

A Brief report on

Landslide Inventory Mapping for 2023 Post Monsoon for Himachal Pradesh



**State Centre on Climate Change
Himachal Pradesh Council for Science, Technology & Environment
Vigyan Bhawan, Kasumpti, Shimla-9**

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15.	Abstract	<p>Himachal Pradesh has witnessed major landslides increase in the recent years. These landslide events occur more specifically during the monsoon period. The monsoon season's intense rainfall is the primary catalyst for landslides, making regions like those in the Himalayas particularly vulnerable. Himachal Pradesh faces severe consequences, including loss of life, damage to property & infrastructure, disruptions in connectivity with other regions and environmental degradation. Heavy monsoon rains in 2023 caused severe destruction across the state. Heavy and prolonged rainfall was a trigger for the landslides. The current study was conducted in Himachal Pradesh and the objective of the work is mapping of landslide inventory of 2023 and create a landslide database for Himachal Pradesh using landslide mapping tool (made by NRSC) and the Field Landslide Inventory Mapping (FLIM) app (made by NRSC). This inventory provides the essential data for spatial analyses, enabling precise identification of landslide-prone areas, data-driven modelling for prediction, informed risk assessments, guided land-use planning and the development of reliable early warning systems, thus significantly enhancing overall landslide risk management.</p> <p>Key words: Database, Landslides, Mapping, Monsoon, Risk management.</p>			

SUMMARY

Himachal Pradesh, with its mountainous and hilly terrain, is highly vulnerable to landslides and other natural disasters. In recent years, the state has witnessed a significant rise in landslide occurrences, with a large portion of its territory under constant threat. Due to its rugged topography, extreme climatic conditions and increasing human activity, Himachal Pradesh faces severe consequences, including loss of life, damage to property and infrastructure, disruptions in connectivity with other regions and environmental degradation. The monsoon season's intense rainfall is the primary catalyst for landslides, making regions like those in the Himalayas particularly vulnerable. To effectively combat these disasters, technological advancements are paramount, with the creation of a comprehensive landslide inventory being the cornerstone of any mitigation strategy. This inventory provides the essential data for spatial analyses, enabling precise identification of landslide-prone areas, data-driven modelling for prediction, informed risk assessments, guided land-use planning and the development of reliable early warning systems, thus significantly enhancing overall landslide risk management. The current study was conducted in Himachal Pradesh and the objective of the work is to map post monsoon landslides of 2023 and create a landslide database for Himachal Pradesh using landslide mapping tool (made by NRSC) and the Field Landslide Inventory Mapping (FLIM) app (made by NRSC). The LISS IV satellite data of (2022) and (2023) having a spatial resolution of 5.8m have been used for the delineation of landslides for the landslides Inventory mapping 2023. Heavy monsoon rains in 2023 caused severe destruction across the state. The three extreme intense spells of rainfall (8th –11th July, 14th &15th August, and 22nd & 23rd August), caused 32 flash floods, and 163 landslides. Heavy and prolonged rainfall was a trigger for the landslides. 13569 landslides were mapped to create the landslide inventory. A total of 4 field visits, covering 12 districts of Himachal Pradesh were conducted to verify the result of the tool. During these field visits, a total of 290 FILM points were collected, and 286 points were verified by NRSC, four points were eliminated because of their identical locations. The results of the analysis reflected that most affected districts due to landslides were Kangra (4027), Mandi (2169), Solan (1930) and Chamba (1666), whereas the least affected were Lahaul and Spiti (31) Kinnaur (65) and Una (98). This work will contribute to the development of a regional landslide early warning system, an integral part of the SILAAS project.

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Table of Content

	Title	Page No.
	Report / Document Control Sheet	i
	Summary	ii
	Acknowledgment	iii
	Table of Content	iv
	List of Figures	v
	List of tables	vi
1	Introduction	1
1.2	Objectives of the Study	4
2	Study area	4
2.1	Geology	5
2.2	Climate	6
2.3	Drainage	7
2.4	Landslide scenario in Himachal Pradesh	7
3	Major disaster events of monsoon 2023	9
4	Dataset	14
5	Methodology	15
6	Result	17
7	Field work	20
7.1	Solan, Bilaspur, Kangra and Hamirpur districts	21
7.2	Mandi and Kullu districts	24
7.3	Chamba districts	26
7.4	Shimla, Kinnaur and Lahaul & Spiti districts	28
8	Conclusion	31
9	Reference	33
10	Annexure – i	1
11	Annexure - ii	3

LIST OF FIGURES

Figure 1: Study area map of Himachal Pradesh.	5
Figure 2: A Massive Landslide near the bus stand of Anni town, Kullu district	9
Figure 3: A Flash flood in Thunag Market in Mandi district	10
Figure 4: Flash flood in Morang in Kinnaur district	10
Figure 5: Landslide in Shamti in Solan district	11
Figure 6: Landslide in (a) Krishna Nagar in Shimla & (b) Shiv Mandir, Summerhill, in Shimla district	12
Figure 7: Methodology for landslide inventory preparation of Himachal Pradesh for the year 2023.	16
Figure 8: Landslide Inventory map of Himachal Pradesh	18
Figure 9: FLIM points map of Himachal Pradesh	18
Figure 10: Landslides from Solan, Himachal Pradesh. Pre Image: Resourcesat 2, LISS IV MX, 8th Apr. 2023, Post Image: Resourcesat 2 LISS IV MX, 5th Oct. 2023	19
Figure 11: Landslides from Sirmour, Himachal Pradesh. Pre Image: Resourcesat 2 LISS IV MX, 7th Jan 2023, Post Image: Resourcesat 2 LISS IV MX, 9th Dec. 2023	19
Figure 12: Landslides from Sirmour, Himachal Pradesh. Pre Image: Resourcesat 2 LISS IV MX, 7th Jan 2023, Post Image: Resourcesat 2 LISS IV MX, 9th Dec. 2023	20
Figure 13: Landslides in Bilaspur district	23
Figure 14: Landslides in Kangra district	23
Figure 15: (a) Landslides in Solan district	23
Figure 15 : (b) Landslides in Solan district	24
Figure 16: Landslides in Sirmour district	24
Figure 17: Landslides in Kullu district	26
Figure 18: Landslides in Mandi district	26
Figure 19: Landslides in Chamba district	27
Figure 20: Landslides in Shimla district	29
Figure 21: Landslides in Kinnaur district	30
Figure 22: A Landslide damaged the NH-3 near Sissu, Lahaul & Spiti district	30

LIST OF TABLES

Table 1: Dataset used for landslide inventory preparation	13
Table 2: District wise distribution of landslide mapped for 2023 post monsoon of Himachal Pradesh	17
Table3: District wise distribution of FLIM Points for Himachal Pradesh	20

1. INTRODUCTION

The alarming global surge in landslide activity, frequently linked to both natural phenomena and anthropogenic factors, has demonstrably impacted thousands of individuals, resulting in a complex web of social, economic and environmental consequences. As per National Disaster Management Authority (NDMA), Landslides are downward and outward movement of slope materials such as rock debris and earth, under the influence of gravity. Landslides are devastating geological events, causing widespread destruction to infrastructure like roads, bridges, & homes, and tragically, often resulting in fatalities. These events arise from a complex interaction of geological, geomorphological and meteorological factors (Rawat *et al.*, 2015). India ranks among the top four countries with the highest landslide risk, with an estimated loss of life exceeding one per 100 km² annually. Most landslides in the country occur during the monsoon season (June to September). Globally, India accounts for 16% of rainfall-triggered landslide events (Landside Atlas of India, 2023).

Several studies have been conducted on landslides in India, focusing on hazard assessment, risk mitigation and early warning systems. The Nilgiris district in Tamil Nadu has seen a notable rise in casualties and damage from landslides due to the influence of monsoons. Changing rainfall patterns on vulnerable hill slopes are a significant factor in increasing landslide frequency and resultant damages. Analyses of 30 years of rainfall data combined with landslide records show that extreme rainfall, more frequent storms and shifting monsoon patterns—likely influenced by climate change and urbanization are increasing landslide frequency and intensity (Chellamuthu & Ganapathy, 2024). Heavy rains in Kerala, India, during August 2018 triggered a massive wave of landslides, primarily in Idukki, Wayanad and Thrissur districts. This disaster resulted in approximately 500 deaths, displaced 1.25 million people and severely damaged around 20,000 homes. The event was documented using field observations, geotechnical tests, satellite imagery and Google Earth mapping to create a record of the landslides. The 2013 Kedarnath tragedy in Uttarakhand saw widespread devastation from flooding and landslides, reportedly causing over 5,700 deaths and impacting thousands of villages. (Jindal *et al.*). On July 30, 2024, a devastating landslide struck the Wayanad district in southern India, within the ecologically sensitive Western Ghats mountain range. This massive landslide, among the largest in India's history, resulted in the tragic loss of over 239 lives and was

triggered by pre-existing geological fractures in the area as well as heavy rainfall (Yunus *et al.*, 2024). Landslides, a recurring global disaster, frequently devastate mountainous areas, including the Indian Himalayas. This region, experiencing 15% of global rainfall-triggered landslides, suffers significant impacts on its economy, particularly transportation & agriculture, and often results in fatalities. A review of landslide research in the Himalayas reveals a need for progress in understanding the influence of climate change, utilizing higher resolution data and employing new methodologies like physical and computational approaches. Current research primarily focuses on susceptibility mapping, landslide identification, and slope stability analysis (Dikshit *et al.*, 2020). Himachal Pradesh, with its rugged terrain and heavy monsoon rains, is highly susceptible to landslides, posing significant risks to life and infrastructure. In Himachal Pradesh's history, some significant landslides that caused significant damage include the 1968 Maling landslide, which devastated 1 km of NH-22 and is still active today. A landslip at Sholding *Nala* in December 1982 caused three bridges to collapse and 1.5 kilometres of road to disappear. On September 12, 1995, a landslide at Luggarbhathi buried 65 people alive. The Kotrupi landslide, a major disaster in Himachal Pradesh's history, first occurred in 1977 and reactivated in 1997, demonstrating the danger of pre-existing slope scarps. In 2017, a massive landslide struck near Kotrupi village on National Highway-154 (Mandi-Pathankot), claiming 46 lives and destroying livestock, farmland and a large section of the highway (Surya and Anil, 2021).

In Himachal Pradesh, several organisations are working actively, like **HPSDMA** for disaster management, **GSI** for geological assessments and **IIT Mandi** for early warning systems. **HIMCOSTE** works on environmental research and policy development. **NDRF** and **SASE** handle rapid response and monitoring in landslide-prone areas. Additionally, **Intiot Services** and **Pragya** focus on technological solutions and disaster relief efforts. In response, the state has also implemented several initiatives to mitigate these hazards and enhance early warning capabilities. In April 2022, early warning and land monitoring systems were installed at Batseri and Nigulseri in Kinnaur district. These systems utilize sensors atop mountains to detect ground movements, alerting district disaster centers and local panchayats. Visual signals, such as blinking red lights and audible alarms are activated to warn drivers and pedestrians of potential landslides (The Tribune, 2022). **iIoTS**, an initiative by IIT Mandi, has developed a Landslide Monitoring and Early Warning System along the

Mandi-Joginder Nagar highway. This system provides real-time alerts about soil movements, enabling timely evacuations and preventing infrastructure damage. The State Disaster Management Authority, Himachal Pradesh is piloting Vetiver Grass Technology (VGT) in Solan district to stabilize soil along retaining walls and combat erosion. Initially, the focus is on the Shamti, Sanwara, and Mansar areas of Solan District. Vetiver Grass Technology (VGT) is known for its exceptional soil-binding properties. A cluster approach will integrate PWD and DDMA efforts, categorized as “black intervention,” for mitigation work (The Tribune, 2024). In February 2025, the Government of India approved the LRMS (**Landslide Risk Mitigation Scheme**) with a financial outlay of ₹1,000 crore for 15 landslide-prone states, including Himachal Pradesh. The scheme focuses on disaster preparedness, capacity building and the implementation of landslide mitigation projects (Press information bureau). The Geological Survey of India categorizes landslides based on their size and potential impact, ranging from minor, isolated events (Category IV) to major, devastating ones threatening populated areas (Category I). These classifications help authorities assess risk, prioritize responses and issue targeted warnings to affected communities. This system is crucial for effective disaster management and minimizing the impact of landslides (SDMA report). Himachal Pradesh can lessen landslide dangers and create stronger communities by combining climate adaptation strategies, enforcing building codes, using natural solutions and improving early warnings (Sehgal, 2023). The State is proactively working to mitigate landslide threats using early warnings, soil stabilization and national programs. However, continuous evaluation and improvement of these strategies are crucial for the State to effectively address the constantly changing landslide challenges. The objective of the work is to map post monsoon landslides of 2023 and create a landslide database for Himachal Pradesh using landslide mapping tool and Field Landslide Inventory Mapping (FLIM) app (made by NRSC). This work will be useful for development of regional landslide early warning system which is an integral part of the SILAAS project.

The status report designed to provide the detailed information about the post monsoon landslides of 2023 and created with two tools made by NRSC. Report consists of overview of Himachal Pradesh’s geology, drainage and climatic conditions and major landslide events of the Himachal Pradesh. A total of 4 field visits covering 12 districts of Himachal Pradesh were conducted to verify the results of the tool. This report

explains overall status of the landslide inventory preparation, number of landslides mapped, number of field points visited, major findings such as most affected districts in monsoon 2023.

1.2 Objectives of the Study:

The main objective of the study area is to prepare landslide inventory mapping of 2023.

- Landslide inventory database (per 1:50k sheet) in ESRI shape file (.shp) with standard attributes as mentioned in SOP (to be provided by NRSC) for the year 2023.
- Field data collected through FLIM app (photographs and observations).
- Field validation of landslide alert generated (if any) through SILAAS project
- Brief report of the work.

2. STUDY AREA

Himachal Pradesh lies in the western Himalayas. The state is compact in shape and almost mountainous, with altitude varying from 300 meters to nearly 7000 meters. It is located between latitude 30°22' 40" N and 33°12' 20" N and longitude 75°45'55" E and 79°04'20" E. It covers a geographical area of 55,673 sq. km, which is about 1.69% of India's total geographical area. Himachal Pradesh is flanked by the state of Jammu and Kashmir from the north. Punjab and Haryana surround the state from the south and southwest. Towards the southeast, the state merges into Uttarakhand, and in the northeast, it forms India's border with Tibet. The state has an international boundary of about 200 km and a state boundary of 1170 km. Himachal Pradesh lies in the Western Himalaya and embraces a vast mountainous terrain between the Ravi River in the northwest and the Tons-Yamuna in the southeast. Physiographically, the state is essentially a hilly and mountainous terrain. The landscape has been shaped in the Quaternary period by glacial and fluvial activities. It displays prominent relief characterized by high mountains and deep valleys with gradual blending of different forms of relief and slopes. There are both longitudinal and transverse ranges

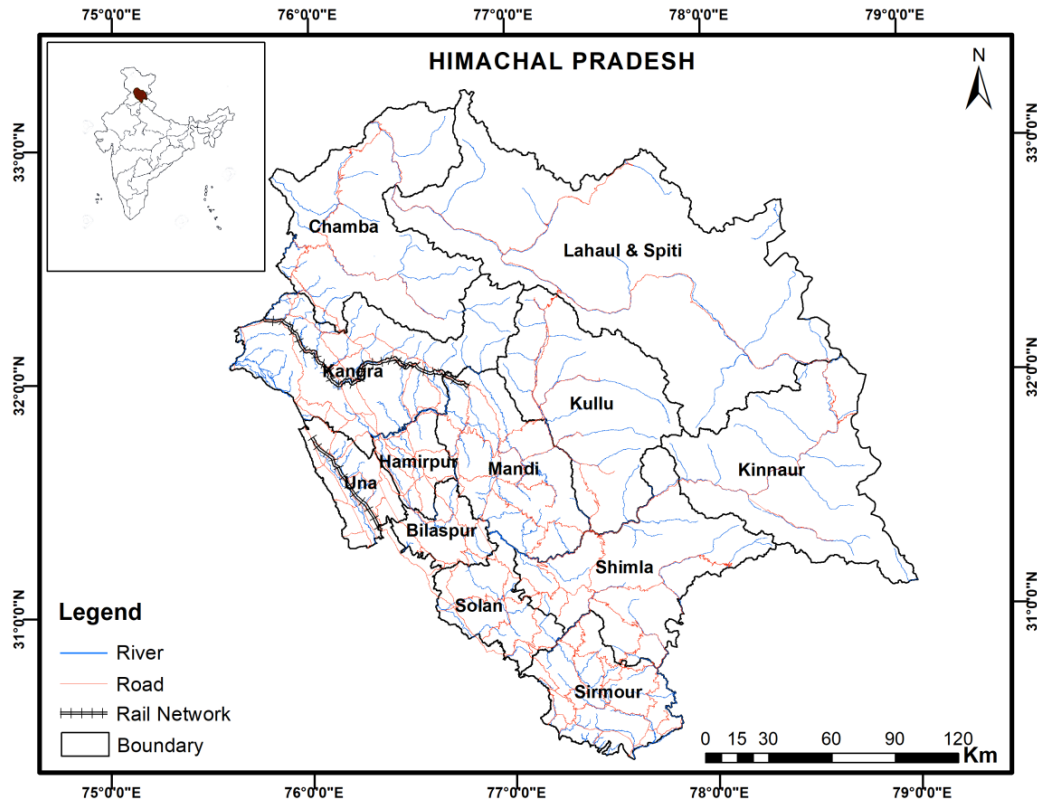


Figure 1: Study area map of Himachal Pradesh.

2.1 Geology

The Himalaya is a classic example of continent and continent collision due to the convergent movement of the Indian Plate towards the Eurasian Plate. It comprises two contrasting tectogens with their distinctive geological history. The dividing line between these two tectogens represents a major tectonic discontinuity designated by several local names. Himachal Pradesh with its complex geological structures presents a complicated topography with intricate mosaic of mountainous ranges, hills and valleys, composed of recent Alluvium. The Shiwalik hills are made up of rocks such as sandstone, shale and clay that came into existence during the Eocene, Miocene and Pliocene period.

The central part that extends from Chamba district in the north to Shimla district in the south is mainly represented by Jatog group of rocks which originated in middle Proterozoic period. In the north eastern portion unclassified Granites borders the central part in between Kullu, eastern Shimla, Lahaul-Spiti and parts of Kinnaur district.

The eastern greater Himalaya presents the Triassic formation which is found in Kaza tehsil of Lahaul & Spiti district. The oldest rocks are Granites found at Jeori-Wangtuand Bandel near Largi in Kullu district. These granites date back to a stage of the crust at a time when India was located 8000 Km southwest of its present position.

2.2 Climate

There is a great variation in the climatic conditions of Himachal Pradesh due to extreme variations in elevation. The climate varies from hot and sub-humid tropical in the southern tracts to cold, alpine and freezing in the northern & eastern mountain ranges with greater elevation. Broadly, the state experiences three marked seasons: hot weather season, cold weather season and rainy season. Evaporation generally exceeds rainfall over six months from October to December and April to mid-June. Summer lasts from mid-April till the end of June, and most parts become very hot (except in the alpine zone, which experiences mild summer) with average temperatures ranging from 28°C (82°F) to 32°C (90°F). July to September is marked by the rainy season when the monsoon is vigorous in the state. Winter lasts from late November till mid-March, when temperatures plummet to sub-zero. The average rainfall in Himachal Pradesh is 1,111 mm, varying from 450 mm in Lahaul & Spiti to over 3,400 mm in Dharamshala, the headquarters of Kangra district. Precipitation declines from west to east and south to north. Winter precipitation occurs as snow at elevations above 1800 m. An average of three meters of snow is experienced between December and March at high altitude.

2.3 Drainage

The state is characterized by a well-developed drainage system wherein ninety percent of the drainage forms part of the Indus River System and only ten percent belongs to the Ganga River System. There is a network of perennial rivers in Himachal Pradesh, which have glaciers as their sources. Himachal Pradesh is nourished by the network of rivers, including the Satluj, Beas, Ravi, Chenab, Spiti, Parbati, Pabbar, Tons, and Giri, among which the Satluj is an antecedent river, originating in the highlands of Tibet. Most of the rivers flow following the trend of the main structural grain of the region. Nearly 17% of the total area of Himachal Pradesh is covered by glaciers. A study in 2004 by CSK Himachal Pradesh Agricultural University (CSKHPAU) collaborated

with ICIMOD documented 2,554 glaciers in the state, (Jack D. *et al.*, 2010) which are the source of fresh water to the rivers of North India. Bara Shigri is the largest glacier in the state, which is located in the Chandra valley of Lahaul and feeds the Chenab River. The glacier is more than 25 km long and about 3 km wide. Chandra Nahan, Bhadal, Bhaga, the Lady of Keylong, Mukkila, and Hamata are other major glaciers in the state. There are many freshwater lakes in Himachal Pradesh. The Chandra Tal, Suraj Tal, Yonam Tso, and Nako Lake are the lakes formed due to the damming of glaciers, while the Rewalsar and Renuka lakes are formed due to the damming of river/stream courses. Gobind Sagar, Pong, and Pandoh are the artificial lakes in the Himachal Pradesh formed by dam construction on the Satluj and Beas rivers.

2.4 Landslide scenario in Himachal Pradesh

Landslides in Himachal Pradesh are a recurring and significant natural hazard due to the region's mountainous terrain and heavy monsoon rainfall. In the monsoon season, which lasts from June to September, Himachal Pradesh receives average rainfall of around 730 mm. The region is also prone to intense storms and cloudbursts. Himachal Pradesh's topography consists of steep slopes, deep valleys, and fragile rock formations. These slopes are often unstable, especially in areas where roads, settlements, or agriculture have altered the natural balance. Excessive rainwater infiltrates the slopes of the mountains, weakening the soil and rock formations. Heavy rainfall or a cloudburst over the mountains can trigger a landslide.

In some cases, road construction/widening or deforestation may exacerbate the instability of the land. Roads and highways often get blocked by debris, rocks and mudslides. National highways got blocked, like the NH-22 and NH-5, which pass through mountainous areas and are vulnerable to landslides. Landslides cause significant delays in travel, supply disruptions, and road accidents. Landslides cause fatalities or injuries to people if they occur near villages or towns. Houses may be grounded, and infrastructure like roads, bridges, or electricity lines may be destroyed. Vehicles on the roads may get trapped in debris, causing further damage and loss of life.

The state's disaster response teams, including the National Disaster Response Force (NDRF), police SDRF, Home guard and Army, are often deployed for rescue and

relief operations. The landslide causes extensive environmental damage as it displaced or destroyed vegetation, soil and wildlife habitats. The landslide's aftermath can lead to further soil erosion, leading to long-term environmental degradation. The state government, along with local authorities, often works on recovery measures and mitigation plans. These may include restoring damaged infrastructure, replanting trees to prevent further soil erosion and improving early warning systems for landslides. The landslides in the Kullu and Mandi region during the monsoon led to the collapse of several roads and significant damage to the surrounding areas. The landslides occurred in Chamba, where continuous rainfall caused a massive chunk of rock and debris to crash down on roads and nearby settlements, forcing evacuations. The rockslides/landslides occurred at Kinnaur due to weak formation of rocks and steep slopes, which contribute to instability. The lower region of Himachal Pradesh comes under the Shiwalik Himalayas, Shiwalik are young Himalayas composed of unconsolidated material like gravel, sand and debris this make them highly susceptible to landslide. Landslides in Himachal Pradesh need better infrastructure planning, early warning systems, and more resilient disaster management strategies. The unpredictable nature of such events makes it crucial to constantly monitor weather patterns and land stability in vulnerable areas.

3. MAJOR EVENTS OF 2023

The 2023 monsoon season in Himachal Pradesh was severe, marked by 1334.9 mm record-breaking rainfall. The unprecedented rainfall triggered floods and landslides across the state. Here are some major events of 2023.

Kullu District

The district's major river valleys—the Beas, Parbati, Sainj, Tirthan, and Banjar valleys—saw devastating floods on July 9th, 10th, and 11th of 2023 as a result of the unrelenting rainfall that began on July 8th and persisted at the same intensity for more than 60 hours. Almost 60 houses/commercial buildings/shops in the main Sainj market were destroyed by the flash flood on July 10th and 11th. The main bridges on the Beas River, i.e., the Akhara Bazaar Bridge, Bhunter Valley Bridge, and Patlikuhl Bridge, got badly damaged, whereas the footbridge at Seobagh was washed away. The connectivity of Sainj Valley was severely affected as many bridges across the Sainj River have been damaged/washed away, which has cut off around six panchayats of

the valley. On 25th August 2023, eight multi-storey buildings were destroyed while two others suffered partial damage due to a massive landslide near the new bus stand in Anni town of Kullu district. However, there was no loss of life as the district administration had already got the buildings vacated.



Figure 2: A Massive Landslide near the bus stand of Anni town in Kullu district

Mandi District

On July 9th and 10th, 2023, the district of Mandi experienced heavy rainfall, causing severe flooding in various areas. In response to the rising water levels, the Larji and Pandoh dam's authorities had to release water as a precautionary measure. Unfortunately, this led to the submergence of parts of Pandoh Bazar and houses located near the river. Huge flash flood in Thunag market washed, about 60 houses and shops were damaged. Water, along with boulders, wood logs, gushed down through the middle of Thunag market, creating havoc and huge loss. Due to flash floods and waterlogging in various parts of Mandi District, huge losses to both life and property were reported.



Figure 3: A Flash flood in Thunag Market in Mandi district

Kinnaur District

Due to very heavy rain on 08th and 09th July, 2023 in Tehsil Moorang, an incident of flash flooding was reported at Village Ribba, in which 03 private vehicles and 01 JCB were washed away. Around 100 houses (Kacha and Pakka), 13 shops and 20 cowsheds were damaged. Other than this, electricity transformers, forests, agriculture & horticulture crops, and community assets were also damaged. On 13th July 2023, the district administration of Kinnaur rescued the 118 tourists from Sangla with the help of the Air Force, Army, ITBP, and Police.



Figure.4: Flash flood in Morang in Kinnaur district

Una District

On 09th & 10th July 2023, due to heavy rainfall in district Una, one side of Ghaluwal Bridge over the Swan River NH-503A Una, Hoshiarpur (Punjab) road was severely damaged. Water logging/pounding issues in residential colonies of urban and rural areas of the district damaged the houses. 12 persons were rescued from being stranded in the Swan River near the village of Rampur, Una-Haroli bridge by the rescue team of the Fire and Home Guards.

Solan District

A land mass subsided at Shamti area MC Solan due to continuous and heavy downpour in the area. 50 multi-storey houses were damaged due to sinking of hill mass. About 50 buildings were vacated, and 100 families were immediately shifted to safe locations. This sudden dislocation of the hill has caused a loss of private property to the tune of about 40 crores. On 14th August, 2013, a devastating landslide incident occurred in the village of Jadon, P.O. Dhawla, Sub-Tehsil Mamligh, Sub-Division Kandaghat. As a result of this calamity, two houses and one cowshed have been washed away.



Figure 5: Landslide in Shamti in Solan district

Shimla District

On 09th & 10th July 2023, due to very heavy rainfall in the Shimla district, 06 major incidents occurred (Shimla Rural, Theog, Kumarsain, Jubbal, and Rohru) due to heavy rainfall, in which 06 houses were buried under debris, and 12 lives were lost in Village Thaitvadi, GP Tangnu, Tehsil Chirgaon, Sub Division Rohru, and 11 houses were vacated due to the threat of landslide. Houses are on the verge of collapse due to continuous rainfall that occurred between the 7th and 13th of July at the Sub-Division Jubbal and Kotkhai.

On 14th August, 2023, a tragic incident unfolded near the Shiv Temple in Summer Hill, Shimla, a devastating landslide occurred and leading to the tragic loss of 20 lives. Second, landslide incident occurred in Phagli, resulting in a tragic toll of 5 fatalities and leaving 3 individuals injured and third incident of a landslide occurred in Krishna Nagar, resulting in the collapse of approximately 5-7 houses and the Slaughter House.



Figure 6: Landslide in (a) Krishna Nagar in Shimla and (b) Shiv Mandir, Summerhill, in Shimla

Chamba District

Due to incessant rainfall which started in the district on 8th July and continued for more than 50 hours, various sub-divisions of district Chamba i.e., Chamba, Bharmour, Churah, Salooni, Dalhousie, Bhattiyat and Pangi experienced heavy damages on 9th, 10th and 11th July. On 9th July the rainfall was 12.50 times more than the normal rainfall. About 184 roads, 664 DTRs and 361 JSV water supply schemes were damaged in district Chamba. About 90 houses, commercial buildings/shops of Tissa and 44 cattle sheds got damaged due to heavy rainfall on 9th and 10th July, 2023. About 96 cattle were reported dead. Two foot-bridges at Bakani and Kunda-Jatkari Bridge collapsed in Muhal Bhariyan. About 23 houses and 16 cattle-sheds were damaged in Sub-division Salooni. 27 houses and 5 cattle-sheds were damaged in Sub Division Bharmour. Sixteen Houses were damaged in Sub-Division Pangi were damaged. About 200 sheep/goats were washed away in Sub-division of Pangi.

4. DATASET

The Orthorectified Resourcesat-2, LISS-IV Multispectral (pre and post landslide data) –Scenes shared by NRSC and downloaded from Bhoonidhi has been used.

Table 1: Dataset used for landslide inventory preparation

Sr. No.	Satellite Data	Resolution	Date	District Covered
1.	RS2-LISS IV,95/49c	5.8 m	05-10-2023	Solan
2.	R2A-LISS IV,94/47c	5.8 m	12-10-2023	Chamba
3.	RS2-LISS IV,95/49c	5.8 m	22-11-2023	Solan
4.	R2A-LISS IV,96/49a	5.8 m	09-12-2023	Shimla, Kullu and Kinnaur
5.	R2A-LISS IV,96/49b	5.8 m	28-09-2023	Kinnaur and Shimla
6.	R2A-LISS IV,95/47c	5.8 m	30-08-2023	Lahaul & Spiti
7.	RS2-LISS IV,95/49b	5.8 m	29-10-2023	Shimla, Mandi, Kullu Solan and Sirmour
8.	R2A-LISS IV,94/48a	5.8 m	16-01-2024	Chamba and Kangra
9.	RS2-LISS IV,94/48c	5.8 m	06-09-2023	Kangra and Una
10.	R2A-LISS IV,94/47	5.8 m	01-08-2023	Chamba and Lahaul & Spiti
11.	RS2-LISS IV,95/48b	5.8 m	11-09-2023	Lahaul & Spiti and Kullu
12.	R2A-LISS IV,95/48a	5.8 m	30-08-2023	Chamba, Lahaul & Spiti, Kangra and Kullu
13.	R2A-LISS IV,96/48d	5.8 m	02-01-2024	Kinnaur
14.	RS2-LISS IV,96/48c	5.8 m	21-12-2023	Lahaul & Spiti, Kinnaur and Kullu
15.	R2A-LISS IV,94/48b	5.8 m	05-11-2023	Chamba and Kangra

16.	RS2-LISS IV,95/48d	5.8 m	29-10-2023	Lahaul & Spiti, Mandi, Kinnaur, Shimla and Kullu
17.	R2A-LISS IV,94/48d	5.8 m	05-11-2023	Kangra, Mandi, Una, Hamirpur and Bilaspur
18.	RS2-LISS IV,94/48d	5.8 m	24-10-2023	Kangra, Mandi, Una, Hamirpur and Bilaspur
19.	RS2-LISS IV,95/48c	5.8 m	05-10-2023	Kangra, Mandi, Kullu and Hamirpur
20.	RS2-LISS IV,95/49a	5.8 m	05-10-2023	Bilaspur, Hamirpur, Solan and Mandi
21.	R2A-LISS IV,93/47d	5.8 m	18-09-2023	Chamba
22.	RS2-LISS IV,94/49a	5.8 m	09-05-2023	Una
23.	RS2-LISS IV,93/48b	5.8 m	10-04-2023	Chamba and Kangra
24.	RS2-LISS IV,94/47c	5.8 m	29-10-2023	Chamba
25.	RS2-LISS IV,95/49c	5.8 m	27-03-2023	Solan
26.	RS2-LISS IV,95/49c	5.8 m	14-05-2023	Solan
27.	RS2-LISS IV,94/48a	5.8 m	10-04-2023	Kangra
28.	R2A-LISS IV,95/49a	5.8 m	08-04-2023	Bilaspur, Hamirpur, Solan, Una and Mandi
29.	R2A-LISS IV,96/48d	5.8 m	27-10-2023	Lahaul & Spiti, and Kinnaur
30.	RS2-LISS IV,95/48a	5.8 m	03-11-2023	Lahaul & Spiti, Chamba, Kullu and Kangra
31.	R2A-LISS IV,96/49a	5.8 m	13-04-2023	Shimla, Kullu and Kinnaur
32.	RS2-LISS IV,95/49b	5.8 m	03-03-2023	Sirmour, Solan, and Shimla
33.	R2A-LISS IV,96/49c	5.8 m	07-01-2023	Sirmour and Shimla
34.	RS2-LISS IV,94/48c	5.8 m	16-12-2022	Kangra and Una
35.	RS2-LISS IV,94/49b	5.8 m	15-04-2023	Bilaspur, Solan, Una and Hamirpur
36.	R2A-LISS IV,96/49c	5.8 m	24-02-2023	Sirmour and Shimla
37.	RS2-LISS IV,94/48a	5.8 m	16-12-2022	Chamba and Kangra
38.	R2A-LISS IV,95/49b	5.8 m	22-10-2022	Shimla, Mandi, Kullu, Solan and Sirmour
39.	RS2-LISS IV,95,48c	5.8 m	21-12-2022	Kangra, Mandi, Kullu and Hamirpur
40.	RS2-LISS IV,94/48b	5.8 m	05-10-2022	Lahaul & Spiti ,Chamba and Kangra
41.	R2A-LISS IV,94/48d	5.8 m	04-12-2022	Kangra, Una, Hamirpur, Mandi and Bilaspur
42.	RS2-LISS IV,94,47	5.8 m	05-10-2022	Lahaul & Spiti, Chamba

43.	RS2-LISS IV,95/47	5.8 m	16-09-2022	Lahaul & Spiti
44.	R2A-LISS IV,95/48	5.8 m	22-10-2022	Lahaul & Spiti and Kullu
45.	R2A-LISS IV,95/47d	5.8 m	22-10-2022	Lahaul & Spiti
46.	R2A-LISS IV,95/48d	5.8 m	22-10-2022	Kullu, Mandi, Lahaul & Spiti
47.	R2A-LISS IV,96/48d	5.8 m	27-10-2022	Kinnaur and Lahaul & Spiti
48.	RS2-LISS IV,96/48c	5.8 m	15-10-2022	Lahaul & Spiti, Kullu and Kinnaur
49.	R2A-LISS IV,96/49b	5.8 m	27-10-2022	Kinnaur and Shimla
50.	RS2-LISS IV,9749a	5.8 m	25-11-2022	Kinnaur
51.	RS2-LISS IV,97/48c	5.8 m	02-09-2022	Kinnaur
Other Dataset:				
Geology, Bhukosh				
CartoDEM				
Geomorphology, Bhukosh				
LULC, NRSC				
Basins and Sub basins, WRIS, NRSC				

ARC GIS 10.8 and ERDAS Imagine

ArcGIS is a geographical information system (GIS) software that allows handling and analyzing geographic information by visualizing geographical statistics through layer building. It is a complete platform that allows users to create, manage, analyze and share geographical data. ERDAS Imagine is a software package that helps users extract information from imagery. It's used for remote sensing, photogrammetry, and geospatial analysis. The features of ERDAS imagine are Create base imagery for GIS and ESRI Geodatabases, Analyze image data, Support multiple workflows, including data conversion, orthorectification, and color balancing and Terrain creation, editing, and analysis.

Landslide Mapping Tool

A high resolution multispectral LISS-IV Mx (5.8 m) image with three bands (green, red, and NIR) has been used in the model. The slope map was prepared using a high resolution (10 m) digital elevation model (DEM) produced from Cartosat-1 (2.5 m) using a digital photogrammetric approach. The model will automatically scale the DEM data to a resolution of 5 m. The application would make it easier for state and federal organisations to quickly create landslide / landslip inventory maps.

Field Landslide Inventory Mapping (FLIM) Mobile App User field guide for ground truthing and field verification.

NRSC/ISRO develops the FLIM mobile app. SDMAs, DDMAs, government agencies, and researchers with a reasonable understanding of landslides were the intended users. The primary goals of the app are to gather field landslide data and use that data to develop a landslide warning system for the region.

Data collected from the field through this app, sent to the BHUVAN and NDEM servers for analysis and visualization. Consequently, the app will help state officials to report the instances of landslides.

5. Methodology

The LISS IV satellite data of 2022 and 2023, having a spatial resolution of 5.8 m, have been used for the delineation of landslide in 2023. The pre-processing of images i.e. layer stacking, Geometric rectification etc. was done using polynomial transformation of third order with resulting Root Mean Square (RMS) error less than one pixel using ERDAS software. The landslides were mapped using Arc GIS 10.8. All the polygons have been assigned polygon ID's. The flowchart explaining the methodology is given in Fig. 7.

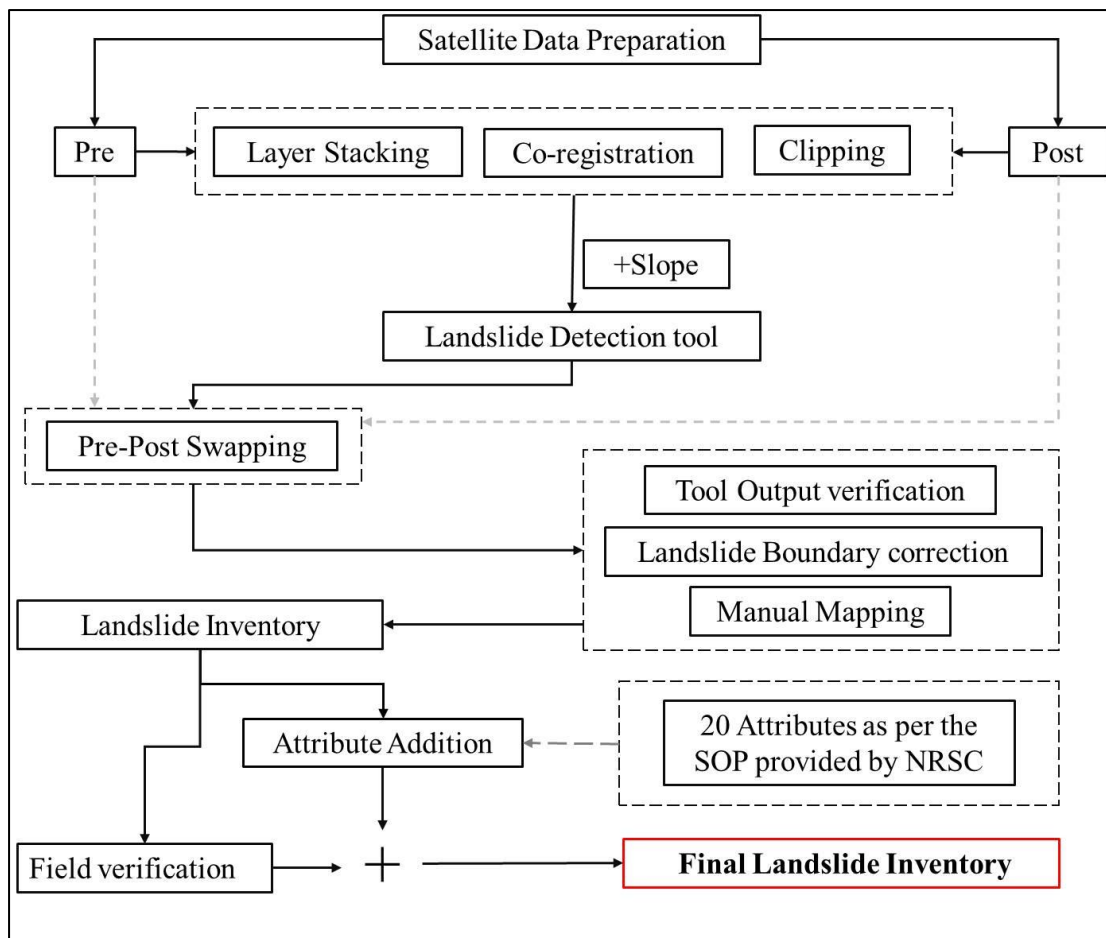


Figure 7: Methodology for landslide inventory preparation of Himachal Pradesh for the year 2023.

6. RESULT

The state has been devastated by the unprecedented rains that have fallen in several areas during the 2023 monsoon season. Life was destroyed throughout the state by extreme events, including flash floods, cloudbursts and the landslides that followed, as well as by the sinking and subsidence of land and the whole collapse of populated hill slopes. The three extreme intense spells of rainfall (8th –11th July, 14th & 15th August, and 22nd & 23rd August), caused 32 flash floods, and 163 landslides. Most affected districts due to landslides were Kangra (4027), Mandi (2169), Solan (1930), and Chamba (1666), whereas the least affected were Lahaul and Spiti (31), Kinnaur (65), and Una (98). According to SDMA estimates, many incidents throughout the state have resulted in the deaths of 428 people, whereas 427 have grievous injuries and 200 have minor injuries. In addition to the enormous death toll, 2,600 households whose houses were completely damaged were forced to look for other places to reside, and

5,000 households lost their huts and cowsheds. In Himachal Pradesh, 481 big animals, 9000 small animals and 10150 birds (poultry) died during the 2023 rainy season.

Table 2: District wise distribution of landslide mapped for 2023 post monsoon of Himachal Pradesh.

District Name	Number of landslide
Bilaspur	442
Chamba	534
Hamirpur	1666
Kangra	4027
Kinnaur	65
Kullu	729
Lahaul and Spiti	31
Mandi	2169
Shimla	483
Sirmour	1395
Solan	1930
Una	98

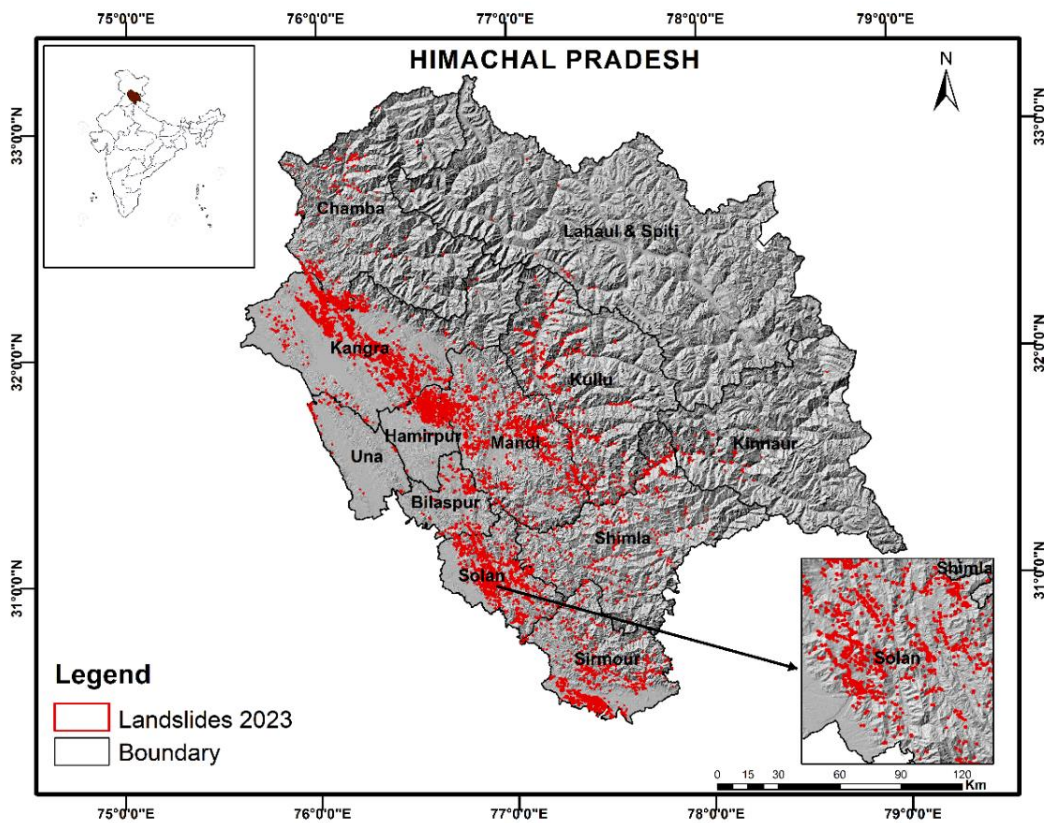


Figure 8: Landslide Inventory map of Himachal Pradesh

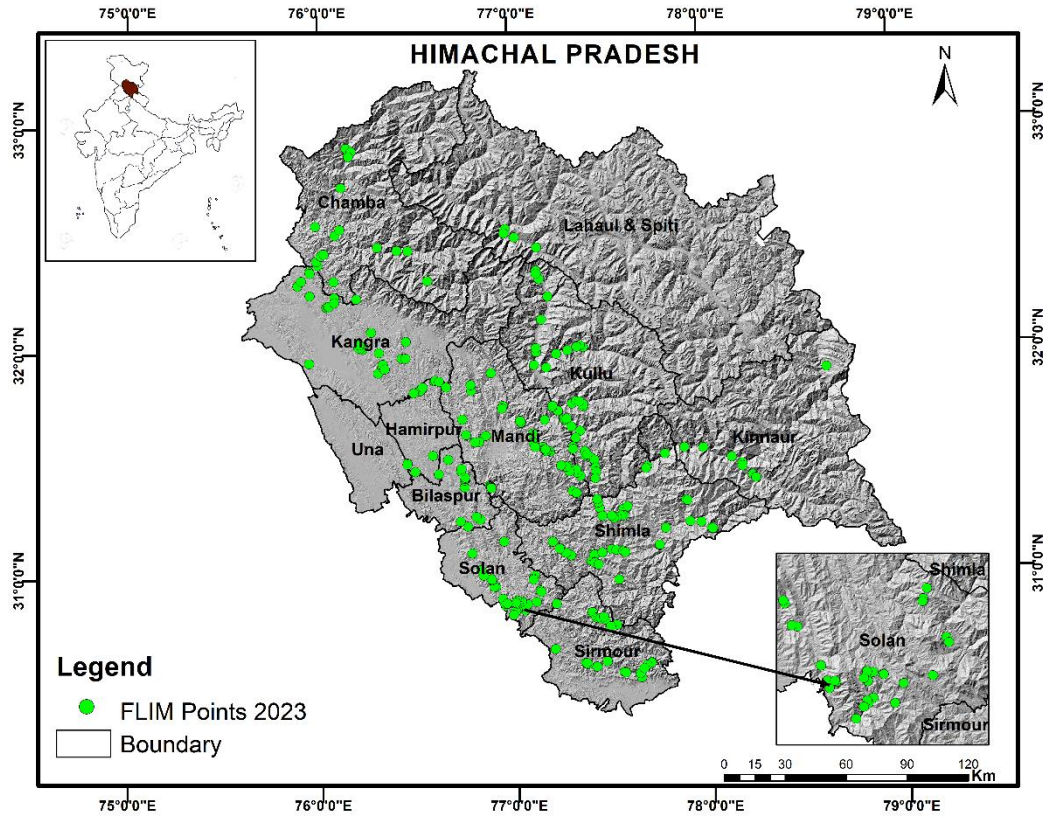


Figure 9: FLIM points map of Himachal Pradesh

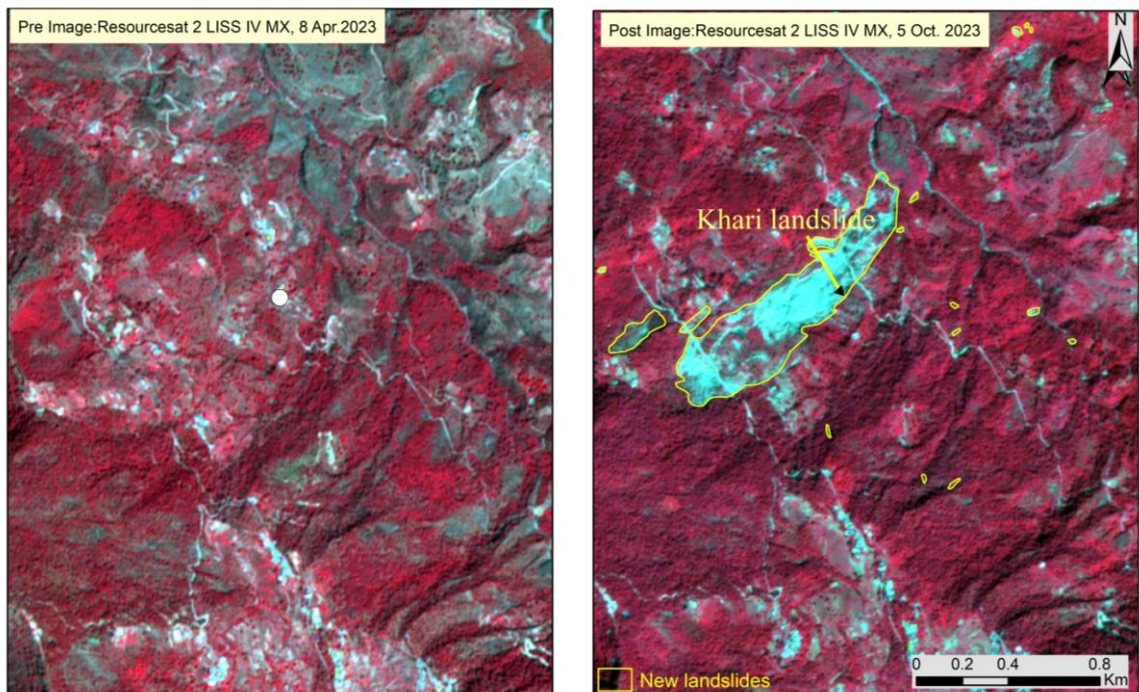


Figure 10: Landslides from Solan, Himachal Pradesh. Pre Image: Resourcesat 2 LISS IV MX, 8th Apr.2023, Post Image: Resourcesat 2 LISS IV MX, 5th Oct. 2023

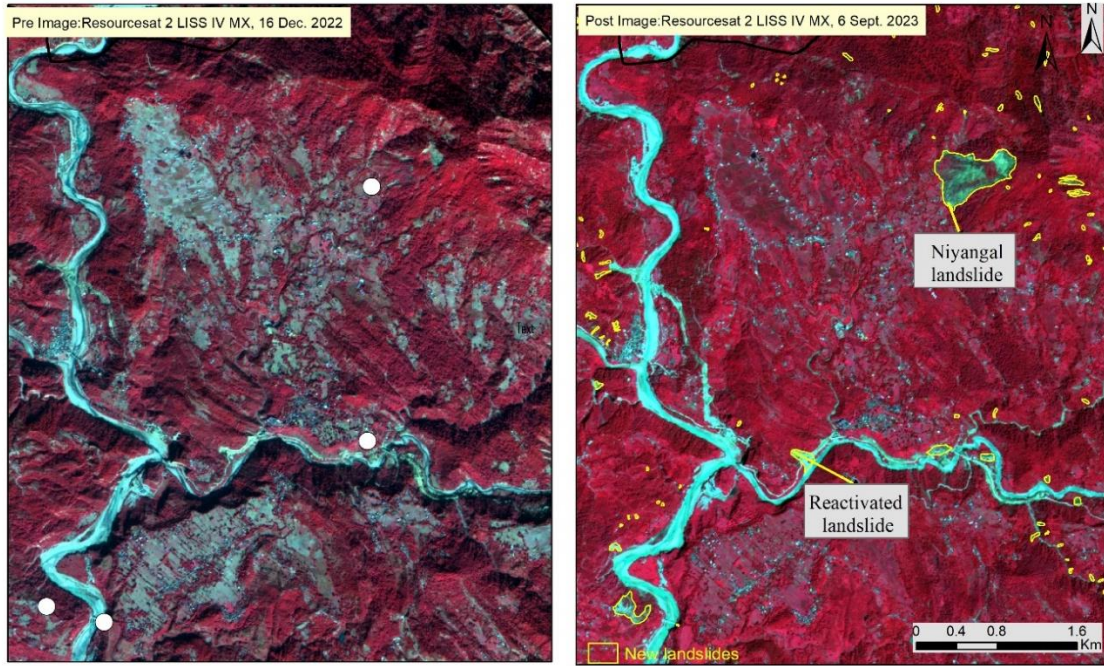


Figure 11: Landslides from Sirmour, Himachal Pradesh. Pre Image: Resourcesat 2 LISS IV MX, 7th Jan 2023, Post Image: Resourcesat 2 LISS IV MX, 9th Dec. 2023

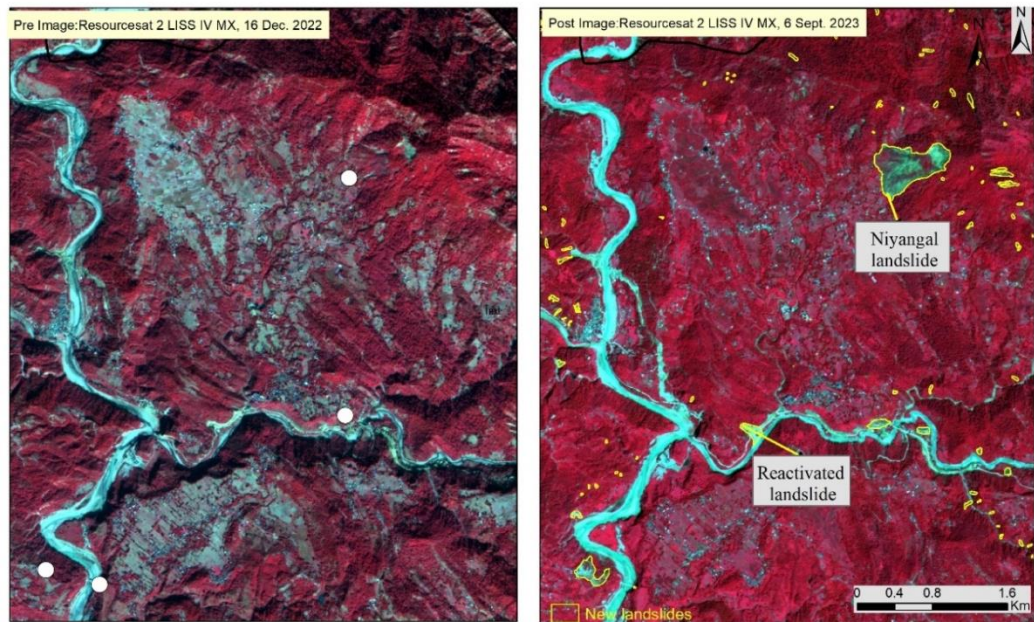


Figure 12: Landslides from Sirmour, Himachal Pradesh. Pre Image: Resourcesat 2 LISS IV MX, 7th Jan 2023, Post Image: Resourcesat 2 LISS IV MX, 9th Dec. 2023

7. FIELD WORK

A total of 4 field visits covering 12 districts of Himachal Pradesh were conducted to verify the result of the tool. During these field visits, a total of 290 FLIM points were collected, and 286 points were verified by NRSC, four points were eliminated because of their identical locations.

Table 3: District wise distribution of FLIM Points for Himachal Pradesh

District Name	Number of FLIM points
Bilaspur	19
Chamba	19
Hamirpur	14
Kangra	28
Kinnaur	08
Kullu	42
Lahaul and Spiti	4
Mandi	46
Shimla	43
Sirmour	28
Solan	35
Una	-

7.1 Solan, Bilaspur, Kangra and Hamirpur

The major landslide areas are Arki, Pipulughat, Bhararighat roads near Bakhlog Kallar, Ghamber bridge towards Brampukhar to Nauni, Swarghat to Kothipura, Jagathkhana to Nauni in Solan and Bilaspur districts. The, major Namhol landslides occurred along the road/National Highway in the post-monsoon period in 2023. The landslides damaged the agricultural land and National Highway 154 very badly. The landslide that occurred at Dehar was a limestone rockfall. Large number of landslides that occurred from 9th to 16th August, spell of 2023. The link road and the main roads were blocked for more than 15 days. The landslides were identified near Kanraer Bridge, near Salapar, Amarsing Pura, Nagni, Shil, Kuthera, and near the Shiv Mandir area in Kangra district. Landslides damage the agricultural land and roads/national highways. Near Harlog village, a landslide damages the agricultural land and houses.

The Bum, Ladhyani, and Sohri Jol villages are the landslide-prone areas in the Hamirpur district. The land was sinking, and cracks were developing on the houses and agricultural land at Jabbal Khariya village. The cracks developed along the bank about 500 m in length and also in houses and agricultural land at Guru da Ban along Sukar Khad. Samtana Khurd hamlet, which is distinguished by the middle Shivalik hills and sandstone area, experienced the cracks in houses and agricultural land as a

result of the depression. Land-sinking areas come under threat in the coming monsoon period.

The Sandhol and road near Palahi Landslides and landslips occurred along the link road. The landslides at Jol, Khari Bajehar, and Sohri Jol were caused by cloudbursts damaging the houses, cowsheds, and the main road. It damages the houses and blocks the road for more than 15 days. The houses and agricultural land in Lagru and Dodru were damaged due to the land sinking and landslide from the steep slope surface. In Chaunki village, damage was due to land sinking caused by heavy precipitation on 13th July 2023. More than 5 houses were destroyed by the land sinking. The landslides were identified at Nalsuha Barwarin, Sukahr, Chalali, Jol, Janddaur, Ban Bilwan, Bali Anutran, Kullalla, Chhatral, Ruri, Bhatroli, Gilendian, Khadloh and Ban Fatehpur areas of Kangra district. Near Anuhi Khas village, a large landslide blocked the roads for more than 10 days. In Jangal Anuhi village, land sinking and displacement occur in the lower area along the riverbed due to heavy rain, damaging more than 9 houses, which collapsed in this natural disaster.

There were landslides near Sanhera, Barmal village in the steep slope area, and Haral upperli along the riverbed due to heavy rainfall. An old landslide reactivated in the monsoon of 2023, damaging the agricultural land in Danni Khas village. There was a huge loss to houses in Ladori Khas due to a large landslide that occurred on the steep slope on the hilltop. The seasonal *nala* was filled with debris, and 9 to 11 houses were grounded with this landslide. The same occurred in Niyangal, where an old landslide reactivated, and more than 13 houses were destroyed by the debris and huge rock boulders. In Mangnial, land was sinking due to heavy precipitation and damaged more than 6 houses. There was a landslide along the National Highway near 32 Mile due to heavy rainfall accompanied by road cutting during the monsoon period of 2023. Due to heavy rain for more than 10 days in August 2023, in Maslaini village, land-sinking and cracks developed in more than 5 houses in this area. The landslide reactivated at old Kangra along the NH 154 due to road cutting. A landslide near Gandrun and Palara village occurred along the road, and it ruined the road, agricultural land, and houses. In Dehara village, due to heavy rain, the resultant land sinking damaged more than 5 houses and agricultural land.

The major landslide area of Solan district is Kiarighat, Kiari and Deoghat along the National Highway. The landslides that occurred here were due to road widening, mostly the Phyllite, a foliated metamorphic rock rich in tiny sheets of sericite mica and Phyllite-Quartzite (PQ) bedded intermixed with overburden. There are some huge hanging loose boulders/rocks on the NH, which are very risky and may result in casualties on the road in the coming monsoon period. The landslide at Shamti that occurred in the monsoon period in 2023 damaged more than three houses and the state highway very badly. Many landslides were identified along the road near Yashwant Nager, Giripul Bridge, Shamoga, Bhog Batewari, Nohradhar Ganduri Charna, Sail and Haripur Dhar towards Shillai.

The major landslide areas in Sirmour district are near Pab Bokala, Kafota, Dugana, Kandun Dugana, Shumahn Pamta, Pamta, Barwas, Kamrau, Khuenal Salaga and Chauki Mirgwal. They occurred along the highway due to road widening and heavy precipitation in the monsoon period of 2023. Due to a cloudburst, a landslide occurred in the Rajban area, resulting in 4 to 5 houses being buried by heavy boulders, sandstones, debris, and trees. Over 15 days, the highway and the link roads remain closed. The road got severely damaged due to debris flows towards Renukaji. The landslide damages the agricultural land and link roads in Manal, Sadddiyar, Ambaun Thana, Knaigna, and Sangrah block of Sirmour district.



Figure 13: Landslides in Bilaspur district



Figure 14: Landslides in Kangra district



Figure 15 (a): Landslides in Solan district



Figure 15(b): Landslides in Solan district



Figure 16: Landslides in Sirmour district

7.2 Mandi and Kullu

The landslides occurred along the Luhri to Karsog road due to heavy precipitation and overburden on the hill slope and damaged the highway. There was a rock slide near Kotlu village, where mainly schist rock accompanied by trees from the scarp area damaged the highway and link road. Landslides occurred near Somakothi, Bethavan, Bisal Dhar, Sunargad, Chattri, Runchar, and Chathinal due to slope failure, overburden, and heavy precipitation on the hill slope in Mandi district. These landslides damaged the NH, the link road, and the horticulture and agriculture land. The landslide damaged horticulture land near Bharari, Manrega Park at Bagciad, Bharari, Ahun, Nerchowk, Chailchowk, and Janjehli areas. Landslides occurred at Keyolidhar, Gadhiman, Kanda, Pansir, near Ahan, Sayogi, Jagar, and Gararu on Rewalser to Kalhkar due to overburden and road widening. The Jawali Landslide, 4 kilometres away from Thati Dhar, started on 12th August at 9.00 PM and continued for two days in 2023. More than 3 houses were damaged; cracks were developed in more than 6 houses, and the agricultural land. The Gehra village, where land was slipped due to high saturation on the 13th and 14th of August 2023, along the hill slope, grounded 5 houses completely. An old Kotrupi landslide that occurred in 2017 reactivated in this monsoon period and damaged the Joginder Nagar National Highway. The area is dominated by red shale, dolomite of the Shali formation, and sandstone and shale of the Siwalik Group.

The landslide at Larji and Sainj, Kullu district, occurred along the hill slope due to slope failure and heavy precipitation from 9th to 14th July 2023. The land slipping continued for 4 days, which grounded more than 80 houses and shops and developed

cracks in the nearby houses and shops. The landslides in Kotla, Banala, Mahra, Shayangarh, Siund, Sachen, Sanshar, and Neharni areas severely damage the roads and agricultural lands.

Due to excessive precipitation and road widening along the highway towards Manikaran, landslides occurred near Jari and Kasol during the monsoon in 2023. The main road was damaged due to a rockslide near Kasol, composed of a white to greyish, thick sequence of quartzite, which has been named the Manikaran Quartzite, along with minor phyllites and slates. The landslide near Biasor took place due to overburden and heavy rainfall along the main National Highway towards Manali. Near Bandrol, Chhatan, Sari, Raisan, Dobhi, Duwara Patlikuh, and Manali roads, landslides occurred due to heavy precipitation in the monsoon period of 2023. The landslides were identified at Burma near Atal Tunnel, Solang, Palchan, Manali, Badgram, Kharal Banala, and Aut areas of Kullu district. The national highway along the Beas River was badly damaged and broken by the flash flood and landslides in the monsoon period of 2023. The landslides near Kotla, Rahi, Dhaman, Bhurah, and Bali Chowki occurred due to overburden and heavy rainfall along the State Highway towards Banjar.

The major landslide near Thati Bir and Chukuthra due to heavy precipitation severely damaged the link road. A landslide occurred at Bali Ckowki, where a crack developed on the hill slope, and 7 houses were grounded on 13th and 14th July 2023. Cracks were also developed in the nearby houses, which is also a threat to the house located downslope. The landslide near the bus stand occurred due to overburden and heavy rainfall along the road towards Luhri; 7 houses were grounded by the landslide, and cracks also developed on the hill slope.



Figure 17: Landslides in Kullu district



Figure 18: Landslides in Mandi district

7.3 Chamba

The lower and upper Shiwalik Sandstone transition zones near Thulel village are dissected hills eroded by heavy rainfall along the river channel as well as the National Highway. In this area, small landslides occurred in the monsoon period of 2023 because this area falls in an erosion-prone zone. Near Patka village, unconsolidated material with granite basic material flowed in the form of a debris landslide on the hillslope, damaging the road badly. Due to road widening, slope failure with unconsolidated loose material towards Chauwari was identified. The landslide along the roads at Kamla, Pharl, Parchor, Parwat, Phala, Narghara Gaar, Sanja Gaar Chawari Khas, and Jot is due to the slope failure. Near the Chantoli debris slide occurred with phyllite rocks on the hillslope. Landslides damaged the agricultural land and link roads very badly in the monsoon period.



Figure 19: Landslides in Chamba district

The Khara Mukh Rock slide occurred on Holi Road, dominated by schist rocks and quartzite formation, blocking the National Highway, 154 A for more than two months. Near Suai, debris slides along the road. The Kulathlath landslide occurred on the 8th and 9th of July, 2023, resulting in crack formation on the scarp area, and it threatened the village. The whole belt along the village is composed of unconsolidated material and underlain by phyllite rocks. Landslide near Uperli Tiari blocked the NH 154A frequently. The landslides were identified along the highway and link roads at Lambu, Pilli, Choli, Garola, and Dalli. The landslide near Durgethi was a chronic landslide reactivated, comprising phyllites and slate material. There was a landslide comprising consolidated material with slate and phyllite rocks near Churi. The landslide along the road at Gurenth, Bhodour, Gehra, Belij, Dunali, Dharwala, Rakh, Kalsuin, Unha, Ranera, and Chamba areas was also identified.

The Sathias is a landslide-prone area with loose unconsolidated material and metamorphic and slate rocks. The Majora Landslide with phylliterock occurred due to heavy rainfall and overburden along the hillslope. In Kalei Sukrali and Langera village, old landslides were reactivated. Landslides along the roads at Bairagarh, Majoga, Ladroga, Ghulei, Utei, Gwari, Sai Kothi Salwin, and Daonri were identified. A landslide at Buin Degree College Tissa damaged the college building and grounds. The debris landslide occurred at Kalhel due to road widening and slope failure on the hill slope. The landslides along the road in Shakar, Kalwala, Chilli, Nakror, Kapilwada, Badoh, Bhadruni, Gutkar, Chanjla, Surangani, Dhargala, Salooni, Salyund, Darobari, Sanghan, Prongul, and Langera were identified.

An old landslide was reactivated near Obari Mangla, comprising unconsolidated material. The landslide near Gajnoi, debris flowed on the road from the scarp area due to the overburden. The landslides along the road near Jankhar, Banadu, Khajjiar, Topi Nala, Lakkarmandi, Kholpukher, Surkhigala, Dalhousie, Goli, Jaokna, Gandhior, Narola Galla, Ghatasani, Lahur, Barala, Baduni Malkwal, Niari, Khanar, and Danni areas were identified.

7.4 Shimla, Kinnaur and Lahaul & Spiti Districts

The landslides at Narkanda, Oddi, and Kumarsain National Highway are due to heavy precipitation in the monsoon period of 2023. Near SSB Camp, the Kumarsain rock slide (schist rocks) grounded a patrol pump. Near Kingal, debris slid with unconsolidated material due to heavy rainfall. At Rampur, a rock slide occurred in the monsoon period of 2023, dominated by quartzite formation, and the main cause of the slide was the widening of the road. An old landslide reactivated along the Bruni Nala comprising quartzite rocks, and mining is also active in the upstream. Landslides along the road from Sanj, Bithal, Riwali, Nirth, Duttanagar, Nirsu, Nogli, Khopri, Lahasa, Jagatkhana Rampur, Malgi, and Jakhari were identified. At Jeori village, a rockslide occurred along the National Highway due to high saturation dominated mainly by schist formation of rocks on vertical cliffs on the hillside.

In Mashobra, two houses are in danger due to the landslide along the highway. The landslide at Sauna, Baldhya, occurred due to construction work, and two people died due to a rock fall on the labour shed. The link road remains closed for 10 days. The Balku link road was broken from so many areas due to landslides. A landslide in Theog occurred on 9th July 2023, swept away the road, and blocked the National Highway-5 for more than one month. A landslide near Parala Mandi at Sainj severely affected the state highway. Towards Chopal, the vertical micaceous rock formations are found along the road, and in the monsoon of 2023, heavy rainfall broke the micaceous rock, and a landslide damaged the road very badly. In Shimla district, Sipur, Bejrolpul, Bhuin, Dharnot, Basadhar, Deha, Guri, Challa, Hulli, Gumma, Pragati Nagar Mahasu, Khoru, Koku Nala, Kotkhai, Chhatri, Kalot, Nihhari, Senal, Patshall, Kharapthar, Praonthi, Jubble, and Hatkoti are areas where landslides were identified.



Figure 20: Landslides in Shimla district

The landslide was identified near Hartkoti Mata Mandir along the road near HPCL colony. The landslide near Samoli Bridge and near Sandasu village along the Pabbar River blocked the road for more than one week. There was a landslide along the road near Kanthali village due to heavy precipitation and damage the road very badly. The landslides mainly occurred in Tikri road, Mandeli, Chirgaon, Andhra, Tikri, Sundha, Shilla Desh, Larot, Gajyani, Dodra and Kwar area of Rohru tehsil of Shimla district. Landslides damaged the agriculture land and link roads very badly in monsoon period.

There was an old reactive landslide on the hillslope with gentle slope Uranitic terrain cliffs on the top at Nigulsari blocked the National Highway. A 70-meter stretch of National Highway-5 (NH-5) near Nigulsari collapsed due to underground water seeping, causing further land subsidence. Unstable terrain led to the sinking of the highway. The landslide near Nathpa Dam, this slide occurred due to slope failure because of high saturation dominated by granite formation. The rockslide over the Nathpa Dam damaged the National highway and link road. The landslides damaged the National Highway and link road at Jakhri, Sanarsa, Jeori, Suru, Chaura, Nigul Sari, Bara Khamba, Chotta khamba, Thikru, Tranda, Bhaba Nagar, Saki, Charang, Nathpa, Wangtu, Yashang, Jani, Tapri, Chagaon, Chooling, Kilba, Urni, Karcham, Rali, and Tangli area of Kinnaur district.



Figure 21: Landslides in Kinnaur district



Figure 22: Landslides in Nigulsari, Kinnaur district

The landslide is identified near Pawari Jangi, Spilo area of Kinnaur District. The unconsolidated loose soil material and erosion-prone area with rainfall triggered the landslides along NH-5. There were debris slides in the upper catchment near Khab towards Nako, which affected the NH-5. An old landslide on Malling Nala is reactivated and damages the NH-5. Landslides were identified at Powari, Boktu, Kashang, Sheelapur, Rarang, Ribba, Akpa, Holdang, Jangi Khas, Chakra, Lippa, Spello, Kanam Gyumil, Sunam, Giabong, Ropa, Thoropa, Pooh, Dubling, Khab, Ka,

Leo, Nako, Malling, Chango, Shilkar, and Sumdo areas. Debris slides severely damaged the agricultural land and roads.

There is a debris slide at Shichling along the road, and the National Highway damaged houses very badly. The debris slide near Tandi of the Lahul region of Lahul & Spiti along the slope is due to slope failure and high saturation along the National Highway. There was a landslide dominated by carbonate rock underlain by chlorite phyllite that occurred near Tila and Gondhla along the NH and damaged it very badly. A landslide occurred near Sissu due to high saturation and slope failure.



Figure 1 A Landslide damaged the NH-3 near Sissu, Lahaul & Spiti district

8. CONCLUSION

Himachal Pradesh experienced a devastating landslide during the monsoon season of 2023, which caused the loss of life and consequential damage to government and private property. The landslides were caused by heavy and prolonged rainfall. The oversaturated soil and unstable slopes led to slope failures and made it very susceptible to landslides. Mandi, Shimla, and Kullu districts were mainly affected. The landslide caused extensive damage to roads, bridges, buildings, and agricultural land; many bridges were washed away, and thousands of houses were damaged or destroyed in Himachal Pradesh. Areas like Kangra, Mandi, Solan, and Sirmour were identified as major landslide zones and highlight the need for comprehensive disaster management strategies, including improved infrastructure planning, early warning systems, and long-term mitigation efforts.

The total number of 13569 polygons was mapped for the landslide inventory preparation based on LISS IV pre- and post-monsoon satellite images of 2023. A total of 286 FLIM points were collected during the field visit. The sluggish landslides at Khari in Solan district, Niyangal in Kangra district, and Chaunki in Hamirpur district continued for 2-3 days. The Kotrupi landslide on National Highway-154 in Mandi District of Himachal Pradesh occurred in 2017 and reactivated every year; it highlighted the vulnerability of the region to landslides, especially during the monsoon season. Due to the devastating rains, a landslide has occurred near the Shiv Temple near Summerhill in Shimla on 14th August 2023. Many people were buried under the debris, and 20 people died tragically. Most of the minor landslides are in the forested Shivalik hills and have not damaged any property or lives.

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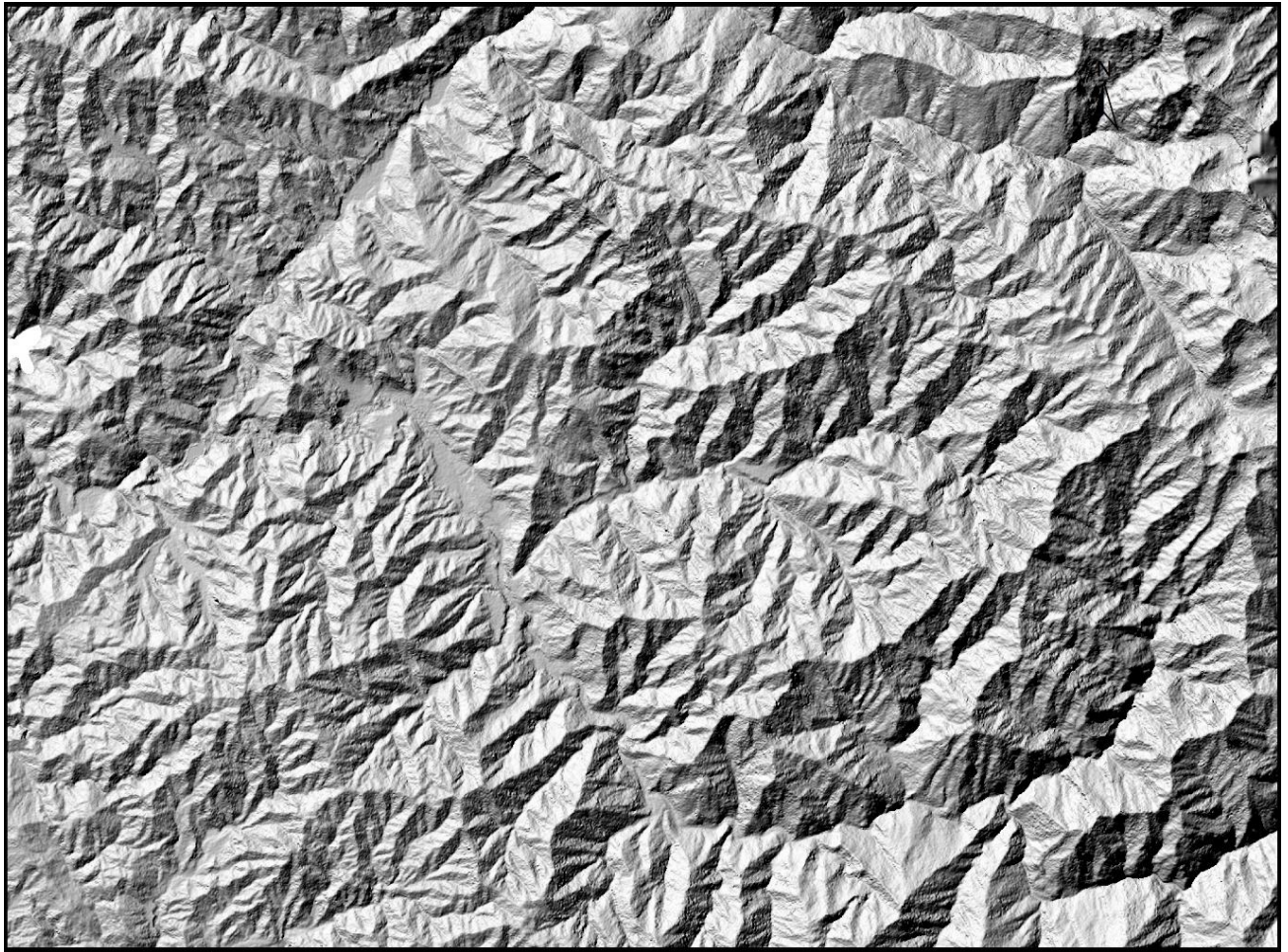
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ANNEXURE – I

Slide No.	State	District	Toposheet	Latitude	Longitude	MBG_ Length	MBG_ Width	Height	Area	Activity	Year	Triggering	Geomorphology	Lithology	LULC	Basin Name	Sub Basin	Source
HP/SI/53F14/2023/1	Himachal pradesh	Sirmour	53F14	30.575	77.758	50.602	26.458	46.51	1031.26	ACTIVE	2023	Rainfall	StrOri - Highly Dissected Hills and Valleys	Limestone, dolomitic limestone with shale	Evergreen Closed Forest	Ganga Basin	Yamuna Upper	RESOURCESAT 2-2A LISS IV, 30m COPERNICUS DEM, BHUKOSH 50K, LULC 10K (2018-19) & India-WRIS
HP/SI/53F14/2023/2	Himachal pradesh	Sirmour	53F14	30.645	77.781	125.171	47.447	138.36	3953.73	ACTIVE	2023	Rainfall	StrOri - Moderately Dissected Hills and Valleys	Shale,quartzite, limestone and conglomerate	Wasteland - Sparse Scrub Land	Ganga Basin	Yamuna Upper	RESOURCESAT 2-2A LISS IV, 30m COPERNICUS DEM, BHUKOSH 50K, LULC 10K (2018-19) & India-WRIS
HP/SI/53F14/2023/3	Himachal pradesh	Sirmour	53F14	30.655	77.766	157.710	38.092	103.87	4324.46	ACTIVE	2023	Rainfall	DenOri - Mass Wasting Products	Shale,quartzite, limestone and conglomerate	Pasture lands	Ganga Basin	Yamuna Upper	RESOURCESAT 2-2A LISS IV, 30m COPERNICUS DEM, BHUKOSH 50K, LULC 10K (2018-19) & India-WRIS
HP/SI/53F14/2023/5	Himachal pradesh	Sirmour	53F14	30.655	77.767	38.672	18.662	24.08	554.05	ACTIVE	2023	Rainfall	DenOri - Mass Wasting Products	Shale,quartzite, limestone and conglomerate	Pasture lands	Ganga Basin	Yamuna Upper	RESOURCESAT 2-2A LISS IV, 30m COPERNICUS DEM, BHUKOSH 50K, LULC 10K (2018-19) & India-WRIS
HP/SI/53F11/2023/6	Himachal pradesh	Sirmour	53F11	30.430	77.530	62.853	25.889	6.83	1218.51	ACTIVE	2023	Rainfall	StrOri - Highly Dissected Hills and Valleys	Conglomerate with friable sandstone and clay	Semi- Evergreen Closed Forest	Ganga Basin	Yamuna Upper	RESOURCESAT 2-2A LISS IV, 30m COPERNICUS DEM, BHUKOSH 50K, LULC 10K (2018-19) & India-WRIS
HP/SI/53F11/2023/7	Himachal pradesh	Sirmour	53F11	30.442	77.556	54.334	22.747	16.67	823.70	ACTIVE	2023	Rainfall	StrOri - Highly Dissected Hills and Valleys	Conglomerate with friable sandstone and clay	Semi- Evergreen Closed Forest	Ganga Basin	Yamuna Upper	RESOURCESAT 2-2A LISS IV, 30m COPERNICUS DEM, BHUKOSH 50K, LULC 10K (2018-19) & India-WRIS

HP/SI/53F11/2023/8	Himachal pradesh	Sirmour	53F11	30.428	77.528	44.840	25.678	9.82	825.41	ACTIVE	2023	Rainfall	StrOri - Highly Dissected Hills and Valleys	Conglomerate with friable sandstone and clay	Semi-Evergreen Closed Forest	Ganga Basin	Yamuna Upper	RESOURCESAT 2-2A LISS IV, 30m COPERNICUS DEM, BHUKOSH 50K, LULC 10K (2018-19) & India-WRIS
HP/SI/53F11/2023/9	Himachal pradesh	Sirmour	53F11	30.428	77.528	46.228	32.471	40.48	1111.92	ACTIVE	2023	Rainfall	StrOri - Highly Dissected Hills and Valleys	Conglomerate with friable sandstone and clay	Semi-Evergreen Closed Forest	Ganga Basin	Yamuna Upper	RESOURCESAT 2-2A LISS IV, 30m COPERNICUS DEM, BHUKOSH 50K, LULC 10K (2018-19) & India-WRIS
HP/SI/53F11/2023/11	Himachal pradesh	Sirmour	53F11	30.428	77.540	49.691	22.691	24.03	852.61	ACTIVE	2023	Rainfall	StrOri - Highly Dissected Hills and Valleys	Conglomerate with friable sandstone and clay	Semi-Evergreen Closed Forest	Ganga Basin	Yamuna Upper	RESOURCESAT 2-2A LISS IV, 30m COPERNICUS DEM, BHUKOSH 50K, LULC 10K (2018-19) & India-WRIS
HP/SI/53F11/2023/12	Himachal pradesh	Sirmour	53F11	30.460	77.544	76.388	28.702	15.25	1497.42	ACTIVE	2023	Rainfall	StrOri - Highly Dissected Hills and Valleys	Conglomerate with friable sandstone and clay	Semi-Evergreen Closed Forest	Ganga Basin	Yamuna Upper	RESOURCESAT 2-2A LISS IV, 30m COPERNICUS DEM, BHUKOSH 50K, LULC 10K (2018-19) & India-WRIS
HP/SI/53F11/2023/13	Himachal pradesh	Sirmour	53F11	30.434	77.551	46.043	18.255	6.74	721.11	ACTIVE	2023	Rainfall	StrOri - Highly Dissected Hills and Valleys	Sandstone with clay intercalation	Semi-Evergreen Closed Forest	Ganga Basin	Yamuna Upper	RESOURCESAT 2-2A LISS IV, 30m COPERNICUS DEM, BHUKOSH 50K, LULC 10K (2018-19) & India-WRIS
HP/SI/53F11/2023/14	Himachal pradesh	Sirmour	53F11	30.440	77.529	50.842	32.124	18.61	1286.04	ACTIVE	2023	Rainfall	StrOri - Highly Dissected Hills and Valleys	Conglomerate with friable sandstone and clay	Semi-Evergreen Closed Forest	Ganga Basin	Yamuna Upper	RESOURCESAT 2-2A LISS IV, 30m COPERNICUS DEM, BHUKOSH 50K, LULC 10K (2018-19) & India-WRIS
HP/SI/53F10/2023/18	Himachal pradesh	Sirmour	53F10	30.509	77.609	40.896	32.480	31.27	1015.44	ACTIVE	2023	Rainfall	StrOri - Moderately Dissected Hills and Valleys	Gravel, pebble and boulder in oxidised sandy mtrx	Semi-Evergreen Closed Forest	Ganga Basin	Yamuna Upper	RESOURCESAT 2-2A LISS IV, 30m COPERNICUS DEM, BHUKOSH 50K, LULC 10K (2018-19) & India-WRIS

HP/SI/53F10/2023/20	Himachal pradesh	Sirmour	53F10	30.512	77.607	54.524	36.046	23.28	1413.43	ACTIVE	2023	Rainfall	StrOri - Moderately Dissected Hills and Valleys	Gravel, pebble and boulder in oxidised sandy mtrx	Semi-Evergreen Closed Forest	Ganga Basin	Yamuna Upper	RESOURCESAT 2-2A LISS IV, 30m COPERNICUS DEM, BHUKOSH 50K, LULC 10K (2018-19) & India-WRIS
HP/SI/53F10/2023/21	Himachal pradesh	Sirmour	53F10	30.524	77.604	317.500	104.091	125.00	11908.00	ACTIVE	2023	Rainfall	StrOri - Moderately Dissected Hills and Valleys	Sandstone, siltstone, claystone with conglomerate	Semi-Evergreen Closed Forest	Ganga Basin	Yamuna Upper	RESOURCESAT 2-2A LISS IV, 30m COPERNICUS DEM, BHUKOSH 50K, LULC 10K (2018-19) & India-WRIS
HP/SI/53F10/2023/22	Himachal pradesh	Sirmour	53F10	30.526	77.599	85.939	31.905	46.92	1729.38	ACTIVE	2023	Rainfall	StrOri - Moderately Dissected Hills and Valleys	Sandstone, siltstone, claystone with conglomerate	Semi-Evergreen Closed Forest	Ganga Basin	Yamuna Upper	RESOURCESAT 2-2A LISS IV, 30m COPERNICUS DEM, BHUKOSH 50K, LULC 10K (2018-19) & India-WRIS
HP/SI/53F10/2023/23	Himachal pradesh	Sirmour	53F10	30.528	77.600	136.938	36.606	66.94	2733.65	ACTIVE	2023	Rainfall	StrOri - Moderately Dissected Hills and Valleys	Sandstone, siltstone, claystone with conglomerate	Semi-Evergreen Closed Forest	Ganga Basin	Yamuna Upper	RESOURCESAT 2-2A LISS IV, 30m COPERNICUS DEM, BHUKOSH 50K, LULC 10K (2018-19) & India-WRIS
HP/SI/53F10/2023/25	Himachal pradesh	Sirmour	53F10	30.530	77.597	48.108	28.119	11.07	1106.98	ACTIVE	2023	Rainfall	StrOri - Moderately Dissected Hills and Valleys	Sandstone, siltstone, claystone with conglomerate	Semi-Evergreen Closed Forest	Ganga Basin	Yamuna Upper	RESOURCESAT 2-2A LISS IV, 30m COPERNICUS DEM, BHUKOSH 50K, LULC 10K (2018-19) & India-WRIS

<H:\maps\Attribute landslides 2023.xlsx>

ANNEXURE - II

<I:\maps\FLIM POINTS.xlsx>

Remarks: table contains more than 1350 so can't adjust.