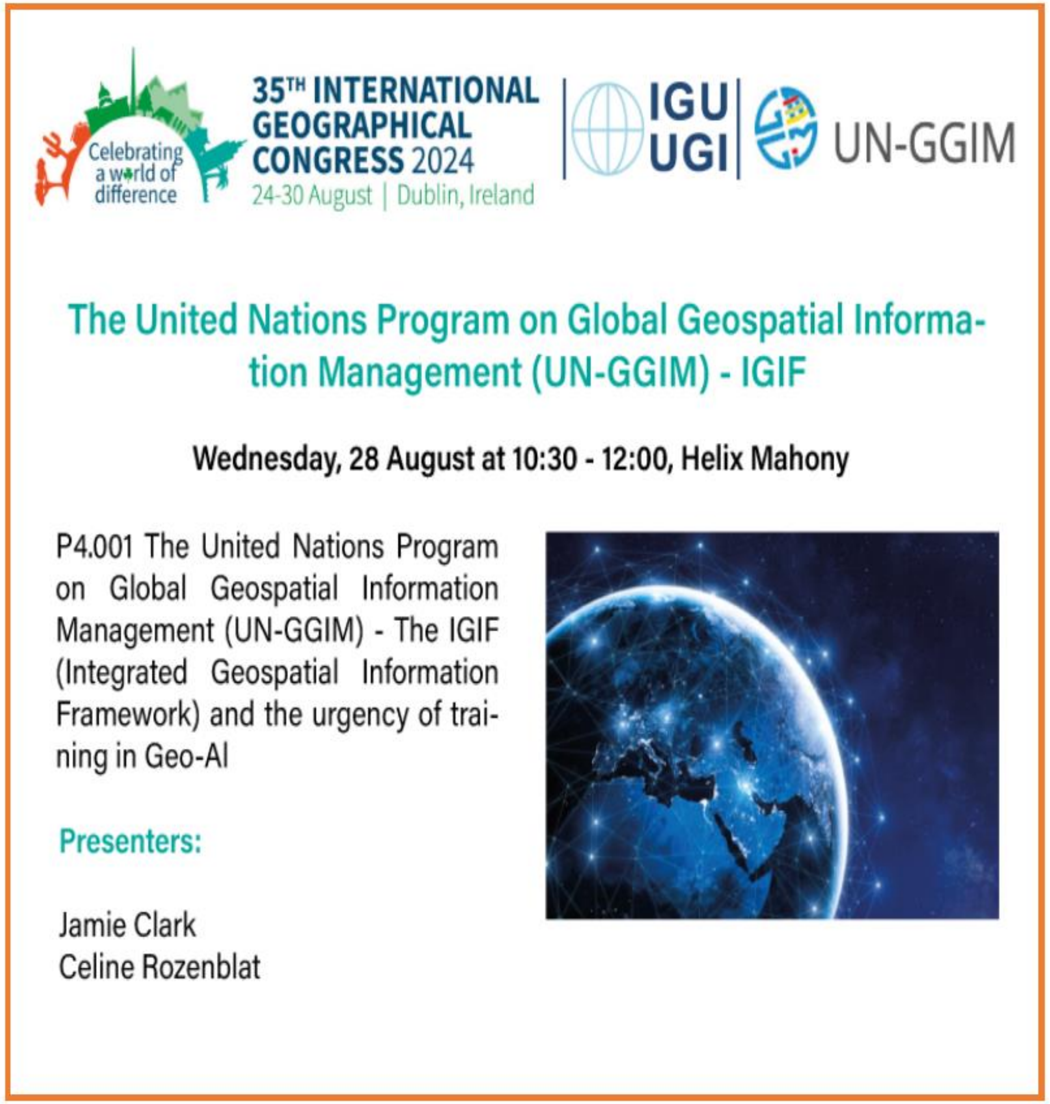
C20.34 Modelling Geographical Systems
Chair, Professor Dr. Min Chen, Vice Director, Key Laboratory of Virtual Geographic Environment, Nanjing Normal University, **China**
Website URL: http://www.igu-geomodeling.com/

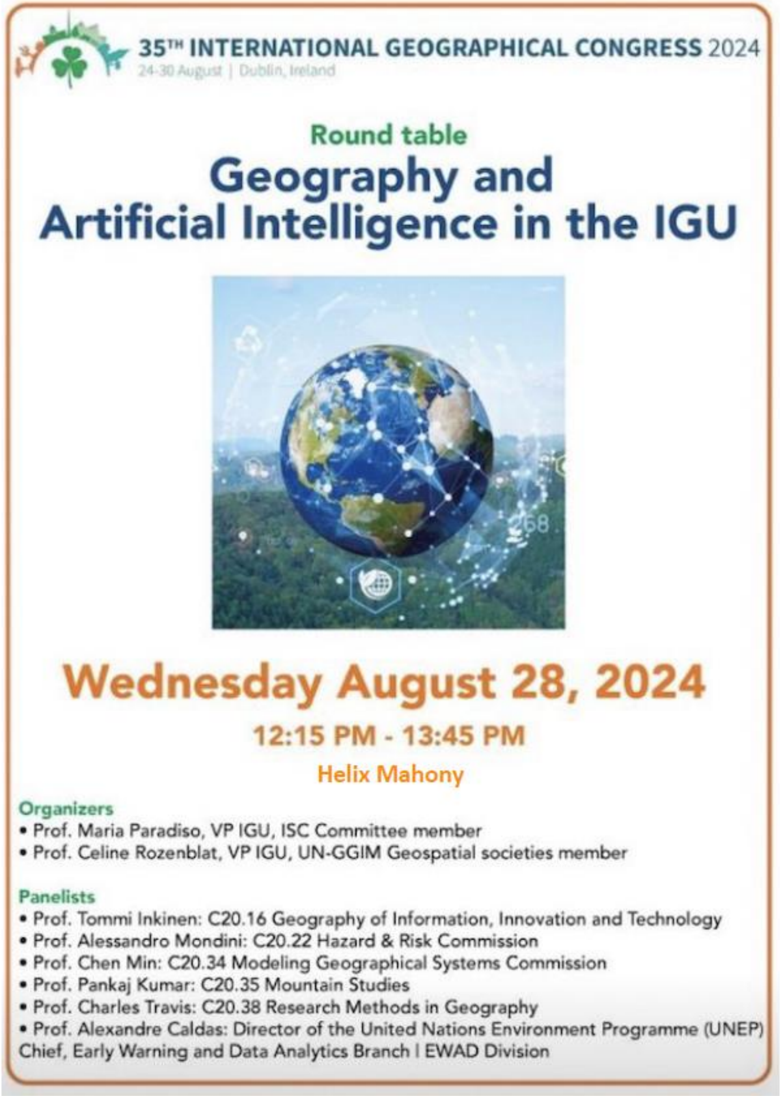
Geospatial Societies in 2024 (11 in Number)



OS-GEO and **ISC-CODATA** joined this Geospatial Societies

Round table on Geospatial Technology in IGC Dublin 2024





Geospatial Societies initiatives

The Geospatial Societies network of the UN-GGIM (United Nations - Global Geospatial Information Management) is collecting information on all the centers of the world providing Trainings / Webinars in *Geospatial data management, Geomatics and GEO-AI*.

More than 122 Centers already filled the survey (167 trainings). The information will be published on a web mapping site.

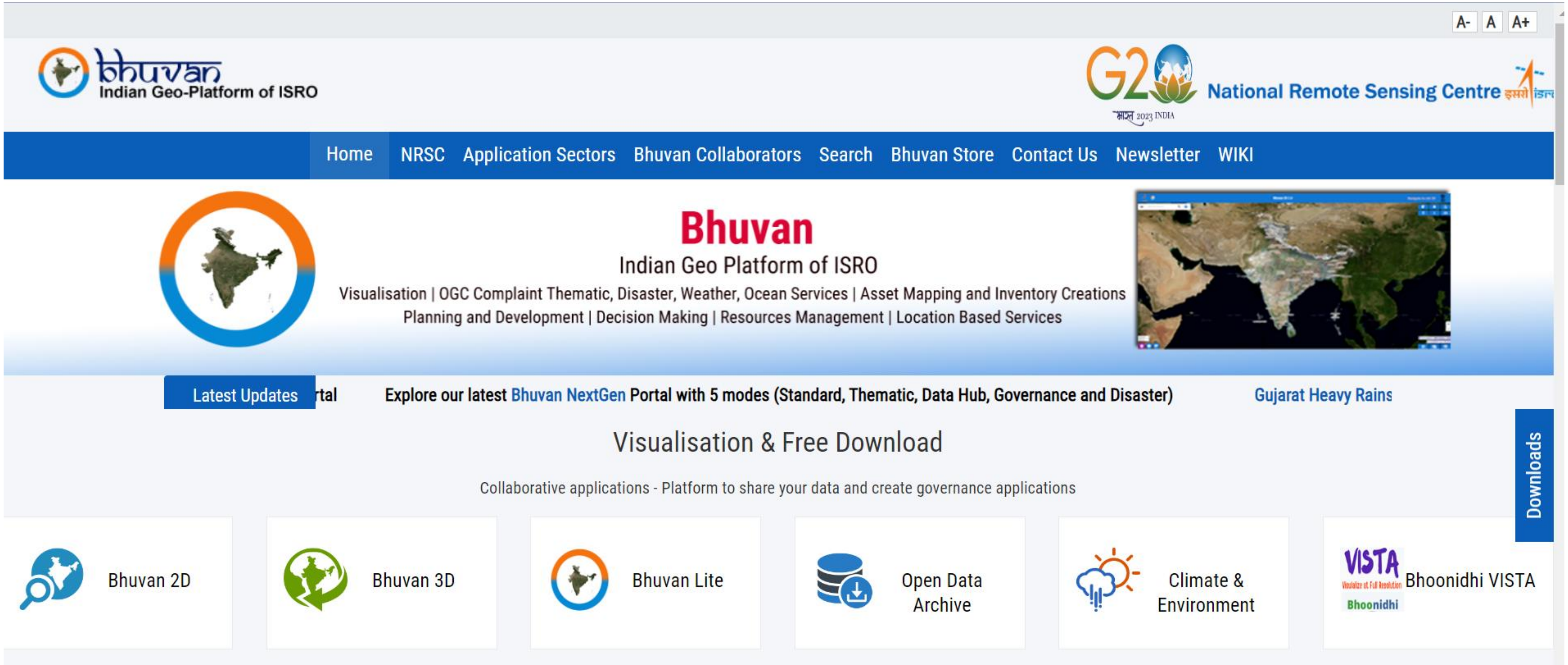
Celine Rozenblat,
Chair of the UN-GGIM Geospatial Societies,
Former Vice President, International Geographical Union (IGU)

Open GIS: FOSSEE GIS

- **“IIT Bombay FOSSEE GIS”** is the geospatial arm of the FOSSEE project Promotes the usage of Free/Libre Open Source Software and Open Source Hardware in academia and industry funded through the National Mission on Education through ICT (NMEICT), Ministry of Education, Government of India.

Partners

Indian Earth Observation (EO) products



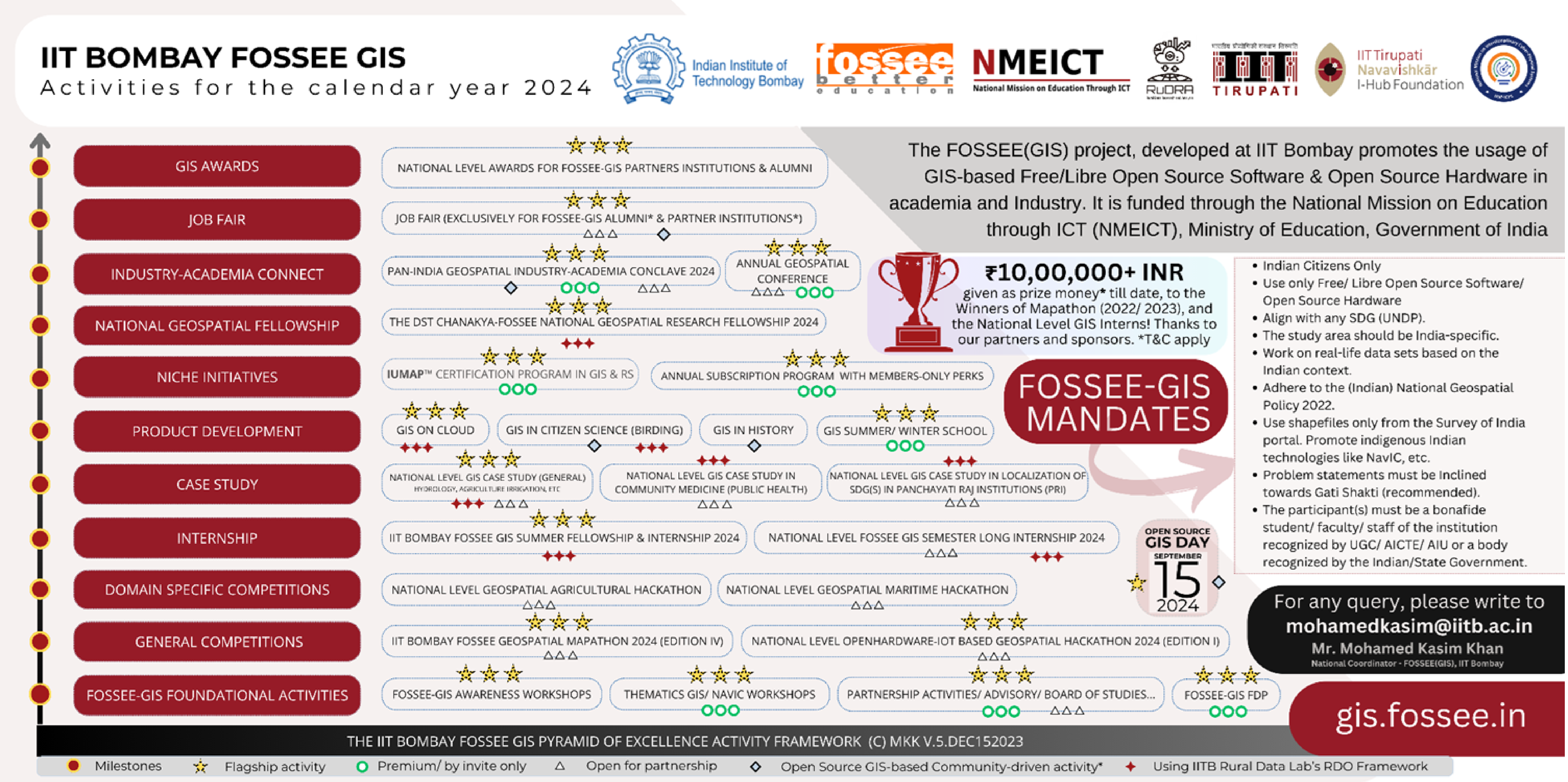
https://bhuvan.nrsc.gov.in/

Projects

Scilab	Python	eSim
Osdag	DWSIM	OpenFOAM
OpenModelica	OpenPLC	FLOSS Arduino
SBHS	R	QGIS
FOCAL	SOUL	

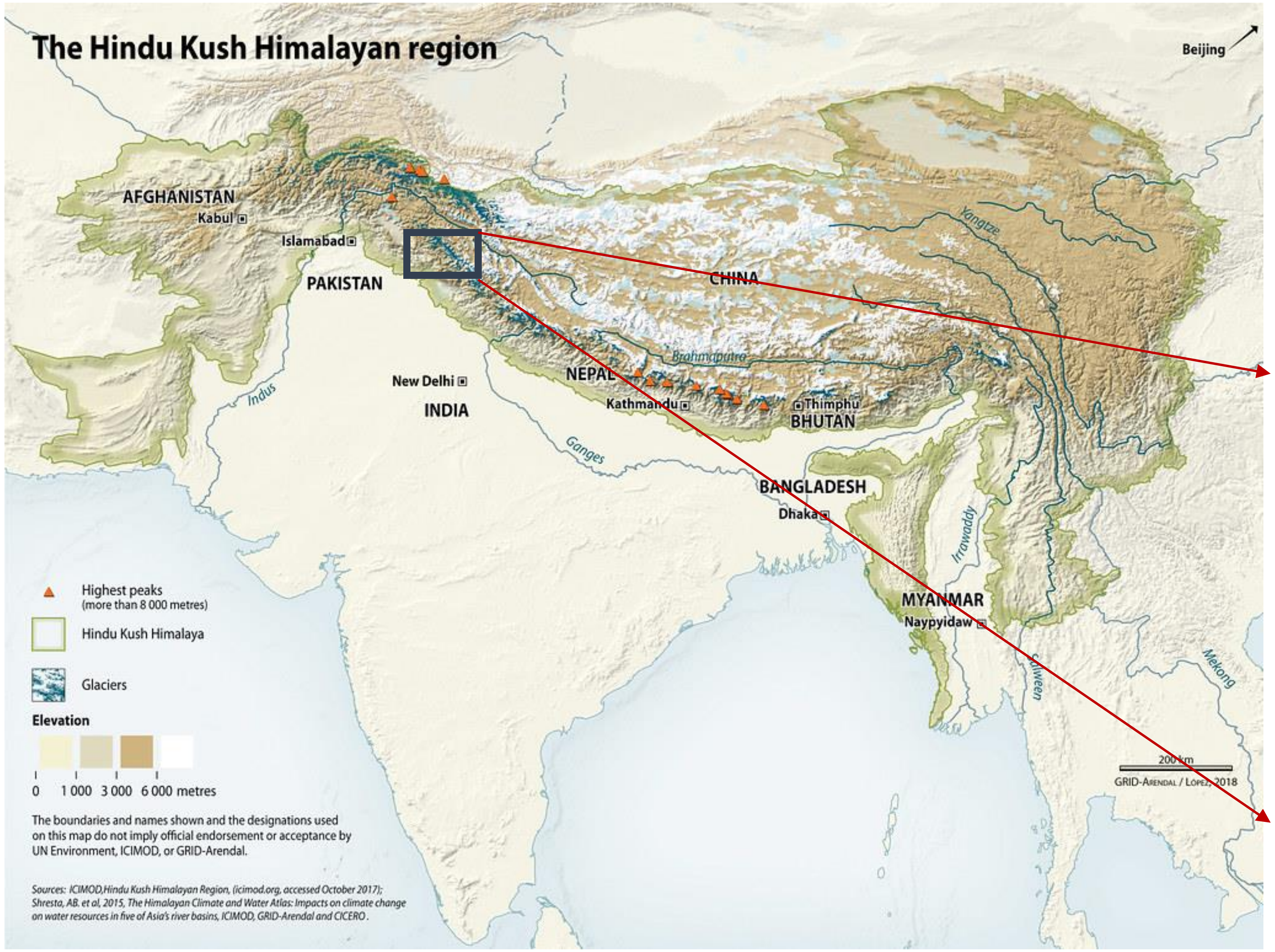
https://fossee.in/

Activities organized by IIT Bombay FOSSEE GIS

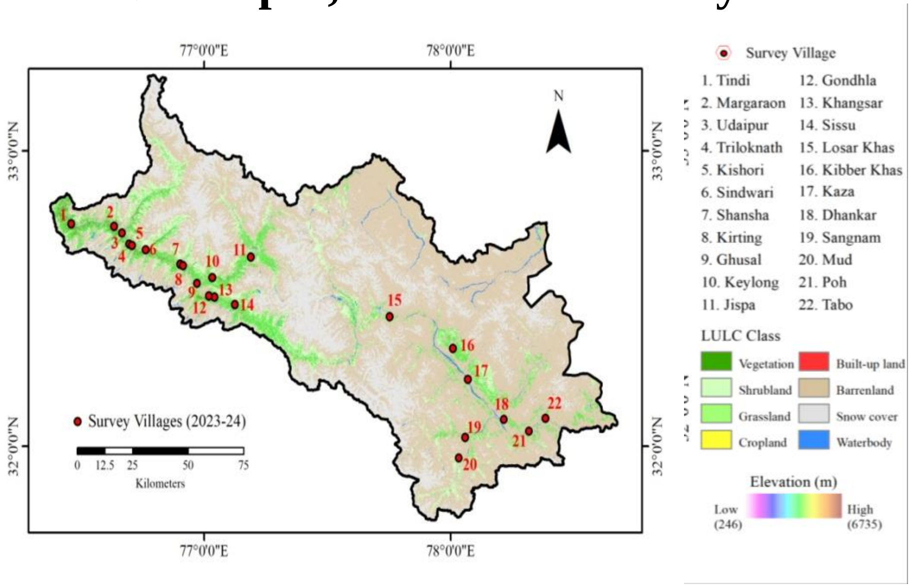


https://gis.fossee.in

Case Study: Glacial Lakes & Potential GLOFs

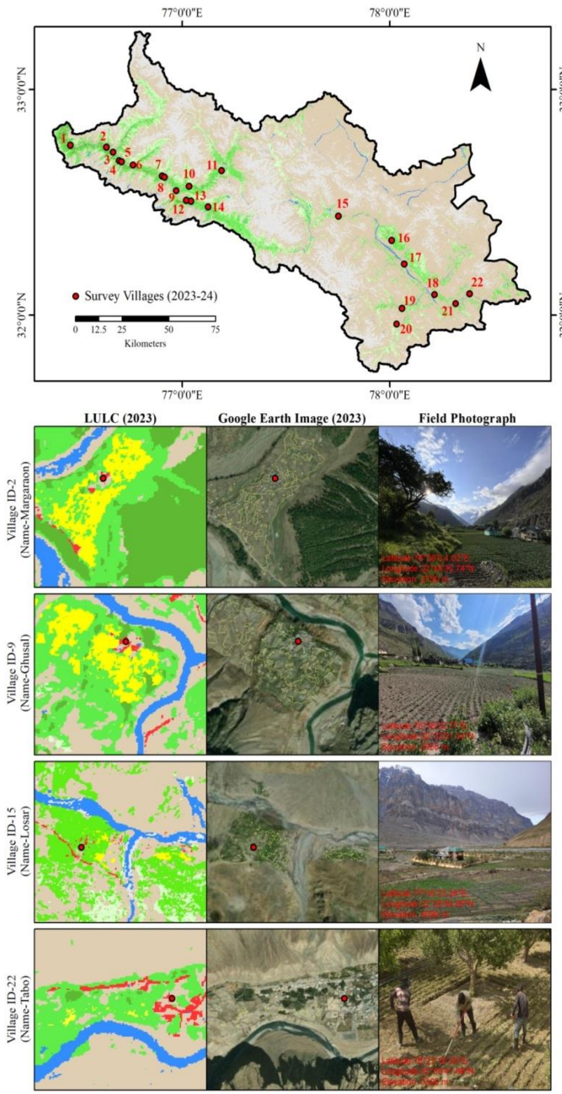


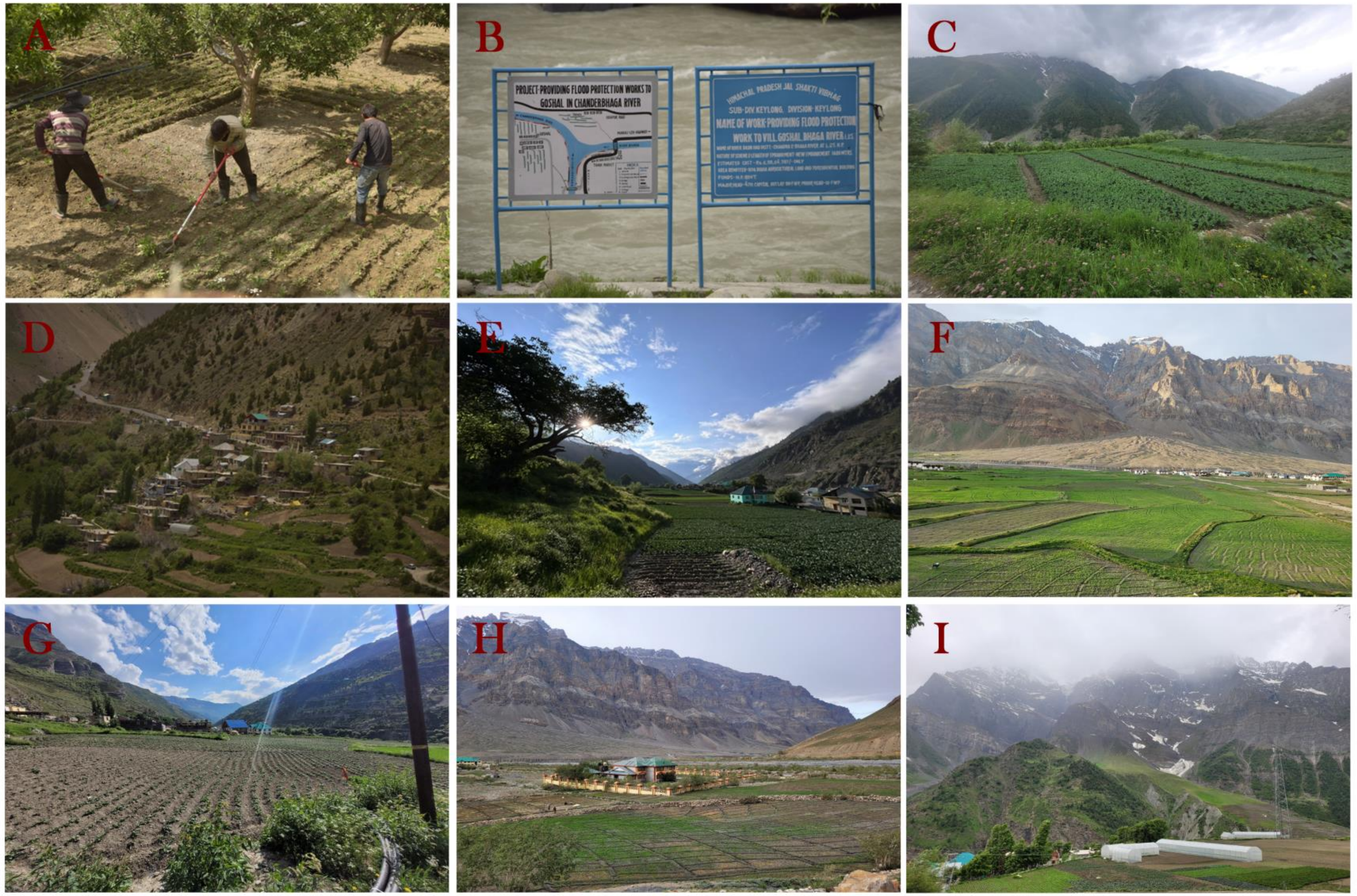
Lahaul & Spiti, Himachal Himalaya

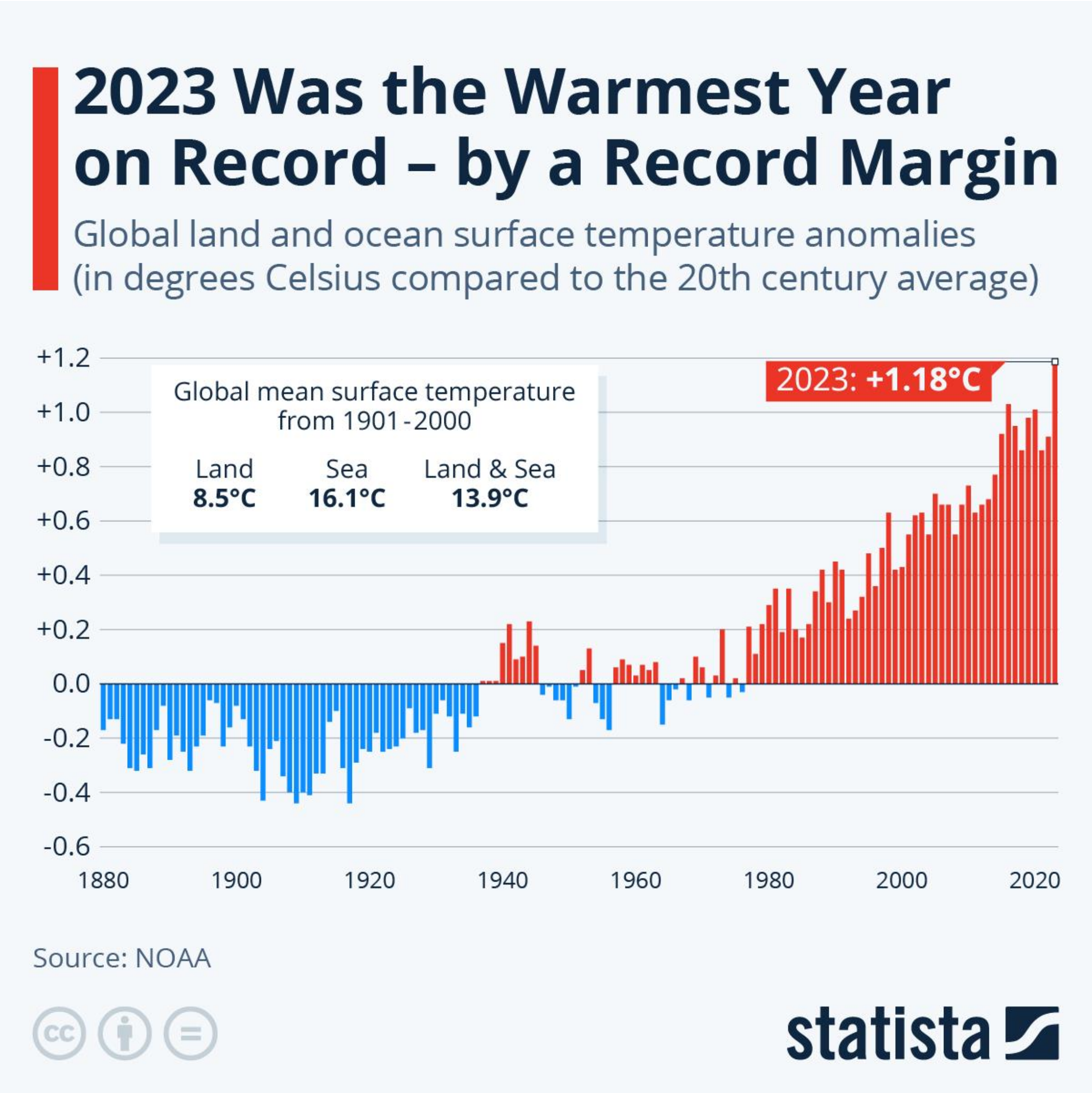


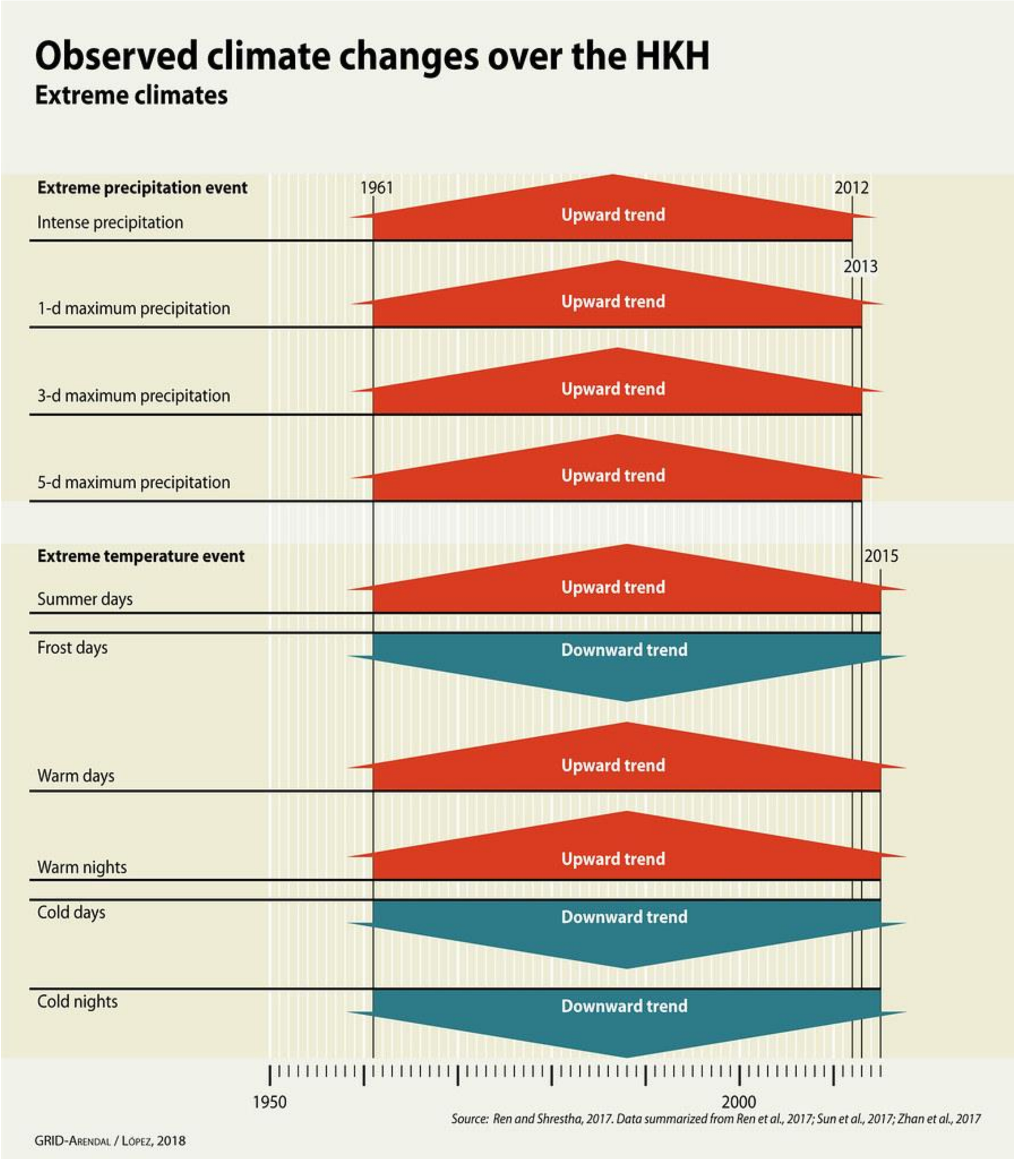
- ❑ The altitude in the district ranges from 2,650 to 5,600 meters with consists of two great valleys Lahaul and Spiti.

Agricultural Fields






2023 Was the Warmest Year on Record – by a Record Margin
Global land and ocean surface temperature anomalies (in degrees Celsius compared to the 20th century average)
Global mean surface temperature from 1901-2000
Land 8.5°C
Sea 16.1°C
Land & Sea 13.9°C
2023: +1.18°C
+1.2
+1.0
+0.8
+0.6
+0.4
+0.2
0.0
-0.2
-0.4
-0.6
1880
1900
1920
1940
1960
1980
2000
2020
Source: NOAA
statista


Observed climate changes over the HKH
Extreme climates
Extreme precipitation event
Intense precipitation
1961
2012
Upward trend
1-d maximum precipitation
2013
Upward trend
3-d maximum precipitation
Upward trend
5-d maximum precipitation
Upward trend
Extreme temperature event
2015
Summer days
Upward trend
Frost days
Downward trend
Warm days
Upward trend
Warm nights
Upward trend
Cold days
Downward trend
Cold nights
Downward trend
1950
2000
Source: Ren and Shrestha, 2017. Data summarized from Ren et al., 2017; Sun et al., 2017; Zhan et al., 2017
GRID-Arendal / López, 2018

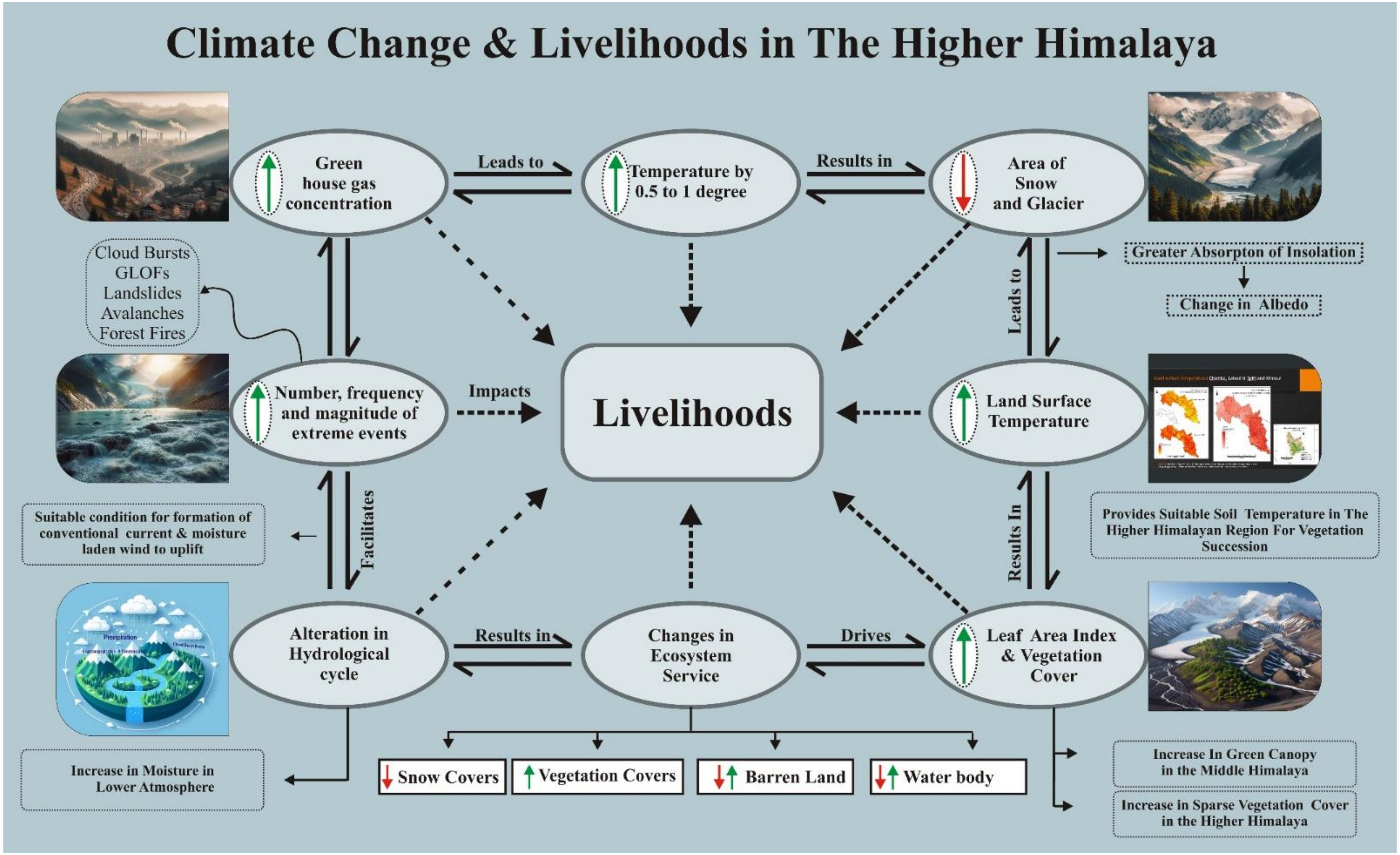
Western Himalaya and Climate change

Brohan et al. (2006), Diodato et al. (2012)	Dash et al. (2007)	Dimri and Dash (2012)	Bhutiyani et al. (2007)
0.5 °C increase in the average maximum temperature (T_{max}) during 1971–2005 compared to 1901–1960	Average increase of 0.9 °C in temperature during 1901–2003	Increase in maximum temperature between 1.1 and 2.5 °C	Increase of temperature 0.16 °C per decade during the century

Table 2 Summary of the various findings about the changes in monsoon and rainfall due to climate warming in Western Himalayas

Bhutiyani et al. (2010)	Sontakke et al. (2009)	Dimri and Dash (2012)	Guhathakurta and Rajeevan (2008)
Downward trend in monsoon and average rainfall during 1866–2006	Decreasing trend in monsoon and average rainfall during 1960–2006	Decreasing winter precipitation during December–February, increase in number of warm days, decrease in number of cold days, and rising trend in number of consecutive dry days in winter during 1975–2006	Increase in pre-monsoon precipitation during 1901–2003

Tewari et al. Forest Ecosystems (2017) 4:13



Climate Change & Livelihoods in The Higher Himalaya
Green house gas concentration
Leads to
Temperature by 0.5 to 1 degree
Results in
Area of Snow and Glacier
Greater Absorption of Insolation
Change in Albedo
Leads to
Cloud Bursts
GLOFs
Landslides
Avalanches
Forest Fires
Number, frequency and magnitude of extreme events
Impacts
Livelihoods
Land Surface Temperature
Provides Suitable Soil Temperature in The Higher Himalayan Region For Vegetation Succession
Results In
Suitable condition for formation of conventional current & moisture laden wind to uplift
Facilitates
Alteration in Hydrological cycle
Results in
Changes in Ecosystem Service
Drives
Leaf Area Index & Vegetation Cover
Increase in Moisture in Lower Atmosphere
Snow Covers
Vegetation Covers
Barren Land
Water body
Increase In Green Canopy in the Middle Himalaya
Increase in Sparse Vegetation Cover in the Higher Himalaya

GLOF cross section

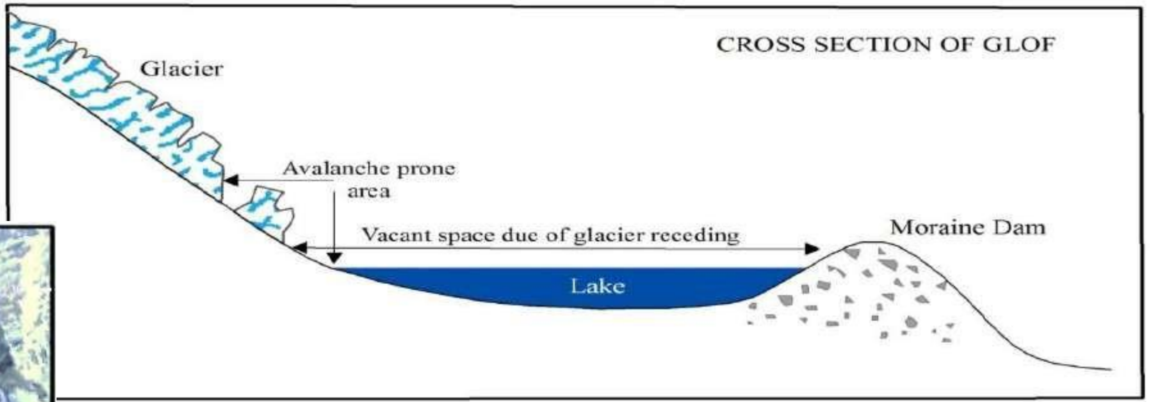


Fig. Cross section of GLOF

Imja Glacier melt, Himalayas

Autumn, circa 1956 - October 18, 2007

NASA IMAGES of CHANGE

Imja Lake coalesced from a series of melt ponds that began forming on Imja Glacier, near Mt. Everest in the Himalayas, around 1960. By the mid-1970s, the ponds had merged into a single body of water, which has grown as the glaciers feeding it have retreated and thinned.

Exceptionally early ice melt, Greenland

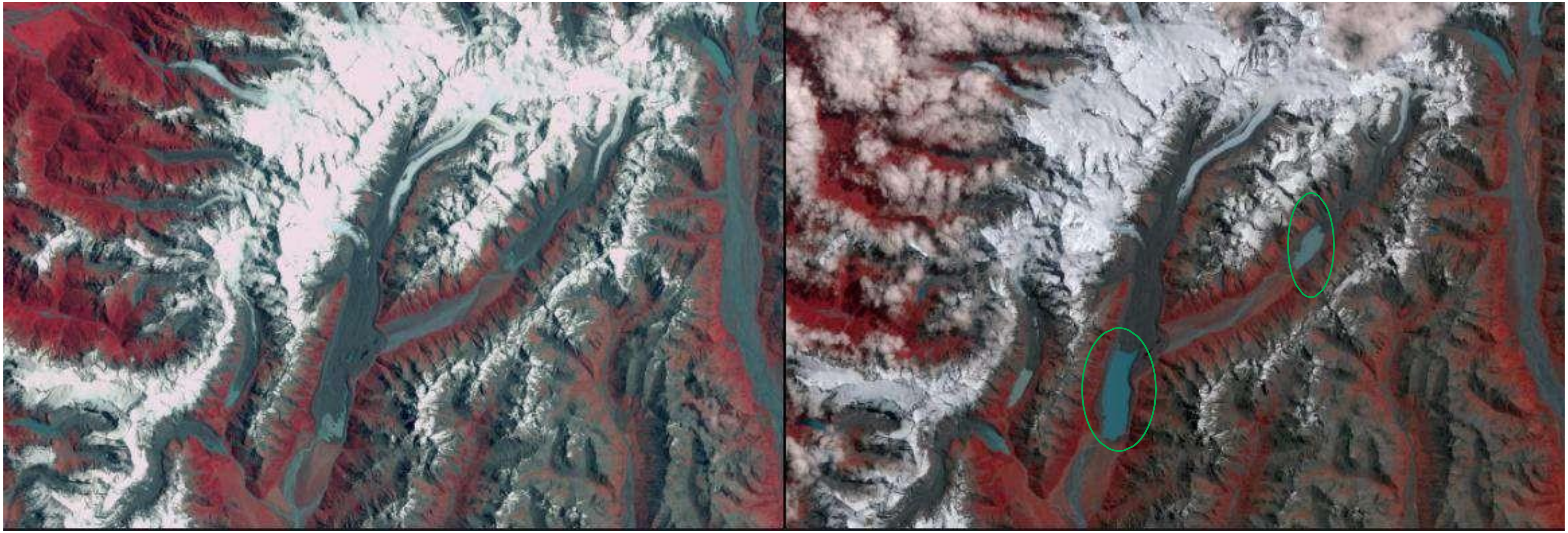
June 10, 2014 - June 15, 2016

NASA IMAGES of CHANGE

June 10, 2014

June 15, 2016

Shrinking Glaciers in New Zealand



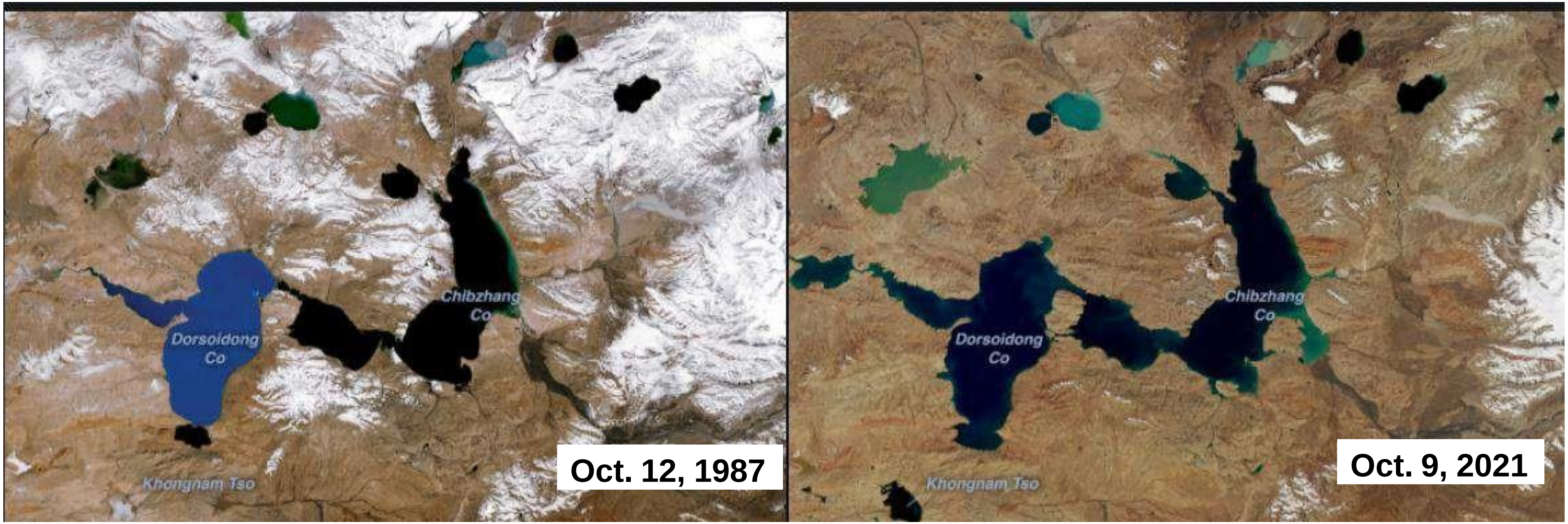
January 12, 1990 January 29, 2017

BEFORE AND AFTER

Melting Glaciers Enlarge Lakes on Tibetan Plateau

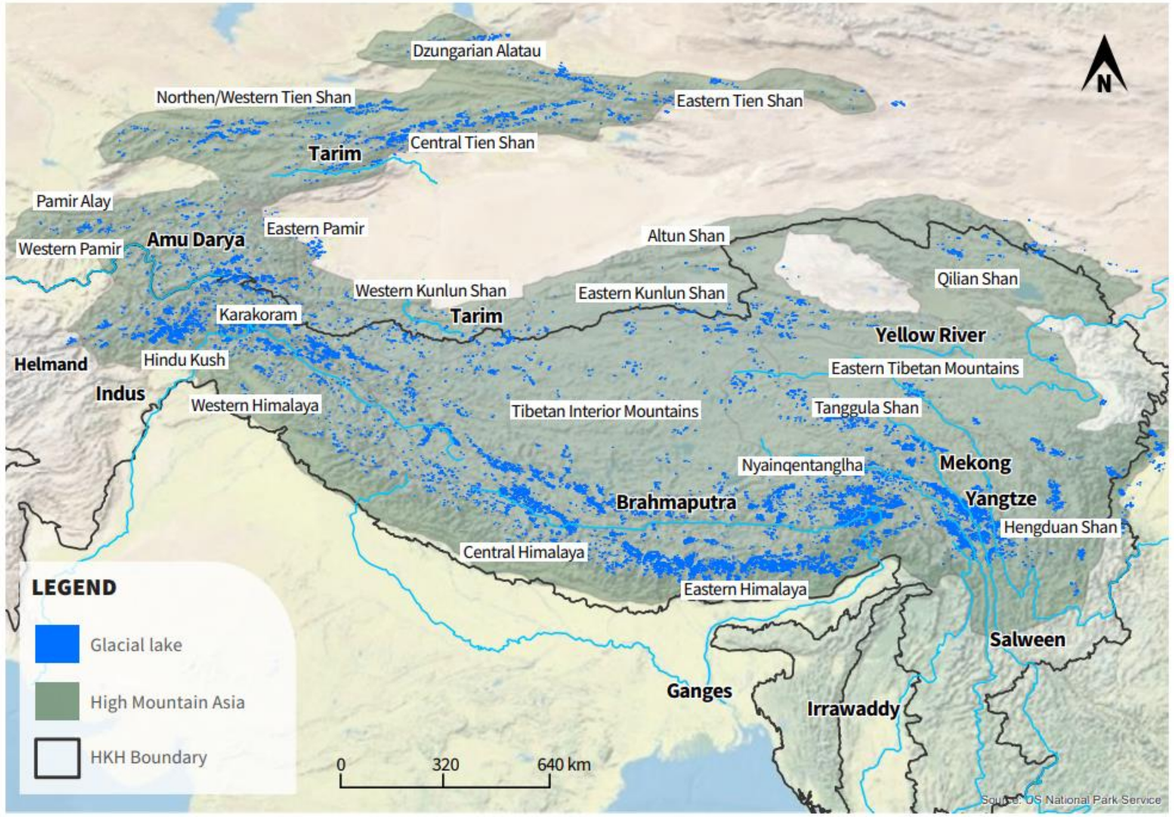
Oct. 12, 1987 - Oct. 9, 2021

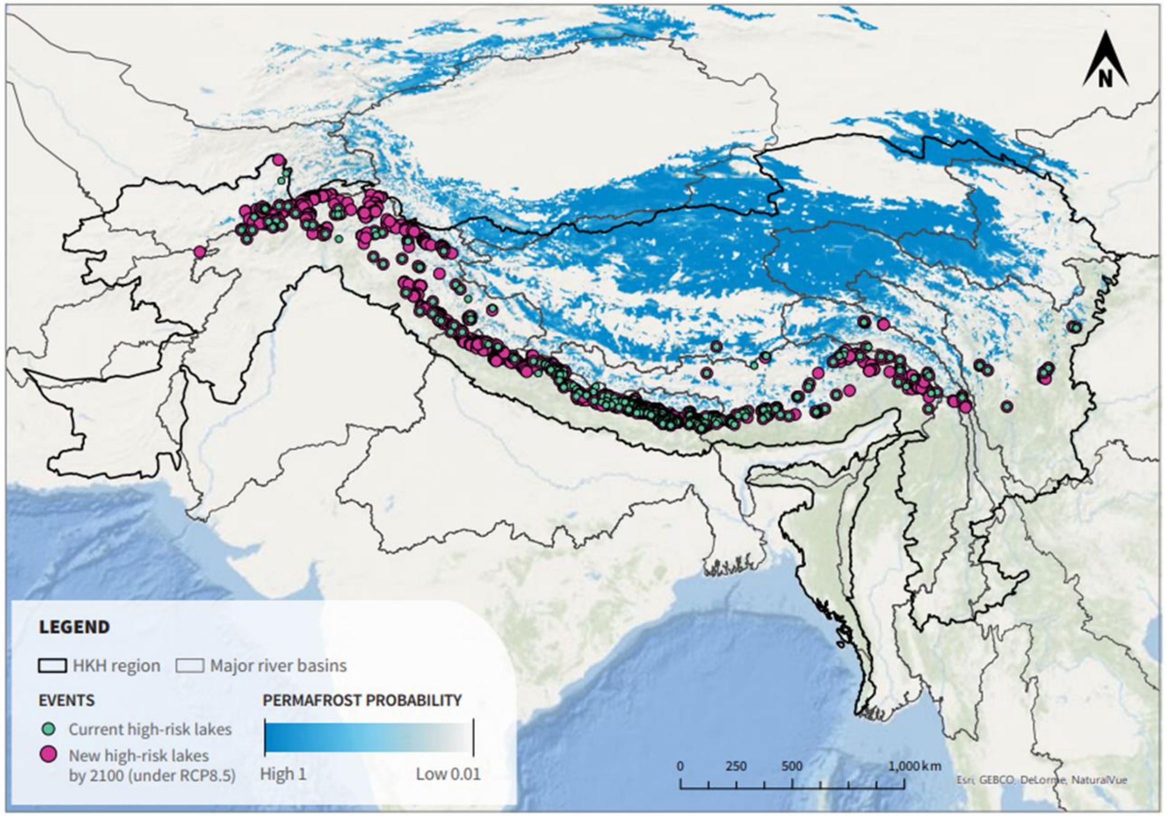
NASA IMAGES of CHANGE



The Tibetan Plateau, home to tens of thousands of glaciers, is very sensitive to climate change. Water from melting glaciers has created hundreds of new lakes and enlarged existing ones. As the water in the two lakes rose, it eventually covered the barrier, merging the lakes by the time of the 2021 image. Read more at NASA's Earth Observatory

Distribution of glacial lakes in the Hindu Kush Himalaya





Source: Glacial lakes data X. Wang et al. (2020), HMA boundary Bolch et al. (2019)

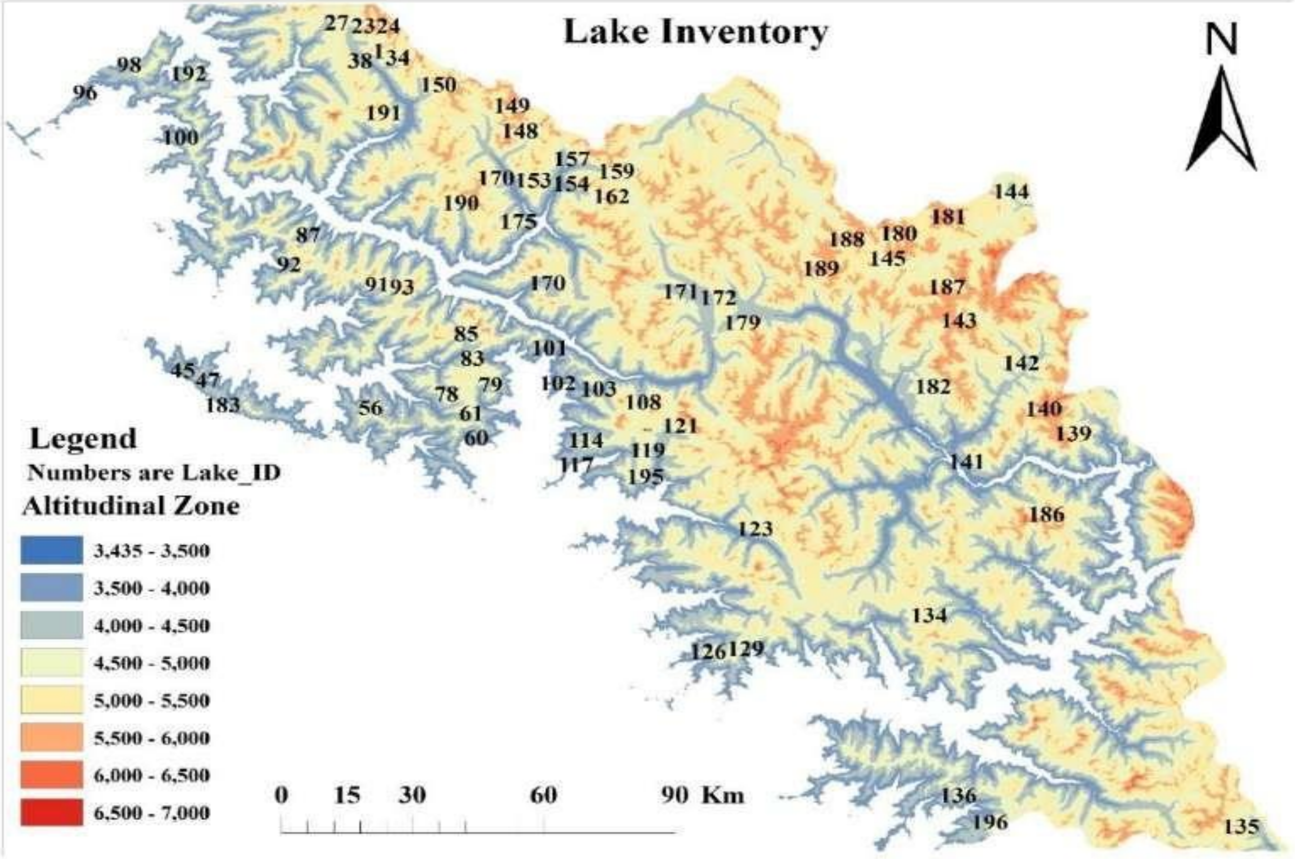
Glacial Lake inventory

It is estimated that there are over **8,000 glacial lakes** in the Hindu Kush-Himalayan region with more than 200 of them identified as potentially dangerous.

UNDRR, 2010

A total of **25,614 glacial lakes** covering an area of 1,444 sq. km were identified within the five major river basins — Amu Darya, Indus, Ganges, Brahmaputra, and Irrawaddy, including Mansarovar Interior Basin — in the HKH.

ICIMOD, 2018

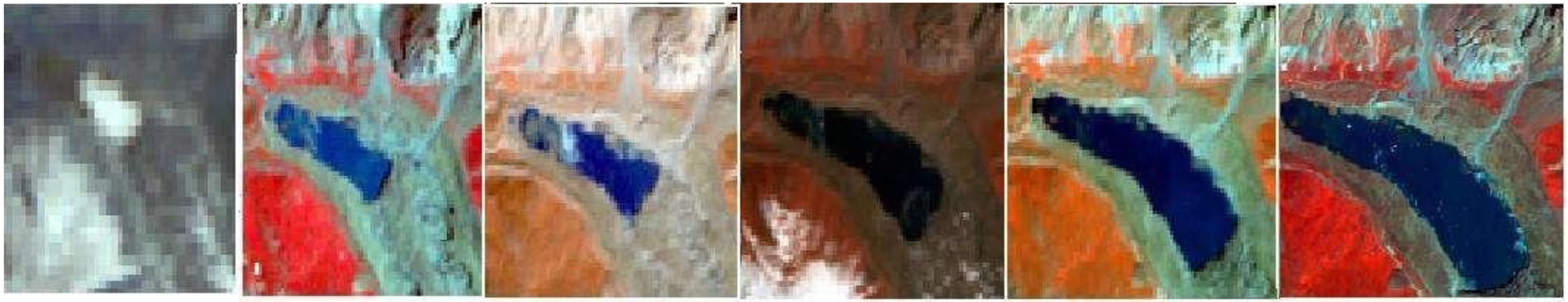


Around 200 GL has been identified in L&S district using 30 m spatial resolution Landsat images

Volume and Q_{max} of Glacial lakes of Lahaul and Spiti District

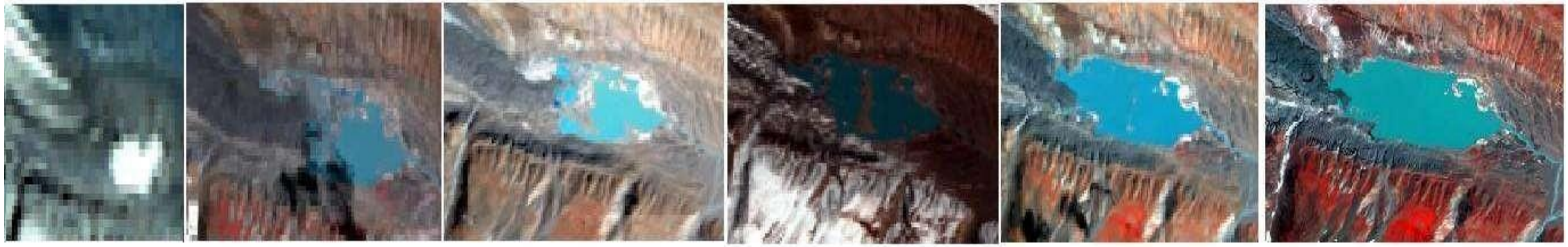
Lake Name	Longitude	Latitude	Area	Average Depth	Volume (million m^3)	Q_{max} (m^3/s)
L&S_gl_3	76°55'53.79"E	32°52'0.55"N	26422.36	20	528440	49
L&S_gl_7	77°30'5.16"E	77°30'5.16"E	25551.68	20	511020	48
L&S_gl_8	77°11'42.70"E	32°45'43.73"N	65510.32	20	1310200	90
L&S_gl_9	77°16'48.46"E	32°50'40.01"N	49434.56	20	988680	74
L&S_gl_10	77°19'45.97"E	32°43'22.93"N	40182.65	20	803640	65
L&S_gl_11	77°20'50.52"E	32°42'17.83"N	46623.07	20	932460	72
L&S_gl_13	77°30'7.16"E	32°47'30.94"N	54668.90	20	1093360	80
L&S_gl_14	77°18'22.79"E	32°37'51.75"N	29821.73	20	596402	53
L&S_gl_15	77°13'06.25"E	32°31'36.57"N	778535.38	20	15570700	472
L&S_gl_16	77°37'1.14"E	32°36'16.09"N	57620.80	20	1152400	82
L&S_gl_17	77°32'49.18"E	32°29'54.13"N	1169571.64	20	23391432	620
L&S_gl_18	77°36'52.95"E	32°29'0.69"N	472779.70	20	9455580	338
L&S_gl_19	77°56'32.19"E	32°31'30.42"N	23892.57	20	477840	47
L&S_gl_20	77°26'50.96"E	32°14'43.23"N	47176.11	20	943520	72
L&S_gl_21	77°26'56.61"E	32°14'24.61"N	30683.02	20	613660	54
L&S_gl_22	78°4'56.28"E	32°25'21.49"N	25208.84	20	504160	47
L&S_gl_23	77°45'40.48"E	32°14'33.04"N	20262.83	20	405240	41
L&S_gl_24	78°7'14.23"E	32°22'48.13"N	22407.15	20	448140	44
L&S_gl_25	78°16'17.13"E	32°21'48.18"N	91228.59	20	1824560	112
L&S_gl_28	78°25'4.14"E	32°12'15.09"N	35701.23	20	714020	60
L&S_gl_29	78°29'15.77"E	32°8'56.68"N	46414.34	20	928280	71
L&S_gl_30	78°24'56.46"E	31°57'53.30"N	63320.82	20	1266416	89

Area change of Glacial Lakes



AUGUST 1989 OCT-2000 SEPT-2009 SEPT-2015 OCT-2019 OCT-2020

Lake_170 (**Geepang Gath**) growth since 1976-2019 (source: Landsat Data series)



AUGUST 1989 OCT-2000 SEPT-2009 SEPT-2015 OCT-2019 OCT-2020

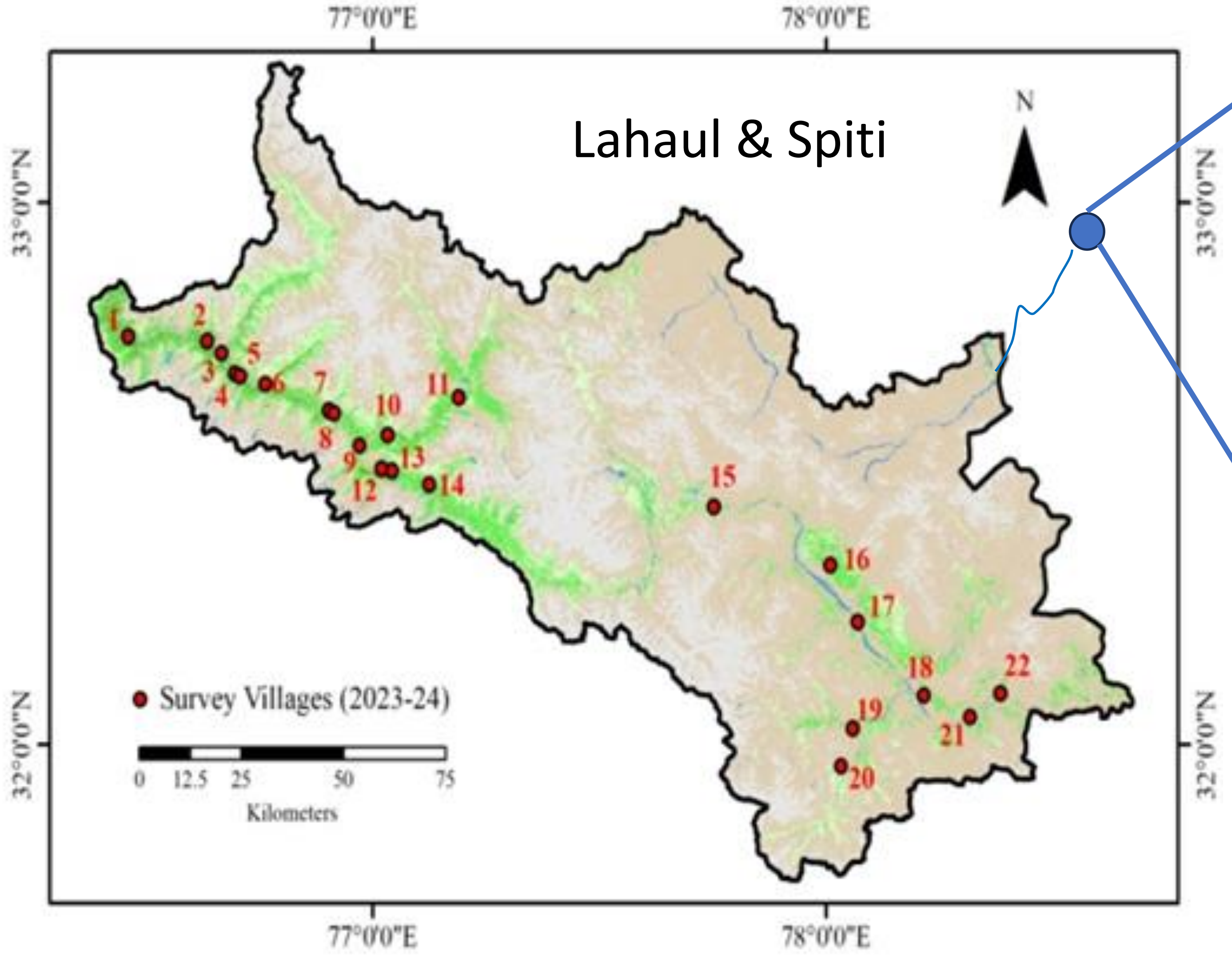
Lake_171 (**Samudra tapu**) growth since 1976-2019 (source: Landsat Data series)

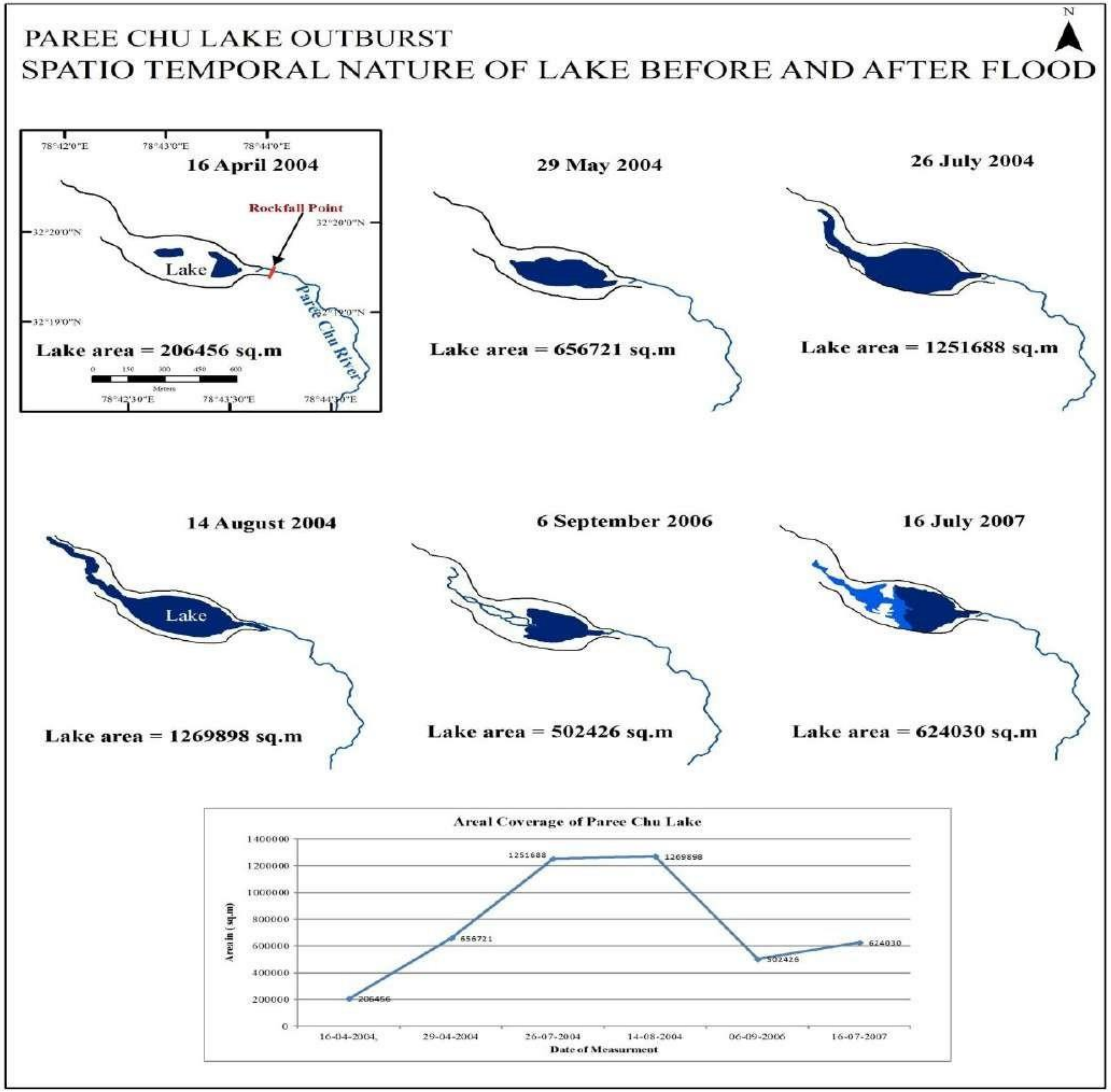
Recorded GLOF events in the Himalayan Region

No.	Date	Lakes	River basins	Country Effected	Cause of GLOF
1	Aug-35	Tara-Cho	Boqu/Sun Koshi	China/Nepal	Dam breach
2	21 Sep-64	Gelhaipuco	PumQu/Arun	China/Nepal	Glacier surge
3	1964	Zhangzangbo	Boqu / Sun Koshi	China/Nepal	Breach
4	25Aug-64	Longda	Gyrong / Trisuli	China/Nepal	Not Known
5	1968	Ayaco	PumQu / Arun	China/Nepal	Not known
6	1969	Ayaco	PumQu / Arun	China/Nepal	Not known
7	18Aug-70	Ayaco	PumQu / Arun	China/Nepal	Not known
8	3Sep-77	Nare	Dudh Koshi	Nepal	Moraine collapse
9	23Jun-80	NagmaPokhari	Tamor	Nepal	Moraine collapse
10	11Jul-81	Zhangzangbo	Boqu / Sun Koshi	China/Nepal	Glacier surge
11	27Aug-82	Jinco	PumQu / Arun	China / Nepal	Glacier surge
12	4Aug-85	Dig Tsho	Dudh Koshi	Nepal	Ice avalanche
13	12Jul-91	Chubung	Tama Koshi	Nepal	Moraine collapse
14	13Sep-98	TamPokhari	Dudh Koshi	Nepal	Ice avalanche
15	10Jul-40	Qunbixiama-ho	Kangboqu-Ahmchu	China	Ice avalanche
16	10Jul-54	Sangwang-Cho	Nianchu	China	Glacier advance
17	26Sep-64	Damenlahe-Cho	Nyang	China	Ice avalanche
18	23Jul-72	Poge-Cho	Xibaxiaqu	China	Ice avalanche
19	24Jun-81	Zari-Cho	Yarlung Zangbo	China	Ice avalanche
20	14Jul-88	Mitui-Cho	Palong Zangbo	China	Ice avalanche
21	7Oct-94	Lugge-Tsho	Pho Chu	Bhutan	Moraine collapse
22	June,2005	Parechu	Parechu-Spiti	China/India	Landslide

Source: modified after Mool, 2001

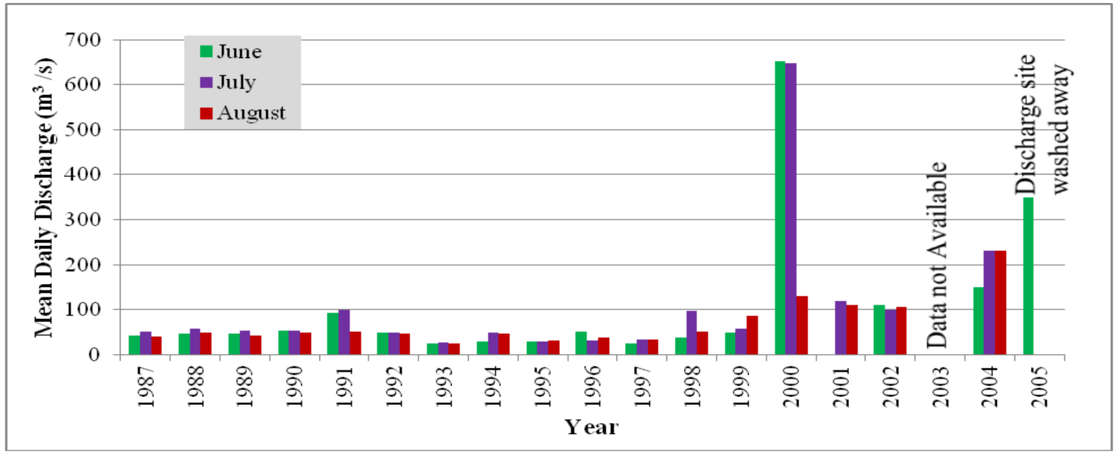
Location of Paree Chu Glacial Lake





Source : prepared from Landsat Satellite imagery

Discharge Characteristics of River Satluj



Water Discharge during GLOF

- The discharge measured at Khab on 26th at 10 am was 834 m^3/s.
- At 11:35 am, the water level rose to about 20 m. After that the discharge station was washed away
- It is calculated that discharge during this GLOF was about 2,000 m^3/s.
- Lake volume and Q_{max} calculated was 48256124 m^3 and 1007 m^3/s respectively

GLOF Hazard and Infrastructure damage

Damaged caused by 2005 GLOF at Sumdoh, a) Portion of NH 22 washed away by massive river water and b) An alternative track path developed to communicate to the Shailkher immediate after the GLOF.

Leo Village Before and After Paree Chu GLOF, 2005

Losses incurred
along the Spiti and Satluj rivers

S.No	Elements	Loss during 2005 GLOF
1	Human lives	NIL
2	Animal lives	03
3	Houses	66
4	Population affected	2400
5	Road	20 km
6	Bridges	10
7	Crop damage	20 Ha
8	Horticulture land	16 Ha
9	Total Loss	US $ 186 million

Rehabilitation of Leo Village

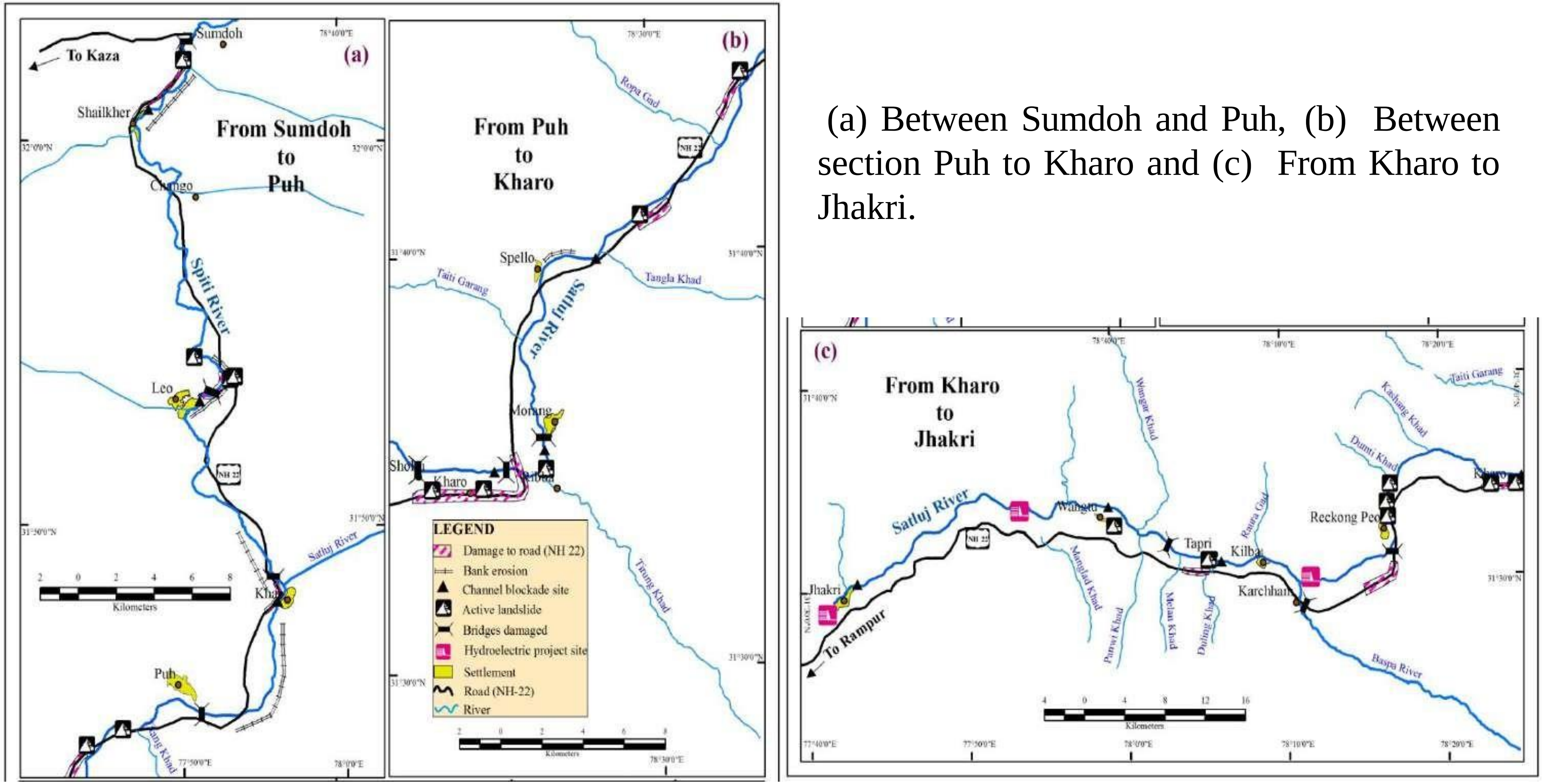
Upper and Lower Leo village, Hangrang Valley, November 2023

Secondary Landslide Lake Outburst (LLOFs) Imprints

Remnant of channel blockage caused by huge landslide in Satluj river near Spello, Kinnaur

Landslides in route Manali to Kaza

Damage along river Spiti and Satluj after Paree Chu GLOF



(a) Between Sumdoh and Puh, (b) Between section Puh to Kharo and (c) From Kharo to Jhakri.

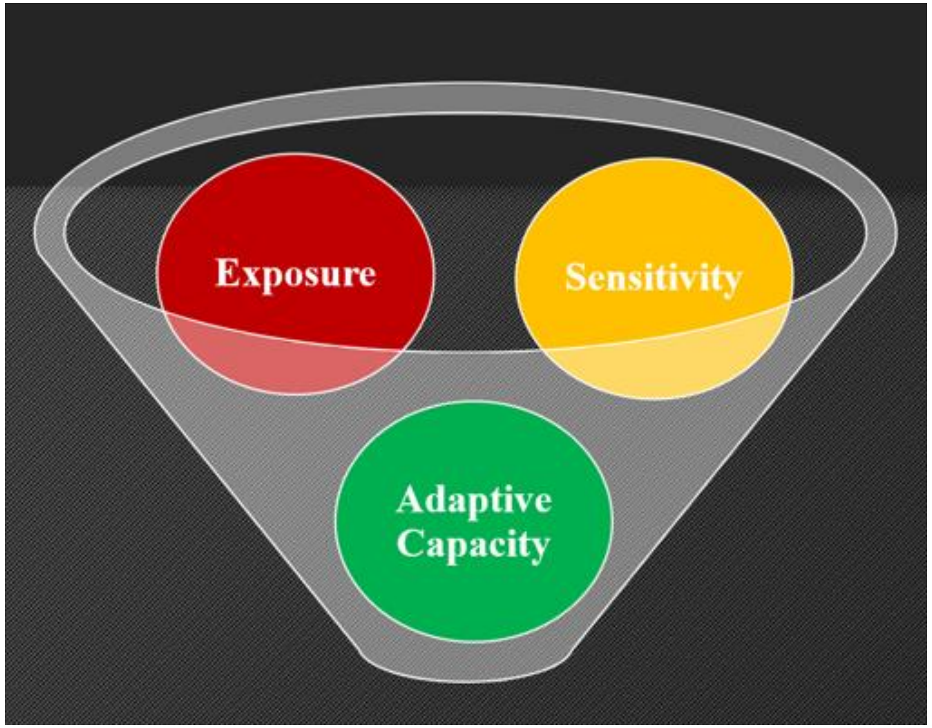
Sendai Framework for Disaster Risk Reduction 2015-2030

UNITED NATIONS

To attain **the expected outcome**, the following goal must be pursued:

*Prevent **new and reduce existing disaster risk** through the implementation of integrated and inclusive economic, structural, legal, social, health, cultural, educational, environmental, technological, political and institutional measures that prevent and reduce hazard exposure and vulnerability to disaster, increase preparedness for response and recovery, and thus strengthen resilience.*

Prime Minister's Ten Point Agenda on DRR



Agenda Point 5

Leverage technology to enhance the efficiency of disaster risk management efforts.

Participatory Geospatial Technology can play important role in increasing adaptive capacity can control exposure and sensitivity

Limitations

- ❑ Accessibility of required technology and meaningful connectivity (digital divide)
- ❑ Implementation of effective early warning system
- ❑ Limitations with regard to ground truthing and validation
- ❑ Prediction of Ungauged Basins (PUB)
- ❑ Spatial and temporal quality of Remote Sensing Data products
- ❑ Use of Geospatial technology in Spatial Decision Support by administration

Thank You

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