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Hydro-Geo-morphometric Dynamics of the Beas River Basin, India

Siba Prasad Mishra*, Bandana Acharya, Trisha Mukherjee and Esha Thakur

Department of Geo-informatics section, Civil Eng., Centurion University of Technology and Management, BBSR, Odisha, India

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*Corresponding Author: **Siba Prasad Mishra** | Email Address: **2sibamishra@gmail.com**

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Abstract

The perennial Beas River sub-basin is housed amidst thrusts and faults inthe Western Himalayas, which are prone to regular earthquakes, forest fires, flash floods, road mishaps, epidemics, landslides, floods, and GLOFs. Theseextremelydevastating eventshave surged from 2021 to 2025.The comprehensive Catalogue for data on disasters is publicly unavailable. The present study attempts to have an initial thrust to the area and uses GIS/RS sources to visualise the physical stratification of the sub-basin.A physical survey of the aftermath of the flash flood of 2023 at Kalath village was conducted. The research reveals the highest escalation in landslide occurrences, followed byflash floods and forest fires,than the other multi-hazard events. It is pertinent to prepare a database for forthcoming researchers to build a safe and disaster-resilient Beas River sub-basin in Himachal Pradesh. A holistic, proactive, and technology-driven strategy including preparedness, response and prevention, and mitigation, through nature-based solutions involving all stakeholders and fostering anaffordable action plan to a resilience culture of shared responsibility.

Keywords: *disasters, the western himalayas, himachal pradesh, GIS/RS, google earth engine*

Introduction

Inconsistent monsoon coupled with global warming, andWestern Disturbance(WD), has led to the highest rainfall accompanied by glacier melt, causing the rivers and glacial lakes toswell,causing irregular flash floods, debris flow, and landslides,increasing wet flow, destroying infrastructures, disrupting power, communication, and electricity, and badly affecting the agriculture sector(1).

The Beas River (BR) (Vipasha River) sub-basin emerges from Beas Kund (Rohtang pass) 4360mwithin the PirPranjalzone of the Western Himalayas (WH) and runs for 246km in HP to enter Punjab and finally debouchesintothe Sutlej River at Harike. The sub-basin has bounty power potential of hydro-electric sources of the Beas River sub-basin is projected at 4877MW (DoE, HP), spread across 51 projects, commissioned 2820.9 MW by 2019 through 22projects, and 15 projects in the pipeline with a total capacity, 947 MW (3).

The BR Sub-basin has received torrential rainfall in itsbasin area of 1404km^{2}in HP State,a tributary to the Sutlej River in the Sindh River System. The heavy rain has disrupted the communication,causing heavy pilgrims to bestrandedon their route from Chamba to Bharmourfor the ongoing Sri Mani Mahesh Yatra in 2023. The BR Sub-basin received 45 cloudbursts, 91 flash floods,and 105 major landslides,resulting in161 people dead, and 40 were missing. 154 people have died in road accidents, 845 houses were fully damaged, and partly damaged 3254 houses, along with 780 roads that are yet functional, 360 water supply schemes are inoperable, and 2274 transformers are downas of 1st Sept 2025, alarming the HP Govt.,vide HP Rev Dept. (DMC) lr. No 11-1/2023 /01.09.2025. (40)

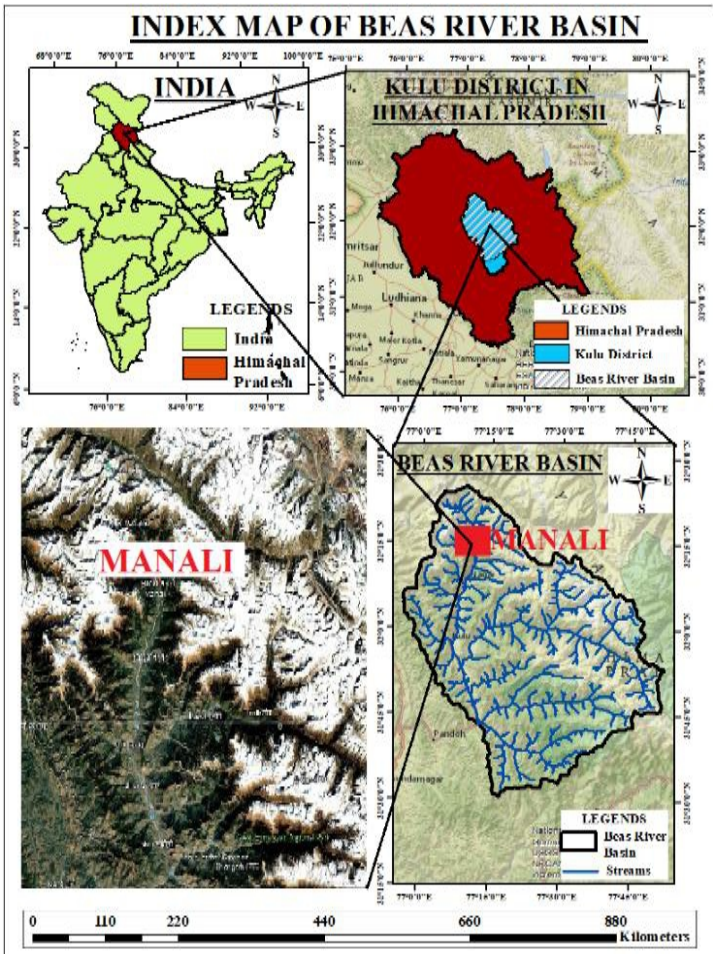


Fig 1: The index map of the study area in the Beas River Basin, Himachal Pradesh (HP)

Table 1: The status of disasters in HP, India, from 2020 to 2025, including damages caused

Year	Items of disaster	Death/Financial Loss in HP	Source
	In numbers	numbers/INR in Million	
2020-21	CB: 3;	8650mi INR; 161 deaths;	Him Dhara; 1/8/2025; Env. Research and Action Collective; Monga Bay; SANDRAP-2023
2021-22	16-LS; FF:17; CB 30	11510mi INR; 246 deaths and in damages, where Landslide death was 218	
2022-23	LS:117; CB:20; FF:75; Mandi,18 Lahaul&Spiti, 15	25160 mi INR; 276 deaths; Nigulsari landslide; Batseri and Nalada LS.	The Economic Times; PTI;Last Updated: Mar 12, 2023
2023-24	LS:5748; CB: 45; Floods: 83	90570 mi INR/ 428 dead; 427 injured; 39 missing; 135013ha/ 16000 live-stocks dead.	Him Dhara; 1/8/2025 Env-ironmen Research and Action Collective
2024-25	CB:46; Flash floods: 98; Major LS: 146	16130 mi INR; 358 dead; 46 missing; 209 stranded; 145 cattle dead; 20 road bridges damaged	Himdhara;1/ 8/2024 Environment Research and Action Collective (Rajat et al, 2023).
2025-26 (June 20, 2025, toSept 9, 2025).	CB:45; FF:97; Major LS:146;	≈43130INR mi; 393; Injured 437; dead; 43 missing; FHD: 1237; WSS:423: PHD: 5319 houses, 26955cattle missing,	Himachal watcher 11th July 2025; People's democracy 14 Sept 2025. (updated)

The estimated loss to crops is Rs 5164 lakhs, and Rs 2,743 lakhs to horticulture crops in 2023.Cloudbursts, flash floods, and landslides are common in the Beas River sub-basin.The Himalayas'transformation from more rain to less snow is exacerbating the devastation.(4), (5), and (6).

The Beas River Sub-Basin (study area)

The BR subbasinemerges from Rohtang Pass at Beas Kund, flows for 470km, and has a catchment area of 20,303 km^2, with a glacier area of 777 km^2 (39).The source of flow is snowmelt fromParvati Glacierduring summer, SW monsoon precipitation,and westerly disturbances in winter. ThePandoh, Pong Largi, and BasaiDams are the major hydraulic interventions. The elevation of the basin as per the DEM map varies from 853 m (at Pandoh dam) up to 6533 m (on the Northwest Border) (7).The Beas River sub-basin includes major drainage systems from the districts Kangra(89%), Hamirpur (73%), Kullu (87%), Mandi(73%),Chamba (9%), and Una (5%). The mean annual R/F of the subbasin is 1821.9mm/year. (41).

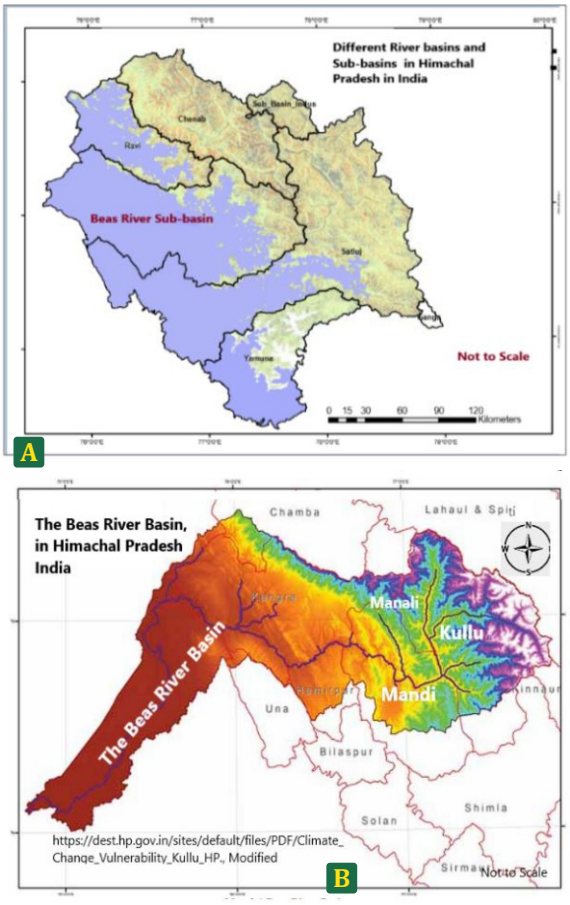


Fig. 3 (a-b); a)Thedrainage map of Manali (b) The BR Sub-Basin in HP

Source: *https://dest.hp.Gov.in/sites/default/files/PDF/Climate_Change_Vulnerability_Kullu_HP*

The Beas River sections

Beas is a tributary of the Sutlej of fifth order following the regional slope, in its upper U-shaped valley. But near Aut (Mandi and Kullu border) at the Dhauladhar range, the U-shaped valleys are a narrow Gorge, theLargi Gorge (Fig 3 (a-d).

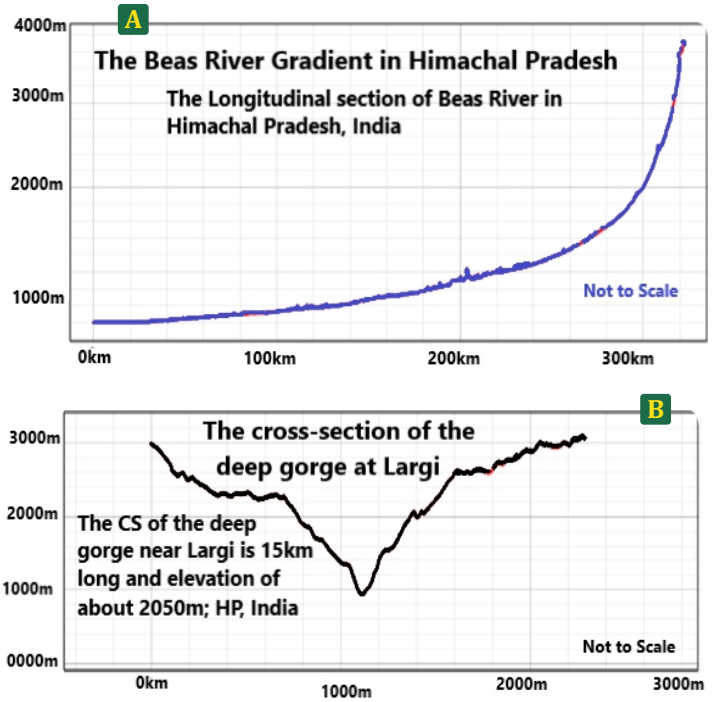


Fig 3(c-d): (a) The longitudinal Section of the Beas River (b): The cross-section of the deepest gorge at Largi (15km long)

The V-shaped Beas River entersHP at *Sandhol(Kangra)up toAut (steep slope about 40m/km) and U-shaped latertill Pong damwith a gentle slope(≈3 to 4m/km)* near *Beas* cut through the Dhauladhar range, having polycyclic terrace(erosion and deposition). The Largi Gorgeformationindicatesthat BR evolvedas a precursor to Dhauladhar,Fig. 3 (c and d)

Review of Literature

The cloudbursts in the Himalayas trigger the disaster intensities, glacial melts, and devastating floods. The anthropogenic pressures and climate change are magnifyingthe disasters in HP. Himachal Pradesh experienced numerous extreme events, including rainfall, landslides, and flood hazards, at various locations during the 2023 southwest monsoon, resulting in 428 fatalities; however, the actual report indicates higher figures. (8).

From 2014-2017, monsoon-induced disasters caused 3058 accidents, 1199 deaths, when the population was about 7.36 million (9).

The disasters in HP state have multiple disasters, monsoon-induced, disrupting the power, transport, water supply,and communication (10),(11),(12), (38).

By mid-September 2025, HPconfronted devastating heavy precipitation,followedbyextensive flash floods, debris flow, and landslides, causing over 400 reported fatalities and colossal financial losses≥₹459.5 million INR The state the HP is a hub for disaster-prone special BR sub-basins.People's safety in unsafe places remained the top priority, and reliefwas allowed to the needy bythe HP Government, during Heavy rainfall on 16th Sept 2025(42).

During the 1905 Kangra earthquake, numerous landslides occurred in the Beas River (BR) valley between Kullu and Manali. The players in landslides in the Beas River sub-basin include unsafe road-cutting slope, roads without drainage, high monsoon rain, soil overburden, and high soil pore pressure. (13), (14), (15), (16) & (17).

The Himalayan ecology is under jeopardy due to Population rise, tourism, and industrial activity strain the fragile Himalayan ecology. The common playersare deforestation, soil erosion, Hydropower, built-up area augmentations, Urban developments, tourism,and pressure on limited land (18).

The trend in aggravation of Geo-hydro disasters in the Beas River basin is sparsely studiedusingmodern geo-informatics tools. The presentsearch is an attempt to collect historical records and analyse them to reach an effective river basin management plan.

Objectives

The Beas River Sub-Basin is a land of disasters in the valley of the Gods**.** The objective of the study is to have a glimpse of the various geohydrological disastersthat kept the stakeholders of the state in constant fear. The present study is envisaged with the objective:

I. The BR sub-basin isvulnerable to multipledisasters and the conducive factors that induce these geo-hydrological disasters.

ii. The study of the area using the geographical Information system (GIS) is causing the vulnerability.

iii. A case study of the flash-flood disaster in 2023 in the Kalath Village nearManaliis discussed.

Methodology

The districts of Kangra, Kullu, Mandi, Hamirpur, and Chambaare within the BR Sub-basin.The Data used in the study are HiFlo-DAT (Himalayan Flood Database): Kulluin HP, HPSDMA data, Revenue Dept. data, and Him Dara, newspapers;Specifically, in the present study, the analysis of the flood disaster of the Manali water shade region atKalath Village near Manali bythe field survey and GIS, and Remote sensing analysis was conducted using QGIS 3.14 software. For stream ordering,the Strahler law has been followed. This study needs the morphometric analysis using the most efficient tool, the GIS & remote sensing methods, Nayak et al, 2020, (34)(Fig. 2)

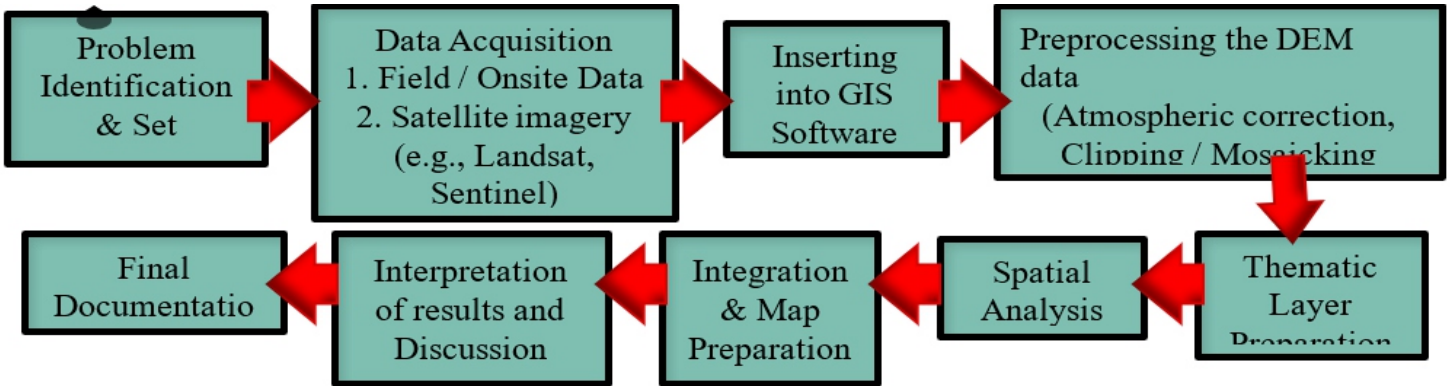


Fig 2: The index map of the Beas River (BR) in HP in the Sindh system, India

The spatial maps, like Administrative, DEM, and Land use and land cover maps, and non-special data such as Climate and weather data received and analysed for climate change (CC) vulnerability and adaptations. The open-source interface management, Quantum GIS, is used for geo-morphometric analysis and trend analysis.

Geographical and Physiographical setting

The touristcity in the high-altitudeSub-Himalayas isManali in the Kullu Valley,Mandi, etc.,locatedat an altitude of 2050m, and is north-oriented. The mountains haveperennialsnow-covered peaksat 5000m MSL.The important tourist explored peaks are the Solang Valley (≈3000m), Leh–Manali Highway (in Lahaul and Spiti), Atal Tunnel, and Rohtang Pass, etc.

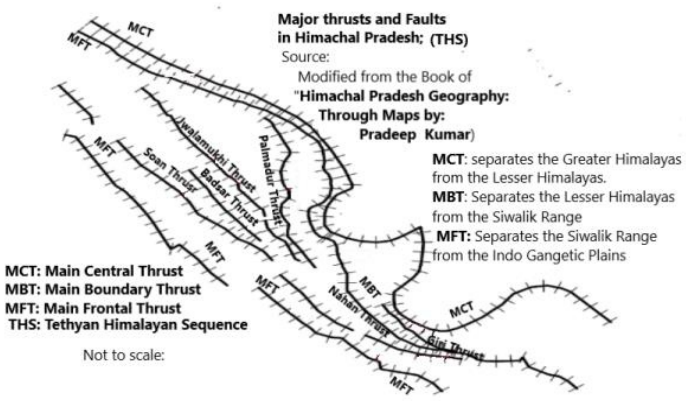


Fig 3: The Major paleo-seismological thrusts and faults passing the BR sub-basin ; (HP)

The Himalayas formed 50-60 mi YBP, due to the collision of the Indian plate with the Eurasian plate. Continuous northerlymove of the Indian plate created fault lines along the entire length of the Himalayas arethe Main Central, Main Boundary, and Main Frontal Thrusts,called as (MCT, MBT), and MFT,respectively, with many paleo-seismological signatures.They are responsible for Landslides and earthquakes (Eqs).

The Drainage System of the Beas Sub-basin

The main tributaries that join the BR sub-basin are the Parbati, Sainj, Tirthan, and Suhail rivers, along with the Chakki, Gaj, Luni, Bain, Banganga, Uhal, Harla, and Suketi etc. Some Major tributaries to the BR Sub-basin are in Table 2 and Fig. 4.

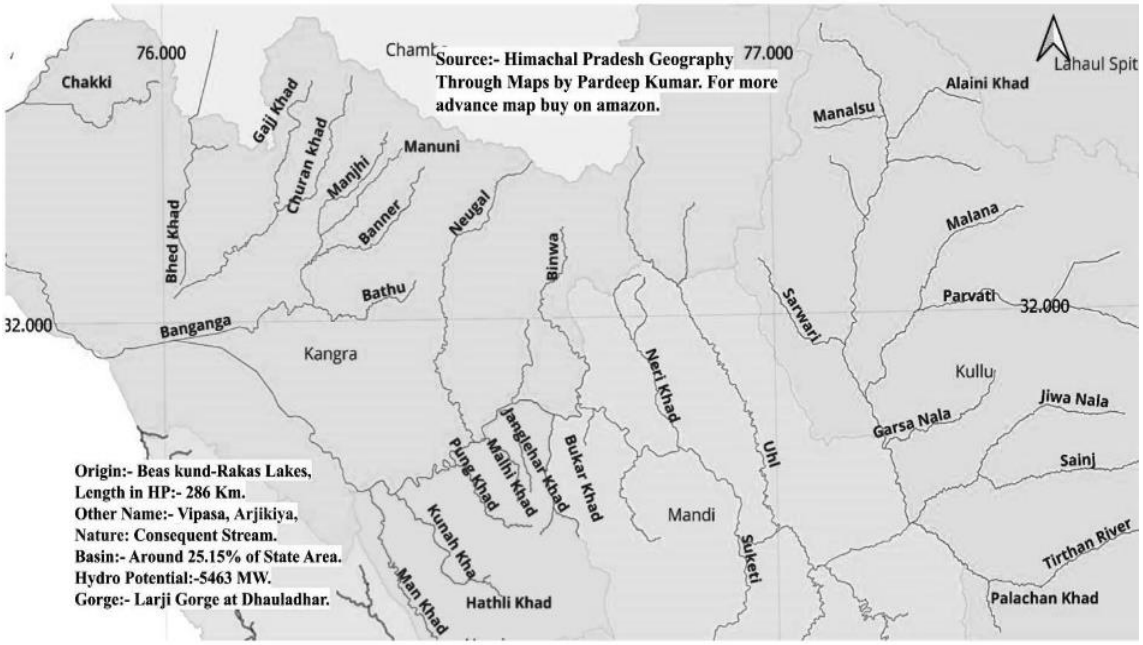


Fig 4: The various tributaries that join the BR River and their details, Himachal Pradesh. (43)

Table 2: Some important tributaries to the Beas River through the Western Himalayas in HP

#	Rivers (R.)	Originating from	Feeding valley	Flow Direction
1	Awa River	Dhauladhar range	Snow & water from the Kangra valley	Southwest
2	Banner Khad (River)	Southern slopes of the Dhauladhar range	Palampur (Central Kangra valley)Small snow-fed channel	South west
3	BangangaR.r	Southern slopes of the Dhauladhar range	Kangra Valley,snow-mixed waters and springs.	Southwest
4	Chakki R.	Southern slopes of the Dhauladhar range	Fed by snow and rain near Pathankot.	South-west part of HP
5	GajKhad	Southern slopes of the Dhauladhar range, Kangra dist.	Join BR in U/S of the Pong dam (MaharanaPratapSagar.	South-west part of HP
6	Luni R.	Southern slopes of the Dhauladhar range	Central part Kangra valley; Join the Beas	South-west part of HP
7	Uhl River	Lake of Thamsar Glacier,Dhauladhar	Upper Himalayas, Join the Beas at Mandi	Flows southeast
8	Manuni R.	SW slope of Dhauladhar; JoinsBaner R. then meets Beas at Haripur	Join Beas through a high gradient;it flows in the Kullu and Kangra valleys. Huge terraces for cultivation	Flows with many drains SW-ly
9	Parvati R.	Man Talai Glacier, Near Geothermal Spring Manikaran,ParvatiValley	Joins Beas at Bhuntar near Kullu.MalanaNala, Mani-karanNala, and ChalalNala	With other drains. Fall in the Beas R. from SW.
10	Sainj R.	Origin: Great Himalayan National Park and joins the Beas River near Larji	Confluence Pt. of the Beas and Sutlej in the lower Himalayas(Sainj valley); A hidden paradise	Flows SW-ly

Source: *Joktacademy (44)*

Forest Fire in the Beas Sub-Basin

The BRsub-basin is expectedto have fluctuations in numbers and area of lakes, particularly smaller ones susceptible to outburst events. The CC is a pivotal player in accommodating more meltwater and the possibility of moraine-dammed lakes (rock and debris) breaching, creating dangerous flood settings in the downstream basins. Monitoring these lakes with satellite data is essential to know about the risk to survival and infrastructure. In the BR sub-basin of HP, the forest fire events are a recurring threat during the dry period, from March to June. The lightning triggers the fires; Anthropogenic activities initiate the hazard. There was a paucity of rainfall and intense snowfall in the winters of 2023–2024 in the BR Sub-basin, which exacerbated an increase in fire incidents. The list of forest fires fromJanuary 23 to January 25 is in Table 2.

Table 2: The exaggerated forest fire in the various districts in the BR Sub-basin HP state from Jan 2023 to Jan 2025

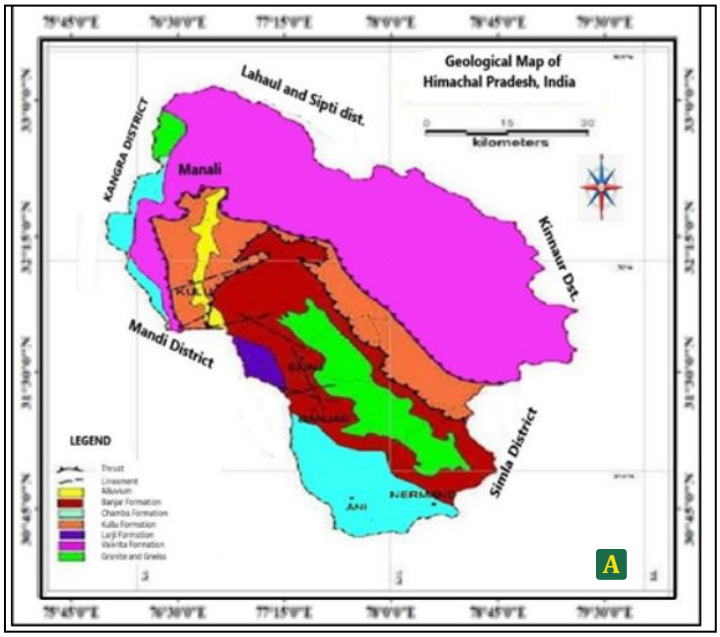
	AdministrativeArea2	Date	Area
1	Chamba district	2024-01-01	941 km^2
2	Mandi district	2024-04-01	876 km^2
3	Chamba district	2025-01-25	855 km^2
4	Hamirpur district	2024-04-24	787 km^2
5	Kangra district	2024-05-17	774 km^2
6	Kangra district	2023-04-04	697 km^2
7	Mandi district	2024-02-14	610 km^2

The forest fire has not only burnt out the forest vegetation, destroyed the ecosystem, and invited greater disastrous events like flash floods, cloudbursts,and GLOFs.As per the Central Water Commission, GLOFs (Glacial Lake Outburst Floods) have a risk in the basin.Kullu district has only high and very high-risk zones for Forest fire, which are 1,187Km2 and 1324 Km2 out of the total forest area 5495Km2.

Limnology and Paleo seismology BR Sub-basin

Geologically, duringthe Proterozoic formations (middle period),the HP was formed. The rocksarephyllite, slate, quartzite, limestone, schist, and granite,after the rock types or local names. The groups are the central genesis of the Kullu formations, the Banjar formation, and the tourmaline granite. The large formation contains thick layers of grey dolomite and pink limestone, besides slates, phyllite, and quartzite. The intrusive tourmaline granitesare the sources of high radioactivity, characterized by the existence of hot springs.The geological setting is amongst Bery (gemstone), Slate quartzite (Construction stones and roof slabs).

The positioning in the foothills of the Himalayas (juncture of two active tectonic plates), the BR sub-basin is highly susceptible to severe seismic activity, as it lies in the seismic zone IV and V of India (Fig. 3 b) covering 53.1 % of the basin for the severest EQ of MSK IX or more.



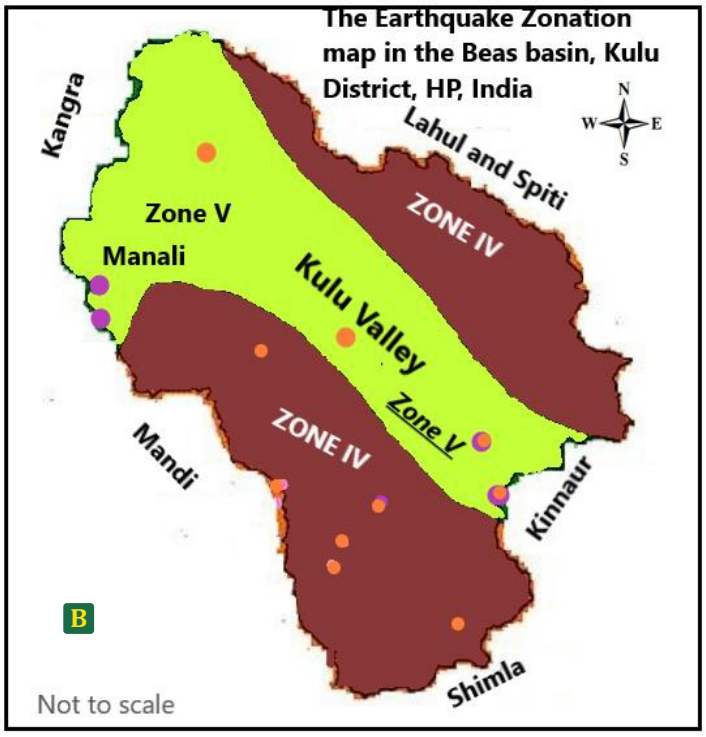


Fig 3(a & b): (a) The Geological map of the Beas River basin, (b) The EQ zonation map, the Kullu valley in HP. India (Source modified: HPSDMA)

The BR sub-basin is seismically dynamicas housed in the Indian continental collision zone, and linked to major fault systems,i.e., the Main Boundary Thrust (MBT) and Main Central Thrust (MCT). Since 2024, the BR sub-Basin (Kullu dist.) has encountered 25 quakes of optimum magnitudes up to 4.2: Richter Scale (RS), (19) shown in (Table 2).

Table 2: The Earthquake Disasters and the land of the Beas andKulluvalleys, H.P., India

Type	RS	Affecting the area	Details and Losses
4th April 1905	7.8	Kangra (Himachal Pradesh)	28000 dead, damaged 20000houses, 29mi INR
28th Feb 1906,	6.4	Plate tectonics(Karshing),	26-year-old, 45 injured
11th May 1930	6.0	East of Sultanpur HP.	No report about damages.
22nd June 1945	6.0	At Padua, the HP and JK border	Damage report not found
10th July 1947	6.0	At Padua, the HP and JK border	Damage report not found
12th Aug 1950	6.0	At Padua, the HP and JK border	Damage report not found
12th Sept 1951	6.0	Near Chamba, HP,& JK border	Damage report not found
17th June 1955	6.0	At Lahaul&Spitiin HP	Damage report not found
17 June 1962	6.0	ChambaUdhampur in HP	Damage report not found
19th Jan 1975	6.2	Kinnaur, Lahaul&Spiti, DutungHP(Indo-China border)	60 killed/2000 homes damaged.
April 1986	5.5	Dharamsala Area (HP)	6 died, highhouse damage
March 1995	4.9	Chamba (HP)	>70 % houses faced cracks
July 1997	5.0	Sunder Nagar (HP)	Sunder-Nagar part affected
11th Nov 2004	5.1	Kangra Valley and the Dhaula-dhar Mountains (moderate)	RoadKangra-Dharamsalawasruined, and thehousewas damaged
08th Oct 2005	7.6	The India-Pakistan border, but HP was affected	In North India, 10people died.
19 May 2014	4.0	Kullu Valley Beas basin	No death and less stuff loss
20th May 2014	4.0	Kullu Valley Beas basin	No death; less property loss
27 Aug. 2016	4.6	Kullu district	No death or property loss
14th Mar 2025	5.1	Southwest of Padam, HP	Less damagewith cracks
18th Aug 2025	4.2	Himachal Pradesh,	Structures were cracked

Source: *(20), (32), (45), (47)*

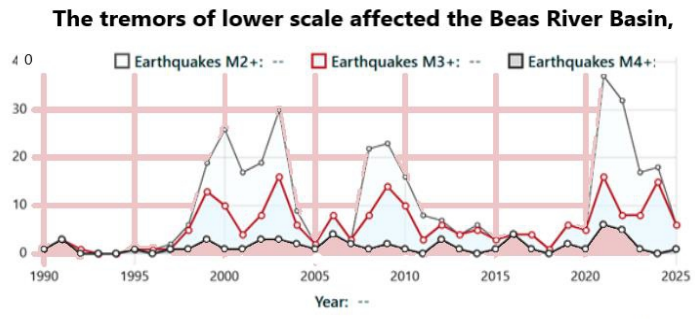


Fig 3: The surge in the number of small earthquakes in the Beas River basin (1990-2025)

source: *https://www.volcanodiscovery.com/earthquakes/india/himachal-pradesh/kullu/stats.html*

About 17120 landslide-prone sites are in the HP state, India. The statistics of no of identified landslides in BR sub-basins areChamba (133pla), Mandi (110), Kangra (102), Una (63), Kullu(55), Shimla (50), and Kinnaur (15), respectively, as per HPSDMA.During 2023,as per the Economic Times, Mar 12, 2023. The causes of these huge landslide hotspots are attributed to significant light tremors, extensive cutting of hill slopes for road upgrades, blasts for tunnel construction, hydroelectric projects, and mining activities.

Table 3: The major landslides prone hotspots created in the Beas Sub-basin 1968-2025

Area	Date/month/year	Place	Damages made
Maling	1968		Damaged 1 km of NH-22
Kinnaur	Dec 1982		SholingNallacollapsed;a 1.5 km road with 3 bridges waswashed..
Jhakri	March 1989	Npatha	The 50m road was disrupted
Luggar Bhatti	12.09.1995	Luggar Bhatti	65 people buried (Govt report is 39)
Solang, Kullu	07-08-2003	KangniNallah	30 dead, 19 injured, 9 missing, and 2 dead (in the Bahangnallah LS.
Anni sub-division	21/22 Aug 2001	KulluBadhali and Sarli Vil.	Badhali: two buried, two injured, Sarli: 7 dead and land/bovines lost.
Between Raison and Manali	26.02.2011	Manali	Collapsed terraces, uprooting and falling of trees, disrupting vehicular traffic at Raison, Dobhi, Alu Ground, Rangri, and Manali.
Snow Weight	05.03. 2011	Manali	Blocked roads, tele-wed and electricity disrupted, and a four-story building collapsed in Malana vil.
Rohtang	21.7.2011	Kullu District	Two killed, 22 injured, and at least a dozen missing (TOI)
Manali- Leh	16.09.2012	Manali -Leh Highway	The blocked Manali-Leh highway is leaving people stranded in between.
Kullu – Anni Highway	28.8.2013	AnnefromNirmand disconnected	Blocked villages falling under 58 panchayats in Anni and Nirmand of Kullu dist., cut off for one week.
ManikaranGurudwara-Kullu	18.08.2015	Manikaran	Derelict a Gurudwara building. 7 pilgrimswere dead/11 injured with loss of Rs. 2.910mi million. INR.
Pancha-Manihar Road	02.09.2016	Parbati HE Proj., Stage-II	9 people were affected (5 killed + 4 injured); buried alive during the slide.
Kotrupi Land slide	12^{th} -13^{th} Aug 2017	Near NH 154 (Road Mandi to Pathankot	Engulfed forty-six human lives and Cattle, Agriculture farms and NH
Nagar-Patti-Kuehl road	09.07.2023	Landslide and flood	Bank erosion and incumbent load washed away the abutment
LS: Landslide R/F : rainfall; HE Projects: Hydroelectric;TOI : Times of India; Proj: project			

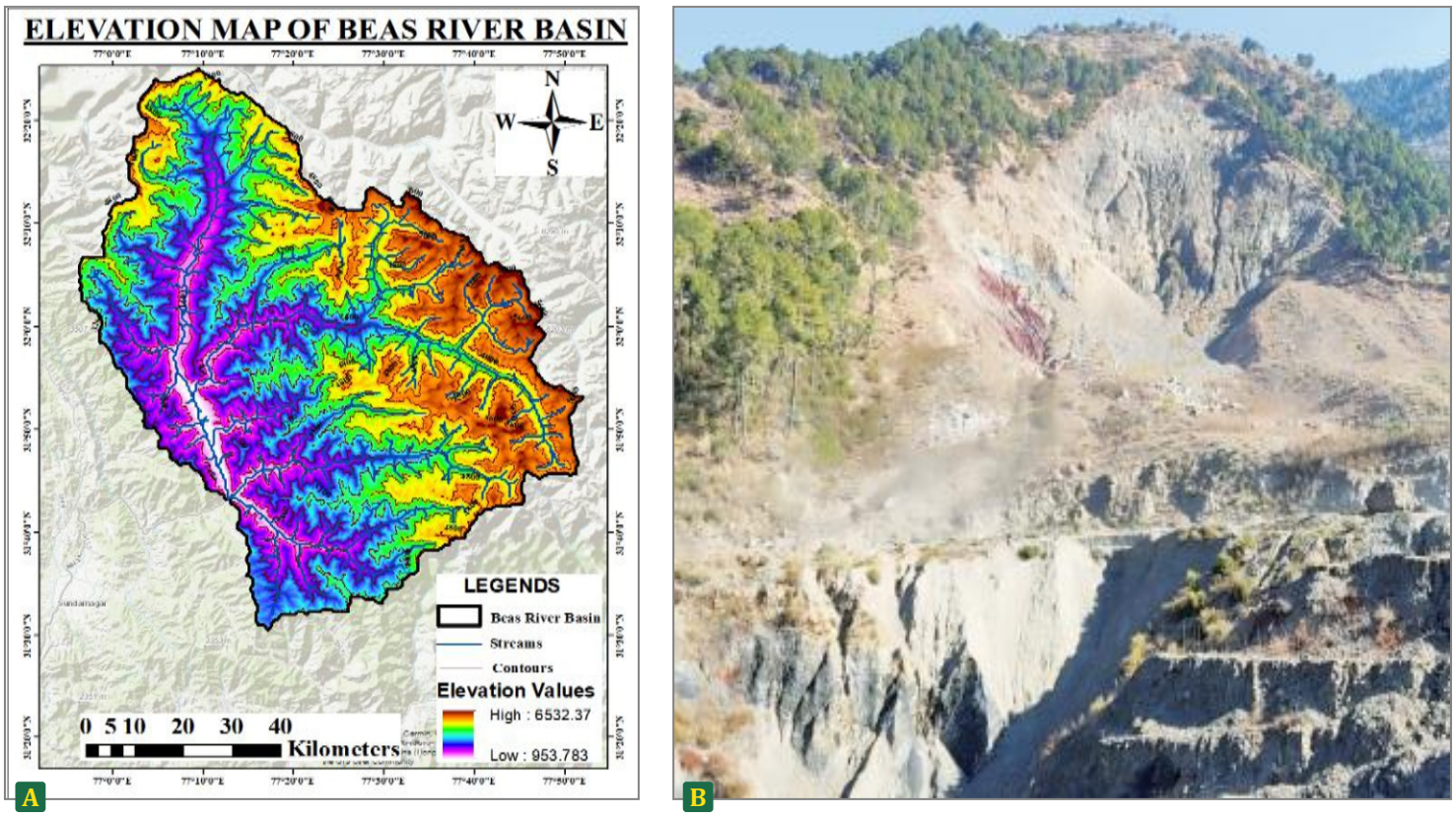


Fig 4: (a -b): (a) Elevation map of the Bias basin,b)Kotrupi Landslide, HP 2017

The major landslides in the Beas River valley are at Marhi, Chhyal, Bhang,and Mandu in the upper catchment of the Beas River (BR). The BR Sub-basin) includes Kullu, Mandi, Kangra, Hamirpur, and Una in Himachal Pradesh.The elevation of the Kullu district lies between 950m and 6530m, indicating the terrain in the high mountain range. The tributaries decanting to the Beas have deep gorges, and the NW part of the basin is in mountains with low drainage density. The landslide proneness of the districts as compiled by the BMTPC is as under Table 4 (a)

Table 4 (a) Landslide Prone Areas of BR Sub-basin, Himachal Pradesh by BMTPC

District	Severe to very High	High	Moderate to Low	Unlikely	Total Area (Km^2)
	places	places	places	places	places
Una dist.	2	678	517	311	1508
Hamirpur district	0	851	204	45	1100
Kangra dist.	123	3698	1233	557	5611
Kinnaurdist	868	4956	498	0	6322
Kullu dist.	1820	3512	65	3	5401
Mandidist.	968	1978	826	98	3870

Source: *BMTPC, (49)*

The major areas in India susceptible to landslide exposure are the Northwest Himalayas (66.5%), followed by NE states (18.8%), and the Western Ghats 14.7% (49)

Avalanche vulnerabilities in the Upper BR Sub-basin

The higher hills of the districts of Kinnaur, Lahaul&Spiti, Chamba, and Kullu are vulnerable to avalanche risks. Thedevastationoccurreddue topast avalanches of the HPin the higher mountains, Table 4 (b)

Table 4 (b): The historically devastating avalanches in the BR Subbasin in HP

LOCATION	DATE/YEAR	DAMAGES OCCURRED
Lahaul&Spiti	Jan 1975	EQ tremor shocks triggered an avalanche of great dimensions, damaging the road web.
Lahaul&Spiti	Mar 1978	About 30 dead, and roads/propertywere damaged, whichwas pretentious the BR Sub-basin.
	Mar 1979	In the Lahaul valley, about 237 people were killed. Roads disrupted
Tinku	Mar 1991	Tinku avalanche occurs annually 4-5 times from January- Mar. Blocked road was blocked for 40 days in 1991
	Sept.1995	Due to an avalanche, a huge chunk of debris came down, which later changed into a flood.
Lahaul and Spiti	March 2011	Lahaul and Spiti, March 2011,PindriNala, 2 laborers die. PindriNala, 2 workers died.
RohtangAvalanche	January 2021	Stranded tourist vehicles and stopping all on the ManaliRohtang road.

Source: (50)

The BR Basin in Kullu Valley has suffered from Avalanche events in the mid-1990s and over 15 events from 2000 to 2008. The notable largest records were in March 2002, March 2003, January 2006, and January 2008. Studies show a correlation between climate change, increased snowpack instability, and the frequency of wet snow avalanches in the region. The avalanche accidents in the BR Basin in HP in Chamba, Kannaur, Kullu, and Shimla districtswere 12, 32, 6, and 2, killing 53, 129, 9, and 01, respectively, as per SASE Chandigarh; DRDO, by 28th May 2014.

The Slope and Aspect Map of the Beas River basin

Slope can be steep or gentle, which helps to identify areas prone to erosion, unsuitable for agriculture, or requiring specific development planning. For example, closely spaced contour lines or darker colours on a slope map signify a steeper incline, while widely spaced lines or lighter colours denote a gentler slope.

An aspect map is a geographical representation showing the direction a slope faces, generated from a Digital Elevation Model (DEM), derived from the SRTM 30 m DEM in QGIS 3.40 and validated with SOI and GSI data.This is interpreted by understanding that colour or its value relates to the slope direction. For north, east, 00, 900, 2700, and 3600, respectively, give south and west directions. It reports the risks and impacts like solar radiation exposure, soil erosion, vegetation, and landslide risks, which help in planning LU and farming (Fig. 5).

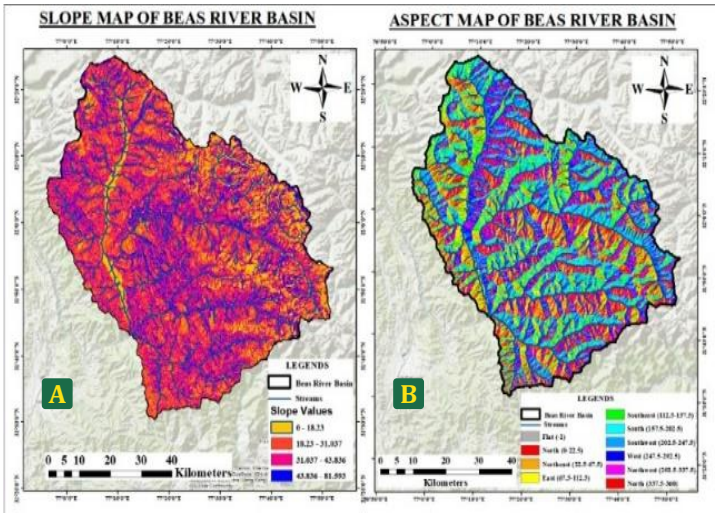


Fig 5: The Slope map and the Aspect Map of the BR basin, Himachal Pradesh, India

Drainage

The drainage pattern is dendritic and av. Drainage density is 0.42km^2. The average bifurcation ratio is 2.275,which indicates the terrain'sminimal structure disturbance. These nalas bring a huge amount of rainwater along with rocks, rubble, and pebbles, and ultimately drain into the Beas.The drainage density (DD) of an area is given by (Km/Km2), where at various stream order numbers it varies from 0.25 to 2.43Km/Km^{2,} where the DD = (Total Length of all streams (L))/(Total Area of the Basin (A)) =L/A…….(iii)The values vary, ranging from 0.25 to 2.43 km/km^2.

The drainage density (DD) is influenced by climate, rock type (impermeable rocks have high density), green cover, soil type, and topography. When the DD is high, it indicates more relief, gulleys and drains induce high runoff that increases erosion potential, whereas low DD talks about sparse drains and high infiltration. In the present case, the DD lies between 00 to 0.83, which lies in the mid value and coarse drainage structure (DD<2), March. Western disturbances cause winter rainfall.

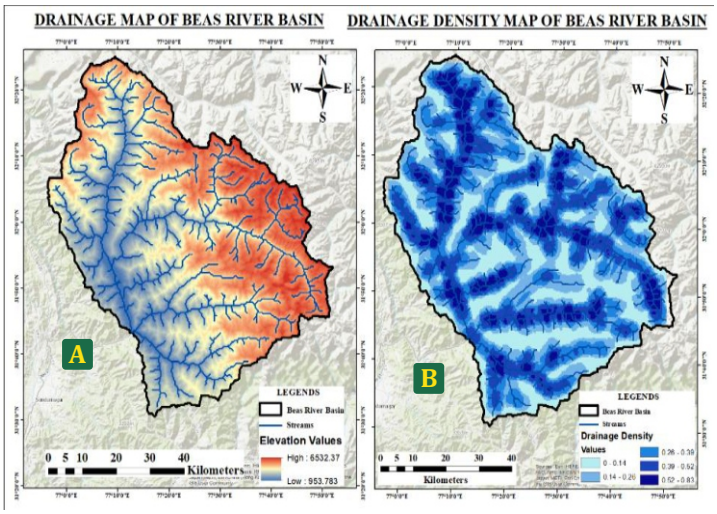


Fig 6 (a-b): (a) The drainage map of the BR Sub-basin,(b) The Drainage Density map of the Beas River basin

Climate: The Beas Basin in the Kullu Valley, near Manali, enjoys a subtropical humid continental climate (Köppen scale:Dfc). The area enjoys warm to hot/humid summers and cold/wet winters with snowfall, in high altitudes.The study area topographies possess a subtropical highland climate (CFB) with medium heat summer, relatively cold winters, and a high annual temperature range (-7°C to 30.7°C) (22), (23)(24)(25).

The winter has an average minimum temperatureof 4.7°C from December to January.

The monthly precipitation (snowfall and monsoon rainfall) is 1350mm. The average annual rainfall of HP has been 1284.2mmsince independence occurred, withina range from 705mm to 2063mm (1951-2020). The NW districts,Kangra and Chamba, receive the maximum average,whereas Kinnaurin the east enjoys the least. The district experiences snowfall between Dec-March (26) (Table 5).

Table 5. The table of climate and weather of Manali in Kullu District, HP. (Data: 1991-2021)

Avg.	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Temperature °C	-8	-5.9	-3	0.9	4.8	8.8	12.1	12.1	8.8	2.8	-2.4	-6.3
Min. Temp. °C	-12.8	-10.7	-9.4	-6.1	-2.9	1.9	8.2	8.5	3.2	-4.8	-9.2	-12.1
Max. Temp. °C	-2.9	-1.1	2.7	6.8	10.7	14.2	16	15.7	13.8	9.7	4.5	-0.1
Precip./ RF mm	203	255	226	136	102	129	233	215	131	54	63	104
RH (%)	45%	50%	50%	60%	68%	78%	87%	87%	79%	66%	49%	43%
Wet days (d)	12	13	13	9	13	16	21	20	16	9	6	8
Avg. Sunny hrs	6.1	6	7.8	8.9	8.9	7.6	5.6	5.2	6.4	8	7.8	7.1
Max. Temperature °C (°F), Min. Temperature °C,Rainfall mm (in), Relative (RH) in %: Humidity, Rainy days. Data: 1999 - 2019: avg. Sun hours												

Source: (51)

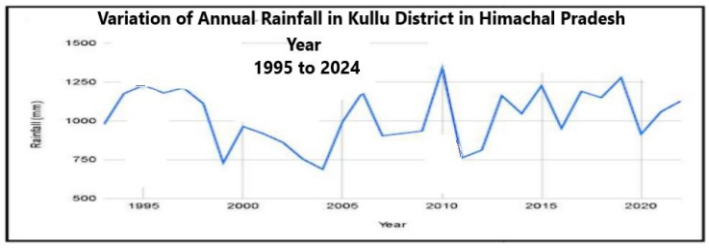
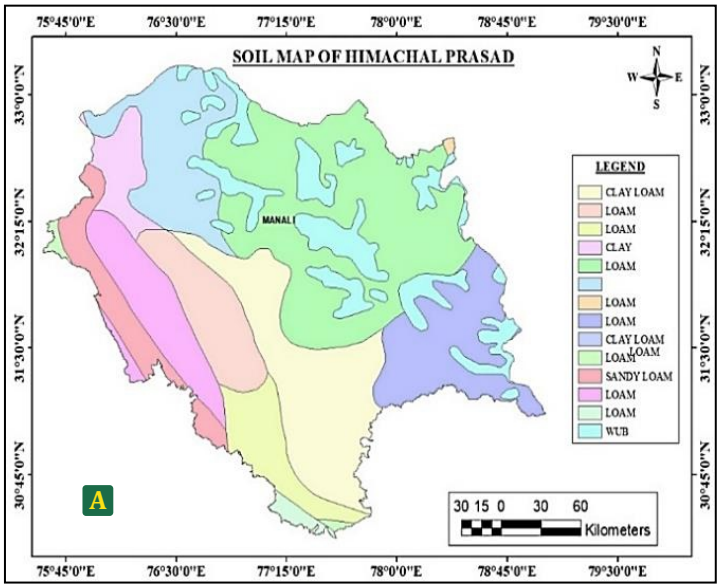


Fig 7: The annual Rainfall, Kullu valley, in HPfrom 1995 to 2024

The analysis of the highest rainfall of the century was in June-July 2023. The BR Sub-basinreceived an average rainfall was 833.82 mm, a +94% from the previous maximum of 429.02 mm in 2021 and a 270% hike of the 20-year average. The annual rainfall amounts in these years were1995, 2010, and 2019 were 768mm, 1337.69 mm, and 1279.31 mm,respectively (Table 1 and Fig.7).

Soil and Vegetation: Soils of this region are of the entisols-inceptisols type, while the affisols are in the forest zones. The soilsurface texture is sandy, loamy, and loamy skeletal. The soils are acidic in nature.(Fig 8 (a-b)).The coniferous trees mainly grow in this region. The thickness of the forests is high in higher altitudes. Important species are deodar, silver fir, chir, walnut, horse, chestnut, oak, pine, etc, that provide valuable timber, medicinal herbs, resin, firewood,etc, are available in Western high altitudes.

The high drainage density (DD), overland flow, climatic inconsistency, and rainfall are hastening the erosion by reducing infiltration and increasing runoff Fig.8 (a and b).



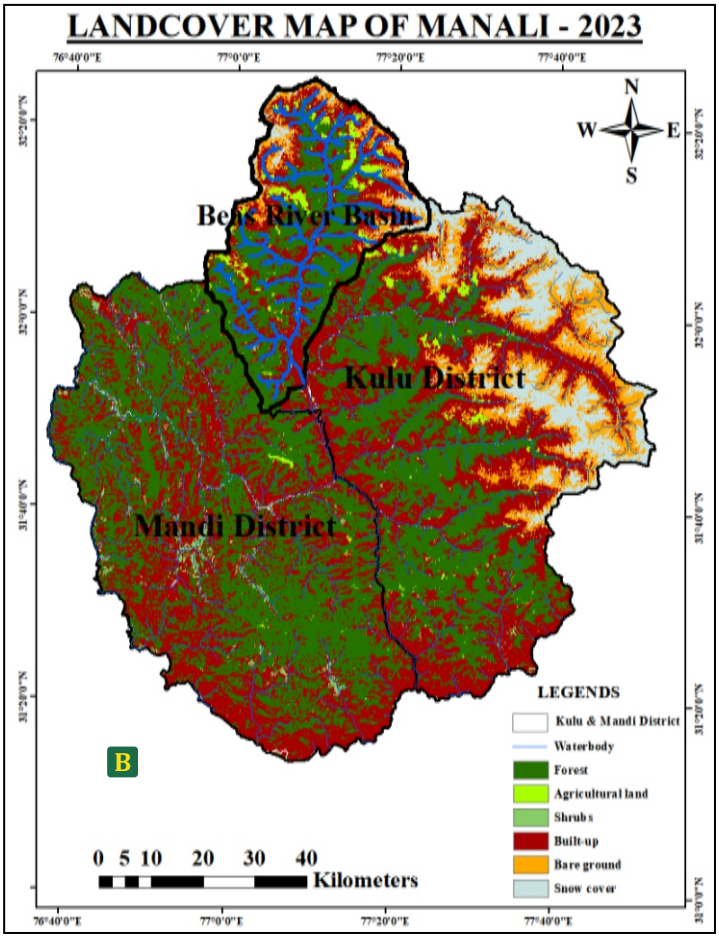


Fig 8 (a - b): (a) The Soil map and the Landscape Map of the Beas basin in HP (Western Himalayas), and (b) the land cover map of Beas Basin in HP

The trend in the number of Disasters in HP

From Figure 6, infer that from 2019 to date, the types and numbers of hydrological and meteorological disasters have beenincreasing from year to year

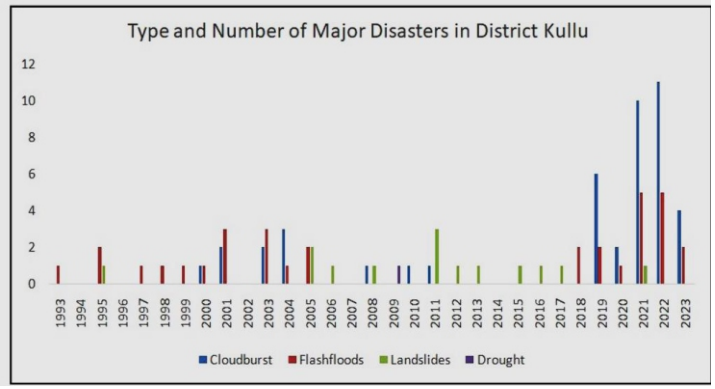


Fig.9: The types of hydrological disasters in Kullu Valley (Source: Singh RK. 2024)

Causes of the Beas River Flood

The HP state in the mid-Himalayas is prone to disaster in the western Himalayas. The Indian Sumer Monsoon(ISM) season, which spans from June to September,provides about 80% of the annual rainfall to the region. In recent years, India has witnessed heavy and intensified weather patterns with erraticprecipitation. These contribute to flooding or flash flooding.

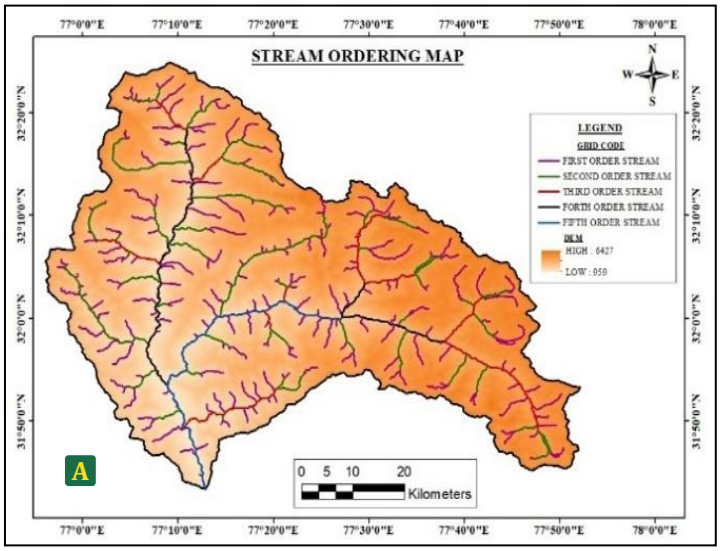


Fig 10 (a-b): (a)The stream Order map of the BR Basin,HP. (b) The floods in the Urban areas

The causes of floods at Kalath are manifold and can be grouped into Natural and Anthropogenic. Persistent rain has caused devastating floods on July 9th and 10th, 2023. The Beas Basin received torrential rain of about 90- 100 mm/ per day, which caused a flood disaster, and the nallahs and the Beas rose totheir full brim.

On July 9th and 10th,2023, the Beas rampaged through the Kalath-Manaliarea, claiming dozens of lives and destroying property worth hundreds of crores. It was the river's fiercest dance of destruction in living memory. Between July 10 and July 11, the region received about three times the normal amount of rainfall. State disaster management authority (SDMA) data also shows that there were about 15 flash floods across the Kalath-Manali area in July alone. Climate experts say that the increasing frequency of high-intensitycloudbursts and flash floodsisasign of climate change caused by global warming.

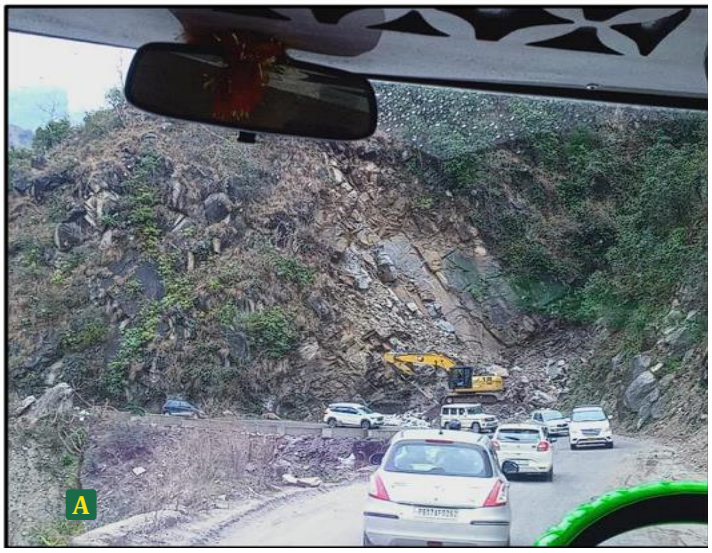


Fig 11(a-b): (a)The Landslide in the Manali Region and (b) Flash flood over the Beas River and flow near the NH Bridge

Land Use and Land Cover (LU/LC) Map

The Land use map of the Beas River basin was developed using GIS/RS tools for the years 2014 and 2024. It reveals that thetrends in expanding agriculture and settlements are increasing, forest cover is declining, and diversion of barren and homestead land has sprawled due to population growth, economic stability, tourism, and climate change.

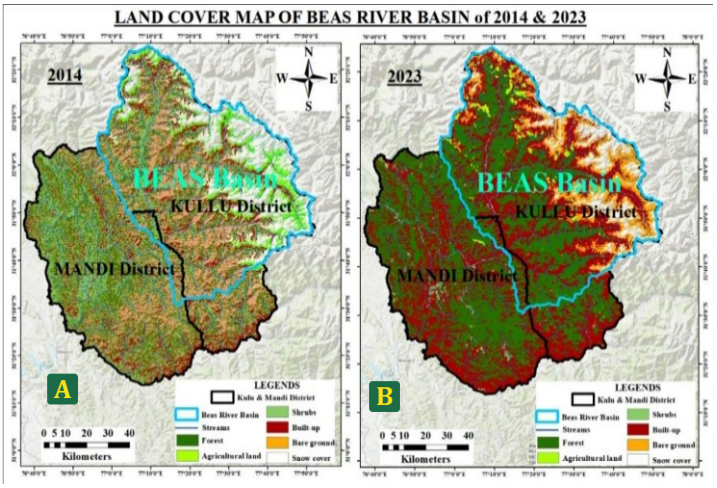


Fig. 12 (a-b): The LC map of the BRSub-basin in Kullu Valley,rise of built-up area

The Climate Change Reports

The increasingtrendin Western Disturbances (WI), atmospheric temperature, chaotic Indian summer monsoon, irregularities in Equatorial Indian Ocean Oscillation (EQUINOO) and El Niño–Southern Oscillation (ENSO), sea surface temperatures (SST) rising high in the tropics,encourages large-scale tropical Sea Level Pressure (SLP) anomalies, which have an impact on Himalayan weather. In the year 2020-21, there were 30 such disasters, 17 of which were cloudbursts. The district statistics reports that Uttarkashi recorded seven (7), Chamoli with five (05), Dehradun and Pithoragarh each have four (4), RudraPrayagregistered three (3), whereas Tehri, Almora, and Bageshwari reported one (1)each district that encountered cloudburst occurrence.

Anthropogenic Interventions

The over-exploitation of natural resources, including forests, water, scenic values, tourism, and cement production for development, leads to the rapid needfor cascaded hydropower projects, causing damage to rivers, the environment, and their ecosystems. In the names of communication, widening of roads without environmental, geological, and engineering impact assessments has altered the land use patterns, agricultural practices, and a shift to cash crop economics has altered the landscape, rivers, and consequent flood scenarios.

The LULC maps indicate the increasing trends in agriculture and settlements, decline in forest cover, and barren lands to homestead and built-up land. The factors responsible arepeople growth, tourism, urban sprawl, and climate change. This study can help and agroforestry practices, towards conservation efforts, and upgradedLU planning in mountain landscapes. (27)

Floods in the Beas River Sub-basin

It is found that 100mm of Rainfall in an area is conducive to a flash flood in the Beas basin.

Table 6: Yearwise Excess rainfall districts in Himachal Pradesh from 1950 to date 2025

District	Excess Rainfall Years (> 125%)	Highest rainfall (% of Normal forthe year
Bilaspur	1973, 1994, 1996, 1998, 2018,2023	218.7 cm in 1998 (174 %)
Chamba	1953, 1954, 1955, 1956, 1957, 1958,1959, 1960, 1961, 1964, 1976, 1977, 1979, 1988, 1992, 1993, 1994, 2018	268.3 cm in 1977 (198 %)
Hamirpur	1955, 1961, 1970, 1990	210.6 cm in 1990 (144%)
Kangra	1976	816.2mm 1976 (126 %)
Mandi	1954, 1955, 1963, 1966, 1967, 1988,1990, 1997, 2018, 2023, 2324, 2025	336.4 cm in 1988 (215%)
Sirmaur	1959, 1961, 1962, 1963, 1964, 1988	288.8 cm in 1963 (215%)
Una	1955, 1988, 2018	237.0 cm in (196%)
Kinnaur	2013	330.7 cm (4309%)
Kullu	1995, 2010, 2013,2018, 2023, 2024, 2025	2025, 816mm (165%)

Source: *(25) (28)*

Cloud bursts and flash floods are common disasters in the Beas R. Basin, mainly in the Kullu district and Mandi. Where the cloud bursts are the players. The hotspot areas in the Manali/Kullu are Gulaba, Kalath, Solang, Prini, and Vashisht. The devastation that occurred at Kalath in the morning of July 9, 2023, continued for two days further down the river valley. Houses, hotels, electricity poles, and water supply pipes were adversely affected. Thenational highway disappeared at Kalath. Cars were tossed around, and trucks,too. A Punjab Roadways bus with at least 11 people on board disappeared in the deluge at the village Aalu Ground before dawn on July 9(Table 7), published in The New Indian Express (30,52).

Table 7: The various districts affected by flash floods/landslides in HP, districts in the BR Sub-Basin

Year	Place	Damages Caused
Dec 1988	SolangVillage near NH-22	15 houses, 21.7 acres of agricultural land, and about 600 apple trees in Solang villagewere washed away. 32 persons dead, 35 cattle lost, 2km stretch of NH-22 across SolangKhadbreached. The HEP of Bhabanagarwas damaged. completely
4thand 5th Sept. 1995 (2 P>M.	Kullu(The deflected left)near Nadar to Patlikuhal near Kalath- and Tapri changed course, KannurDist	185.8 Ac orchards (8736 apples, 687 pears & 293 plum trees) damaged with 725 Ac. of Govt.land,economic loss of Rs. 5.560 mi. INR after the cloud burst at Duling.
11thAug 1997	Chirgaon in HP	Triggered due to a cloudburst. 124 dead officially
4-5 & 12 September 1997	FlashFlood in the Kullu valley and the Beas basin	Flood and Landslide along the Beas River in the KulluValley killed 65people, NH-22 was shattered at many places, and the amount ofloss to the property, road,and bridges was estimatedat US $182 mi.
2nd July 2001 and	A cloudburst in the Sainj valley in the Kulludistrict. The Village Mahiliwas damaged.	Cloud burst in Sainj and JeebaNallahaffected≈40 Families, 2 bridges,and fertileland were washed away. In many places,Roads are disconnected, and twopeople and five cattle were killed. In July,only 6335 people in the Saini valley were affected.
21st& 22nd Aug 2001	Flash flood due to a cloud burst in Anniat Vil.Badhali and Sarali	Village Badhali 2 homeswere washed away,and two people were dead,two were injured.In Vil. Sarali, 7 deaths and 15houses were washedaway,70bovines and about 713 acres of farmlandwere washed away.
16th July 2003	Flash floods froma cloudburst in Gharsa Valley (Kulludist)	21 people were dead, but 21 people were injured, and 9are still missing.
17th Aug 2003	Flash floods in Kangni-nalla near Solang in Kullu district.	30 people dead, 19 injured, and 9 people lost their lives their lives due to a landslide near BahangNalla
24th July 2003	Bahang valley (near Manali)	2 dead, huge property, and houses were damaged
7thAug 2009	Cloud burst; Nirmand area,Kullu	Govt buildings and bridges with roads damaged and communication disrupted.
Sept 2010	Kharahal Valley in Kullu	Many villages are affected and debris flow
June 8, 2014	Largi Dam Failure	washed away Engineering 24 students (the Q rose from 0.6Cum to 13Cum
July 25-26, 2024(2 MW Serai HEP)	Serai River; PagalNallah; Dam break	Damaged the pen stock, trench weir site, and approach road of the project
July 26, 2024; 9 MW Beas Kund HEP	Palchanvillage, 13 km upstream from ManaliTehsil	Damaged control room, power panel, machine hall, generator, transformer yard, pump house, storeroom, etc.
July 25-26, 2024(R/F in Dhundi area	AnjaniMahadev area along the SeraiR,	Palchan, Ruaru, Kulang, Nehru Kund, and Patlikul devastated bovines, houses,the Solang Valley bridge in Palchan, debris blocking the Palchan-Solang road, and the Manali-Leh National Highway (NH)-3.
From 20th June to 15th July 2025	Mandi, Kullu, Chamba, Hamirpur, and Kangra	Recorded 17 landslides, 22 cloudbursts, and 31 flash flood incidents. Jiwa Small HEP damaged.85 lives have been lost, and 34 people are still missing,

Sources: *HPSDMA, Chand I et al, 2025, one-day Awareness workshop HP 28th May 2014*

Glacial Lake Outburst Floods

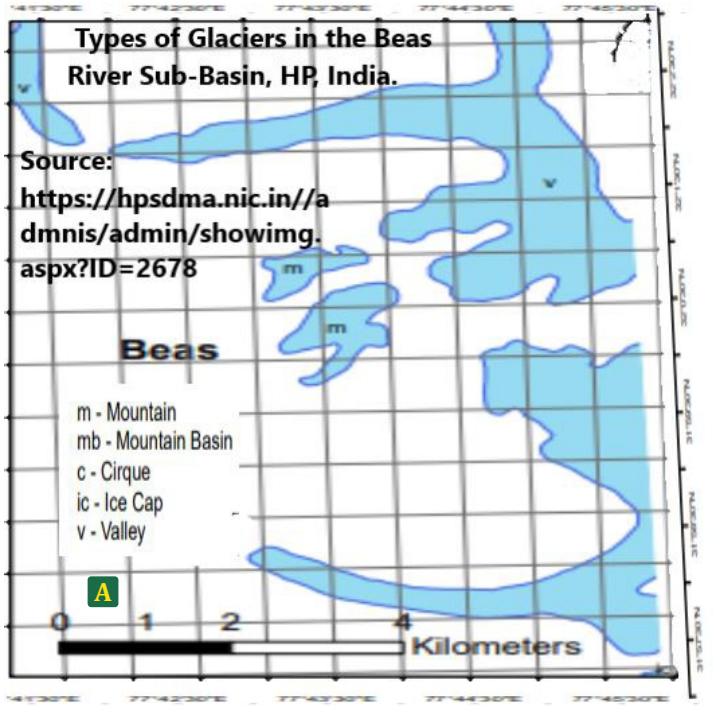
About 3,300 glaciers in the Nepalese Himalayas, and 2,300 of them contain glacial lakes.In the Beas sub-basin, there are 165 glaciers, 13.3% of the total number.As per the National Remote Sensing Centre (NRSC), Indian Space Research Organisation (ISRO), 28,043 glacial lakes were identified in the Indian Himalayan River basins with a total lake water spread area of 131070 ha in HP. About 329 glacial lakes are present in the Indian Himalayan areas as per the Intergovernmental Institution, Int. Centre for Integrated Mountain Development (ICIMOD).

Table 8: The statistics of glaciers and perennialalpine meadows in the BR Sub-basins, HP

Basin Name	Glaciers	Aerial Extent	snow fields	Aerial Extent
	Numbers	Km^2	Numbers	km^2
Beas sub-Basin	51	503.725	503.725	312.564
SainjR. Sub-Basin	9	37.255	59	51.934
Parvati Sub-Basin	36	450.627	131	188 .188
Sutlej Basin	151	616.299	857	544.173

Source: (29), (13)

Satellite data reveal that small but potentially dangerous glacial lakes in the Beas sub-basin grew from 67 in 2013 to 89 in 2015 (Himachal Watcher, 2016). According tothe GB PantInst of Himalayan Environment'sstudy in 2014,it reported that these glacier areas are small and melting more quickly, increasing the risk for the d/s valley (Table 8).



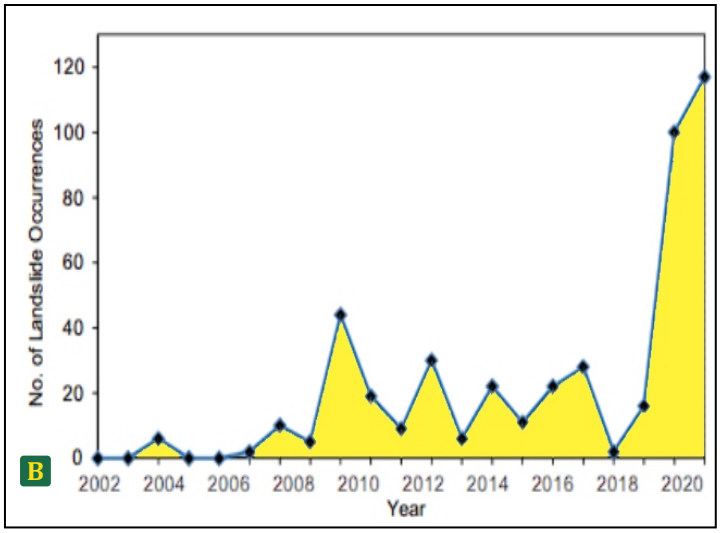


Fig 12 (a and b) The types of glaciers in the BR sub-basin, HP, Source modified HPSDMA (b). The trend freq. of landslides in HP from 2018 to 2025 (source mod: NASA and Paul et al, 2024[29])

The causes of floods in the entire Himachal Pradesh are area-specific and are due to natural precipitation of the Himalayas. Under threshold rainfall and for the Oceanic Niño Index (ONI)status, the retreat of glaciers increases the risks of GLOFs (Glacial Lake Outburst Floods). However, other disasters, such as landslides (LS), flash floods(FF), and GLOFs, are also caused by human overexploitation of nature. Climate Change (CC)and global warming are triggering GLOFs by increasing the water spread area of the lakes.The change in snow cover area BR sub-basin in 2019-2020 and 2020-2021 was2457.68 and 2002.03 (-18.54%) ice-covered area.(31), (32)

Cloud bursts in the Beas Valley

Cloudbursts wrecked HP. Breach in such glacial lakes cannot be ruled out;of 249 glacial lakes identified at present in the HP state, 11 are at the brink of breach. The Beas Sub-basin only has80 Glacial Lakes, out of which Mohal in Kullu is the future source of cloud burst, creating havoc in the basin as per J C Kuniyalm, scientist from GB Pant Inst. of Himalayan Envir.And Development).

The BR Sub-basin is facing a rise intemperature by0.4 degrees from 1960-1990, hopefullyglaciers in the Himalayas to retreat. The glaciers in the basin regularly change their area, gradually downsizing, affecting agriculture and horticulture. In the Beas sub-basin,concerns weremelting of glaciers posing a threat (avalanche, flash floods, GLOFs) to the Kullu valley from 2003 onwards.

Hydro-geomorphological dynamics in the Beas sub-basin

Alu ground to Kalath village,causing damage to structures, NH, APMC Mandi complex, houses, Hotels, and parking places. The other Channel shift and straightening of the river courses within the system are observed in the banks of NH between Patlikuhal to Mahili, and Dolunallah to Raison, etc. High-stage flow (dam/glacier overtopping, lateral erosion/ channel shiftoccurs at places like Hathithan to Bhuntur and Aut, etc. (33), (34), (35).

Introducing the Kalatharea

Kalath is a village of Manali Subdivision, Tehsil, Kullu district, H.P. is situated close to the hamlet Kharal and the village Gojra. The global location of Kalath village is defined by 32° 11' 20" North latitude and 77° 11' 20" East longitude. Being located on the right Bank of the Beas River. The village is at the bank of the river Beas. NH 21 runs through this village. The village Kalath lies between the Beas River in the east and the west of mountain.Being located in the Manali watershed of the Beas River sub-basin, Kalath village is drained by the river Beas and several hilly nalas having an area, havinganaverage area. Drainage density is 0.7, thus indicates high but permeable rocks with more runoff off and high relief.

Drainage texture equals only 0.47, indicating the presence of very low resistant permeable material with high relief. Stream frequency is 0.7. The perenniality prevails almost throughout the year in this section. During the monsoon months, the river Beas remains in Spate. A no of nalas along the slopes of the hilly tracts drain into the areas.

Being located in the transitional zone between the lesser and the greater Himalayas, this area presents a typical Mountainous Topography. Terrain with moderate to high relief. Kalath village lies at an elevation of 2200m above the mean sea level (MSL). The area gives a view of magnificent snow-covered peaks and glaciers. The region consists generally of fossiliferous sediment or metamorphosed cry cooling.

Fig 13 (a-b): The breach is at Kalath in the NH 21 passing on the banks of the Beas River, a change of course in 2018 and then in 2023, Physiography (Kalath Village)

By the 9th evening, the entire village was plunged into darkness with no water, electricity, mobile connectivity, or internet. The Kalath-Manali area was completely cut off, leaving a huge no of tourists.

The Beas changed course and turned more than 100 meters to the right bank side, washing about half of the highway. The HPSDMA has estimated that around 2200 houses and 428 shops were lost in the Kullu district alone. Hundreds of people died. The agricultural fields were badly affected by cloudburst, flash floods, and consequent landslides (Fig. 5 and b).

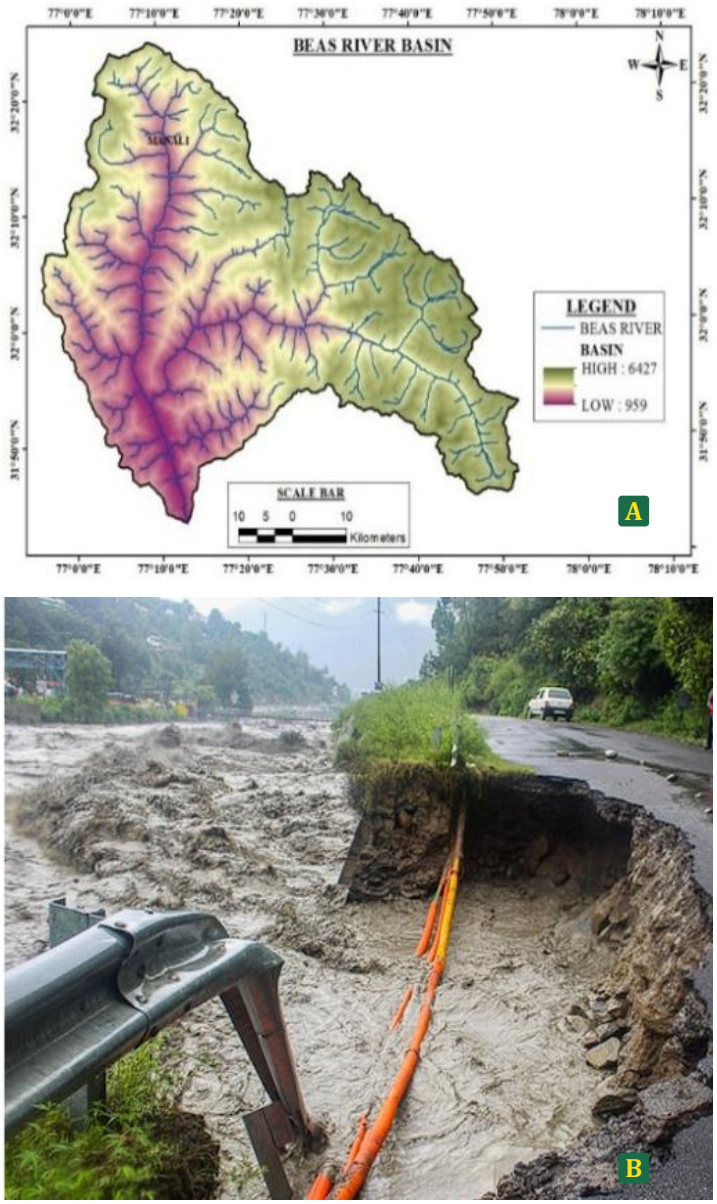


Fig 5: The Basin map of the Beas River HP (b) (c) Breach by erosion due to flood of NH over the Beas River embankment, India Today News Desk (Aug 26, 2025 by Harshita Das)

Pre-Disaster (Mitigation & Preparedness)

According to UNDRR, the knowledge and capacities developed by governments, response and recovery organisations, communities,especially vulnerable groupsand individuals are needed to effectively anticipate, respond to, and recover from the impact of likely imminent or current disasters (36), (37).

Preparedness is based on a sound analysis of disaster risk and good linkage with early warning systems, and includes search activities oncontingency planning. The stockpiling of equipment and supplies, the development of arrangements for coordination, evacuation, and public information, and associated training and field exercises. These must be supported by formal institutional, legal, and budgetary capacities.

A preparedness plan establishes arrangements in advance to enable a timely, effective, and appropriate response to specific potential hazardous events or emerging disaster situations that might threaten Society or the environment.

During Flooding (Response)

Assemble disaster supplies: Never panic before a Landslide or flash flood; be alert and monitor your surroundings.Monitor NOAA weather radio, local television and radio stations, or go to www.weather.gov.com. If a flash flood warning is issued for your low-lying area, immediately move to a safeplace, as Flash floods develop quickly. Disaster awareness programme to be strictly followed as per SAMARTH-24. Do not wait until you see rising water.Keep some drinking water and food for a few daysas evacuation plans, cash, and precious belongings for you and your family, and the cattle. If driving, do not drive through flooded roadways. Keep some used and urgent medicines, clothing, a battery-powered radio, Adhar /Voter cards, insurance papers, a Flashlight, important documents,and first aid, etc.(38).

Review your family disaster plan

Discuss flood plans with your family, meeting place,and contact person if separated.Protect your property, move valuable items and furniture to a higher level, and move hazardous material (such as paint, oil, pesticides, and cleaning supplies) to a higher location.Disconnect the electricalappliances. Do not touch them if you are wet or standing in water. Seal the vents to the basements to prevent flooding.Bring outside possessions indoors or tie them down securely.

Response to Landslide or Flash Flood

During the advancement of rising water, be alert, monitor your surroundings, monitor NOAA weather Radio, local television and radio stations regularly, or go to evacuate www.weather.gov.gov.com. Don't drive unless compelled, but with care, sufficient fuel, and recommended routes only in Himachal Pradesh, avoiding disaster-prone areas.It is advised to follow the HPSDMA UNDRR plans if you want a safe and resilient.

Discussion

The Manali and the Mandiurbanareas are sprawling with an increase in population. The unstable terrace, ephemeral beds of the tributaries of the ephemeral River the Beas, the structures built on the flood terrace, the increased tourism, erosion of mid-channel gravel bars, blockage by tree trunksobstructsflow, and aggravates the flood vulnerabilities.

Findings:

I. No of high and medium-intensity earthquakes is reducing

ii. The frequency of low-intensity tremors is surging.

iii. Climate change has induced Heavy erratic rainfall in the BR sub-basin.

iv. Construction of roads, hydropower units, and anthropogenic interventions has augmented the number of landslides in the hillside slopes.

v. Loss of forests/vegetation, Forest Fire, increase in built-up areas, sprawling of urban areas, mining, over-exploitation, and tourism prospective have changed the climate.

vi. The GLOFs, flash floods, intervention in flow dynamics, and encroachment of levees are causes of floods in the basin.

The urban agglomeration, unplanned growth over vulnerable areas, Connectivity and NH, Government developmental infrastructures, twenty-one Hydro Power Projects, uncontrolled dam releases, the Beas River becomes hostile and undergoes bank collapse, sediment surge, and lateral migration. The rise in flood levels is associated with high concentrations. Sedimentschange the shape of the debouching point between the parent river and its tributary.As the soils of the basin are susceptible to Soilerosion, agriculture and horticulture are greatly affected.

Mountain hazard susceptibility and livelihood security in the upper catchment area of the river Beas, Kullu Valley, Himachal Pradesh, India. After 75years of anthropogenic intervention (post-independence), the basin'sresources have invited more disasters. So, climate change impacts on Glacial Lakes and Water Bodies in the Himalayan Region need to be closely monitoredregularly.CC-driven glacial retreat is mainly responsible for the formation /expansion of such glacier lakes.

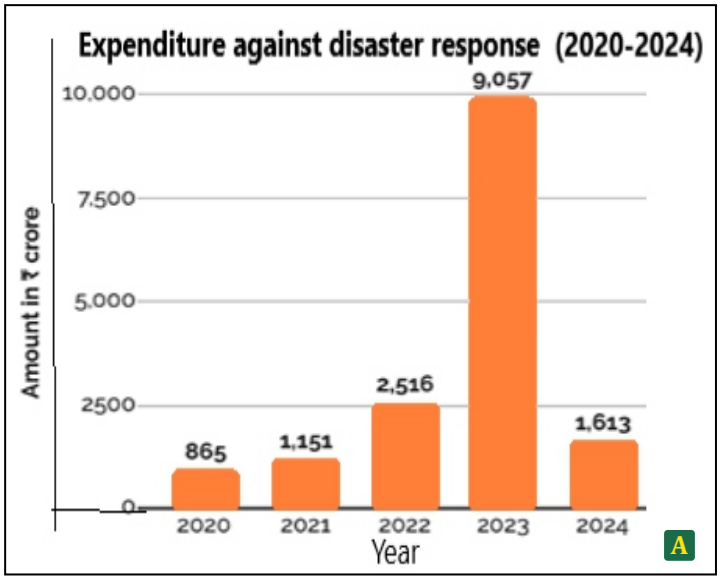
Reasons for the surge in the number of Eqs

There is a surge in the number of tremors in the Beas River basin in the 21st century, which is not because of increased seismic activity, but also due to (i) the number of seismic networks has increased with innovative and sensitive recording techniquesaround the world, and their sensitivity to detect smaller quakes has increased drastically in recent years.(ii) The data availability and public access through cyberspace have increased significantly.

The Disaster Management

Various Relief measures are immediate rescuing. They are (a) Arrangement of rehabilitation shelter, food, and other requisites, short-period free ration, (b) provisions of blankets and clothing to the victims. (c) Providing post-health care and temporary shelters,gratuitous relief for the earning members. (d) Disposal of dead bodies and medical aid to the injured persons and Bovines. (e)evacuationof the affected people to a safer place.(f) Checking the water contamination (g). Special care for children, comorbid, and geriatricpersons.

Suspension/remission of land reverse. As a long-term response to the disaster, i.e.,needfor Postponement of the bank recovery, grant of land in exchange, timber for the reconstruction as rations, new loan for the reconstruction/repair of houses. Further generation of employment programmes, strategic planning for mitigating calamity, and minimisingthe future menace. For the last Five-year fiscal burden due to the BR subbasin disaster impacts needs future preparedness, financing, socio-economic awareness, scientificand engineering innovations given in Fig. 7 (a and b)



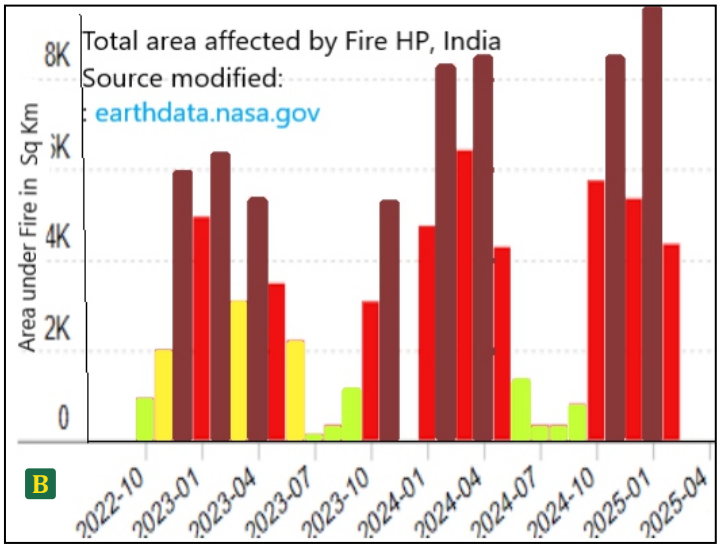


Fig 14 (a-b): Last five years disaster outlay (b) Total area affected by fire 10/2022-1/25

Reducing disasters in the BR Sub-basin:

The points to be stressed to ameliorate disasters in the BR Sub-basin by multiple approaches to mitigate its cataclyism by thwarting its sources, where the major strategic platforms are afforestation, drainage patterns, and Landcover/land-use management. The key players to be focused onare:

I. Enhancing vegetative cover and afforestation.

ii. Properly anastomosed drainage web

iii. Well-judged land use patterns, agricultural, mining, and urban planning.

iv. Embankment construction with adequate dykes and less fewer low dams.

v. To adhereto resilience and reducing reduce accidents/deaths, apply nature nature-based solutions such as use using ecosystem approachesm, like early warning systems, proper preparedness, adopting ecotourism, and infrastructural projects after an Enviornmental Environmental Impact study (EIA).

vi. The constructions over young alluvial plains should emphasisescientific and engineering geological andhydrological assessment.

vii. As a policy framework, the constructions over unstable terraces, debris fans, flood plains, sediment management, and plans with risk-assorted structures.

viii. For flash floods, avalanches, cloud bursts, and debris flow areas should never be considered for new constructions(53).

Long-term Strategic plans

Road infrastructure should be supported, ensuringall-weather accessibility. Strengthening the health infrastructures and engineering innovations for landslide-prone areas. The WASH sector should also be strengthened to avoid sewage treatment plant failures due to disasters, leading to waterborne disease outbreaks.

Uses of GIS/RS GeospatialData

Together with the quickly evolving use of the internet, GIS technology and remote sensing have proven to be a valuable asset for those looking to stay prepared through the means of critical data. They can help in visualising the affected areas for situation awareness, damage assessment, Hazard mapping and prediction, route optimisation, evacuation, communication and coordination, and with resource management.

Micro watersheds development shall address floods and debris impacts by developing mitigation plans effectively.

The five river basins (Beas, Yamuna, Satluj, Ravi & Chenab in the HP contribute to the Indus River & Ganges River basins. These small Watershed needs to be well-planned using the Hydrological models by simulating the surface and subsurface flow to project the quality & quantity of water availability. The environment, the erratic climate change, and land use practices must be well judged for the pipeline hydrological or hydro power projects in the present context.As the sub-basin consists of many units of drainage hydraulic boundaries, watershed prioritisation in the Beas River sub-basin, including organic farming of the Western Himalayas:

The Resilient Beas River sub-Basin

The Himalayan Hazard Atlas must be updated stepwise and freely available for further resources. To alert the vulnerable victims, more cloudburst DopplerRADARSare to be deployed,and for early dissemination of the disaster news, more stress should be broadcast. The number of hydropower stationsshould be reduced, and slope protection works should be encouraged by more plantations along the mountain slopes. For community resilience, the public-private partnership should be encouraged for all infrastructuredevelopment works. CC policies, as laid down by the IPCC,should be followedby formulating a Himalayan climate action plan, revised from time to time, and more research on GLOF activities is essential. The encouragement towards eco-tourism aims to enlighten the people and the stakeholders.

Conclusion

The Kalath Village in Himachal Pradesh floods in 2023 were adevastating and catastrophic event that wreaked havoc on the state, leaving a trail of destruction and despair in itswake. The disaster was unprecedented,and torrential rains and landslides caused widespread damage to infrastructure,property loss of life, livestock, livelihoods,and thousands of people were affected,with many losing their homes, belongings, and loved ones. The state's infrastructure, including roads, bridges, and buildings, suffered extensive damage, disrupting connectivity and commerce. The tourism industry, a significant contributor to a state's economy,was severely impacted, causing significant financial losses.

The floods/flash floods, along with Landslides, haveemphasised the vulnerability of the people residing in the Beas River Sub-basin to disasters. The need for better disaster preparedness. Management and mitigation attempts are necessary to minimise such events inthe future, as they occur unnoticed and apocalypticallycatastrophic. They highlight the importance of having effective emergency preparedness plans and response strategies in place to mitigate the impact on the ecosystem, human lives, and property.

References

1. Sejpada S., Mishra SP., Dash S., Barik KK, Sahu, DK., 2022. Finalizing Alignment of Connector to NH-117a in Hilly Terrain from Kokrajhar to Bilasipara: Assam, Indian Journal of Natural Sciences, 13(73), 46916-46924

2. Singh RK. (2024). Comprehensive Analysis of rainfall pattern, slope vulnerabilities, and mitigation strategies in Kullu Valley, HP. IJDR. 14(12), 67325-67333.

3. Kaur T., Kumar R. (2020). Development of Run-of-the-River Hydropower Projects in the North-Western Himalayan Region of India: A Study about their Env. Sustainability. National Institute of Ecology, Int. J of ecology and Env sciences, 46 (2): 117-128

4. Rajat, RL, Thakur, P., Gouda, KC., Ghosh, S. Shashni, SP., 2023. Impact of the Hydro-Meteorological Disasters in the Upper Beas Basin in the Kullu Valley, HP, India. JGEES, l 27 (6):52–64. https://doi.org/10.9734/jgeesi/2023/v27i6691.

5. Negi R., Rana N, Sati SP, 6 authors, 2024. The Beas River Floods 2023: A watershed moment for paradigm shift towards urbanisation and development in the higher Himalayan Valleys, Current Science 127(1), DOI 10.18520/cs/v127/i1/65-77

6. Dhiman SS., 2025. Natural disasters: factors and mitigation strategies. September 2025, conference: revisiting the environmental history of India: main issues and challenges, At: Himachal Pradesh University Regional Centre, Dharamshala

7. Lakhera N, Kumar N, Shankar V (2016). Water balance study of the Beas River, Himachal Pradesh, using the ArcGIS technique. In: Proceedings of National Conference: Civil Eng. Conf. innovation for sustainability

8. National Disaster Management Authority (NDMA) & Government of Himachal Pradesh. (2023). Report on Post Disaster Needs Assessment: Himachal Pradesh Monsoon – 2023.

9. https://hpsdma.nic.in/index1.aspx?lsid=9046&lev=2&lid=5400&langid=1

10. Chaturvedi S., Guleria S., Bindal M.K., 2020, India disaster report (2014-17), National Institute of Disaster Management, New Delhi, N.D.

11. Prakash, K., Rawat, D., Singh, S. et al. Morphometric analysis using SRTM and GIS in synergy with depiction: a case study of the Karmanasa River basin, North central India. Appl Water Sci 9, 13 (2019). https://doi.org/10.1007/s13201-018-0887-34

12. Singh RK..Dharam Chand, 2023. Unveiling the Catastrophe: Disasters in Himachal Pradesh with a Focus on Kullu District. International Journal of Environmental Sciences. 12(4), 74-79.DOI: 10.13140/RG.2.2.35779.37924

13. Chandel, A. S. (2025). Geospatial and statistical assessment of monsoon-induced disasters in Himachal Pradesh: insights from the 2023 floods and landslides. All Earth, 37(1), 1–48. https://doi.org/10.1080/27669645.2025.2543099

14. Kahlon S., Chande. VBS.,Brar KK, (2014). Landslides in the Himalayan Mountains: A Study of Himachal Pradesh, India. Int. J. of IT, Eng. and Applied Sci. Res. 3(9), 28-35

15. Meena, S. R., Mishra, B. K., &TavakkoliPiralilou, S. (2019). A Hybrid Spatial Multi-Criteria Evaluation Method for Mapping Landslide Susceptible Areas in Kullu Valley, Himalayas. Geosciences, 9(4), 156. https://doi.org/10.3390/geosciences9040156

16. Mishra S. P., Sethi K. C., Md. Siddique, 2020, Emerging threats during Anthropocene as urban Flooding of Bhubaneswar city, India, Water and Energy International, Central Board of Irrigation and Power, New Delhi, 63(RNI No 1); 46-58

17. Prakasam, C., Aravinth, R., Saravanan, R. (2021). Report on NRDMS: DST Sponsored 21-day (Level 2) Summer School on Mountain Disaster Mngt. Landslide from 9 to 29th May 2019. Natl. Acad. Sci. Lett., 45, 95–103 https://doi.org/10.1007/s40009-021-01068-5

18. Paul SR., Sarkar R. (2024). A critical analysis of landslide susceptibility studies in Himachal Himalaya J. Geol. Soc. India 100 (11): 1545-56. doi.org/10.17491/jgsi/2024/174014

19. Lohan, N., Kumar, S., Singh, V., Gupta, R. P., & Tiwari, G. (2025). Analysing an Extreme Rainfall Event in Himachal Pradesh, India, to Contribute to Sustainable Development. Sustainability, 17(5), 2115. https://doi.org/10.3390/su17052115

20. Ruiz-Villanueva, V., Allen, S., Arora, M., Goel, N. K., &Stoffel, M. (2016). Recent catastrophic landslide lake outburst floods in the Himalayan mountain range. Progress in Physical Geography: Earth &Env, 41(1), 3-28. https://doi.org/10.1177/0309133316658614

21. Chandel, V. B. S., &Brar, K. K. (2010). Seismicity and vulnerability in the Himalayas: the case of Himachal Pradesh, India. Geomatics, Natural Hazards and Risk, 1(1), 69–84. https://doi.org/10.1080/19475701003643441

22. Mohapatra, M.; Srivastava, A.K.; Balachandran, S.; Geetha, B. Inter-annual variation and trends in tropical cyclones and monsoon depressions over the north Indian Ocean. Obs. Clim. Var. Change Over Indian Reg. 2017, 89–106.

23. Mishra S. P., Ojha, A. C., 2020, Analysis and Prediction of Upsurge in Cyclogenesis over the Arabian Sea Fabric, J. of Xidian Univ., 4(5), 1275-1286. https://doi.org/10.37896/jxu14.5/140

24. Banerjee, A., Chen, R., E. Meadows, M., Singh, R. B., Mal, S., &Sengupta, D. (2020). An Analysis of Long-Term Rainfall Trends and Variability in the Uttarakhand Himalaya Using Google Earth Engine. Remote Sensing, 12(4), 709. https://doi.org/10.3390/rs12040709.

25. Lohan, N., Kumar, S., Singh, V., Gupta, R. P., & Tiwari, G. (2025). Analyzing an Extreme Rainfall Event in Himachal Pradesh, India, to Contribute to Sustainable Development. Sustainability, 17(5), 2115. https://doi.org/10.3390/su17052115

26. Kemmannu, P. K., &Manjunatha, B. R. (2023). Impacts of Aerosol Orographic Precipitation Interaction Associated with Western Disturbances over India Using Satellite Observations. Water, 15(16), 2901. https://doi.org/10.3390/w15162901

27. Saakshi, BDR., Bhatia A.K. (2025). Land use and land cover analysis in agroforestry and other land use categories in Shimla district of Himachal Pradesh: a GIS-based analysis in the NW Himalayas. *Discov. For* 1, 33 https://doi.org/10.1007/s44415-025-00038-9

28. Meena, S. R., Mishra, B. K., &TavakkoliPiralilou, S. (2019). A Hybrid Spatial Multi-Criteria Evaluation Method for Mapping Landslide Susceptible Areas in Kullu Valley, Himalayas. Geosciences, 9(4), 156. https://doi.org/10.3390/geosciences9040156

29. Gaddam, V. K., Kulkarni, A. V., & Gupta, A. K. (2019). Assessment of the Baspa basin glaciers' mass budget using different remote sensing methods and modelling techniques. Geocarto Int., 35(3), 296–316. doi.org/10.1080/10106049.2018.1516247

30. Paul, S. R., & Sarkar, R. (2024). A Critical Analysis of Landslide Susceptibility Studies in Himachal Himalaya. Journal of Geological Society of India, 100(11), 1545–1556. https://doi.org/10.17491/jgsi/2024/174014

31. Li, L., Shen, M., Hou, Y., Xu, C.-Y., Lutz, A. F., Chen, J., Jain, S. K., Li, J, Chen, H. (2019): Twenty-first-century glacio-hydrological changes in the Himalayan headwater Beas River basin, Hydrol. Earth Syst. Sci., 23, 1483–1503, https://doi.org/10.5194/hess-23-1483-2019,

32. Joshi, V., Singh, D. (2025). A Holistic Overview of Glacial Lake Outburst Flood (GLOF) Hazard in Himachal Pradesh, India. In: Rai, S.C. (eds) Himalaya: Mountains of Destiny. Springer, Cham. https://doi.org/10.1007/978-3-031-94905-0_16

33. Vasistha S., Ammani A., Mittal H., Shankar U., Mishra OP., (2024). Seismic Source Characteristics and Scaling Relations in the Northwest Himalayan Region: Case Study of Himachal Pradesh &Uttarakhand, Pure and Applied Geophysics 182(3):1129-1147, DOI:10.1007/s00024-024-03577-y

34. Rani, S., Jaiswal, H. (2025). Watershed Prioritisation of the Upper Beas Basin of Himachal Himalaya Using Morphometric Parameters and Land Use/Land Cover. In: Rani, S. (eds) Land and Water Nexus in South Asia. Advances in Asian Human-Environmental Res. Springer, Cham. https://doi.org/10.1007/978-3-031-87429-1_12

35. Pandey VK, Rai J., Sharma KK., Singh R. (2025). Analysis of flood and channel dynamics adversity in the Upper Beas Basin during 9- 11 July 2023, Himachal Pradesh. Natural Hazards Research. https://doi.org/10.1016/j.nhres.2025.09.001.

36. Parida A., Mishra SP., Dash SS. (2022). Ghat Road Construction. Indian Journal of Natural Sciences, 13(73), 46832-46842

37. Behera J.K., Pattanaik, S., Mishra S.P., Women in the communities act as disaster managers: an evidence-based study in special reference to Puri district, Odisha, india—International Journal of Management (IJM), 14(6).(2023), Article ID: IJM_14_06_00

38. Mishra SP, Acharya B, Tripathy D., SethiKC.,Ghosh A. 2025. Leveraging Anthropocene Indian Disasters With Python.. Advances in Research 26 (5):458–480. https://doi.org/10.9734/air/2025/v26i51502.

39. Himachal Pradesh Battles Natural Disaster: Urgent Need for National Attention and Aid | Peoples Democracy. (2025). People's democracy In. https://peoplesdemocracy.in/2025/0914_pd/himachal-pradesh-battles-natural-disaster-urgent-need-national-attention-and-aid

40. river_basins - INDIA WRIS WIKI. (2021, August 24). Indiawris.gov.in. https://indiawris.gov.in/wiki/doku.php?id=river_basins

41. Chauhan, S. (2025, October 9). Himachal panchayat elections postponed citing monsoon damage and road connectivity issues. Wise Himachal. https://wisehimachal.com/news/himachal-pradesh/himachal-panchayat-elections-postponed-citing-monsoon-damage-and-road-connectivity-issues

42. A Village Level Climate Change Vulnerability Analysis and Indicative Adaptation Plan Framework. (n.d.). Department of Environment, Science & Technology, Government of Himachal Pradesh. https://dest.hp.gov.in/sites/default/files/PDF/CCVA_DraftReportKinnaurLS_Web.pdf

43. Bureau, T. H. (2025, September 16). Heavy rains over Himachal, Uttarakhand due to clash of easterly and westerly winds, say Meteorologists. The Hindu. https://www.thehindu.com/news/national/india-rains-dehradun-floods-hyderabad-weather-mumbai-rain-live-updates-september-16-2025/article70055612.ece

44. Kumar, P. (2025, August 20). Rivers System of Himachal Pradesh (Part 2) - GeoHimachal. GeoHimachal. https://geohimachal.com/river-system-of-himachal-pradesh-2-2/

45. Beas River and Its Tributaries in Himachal Pradesh – Jokta Academy. (2024). Joktacademy.com. https://joktacademy.com/beas-river-and-its-tributaries-in-himachal-pradesh/

46. Earthquakes in Himachal Pradesh, India. (2008, February 21). Asc-India.org; Amateur Seismic Centre. https://asc-india.org/seismi/seis-himachal-pradesh.htm

47. DISTRICT DISASTER MANAGEMENT PLAN SHIMLA. (n.d.). National Disaster Management Authority, Govt of India. https://ndma.gov.in/sites/default/files/PDF/DDMP/HP/SHIMLA.pdf

48. Landslide Hazards. (2018, December 1). Hpsdma. Nic. In the Himachal Pradesh State Disaster Management Authority. https://hpsdma.nic.in/Index1.aspx?lid=4735&lsid=4840&pid=70&lev=3&langid=1

49. ReferencesLandslide Atlas of India. (2023, March 18). Www.isro.gov.in; ISRO. https://www.isro.gov.in/Landslide_Atlas_India.html

50. Disaster Management | District Mandi, Government of Himachal Pradesh | India. (2024). Hpmandi. Nic. In; Government of Himachal Pradesh. https://hpmandi.nic.in/disaster-management/

51. Manali climate: Weather in Manali& temperature by month. (2024). Climate-Data.org; Climate-data. https://en.climate-data.org/asia/india/himachal-pradesh/manali-24786/

52. Express Web Desk. (2023, July 11). *Rescue efforts gain pace after rain batters north India; 31 dead in Himachal.Key points*. The Indian Express. https://indianexpress.com/article/india/rescue-efforts-gain-pace-after-rain-batters-north-india-31-dead-in-himachal-key-points-8826716/

53. HP General Studies. (2025, July 24). *Unnatural Disasters in Natural Landscapes: A Geomorphic and Anthropogenic Analysis of the 2023 Beas Floods - Himachal Pradesh General Studies*. Himachal Pradesh General Studies. https://hpgeneralstudies.com/unnatural-disasters-in-natural-landscapes-a-geomorphic-and-anthropogenic-analysis-of-the-2023-beas-floods/