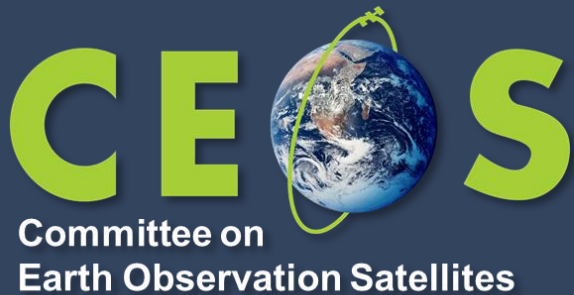


Working Group on Disasters 26 (WGD-26)

*An Earth Observation based approach in
characterization of selected landslides and
debris flows in parts of the Indian Western
Himalaya: From Causes to Early Warning*



Shovan L. Chatteraj, IIRS,

Dehradun, ISRO

Agenda Item: Workshop

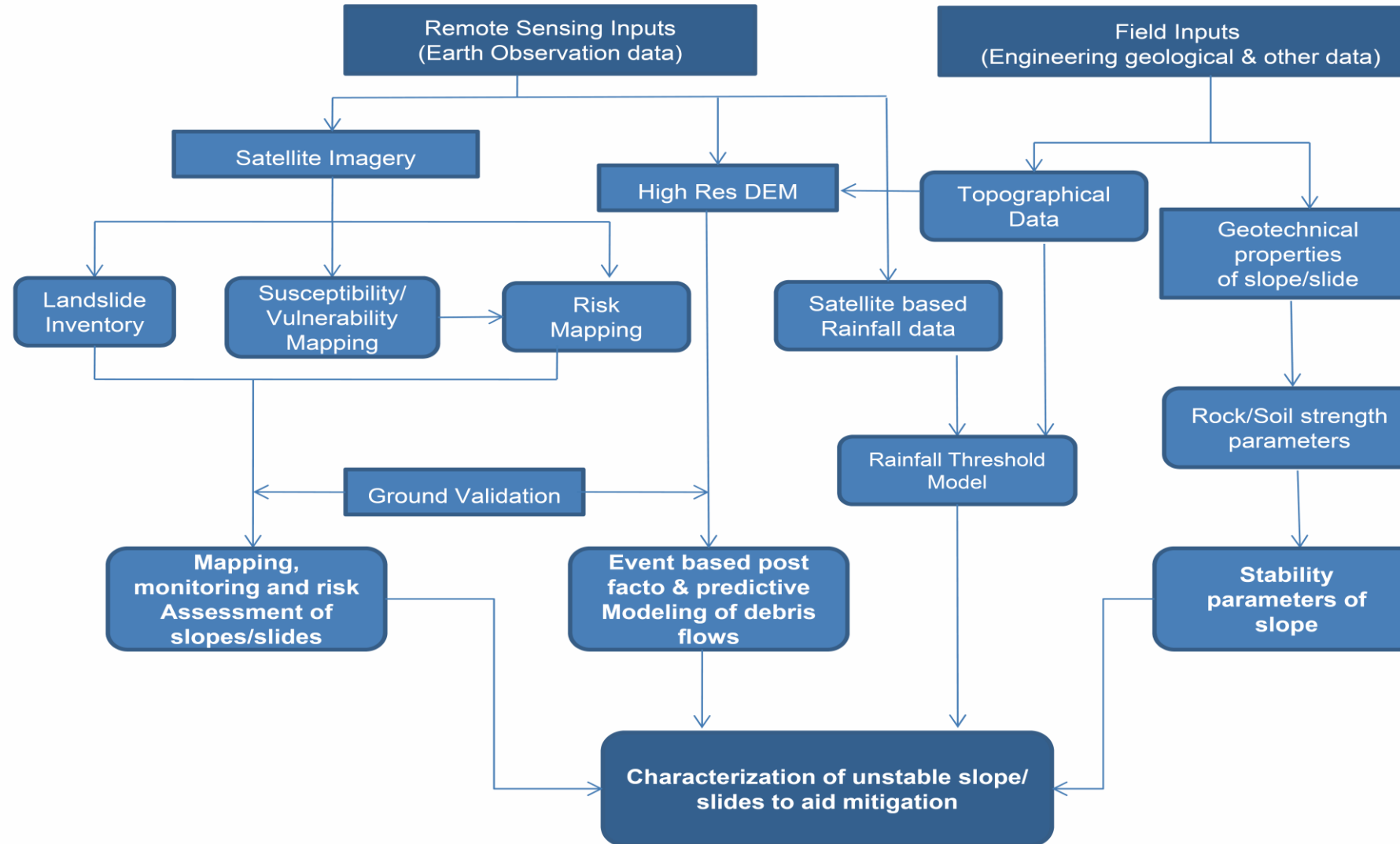
WGDisasters 2026

ASI, Rome, Italy

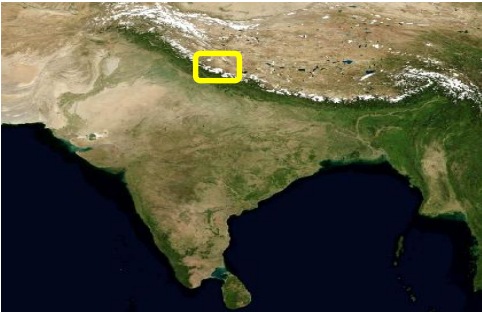
14-18 September 2026

1. Establishment of the risk of unstable slope/slide by mapping (including automated techniques), monitoring and geological characterization in Uttarakhand and Himachal Himalaya, Part of Indian Western Himalaya
2. 3-D Simulation and development of models for old, active and potential debris flows/slides
3. Development of rainfall-threshold models to study initiation mechanism of landslides
4. And thereby, Providing help to Emergency Preparedness and recovery

Flow Chart of Methodology



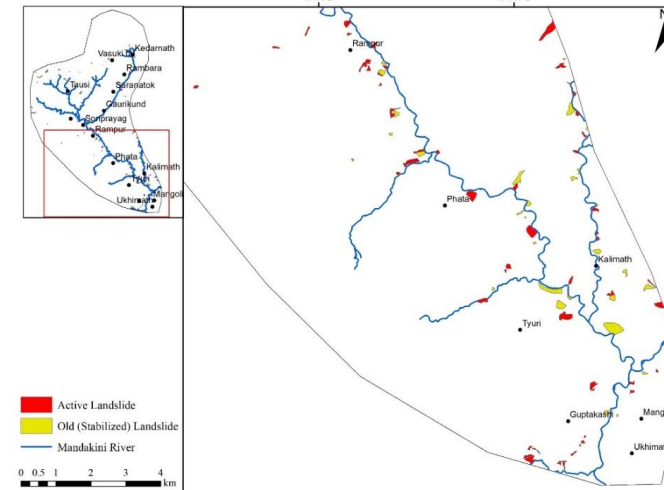
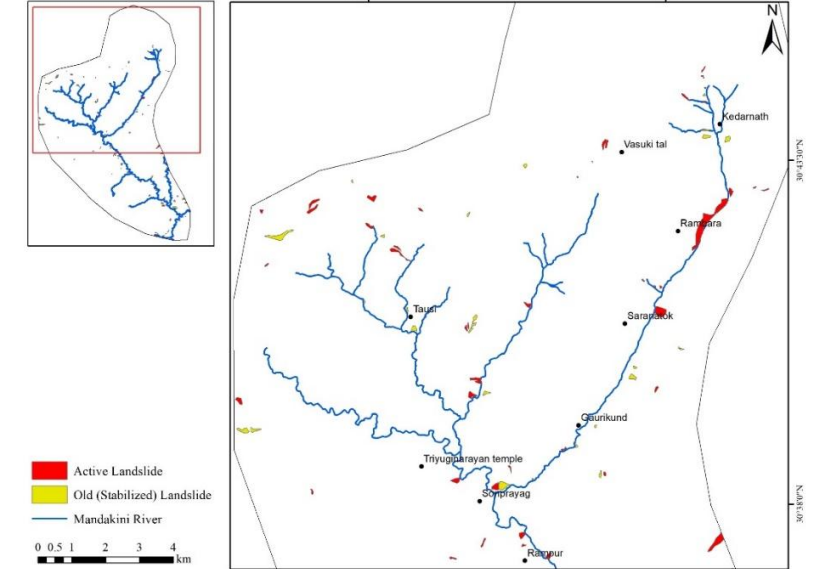
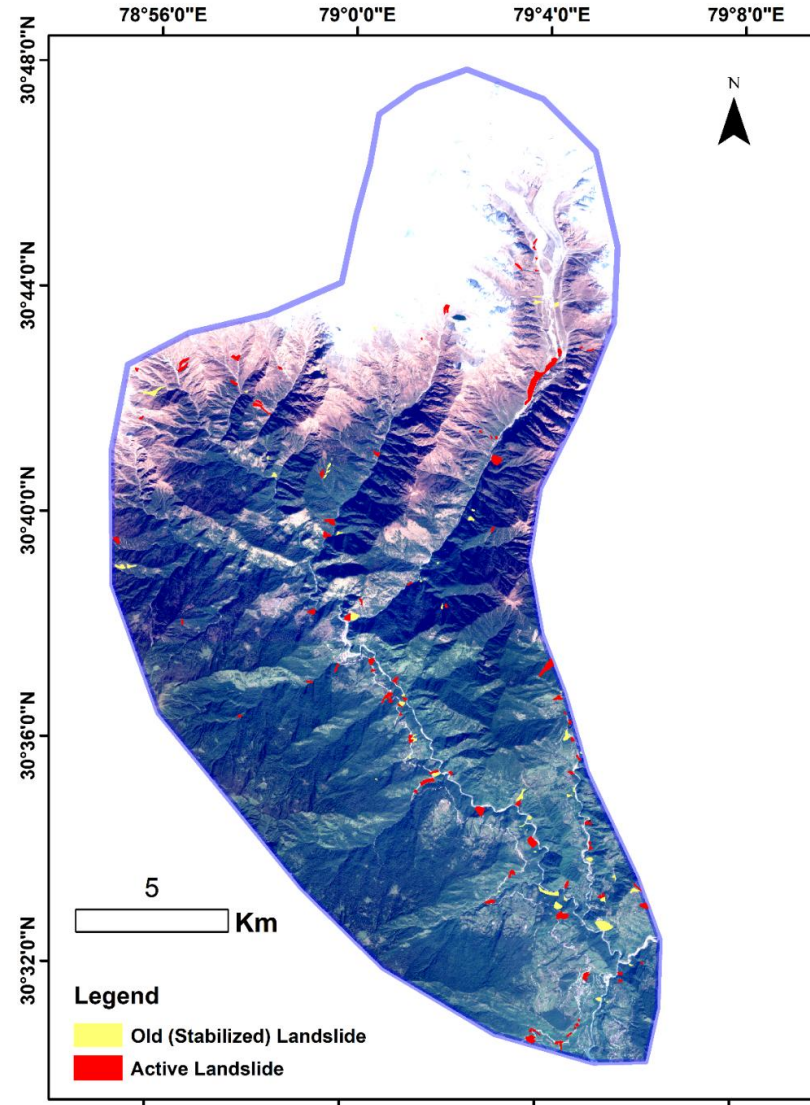
Landslide Inventory (Kedarnath)



Landslide Inventory Map

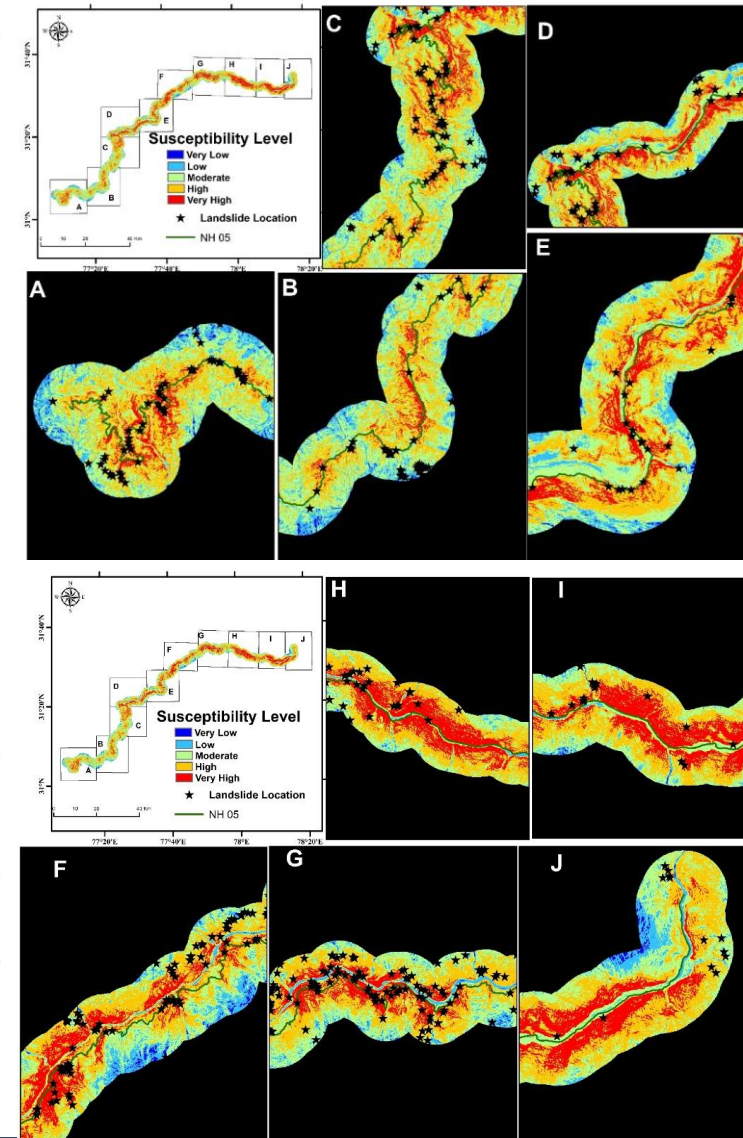
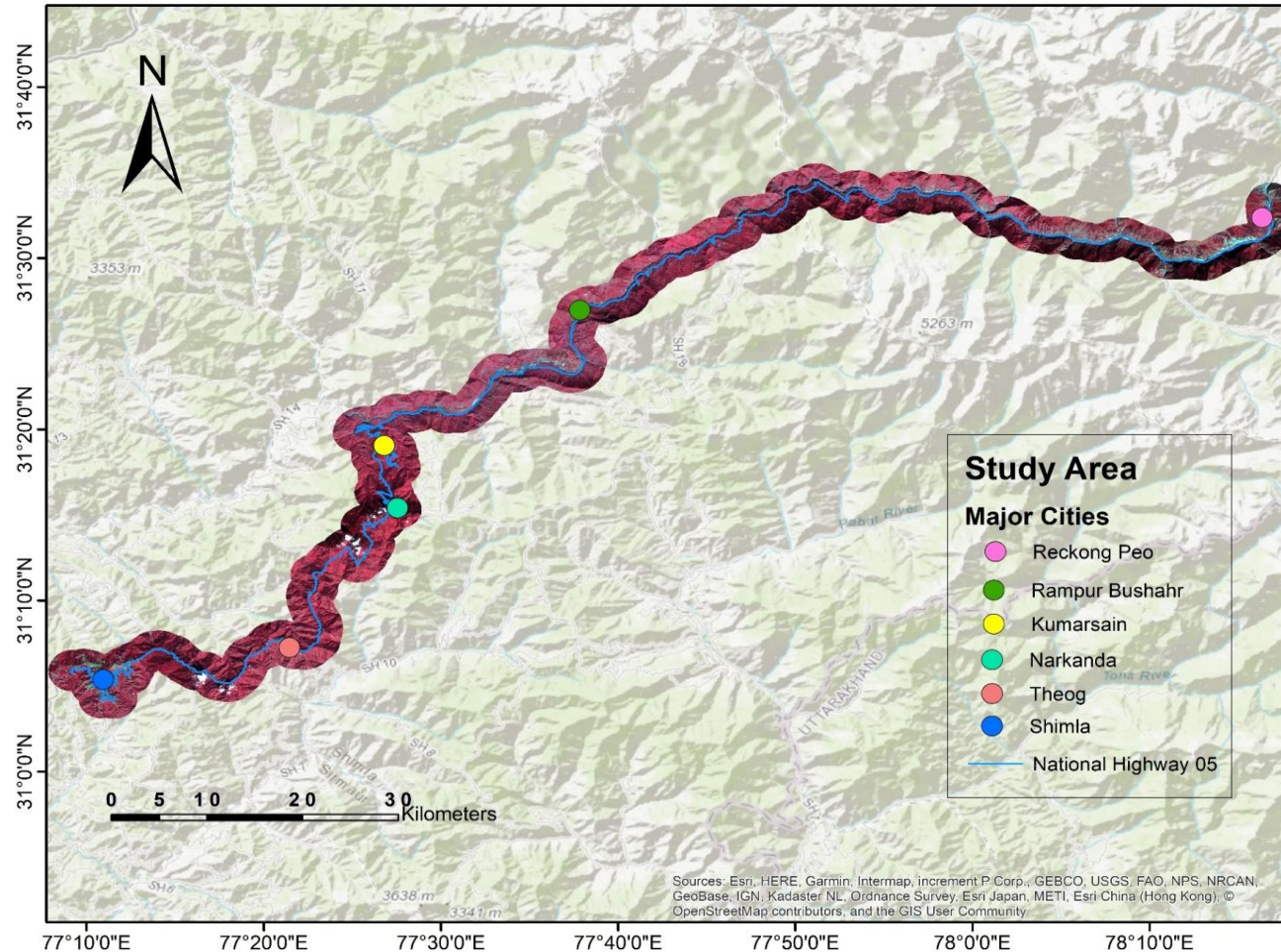
After February 2021 Chamoli disaster, which wrecked a havoc downstream, landslide potential in Upper Mandakini valley was assessed.

The identification and mapping of historical landslide sites are important to study the connection between landslide distribution and the various causal factors. In the present study area, a total of 149 landslide location was recorded with the help of field observation, historical information, and image interpretation in the study area. Remote sensing data may be used to identify landslides based on spectral features, form, and contrast, as well as morphological expression.



Satellite image (natural color composite) showing inventory of old (stabilized) and active landslides in parts of upper Mandakini valley. Data source: Mosaic of Sentinel 2B acquired on Nov 17, 2021 and April 06, 2022 displayed with RGB-432 band combination.

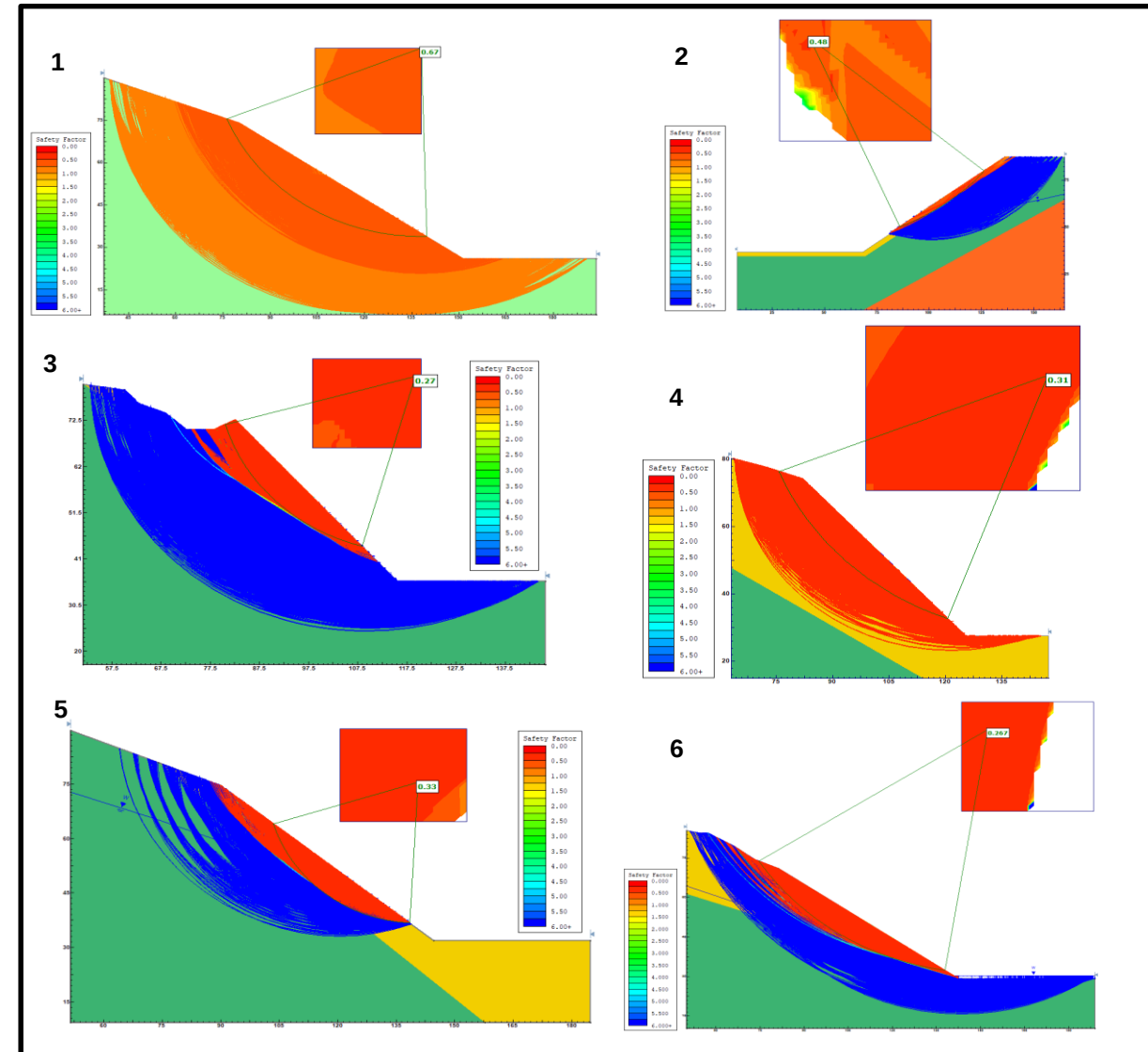
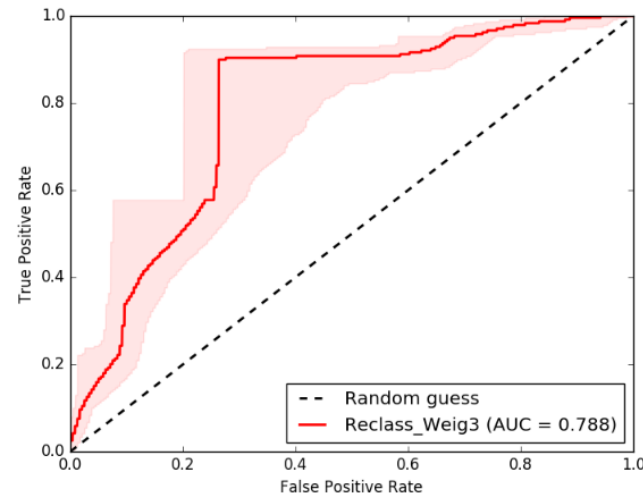
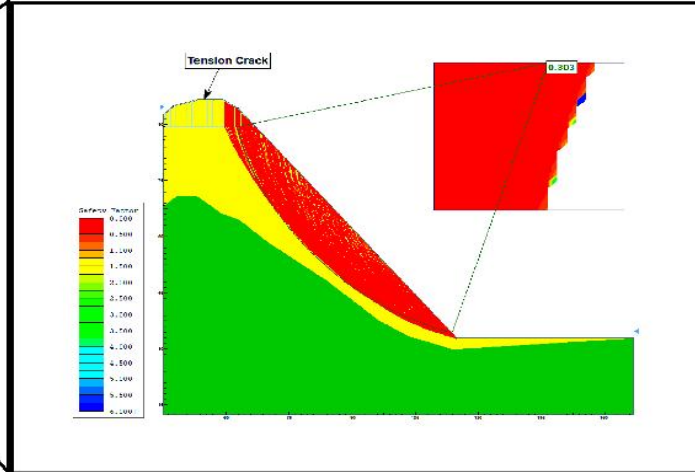
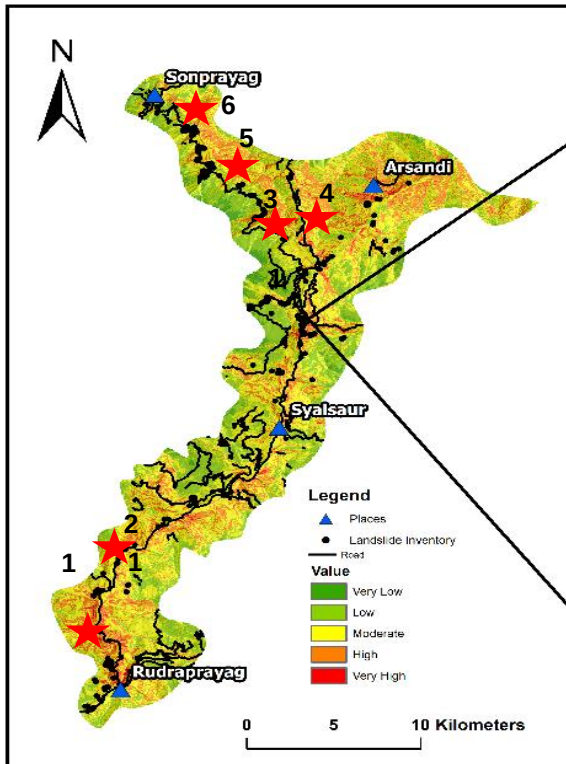
Landslide Susceptibility (H.P)



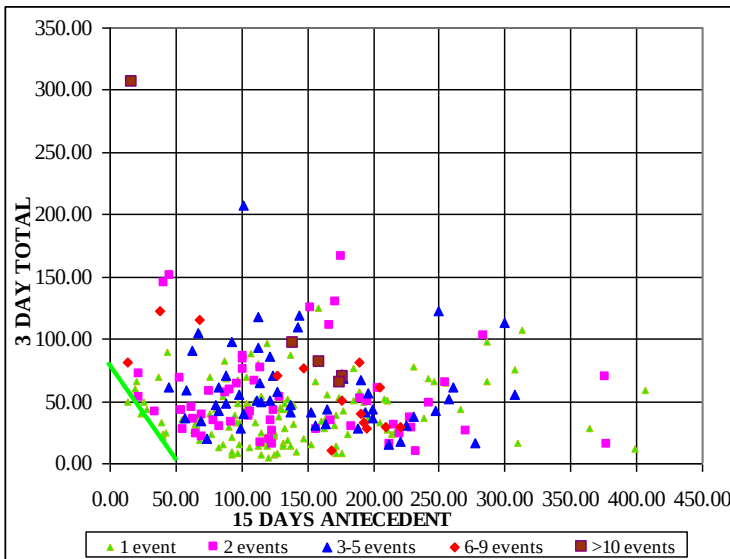
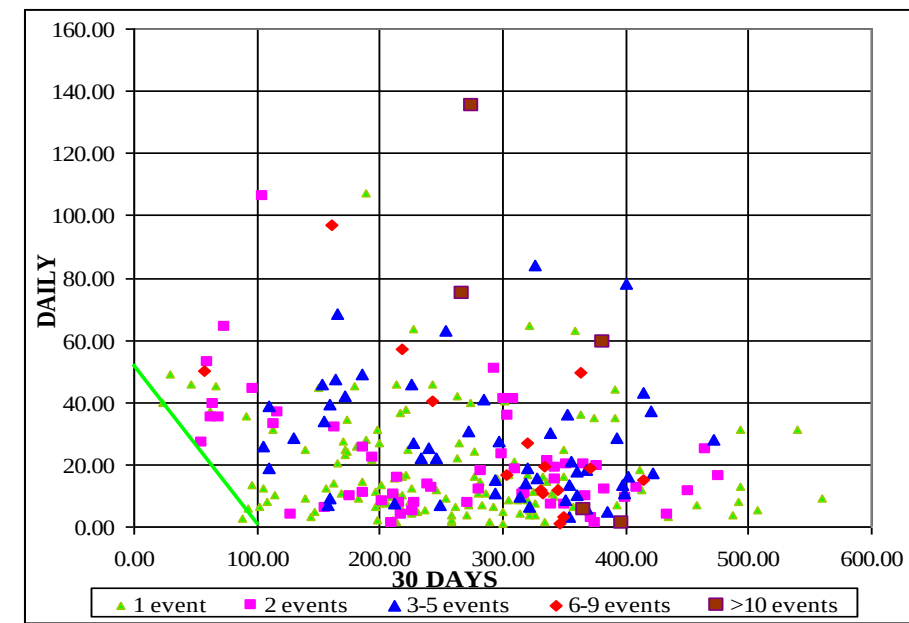
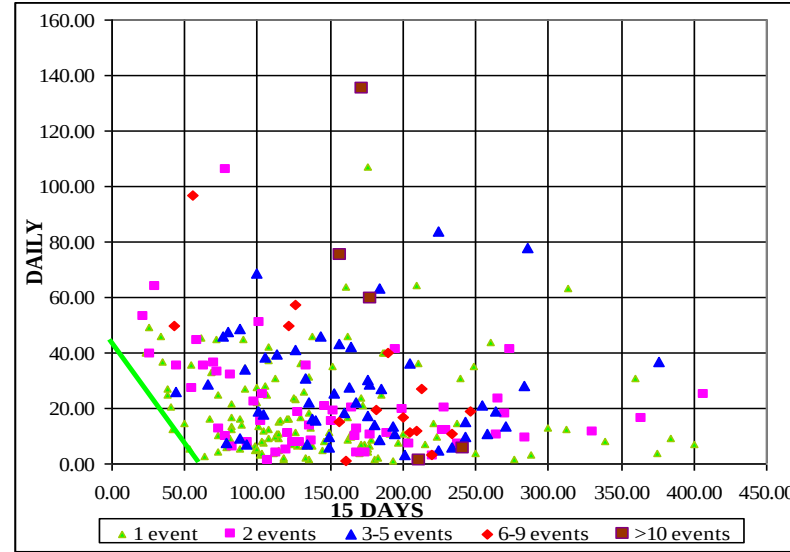
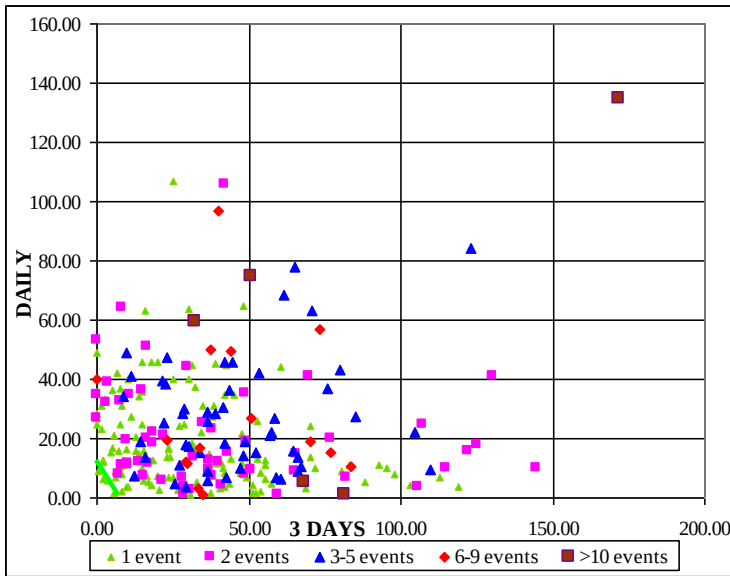
Satellite based Inventory map and LHZ of Shimla-Kinnaur (NH-52 (@1:50k, 10m spatial resolution) study area with active and old/stabilized landslide locations. Total 441 landslide locations were identified in the study area

240 km stretch of National Highway 05 in Shimla and Kinnaur District of Himachal Pradesh.

FoS & Susceptibility: Mandakini



Rainfall Threshold Equation



Sl. No	Type of Threshold	PKC's Eqn. (2007-2018)	SLC's Eqn.(2018-2023)	Reasons of Variation
01	Daily vis-à-vis 3 Days	$T_1 = R_1 + 1.47R_3 - 14.6$	$T_1 = R_1 + 1.56R_3 - 12.0$	- Mandakini and Alaknanda valley requires different amount of antecedent rainfall for landslide initiation - Increase in anthropologically induced landslides R_3 has more control than R_{15} as R_3 acts as triggering factor.
02	Daily vis-à-vis 15 Days	$T_1 = R_1 + 0.55R_{15} - 35.1$	$T_1 = R_1 + 0.68R_{15} - 30.8$	
03	Daily vis-à-vis 30 Days	$T_1 = R_1 + 0.49R_{30} - 51.3$	$T_1 = R_1 + 0.55R_{30} - 49.7$	
04	3 Days vis-à-vis 15 Days	$T_1 = R_3 + 1.56R_{15} - 82.7$	$T_1 = R_3 + 1.541R_{15} - 140.3$ (?)	

Selected Field Photographs



Landslide of Dharasu Bend: Uttarkashi (Length of Car: 7m)



Old Stabilized Landslide, West of Tiffin top, Nainital (Width of Section: ~500m)



Left: Anthropologically mediated landslide; Right: Wedge failure induced rock fall, Joshimath (Width of the Section: 3m & 5m respectively)

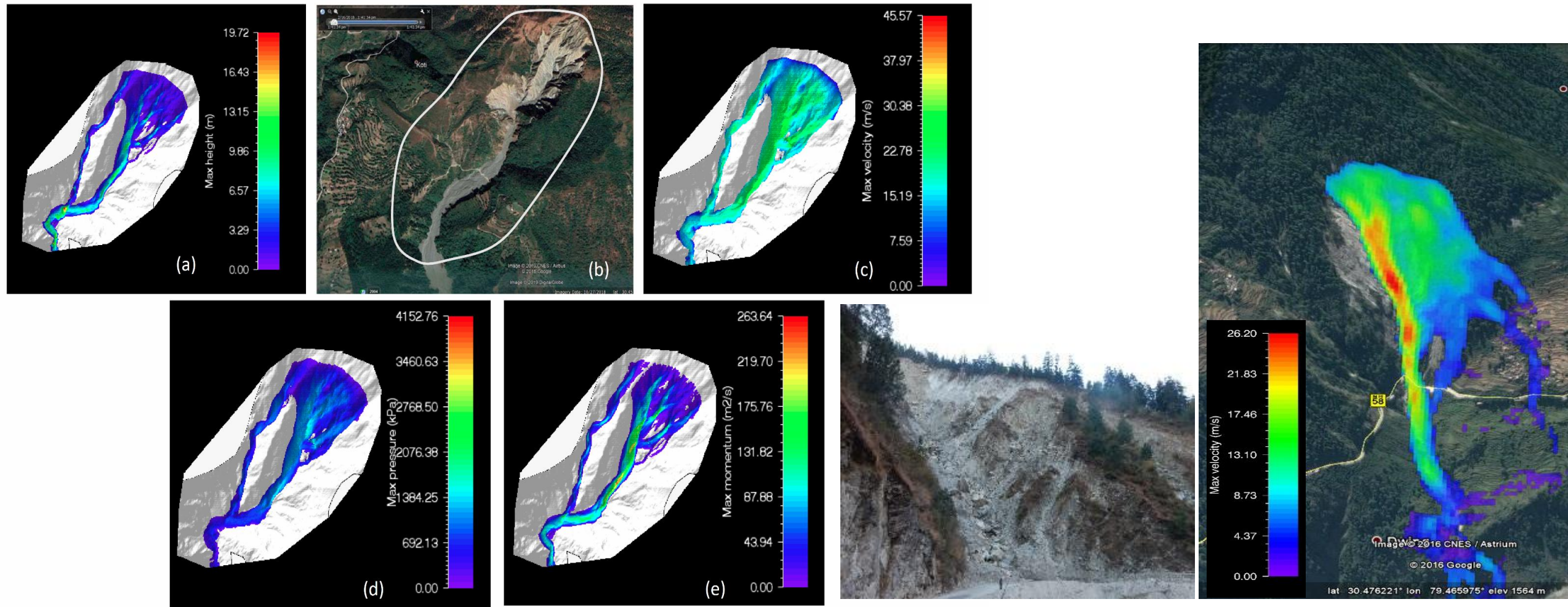


Typical runout of a Debris flow: Mainthana, Alaknanda Valley (Max width at Source: 10m)



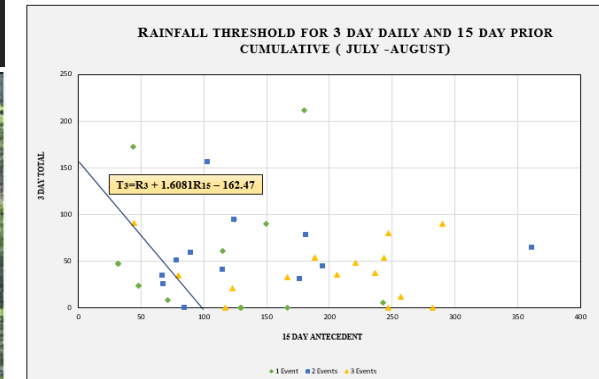
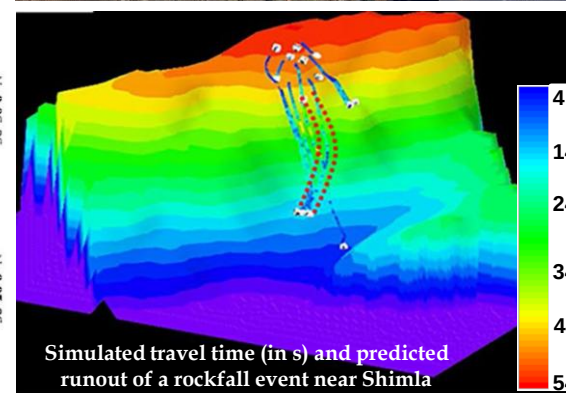
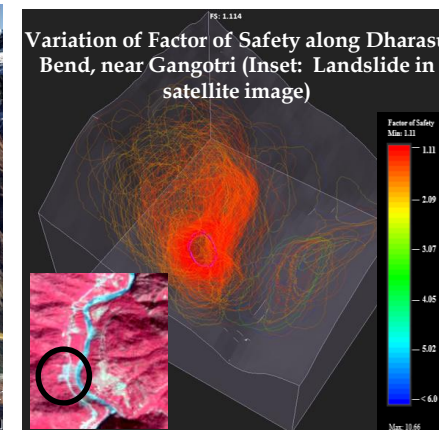
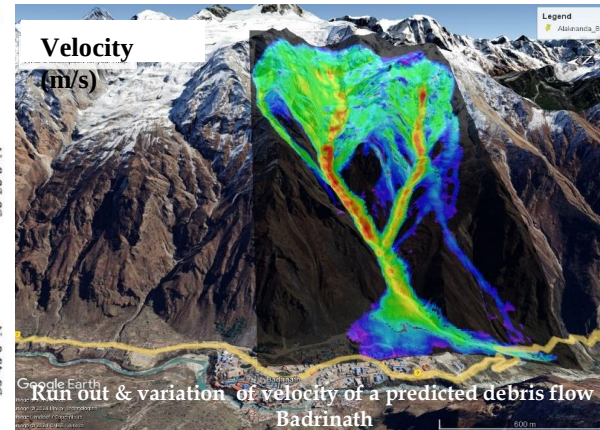
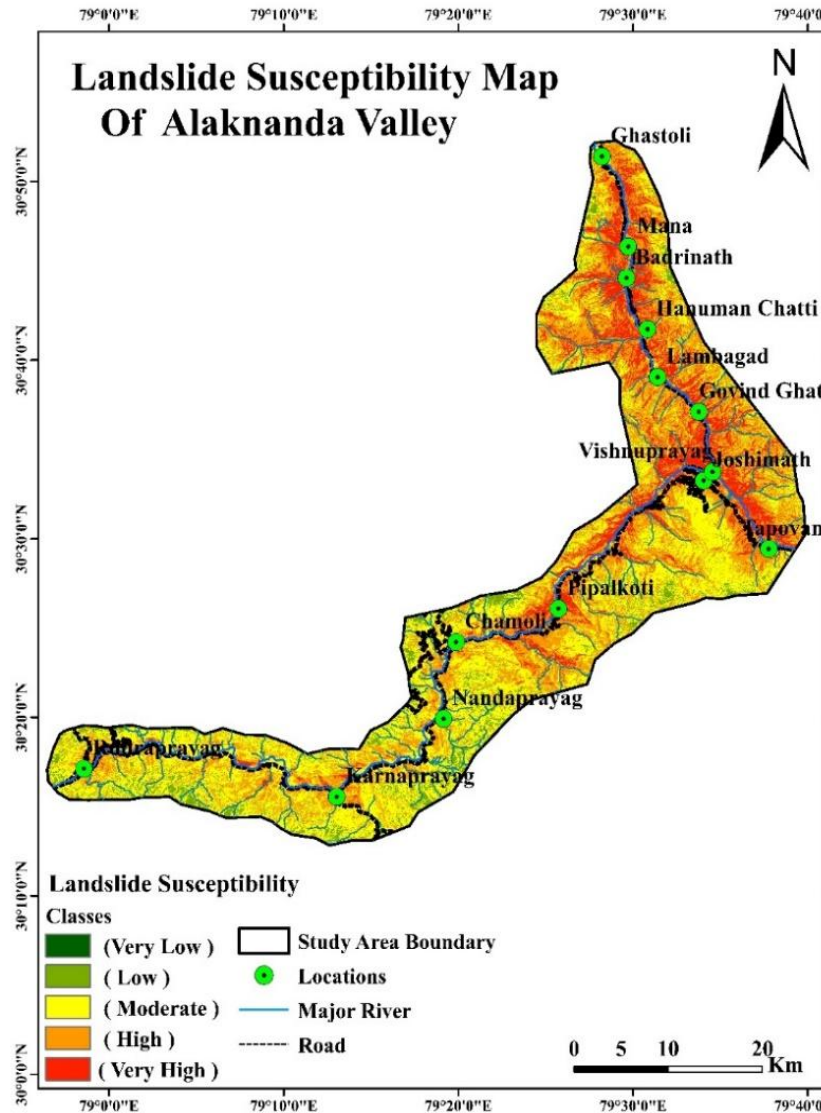
Development of Sympathetic Cracks at source region of a potential landslide at Ukhimath (Length of Hammer: 0.3m)

Model of Koti & Lyansi Landslide



Spatial Variation of simulated flow height, velocity, momentum and pressure of Koti and Lyansi Landslide, Uttarakhand

Key Findings In A Nutshell



Major River Valleys	Locations	Landslide Susceptible Area %					
		Very Low	Low	Moderate	High	Very High	High + Very High
Bhagirathi	Dharasu to Gangotri	12	22	23	25	18	43
	Tehri to Dharasu	13	26	28	23	10	33
Mandakini	Rudraprayag to Sonprayag	2	27	45	23	2	25
	Sonprayag to Kedarnath	4	5	30	35	26	61
	Nainital	9	51	0	33	8	40
	Shimla -Kinnaur	1	5	20	44	32	76
Alaknanda	Rudraprayag to Badrinath	0	7	38	37	17	54
Kali/ Sarda	Pithoragarh to Lipulekh	12	21	30	24	13	37

Take Home Points



- Landslide hazard zoning is a proven technique to assess the probability of landslide hazard in a vulnerable area
- The result shows High and Very High Landslide Susceptibility lies with that Shimla to Kinnaur (76%) route, followed by Sonprayag to Kedarnath (61%) and Rudraprayag to Badrinath (54%). Intriguingly, Rudraprayag to Sonprayag contains only 25%. Bhagirathi Valley as a whole and Pithoragarh to Lipulekh (Kailash Mansarovar) route shows moderate level of landslide susceptibility.
- The findings of this study have important implications for landslide disaster management. Landslide inventories can be useful for damage assessment and emergency response planning.
- Increase in numbers of anthropologically induced landslides in recent times has lowered the T_1 threshold in rainfall induced landslides in Mandakini and Alaknanda Basin
- Predictive numerical simulation and modeling of landslides help to know about their **run out of influence** and other geophysical parameters for similar future incidents to aid mass movement risk preparedness, **extent and type of road/ river blockade and installation of remedial measures like height, width and type of check dams/ retaining walls)** and thus help DRR
- Employing limit equilibrium based frictional models to calculate FoS at different vulnerable locations coupled with analysis of other geotechnical conditioning factors help to develop Level I warning for slope stability at vulnerable locations.



Thank You