ISTP Final Report

The land in the Indian state of Himachal Pradesh is prone to shift due to a combination of seismic activity, monsoon rains, and naturally rocky soil. These motions can range in scale from little stones tumbling downhill to large geographic features dislodging and shifting as destructive landslides. Human activities in the region not only intensify these movements, but also result in severe property and life losses. One of the most significant contributors to this human disturbance is road cutting, which is the act of cutting through the slope of a hill to create the flat surface required for roads. As a result, the scope of this investigation was on the North-South route and how commuters who use it evaluate the risk posed by its construction.

Landslide Vulnerability Assessment in Himachal Pradesh

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Abstract

The Mandi-Bajaura Road in Himachal Pradesh, India, is predisposed to dangerous landslides. We performed a survey of the local IIT-Mandi community to examine their landslip risk experiences and knowledge. Participants were shown real-time sensor data and satellite photos to see how it affected their assessment of landslip dangers between the North and South campuses. The descriptive data had no effect on the participants' perceptions. As a result, we developed a VR-based landslip simulation that will be utilised for instructional and survey reasons in the future.

Fig 1 : Picture of IIT Mandi North Campus

Acknowledgement

We would like to express our heartfelt gratitude to the following people for their direct contributions towards our project and all the other who have contributed to the completion of this project.

- Firstly, we would like to extend our sincere thanks to our mentors, Dr. Varun Dutt and Dr. K V Uday from IIT Mandi, for their invaluable guidance and support

throughout the project. Their expertise and experience have been crucial in shaping our work and providing us with essential resources to accomplish our goals.

- To our esteemed WPI advisors, Dr. Ingrid Shockey and Dr. Uma Kumar, for their invaluable feedback and guidance throughout the project. Their expertise in the field and constructive criticism have been instrumental in shaping our project vision and improving our writing.
- To Akshay K, PhD student of IIT Mandi, for providing us with sensor/satellite data and helping with our data analysis.
- We would also like to thank the participants who took part in our survey and VR simulation. Their participation was essential in providing us with valuable data and insights that were critical to the success of our project.

We acknowledge all these individuals' contributions and express our deepest appreciation for their efforts, which have been instrumental in the completion of this project.

Meet the Team

Harshit Agarwar (IIT)
Greetings, I am Harshit Agarwar, a 3rd year undergraduate pursuing Data Science at IIT Mandi, located in the picturesque state of Himachal Pradesh, India. As a naturally inquisitive individual, I am always eager to gain a comprehensive understanding of my surroundings. In my leisure time, I enjoy embarking on treks in the mountains or engaging in strategic games such as chess. This project enabled me to garner invaluable insights regarding landslides and the corresponding experiences of affected individuals.

Jarrett Gulden (WPI)
Hello, my name is Jarrett. I’m a junior Aerospace Engineer at WPI and originally from Walpole, Maine. I love being outside and exploring new places and have appreciated being in such a beautiful area with lots of great trekking. While the Kamand region is truly spectacular, this project has given me a glimpse of the unfortunate natural hazards that affect everyone here. I hope this project can have a positive impact and help preserve the beauty of this region and improve the safety of everyone in it.

Dylan Hunt (WPI)

Despite being a Computer Science major, I love studying the natural world. All aspects of biology, geology, and horticulture fill my free time. Having been born in New Hampshire, WPI was just close enough to home. India, however, has been much more exciting. This project has allowed me to end my third year at WPI with more exploration than I could have hoped for.

Ethan Lockhart (WPI)

Hey there! My name is Ethan Lockhart and I am a junior from San Ramon, California studying Architectural Engineering at WPI. Being a part of this project has allowed me to experience a place I previously knew little about. I have really enjoyed going hiking, traveling to local towns, and getting to know some of the IIT students. I will certainly miss being surrounded by such beautiful scenery and especially the daily chai tea. Overall I appreciate this opportunity we have been given to better understand this culture and work on a project that aims to help thecommunity.

Dishti Oberai (IIT)

Hi, I am Dishti Oberai, a third year CSE undergraduate at IIT Mandi. I am fascinated by computers and especially virtual reality. I have really enjoyed working on this project along with my team and have learnt alot from it.

Harsh Kumar Verma (IIT)

Hello there! My name is Harsh and I am a 3rd year Btech student at IIT Mandi (Himachal Pradesh). My major is in Electrical and I have always loved to work with sensors and explore nature. This project has helped me a lot to achieve this dream. Ethan, Jarret, Dylan and the other IIT students are all amazing. Overall, we had a very fun and knowledgeable time.

Team Members with Mentor Ingrid Shockey

From Left to Right : Ingrid Shockey, Jarrett Gulden, Dylan Hunt, Ethan Lockhart, Dishti Oberoi, Harshit Agarwar, Harsh Kumar Verma

Executive Summary

Our landslide vulnerability assessment project in the Kamand Valley, Himachal Pradesh, aims to identify the places prone to landslides along IIT Mandi's North-South road. Our goal was to offer a thorough understanding of the risks connected with landslides in this area, as well as to assess the community's perception of these risks. To do this, we carried out a study that used real-time sensor data and satellite photos to identify landslide-prone locations. We also polled the IIT Mandi community to gauge their grasp of landslip dangers.

According to the results of our investigation, there are a number of areas along IIT Mandi's North-South road that are prone to landslides. We found that the majority of the community people who were surveyed had little knowledge of the threats posed by landslides and their possible effects. This emphasises the necessity of better knowledge and readiness in places vulnerable to landslides.

We created a VR-based landslip simulation to help in this endeavour. The risks connected with landslides can be better understood in the future by using this simulation for survey and instructional purposes. Our findings lay the groundwork for

upcoming research and projects aimed at lessening the effects of landslides on communities in landslide-prone areas.

Himachal Pradesh's Kamand Valley is prone to shifting due to earthquakes, monsoon rainfall, and the region's inherently rocky soil. Small stones rolling downhill to entire geographic features dislodging and migrating as destructive landslides are all examples of these processes. Road cutting and other human activity in the area intensify these movements and cause serious losses in both life and property. Therefore, the North-South route was the main focus of our investigation, as well as how commuters there view the threats posed by its development.

We created and carried out a survey with IIT students, employees, and the citizens of impacted areas to obtain information on this subject. Additionally, we gathered information from nearby sensors intended to track ground movement above roads. We then presented survey respondents with this information to evaluate if their perceptions of the risk posed to commuters by any particular stretch of road had changed after seeing the actual number of movements along that portion of the route.

Our survey's findings demonstrated that the respondents' attitudes and behaviours were not significantly altered by the survey's data. These respondents frequently stated that the information just confirmed what they already knew about the risk in the area. Additionally, some respondents added that they would still base their choices on their own experiences even if the data were different. In order to address this, we started working on a VR landslip simulation to explore if experiencing a landslip event indeed altered a recipient's viewpoint more than simply viewing the assembled data.

The main piece of advice from our project is to keep working on the VR simulation. This tool can be used for additional surveying and can help with educational initiatives to improve awareness of the risks connected to landslides. The results of our poll also suggest a need to lessen the justifications for commuting between IIT Mandi's North and South campuses. Most respondents stated that they commute between the two campuses each day for employment, class, or laboratories and that they would do so even if there was a landslip risk. This response, however, was frequently prefaced by a statement to the effect that the respondent wished it were not true that they resided on the other campus, away from the location of these activities. Housing IIT employees and students near their places of employment would significantly reduce needless travel dangers. A second route connecting the North and South campuses should also be made available. A route like this would stop the two campuses from being isolated by a single landslip, as has previously happened. However, road cutting may raise the risk of landslides, hence it is advised that retaining walls and barriers be put in place along the new road's and existing roads' whole lengths to boost stability.

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Introduction

The Kamand Valley area of Himachal Pradesh served as the site for an assessment of landslide susceptibility, and the results and recommendations are presented in this paper. The area is located in the Himalayan mountain range, a rough terrain that presents many difficulties for constructing dependable infrastructure and transit routes. Additionally, the area is extremely vulnerable to landslides due to a unique combination of soil characteristics, seismic activity, and mountain slope. Unfortunately, disastrous landslides, which harm infrastructure, property, and human life, happen much too frequently. Our mentors **Dr. Varun Dutt** and **Dr. KV Uday**, from IIT Mandi, have been trying to create low-cost, real-time sensors that can provide early warning signals to the area through their tech firm, **iIoTs**, in response to this persistent menace. By evaluating how the IIT Mandi community views landslide threats and pinpointing the areas most at danger for landslides along the campus' North-South road, this research seeks to supplement their efforts. In order to locate landslide-prone locations, the research used real-time sensor data and satellite photos. It also conducted a poll of the IIT Mandi community to gauge its awareness of the risks associated with landslides. In addition, a VR landslip simulation was created for future research and instructional reasons. The paper ends with suggestions for upcoming programmes designed to lessen the effects of landslides on communities in landslide-prone areas. The findings of the paper will be crucial in creating efficient mitigation methods to reduce the dangers connected with landslides in the area.

Context

Landslides are a major worry for the local population as well as students at the Indian Institute of Technology (IIT) Mandi in the Himachal Pradesh region of India. Landslides in this region have caused a variety of issues and difficulties for both locals and students.The local population's safety and wellbeing are seriously threatened by landslides. Because of the regular landslides, it is challenging for residents to travel and receive necessary services. When roads are disrupted during the monsoon season, it has particularly negative effects on daily transportation, livelihoods, and emergency response. Additionally, landslides can harm buildings, homes, and utility networks, further aggravating the problems the community is already facing.

Landslides present additional difficulties for IIT Mandi students. Since the institute has campuses in both the North and South, frequent travel is necessary. Road closures and dangerous conditions brought on by landslides frequently endanger students' safety and make it difficult for them to attend class, access resources, or conduct research or lab work. As a result, there may be disruptions in the classroom, delays in finishing projects, and general challenges in maintaining a positive learning environment.

Fig 2: Landslide near the Kamand Region and traffics jams due to the same

Several topographical and geographic elements may contribute to the causes of landslides in the Kamand region. The region is distinguished by its rocky terrain, thin soil, and heavy monsoon rains. The susceptibility to slope failures is increased by the terrain's hills, loose soil, and rocks. Furthermore, the frequency and severity of landslides have increased in recent years, which may be related to climate change and shifting rainfall patterns.

For the development of successful mitigation techniques, it is essential to comprehend the causes and effects of landslides in the Kamand region. Collaboration between key parties is necessary, including the neighbourhood, IIT Mandi, and governmental organisations. It is feasible to reduce the hazards connected with landslides and improve the safety and wellbeing of the inhabitants and students in the area by putting into place measures like enhanced infrastructure, early warning systems, and public awareness campaigns.

Literature Review

Title: Interferometric Synthetic Aperture Radar (InSAR): A Comprehensive Literature Review

Abstract:

Interferometric Synthetic Aperture Radar (InSAR) is a remote sensing technique that has revolutionized the field of Earth observation by providing accurate and detailed information about the Earth's surface. This literature review aims to explore the key concepts, methodologies, applications, and advancements in InSAR technology. It presents an overview of the fundamental principles underlying InSAR, discusses the major challenges faced in its implementation, and highlights its diverse range of applications across various domains. Additionally, recent advancements and future directions in InSAR research are also discussed.

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8.1 Summary of Key Findings

Introduction:

Interferometric Synthetic Aperture Radar (InSAR) has emerged as a powerful remote sensing technique that enables precise and detailed measurements of the Earth's surface. By utilizing the principles of radar interferometry, InSAR has revolutionized the field of Earth observation and has contributed significantly to various disciplines, including geology, environmental science, and urban planning. This literature review aims to provide a comprehensive overview of the fundamental concepts, methodologies, applications, and recent advancements in InSAR technology.

1.1 Background and Motivation:

The development of InSAR can be traced back to the 1970s when the concept of using radar interferometry for Earth observation was first proposed. Over the years, advancements in satellite technology and signal processing algorithms have significantly improved the accuracy and applicability of InSAR. Today, it has become a key tool for studying various natural and anthropogenic phenomena, enabling scientists and researchers to monitor changes on the Earth's surface with unprecedented precision.

The motivation behind the widespread adoption of InSAR lies in its ability to provide valuable information about surface deformation, topography, and changes in vegetation cover. Traditional remote sensing techniques, such as optical imagery, often face limitations due to factors like cloud cover, illumination conditions, and limited temporal coverage. In contrast, InSAR overcomes these limitations by utilizing radar signals that can penetrate through clouds, operate day and night, and offer millimeter-level accuracy in measuring ground displacements. This unique capability of InSAR has opened up new avenues for understanding dynamic processes occurring on the Earth's surface.

1.2 Objectives of the Literature Review:

This literature review aims to provide a comprehensive overview of the key aspects of InSAR, including its fundamental principles, processing techniques, challenges, applications, recent advancements, and future directions. By synthesizing existing knowledge and research in the field, this review seeks to offer a valuable resource for researchers, practitioners, and policymakers who wish to gain a deeper understanding of InSAR and its potential applications.

Through an exploration of the fundamental principles underlying InSAR, the review will lay the groundwork for understanding the techniques and methodologies involved in generating accurate and reliable measurements. The discussion will then expand to highlight the major challenges faced in implementing InSAR, such as atmospheric effects, phase unwrapping, and noise sources, and the various strategies employed to mitigate these challenges.

Furthermore, the literature review will delve into the diverse range of applications where InSAR has made significant contributions. These include land deformation monitoring, volcanic activity monitoring, urban infrastructure monitoring, natural hazards assessment, and many others. The review will also address recent advancements in InSAR, such as improved processing techniques, integration with other remote sensing data, and the utilization of machine learning and big data analytics.

Finally, the review will outline future directions and challenges in the field of InSAR, identifying areas for further research and development. This will encompass enhanced atmospheric corrections, high-resolution InSAR for urban areas, and the expanding applications of InSAR in environmental monitoring.

By consolidating and synthesizing the existing knowledge on InSAR, this literature review aims to contribute to the understanding and utilization of this powerful remote sensing technique, promoting its application in diverse fields and inspiring future research endeavors.

2. Interferometric Synthetic Aperture Radar (InSAR): Fundamentals

2.1 Basic Principles of InSAR:

Interferometric Synthetic Aperture Radar (InSAR) operates by utilizing the principles of radar interferometry to measure the phase difference between two or more radar images acquired from slightly different positions. InSAR combines the benefits of synthetic aperture radar (SAR) and interferometry to generate high-resolution surface deformation maps.

InSAR works by transmitting radar signals towards the Earth's surface and measuring the phase shift of the signals reflected back to the sensor. The phase shift is a result of the difference in distance traveled by the radar signals due to the topographic and deformation-induced changes on the Earth's surface. By comparing the phase shift between two or more radar acquisitions, it is possible to derive precise measurements of surface displacement.

2.2 Interferometric Phase and Coherence:

The interferometric phase represents the phase difference between two SAR images acquired at different times or from slightly different positions. The phase is directly related to the range change between the radar sensor and the ground surface. By unwrapping the phase, the absolute deformation measurements can be obtained. However, atmospheric effects, noise, and other factors can introduce errors in the phase measurement.

Coherence, on the other hand, is a measure of the similarity between the two SAR images used for interferometry. It quantifies the degree of correlation between the two images and is influenced by factors such as decorrelation due to temporal changes, geometric baseline differences, and atmospheric disturbances. High coherence indicates a strong correlation, while low coherence signifies decorrelation and reduced accuracy in deformation measurement.

2.3 SAR Imaging Modes:

InSAR utilizes different imaging modes, depending on the sensor configuration and application requirements. The two primary SAR imaging modes used in InSAR are stripmap and spotlight modes.

- Stripmap Mode: In this mode, the radar sensor collects a continuous strip of data along the flight path. Stripmap mode provides high-resolution imagery but with a limited coverage area.
- Spotlight Mode: In spotlight mode, the radar beam is focused on a specific target area, allowing for very high-resolution imaging. However, the coverage area is significantly smaller compared to stripmap mode.

2.4 InSAR System Configurations:

InSAR systems can be configured in different ways, depending on the desired application and spatial coverage requirements. The two main configurations are:

- **Single-Pass InSAR**: In single-pass InSAR, two antennas are used simultaneously, either on the same platform or on two different platforms flying closely together. This configuration enables near-simultaneous acquisitions and provides accurate measurements of surface deformation.
- **Multi-Pass InSAR**: Multi-pass InSAR utilizes two or more SAR acquisitions acquired at different times or from different orbital paths. By combining multiple acquisitions, it is possible to derive deformation information over a larger area, but at the expense of temporal decorrelation and increased complexity in data processing.

2.5 Factors Affecting InSAR Measurements:

Factors affecting InSAR measurements include atmospheric effects (e.g., water vapor-induced delays), temporal/geometrical decorrelation (due to surface changes and baseline differences), challenging phase unwrapping (in regions with complex topography), topographic effects (requiring correction), and noise/error sources (such as thermal and speckle noise, orbit determination errors). Understanding and mitigating these factors are crucial for obtaining accurate InSAR measurements and reliable deformation information. Advances in processing algorithms, atmospheric correction models, and calibration techniques contribute to improving the accuracy and expanding the applicability of InSAR in various fields.

3. InSAR Processing Techniques:

3.1 Single-Pass InSAR Processing: This technique involves the simultaneous acquisition of two radar images by two antennas on the same or different platforms. The acquired images are processed together to generate an interferogram, which

captures the phase difference between the two images. Single-pass InSAR processing provides accurate and near-simultaneous measurements of surface deformation.

3.**2 Multi-Pass InSAR Processing:** Multi-pass InSAR utilizes two or more SAR acquisitions acquired at different times or from different orbital paths. By combining multiple acquisitions, interferograms are generated to measure surface deformation over a larger area. Multi-pass InSAR processing allows for the assessment of temporal changes and the monitoring of long-term deformation patterns.

3.3 Persistent Scatterer InSAR (PSI): PSI is a specialized InSAR technique that focuses on monitoring stable, coherent targets over a long period. It utilizes a stack of interferograms to extract phase information from persistent scatterers, which are typically man-made structures or natural features with stable radar reflections. PSI provides highly accurate measurements of surface displacement and is particularly useful for urban areas and infrastructure monitoring.

4 Challenges in InSAR:

4.1 Atmospheric Effects: Atmospheric conditions, such as variations in water vapor content and atmospheric turbulence, can introduce significant errors in InSAR measurements. These effects cause delays and distortions in radar signals, resulting in inaccuracies in the derived phase measurements. Accurate modeling and correction of atmospheric effects are crucial to mitigate their impact on InSAR results.

4.2 Temporal and Geometrical Decorrelation: Changes occurring on the Earth's surface between radar acquisitions can lead to decorrelation between the images used for interferometry. Factors such as vegetation growth, surface deformation, and land cover changes can contribute to temporal decorrelation. Geometrical baseline differences, caused by changes in the position or trajectory of the radar sensor, can also introduce decorrelation. These decorrelation effects can reduce the coherence and accuracy of InSAR measurements, particularly for long time intervals between acquisitions or large baselines.

4.3 Complex Topography and Phase Unwrapping: In regions with complex topography, such as mountainous areas or areas with steep relief, phase unwrapping becomes challenging. High deformation gradients and phase ambiguities make it difficult to accurately unwrap the phase and obtain absolute deformation values. Specialized algorithms and techniques, including adaptive unwrapping methods and the integration of additional data sources like digital elevation models (DEMs), are employed to address these challenges and improve the accuracy of InSAR measurements in complex topographic regions.

5. Applications of InSAR:

5.1 Land Deformation Monitoring: InSAR is widely used for monitoring land deformation, including subsidence and uplift. It enables the detection and measurement of ground movements caused by natural processes (e.g., tectonic activity, volcanic deformation) and human-induced factors (e.g., groundwater extraction, mining activities). InSAR provides valuable information for assessing geohazards, land stability, and land management planning.

5.2 Volcanic Activity Monitoring: InSAR plays a crucial role in monitoring volcanic activity by detecting ground deformation associated with magma movement and volcanic unrest. It helps to assess volcanic hazards, such as lava flow mapping, detecting changes in volcano shape, and identifying potential eruption precursors. InSAR offers valuable insights into volcanic processes and aids in volcanic risk mitigation and early warning systems.

5.3. Urban Infrastructure Monitoring: InSAR is utilized for monitoring and assessing urban infrastructure, including buildings, bridges, and infrastructure networks. It enables the detection of subsidence or deformation in urban areas, identification of potential structural weaknesses, and monitoring the stability of critical infrastructure. InSAR assists in urban planning, infrastructure maintenance, and risk assessment in densely populated regions.

5.4. Natural Hazards Assessment: InSAR is employed for monitoring and assessing various natural hazards, such as earthquakes, landslides, and coastal erosion. It provides valuable information on ground movements, fault activity, and slope instability, contributing to hazard mapping, early warning systems, and post-event damage assessment. InSAR helps in understanding the dynamics of natural hazards and improving disaster management strategies.

5.5 Environmental Monitoring: InSAR is used for studying environmental changes, including vegetation dynamics, wetland monitoring, and coastline evolution. It enables the mapping of vegetation height and biomass, assessment of wetland ecosystems, and monitoring shoreline changes due to erosion or sea-level rise. InSAR supports ecological studies, land-use planning, and conservation efforts by providing valuable information on environmental changes over time.

These are just a few examples of the diverse range of applications where InSAR has proven valuable. Its versatility and capability to provide high-resolution surface deformation measurements make it a valuable tool in various fields, contributing to better understanding and management of Earth's processes and resources.

6 Recent Advancements in InSAR:

6.1 Advanced Data Processing Techniques: Significant advancements have been made in the development of data processing algorithms for InSAR. These

advancements include improved phase unwrapping algorithms, advanced atmospheric correction models, and techniques for mitigating noise and error sources. Advanced processing techniques enhance the accuracy and reliability of InSAR measurements, enabling more precise deformation mapping and analysis.

6.2 **InSAR Time-Series Analysis:** Time-series analysis of InSAR data has gained prominence in recent years. It involves the analysis of multiple interferograms acquired over time to study the temporal evolution of surface deformation. Advanced time-series analysis techniques, such as Persistent Scatterer InSAR (PSI) and Small Baseline Subset (SBAS), allow for the identification of subtle deformation patterns, long-term trend analysis, and improved detection of deformation hotspots. Time-series InSAR analysis provides valuable insights into the dynamics of deformation processes and aids in long-term monitoring and trend analysis.

6.3 **Integration with Other Remote Sensing Data:** InSAR is increasingly being integrated with other remote sensing data sources, such as optical imagery, LiDAR, and GPS measurements. This integration allows for a synergistic approach to geospatial analysis, combining the strengths of different data sources. Integration with optical imagery provides valuable contextual information and enhances the interpretation of InSAR results. Combining InSAR with LiDAR and GPS measurements enables the validation and calibration of InSAR data, improving accuracy and confidence in deformation measurements.

These recent advancements in InSAR data processing techniques, time-series analysis, and integration with other remote sensing data sources have expanded the capabilities and applications of InSAR. They have contributed to more accurate and comprehensive monitoring of surface deformation, enabling better understanding of geophysical processes, improved hazard assessment, and informed decision-making in various fields.

7. Future Directions and Challenges:

7.1 Advanced InSAR Techniques for Small-Scale Deformation: One future direction is the development of advanced InSAR techniques that can accurately capture and monitor small-scale deformations, such as those associated with infrastructure, landslides, and urban subsidence. This requires improving the spatial resolution and sensitivity of InSAR measurements, as well as addressing challenges related to decorrelation and noise in complex urban environments.

7.2. Integration of InSAR with Other Data Sources: The future of InSAR lies in its integration with complementary data sources, such as terrestrial and satellite-based LiDAR, GPS, and optical imagery. Integration of multiple data modalities will provide a more comprehensive understanding of Earth's processes, enhance the accuracy of

deformation measurements, and enable more precise modeling and prediction of geohazards.

7.3 Advanced Atmospheric Correction and Mitigation Techniques: Atmospheric effects remain a major challenge in InSAR, particularly in regions with high water vapor content or complex atmospheric conditions. Future research and development efforts will focus on advancing atmospheric correction models and techniques to improve the accuracy of InSAR measurements. This includes the integration of weather models, improved calibration methods, and the utilization of auxiliary data sources to mitigate atmospheric artifacts.

7.4 Expanding InSAR Applications: The future of InSAR also lies in expanding its applications to new domains and sectors. This includes the integration of InSAR data in climate change studies, precision agriculture, and hydrological modeling. By leveraging the capabilities of InSAR and combining it with other remote sensing technologies, new insights can be gained into environmental processes and the impact of human activities on Earth's surface.

As InSAR continues to evolve and mature, addressing these future directions and challenges will contribute to unlocking its full potential as a powerful tool for Earth observation and geospatial analysis. Continued research, technological advancements, and collaboration among researchers and practitioners will play a vital role in shaping the future of InSAR and its applications.

8 Conclusion

8.1 Summary of Key Findings-

In summary, Interferometric Synthetic Aperture Radar (InSAR) is a remote sensing technique that utilizes the phase information of radar signals to measure and monitor surface deformations. InSAR has found wide-ranging applications in various fields, including land deformation monitoring, volcanic activity monitoring, urban infrastructure monitoring, natural hazards assessment, and environmental monitoring. Recent advancements in InSAR include improved data processing techniques, time-series analysis capabilities, and integration with other remote sensing data sources, enhancing the accuracy, reliability, and scope of InSAR measurements. However, challenges remain, such as atmospheric effects, temporal and geometrical decorrelation, and complex topography, which require continued research and development. Future directions for InSAR include the advancement of small-scale deformation monitoring, integration with multi-modal data sources, and the development of advanced atmospheric correction techniques. Addressing these challenges and future directions will unlock the full potential of InSAR and enable more comprehensive and accurate monitoring of Earth's surface deformations.

A review of the literature on studies that have evaluated the efficacy of early warning systems (EWS) for landslides can be found in the paper "Assessing the effectiveness of early warning systems for landslides: a review" by Laigle and Gariano (2022). The authors claim that by sending timely and precise warnings to impacted areas, EWS can help to lower the probability of landslip tragedies. The accuracy of the monitoring and warning systems, the efficiency of the communication and warning dissemination, and the ability of the communities to respond all play a role in how effective these systems are. The literature review focuses on the assessment of landslip EWS and encompasses research published between 2000 and 2021. The authors found a total of 58 studies that satisfied the inclusion requirements and evaluated them according to their goals, procedures, findings, and restrictions.
The analysis points out that the majority of research concentrate on assessing EWS's technical components, such as the effectiveness of monitoring and warning systems. Few studies, however, have examined how well warnings are communicated and disseminated or how well communities can respond to them. The majority of studies, with relatively little study in developing nations, have been carried out, according to the authors, who also make this observation.

The review comes to the conclusion that there is no one-size-fits-all solution and that many circumstances affect how effective EWS is at preventing landslides. The authors stress the value of conducting a thorough assessment of EWS performance, taking into account technical factors, warning communication and dissemination, and response capability. They also advocate for greater study into how well EWS works in impoverished nations, where inadequate infrastructure and scarce resources can make landslides more damaging.

Overall, the literature review provides a comprehensive overview of the studies that have evaluated the effectiveness of EWS for landslides. It highlights the need for a more comprehensive evaluation of EWS and the importance of considering factors beyond the technical aspects of the systems. The review provides a valuable resource for researchers and practitioners working on landslide risk reduction and disaster management.

Methodology

The methodology for the project consisted of three key components, each designed to address different aspects of landslides and their implications.

The first component involved analyzing satellite data obtained from INSAR, a powerful technique that utilizes synthetic aperture radar to measure ground surface movements with high precision. By examining this satellite data, we aimed to identify and monitor potential landslides in the study area. Additionally, we compared the findings from the satellite data with sensor data specifically collected from the Kamand area. This comparison allowed us to assess the accuracy, reliability, and cost-effectiveness of both the INSAR and sensor-based methods for detecting and monitoring landslides. Furthermore, we explored the potential of these techniques in developing effective alerting systems that could provide timely warnings about impending landslides.

The second component of our methodology involved the development of a virtual reality (VR) simulation. We created an immersive and interactive VR experience using the Unity coding environment. The simulation aimed to provide users with a realistic and engaging representation of landslides, allowing them to experience the event virtually. To make the simulation accessible to a broader audience, we deployed it using Google Cardboard goggles, which provide an affordable and user-friendly VR viewing experience. The purpose of this VR simulation was to educate people about the risks associated with landslides and increase their awareness and understanding of the phenomenon. By immersing users in a simulated landslide scenario, we aimed to enhance their knowledge and promote informed decision-making regarding safety measures and preparedness.

The third component of our methodology involved conducting extensive surveys among various groups directly affected by landslides in the Kamand region, as well as individuals who regularly use the north-south road. These surveys aimed to assess the risk perception of the participants and gather insights into their understanding of landslides, their preparedness measures, and their attitudes towards potential mitigation strategies. Participants were shown the VR simulation and then asked to complete post-surveys to evaluate the impact of the VR experience on their decision-making processes and their perception of the effectiveness of VR as an educational tool. By gathering data through surveys, we aimed to gain a comprehensive understanding of the effectiveness of the VR simulation in influencing risk perception and promoting behavioral changes related to landslides.

Overall, this multifaceted methodology integrated data analysis, VR simulation development, and surveys to comprehensively address the different dimensions of landslides. It enabled us to evaluate monitoring techniques, assess risk perception, and measure the educational effectiveness of the VR simulation, with the ultimate goal of enhancing awareness, preparedness, and decision-making related to landslides in the Kamand region and along the north-south road.

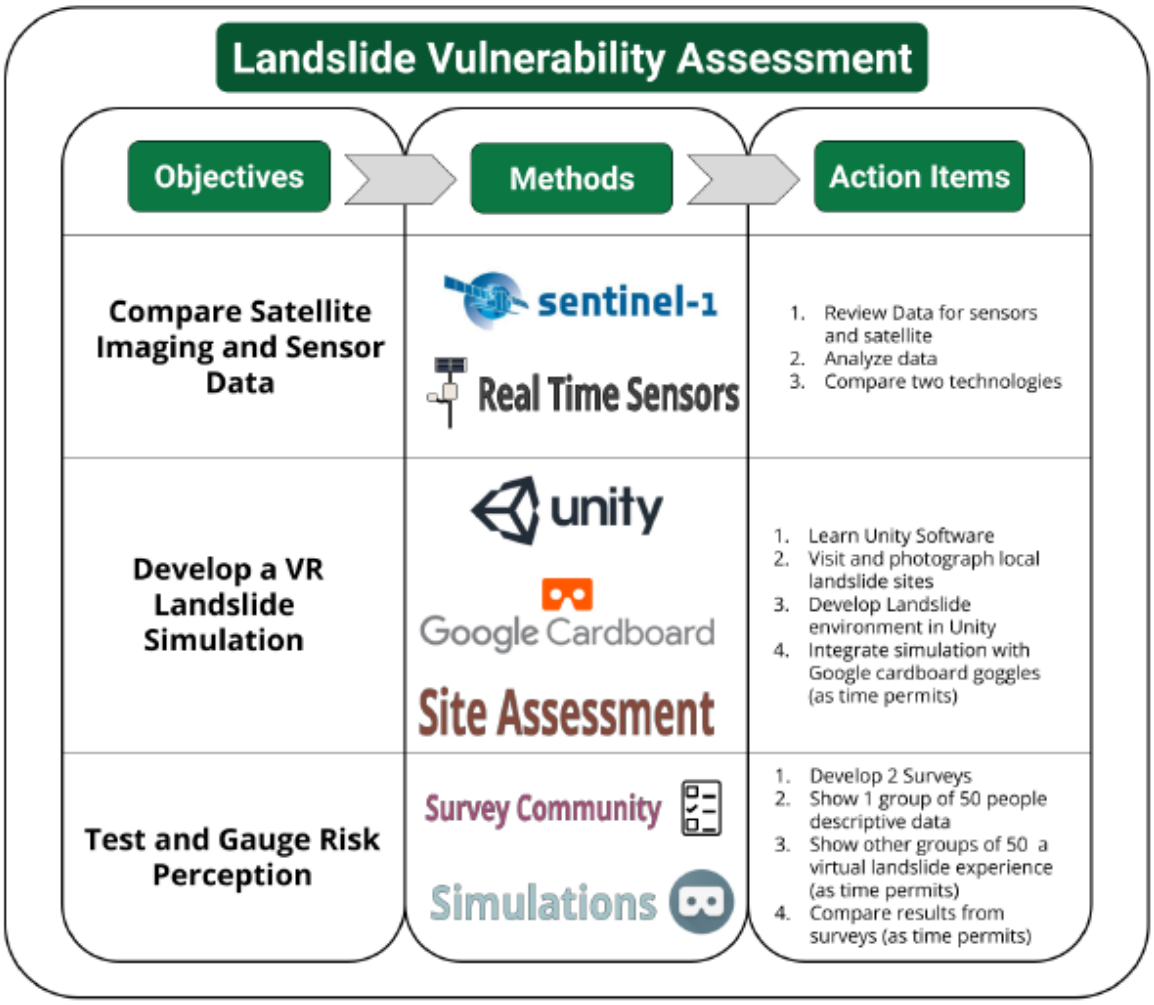
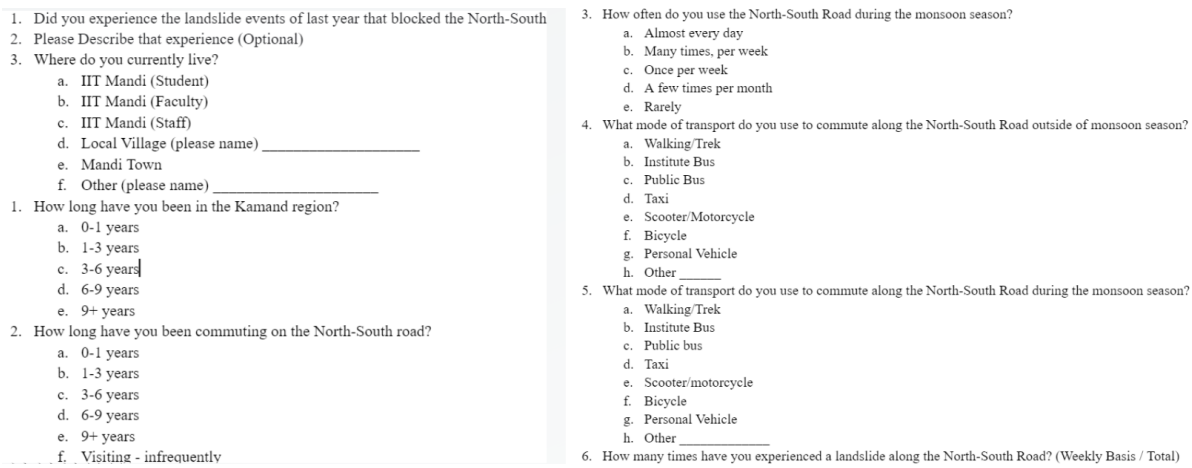


Fig 3 : Illustration depicting the sequential actions to accomplish our overarching objective



1. Did you experience the landslide events of last year that blocked the North-South
2. Please Describe that experience (Optional)
3. Where do you currently live?
   a. IIT Mandi (Student)
   b. IIT Mandi (Faculty)
   c. IIT Mandi (Staff)
   d. Local Village (please name) _____
   e. Mandi Town
   f. Other (please name) _____
1. How long have you been in the Kamand region?
   a. 0-1 years
   b. 1-3 years
   c. 3-6 years
   d. 6-9 years
   e. 9+ years
2. How long have you been commuting on the North-South road?
   a. 0-1 years
   b. 1-3 years
   c. 3-6 years
   d. 6-9 years
   e. 9+ years
   f. Visiting - infrequently
3. How often do you use the North-South Road during the monsoon season?
   a. Almost every day
   b. Many times, per week
   c. Once per week
   d. A few times per month
   e. Rarely
4. What mode of transport do you use to commute along the North-South Road outside of monsoon season?
   a. Walking/Trek
   b. Institute Bus
   c. Public Bus
   d. Taxi
   e. Scooter/Motorcycle
   f. Bicycle
   g. Personal Vehicle
   h. Other _____
5. What mode of transport do you use to commute along the North-South Road during the monsoon season?
   a. Walking/Trek
   b. Institute Bus
   c. Public bus
   d. Taxi
   e. Scooter/motorcycle
   f. Bicycle
   g. Personal Vehicle
   h. Other _____
6. How many times have you experienced a landslide along the North-South Road? (Weekly Basis / Total)

Fig 4: Depiction of the question asked in survey for background check of individuals

10. How likely would you be to commute along the North-South road during heavy rains? (1 extremely unlikely, 5 extremely likely)
    a. 1-5
    b. Unsure
11. How likely would you be to commute along the North-South road if you heard that a landslide had occurred within the last week? (1 extremely unlikely, 5 extremely likely)
    a. 1-5
    b. Unsure
12. What do you think the chances of encountering any landslide during monsoon season on the North-South road are in a week?
    a. 0%-100%
13. Under which circumstances would you be willing to risk encountering a landslide while commuting?

14. Did the Data/Experience change your view of landslides in general
    a. Yes
    b. No
    c. Maybe/unsure
15. How likely would you be to commute along the North-South road during heavy rains?
    a. 1-5
16. How likely would you be to commute along the North-South road if you heard that a landslide had occurred within the last week?
    a. 1-5
17. What do you think the chances of encountering a landslide during monsoon season on the North-South road are in a week
    a. 0%-100%
18. Would you still risk encountering a landslide for the circumstances given in question 13

Fig 5: Sample of Pre and Post Survey questions asked from individuals

Results and Analysis

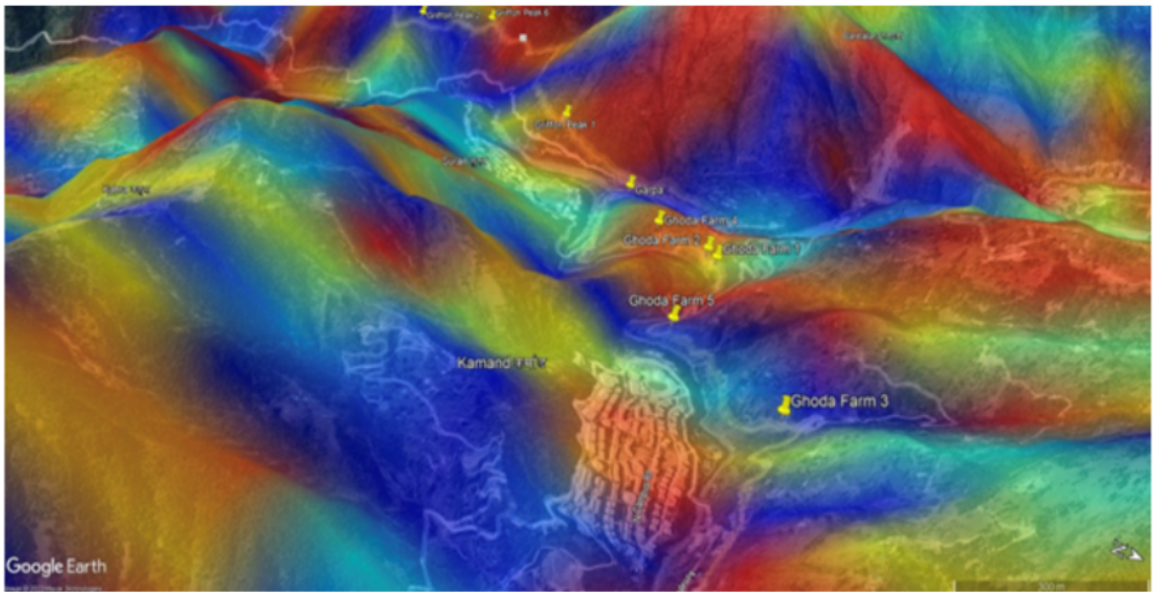
Compare and analyze satellite imaging and sensor data

We spoke with local authorities, specifically representatives of the District Disaster Management Authority (DDMA) in Mandi, in order to gain insightful information on the sensor and detection infrastructure that is currently in place. Concerns concerning the current sensor system were raised throughout these interviews, including numerous false positives and the theft of over half the sensor network. Since warning systems are not the main focus of disaster management activities in the area, DDMA officials stressed the need to raise community knowledge of the risks of landslides. Programmes to raise awareness are being run through live events and social media sites like Facebook.

Professor Varun Dutt, a specialist in landslides, provided us with important information about the sensor technology that is used to detect movement and categorise its severity. Although the sensors are tuned to detect motions as small as 1 cm, in most cases, such tiny data are not useful. The sensors can assess the movement's severity based on its size and can alert management officials if necessary. We received satellite and ground sensor data from the Kamand Valley during the 2022 monsoon season, which included a subsidence map created with the SARProz programme to show how the terrain changed throughout the season. We were able to determine the probability of sensor movement throughout the monsoon season thanks to the movement information provided by the sensor data. During this time, each sensor averaged 0 to 7 movements each week. It's crucial to understand that sensor activity could instead signify activity in a particular location, such as rocks or other land features, rather than a complete slope fall into the road. An integer count was used to indicate the frequency and intensity of the movement, with values over 10 indicating a severe landslip occurrence.

Our knowledge of the landslip danger in Kamand Valley has been significantly improved by the data gathered from interviews, sensors, and satellite analysis. The

frequent landslides during the monsoon season were emphasised as a source of high risk. The prediction capacities of the existing detection technology are nevertheless constrained by issues like false alarms and theft.



Red regions show movement downward (potential landslide hazard) and blue regions show movement upward.

Fig 6 : Image from an INSAR analysis of IIT Mandi with a subsidence overlay. Red areas indicate downward movement (possible landslip hazard), whereas blue areas indicate upward movement. The measurement range is -12mm to +12mm.

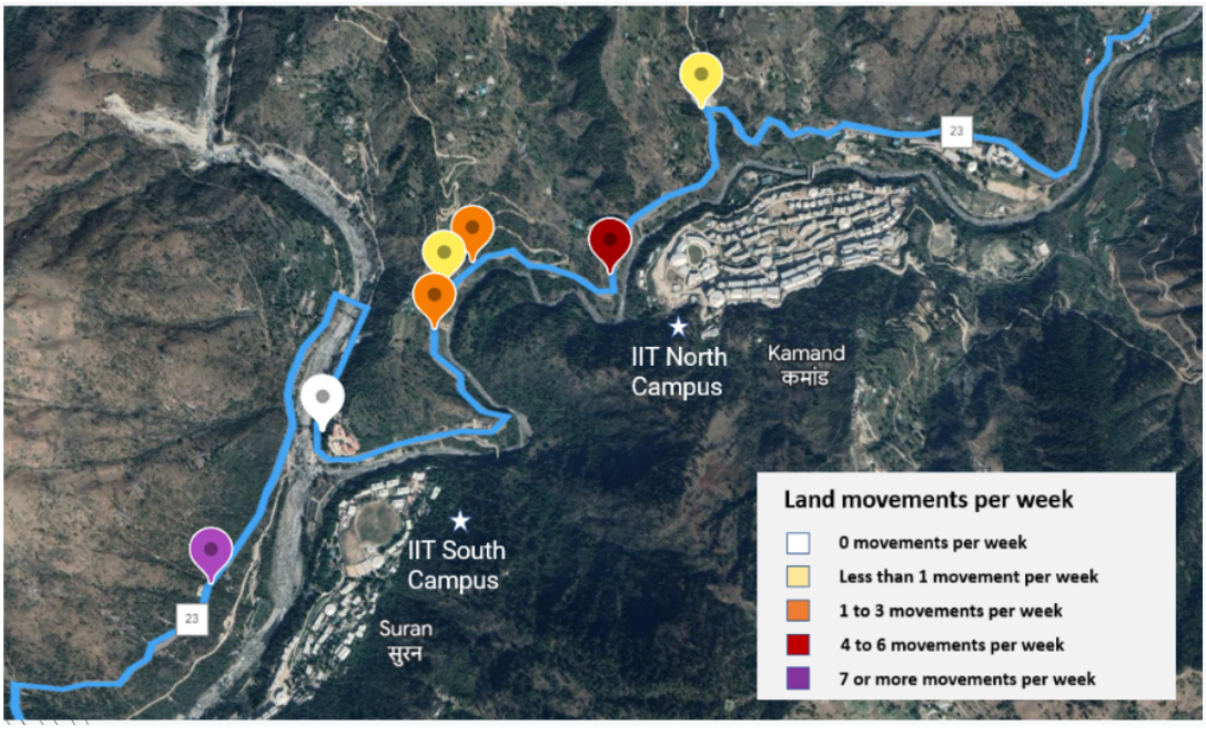


Fig 7 : Depiction of the land movements in the kamand region

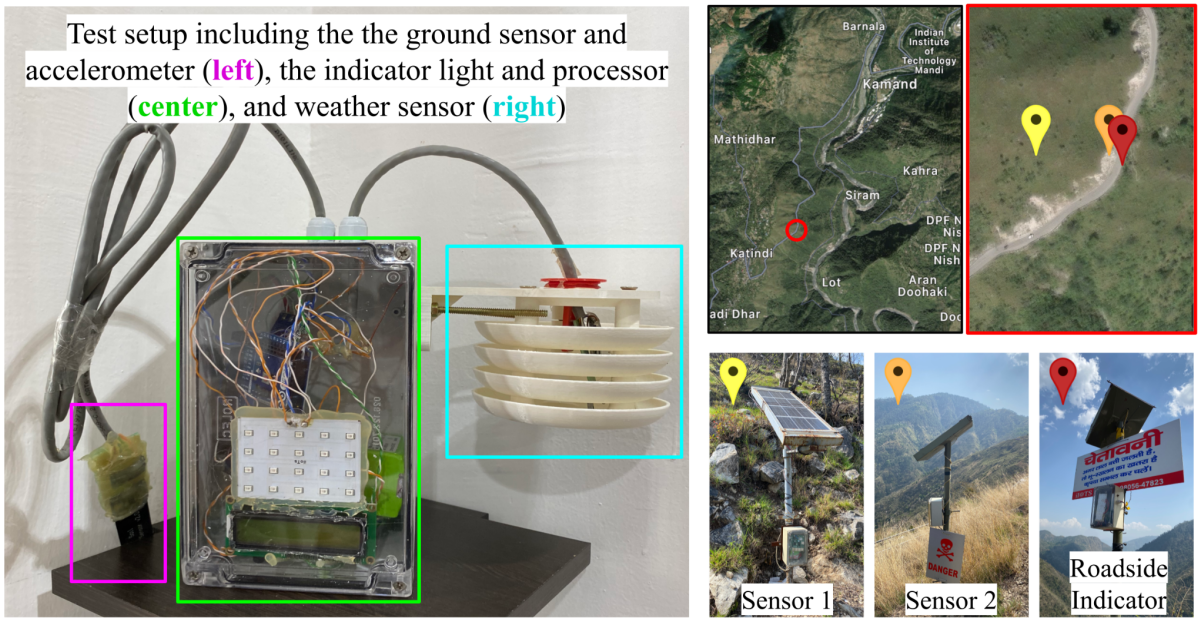


Fig 8: Pictures of sample sensors and equipments in Kamand Region

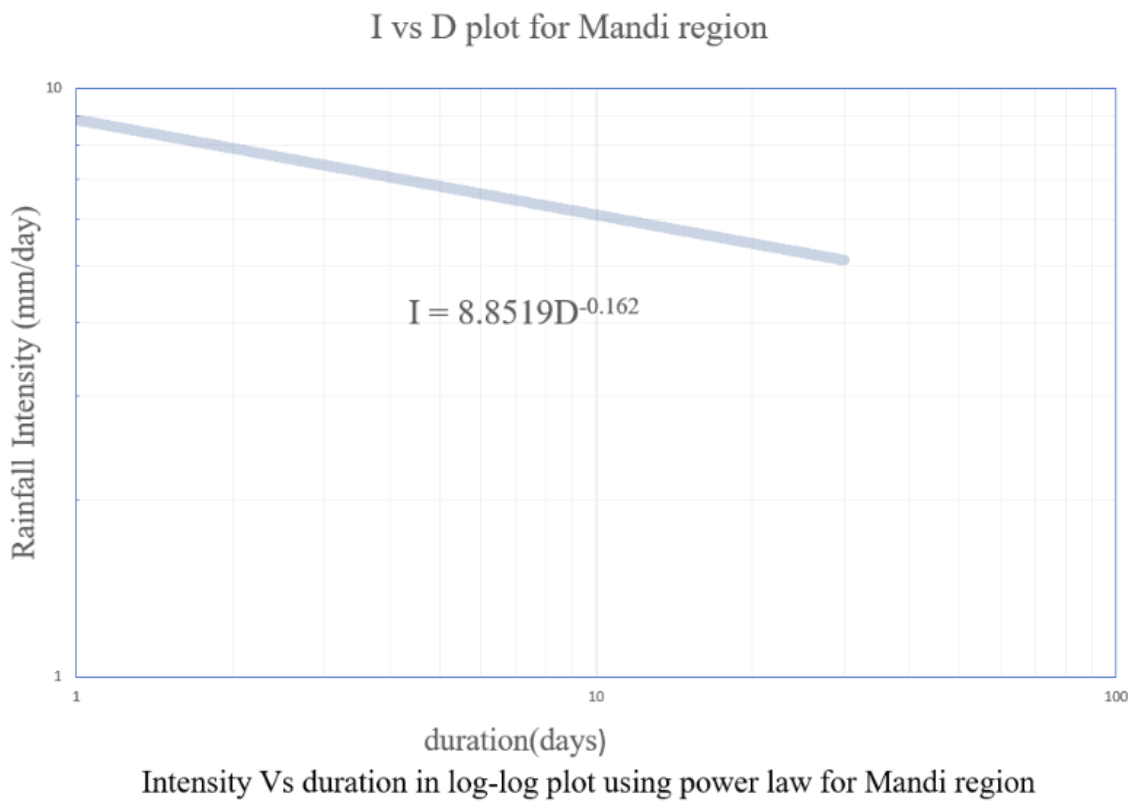


Fig 9: Findings from the sensor-data

In the Kamand Valley, landslides have a 3 out of 7 day likelihood of happening during the monsoon season. Long stretches of light continuous rain that continue more than 10 days have been found to be a significant contributing cause to landslides. Landslides are considerably more likely to occur after 16 days of nonstop mild rain, and this association is consistently seen. The likelihood of landslides is also heightened by three days of intense rain.

Development of a virtual reality (VR) simulation

The creation of an immersive **Virtual Reality (VR) simulation** that could accurately represent the circumstances and dangers of landslides in the Kamand Valley was our second goal. Through an interactive experience based on the gathered sensor data, this simulation aimed to increase **participant awareness**.

To do this, we used tools like Cadmapper for the landscape and textures from the Unity components store to produce a topologically correct portrayal of the valley. To better match the road, the topography was adjusted, and realistic-looking textures like grass, dirt, and stones were added. To improve the sky graphics, we have added an **HDRI** (High Dynamic Range) image. To ensure compatibility, integration with the **Google VR headset** needed particular settings.

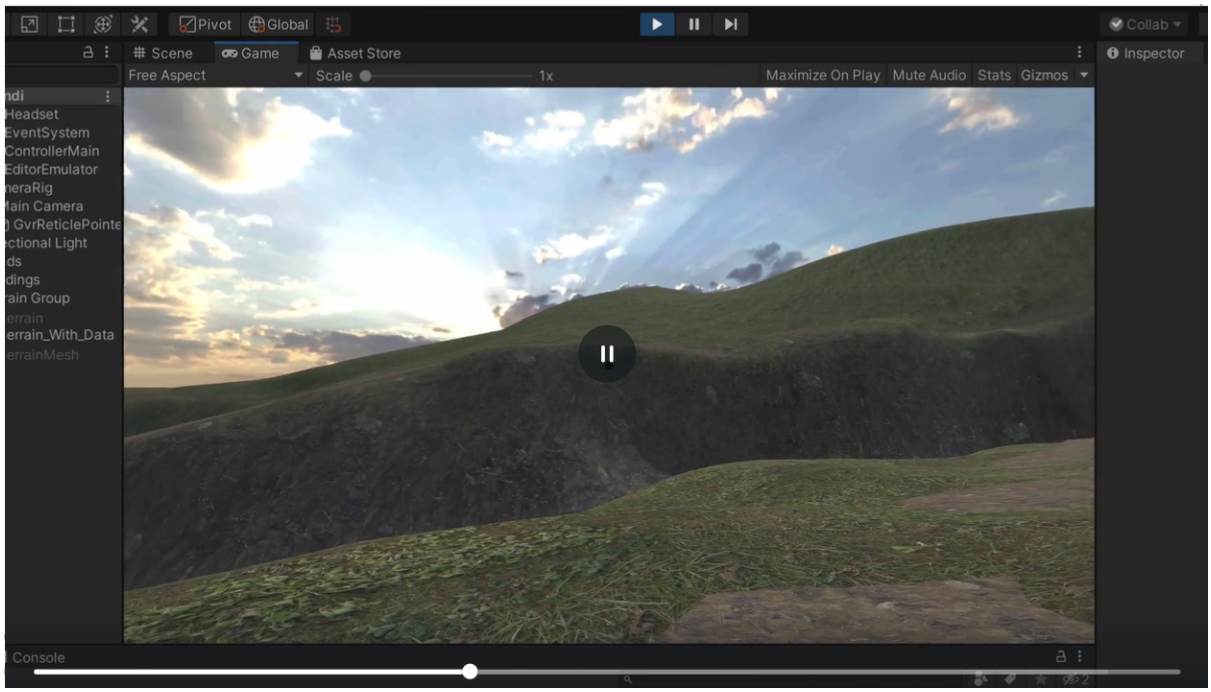
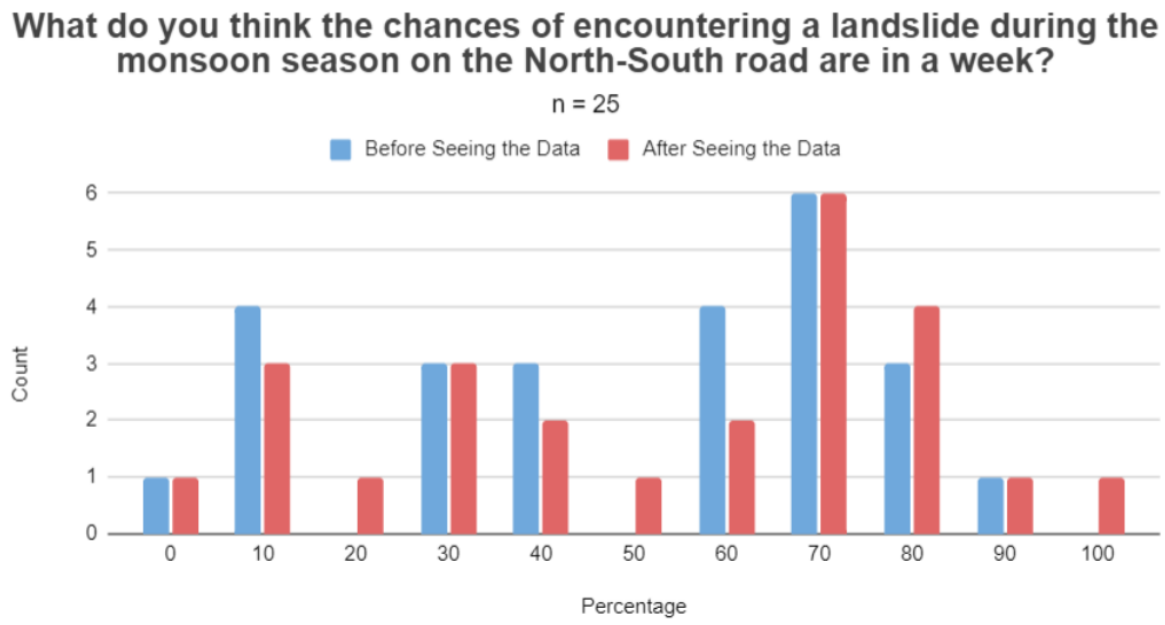
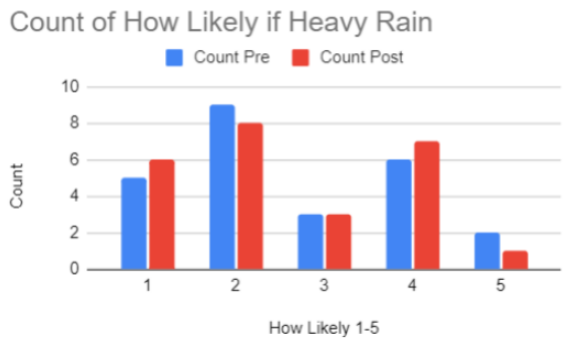


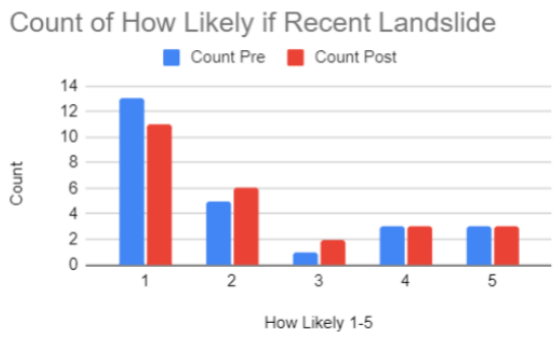
Fig : Screenshot of the developed VR environment in Unity

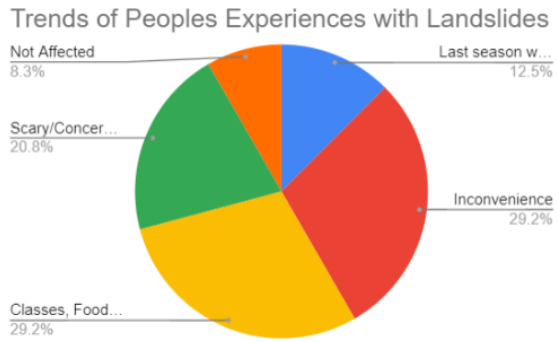
Although we were successful in creating a precise depiction of the Kamand Valley, the landslip simulation was not effective. In order to provide a realistic representation of landslides within the VR experience, additional work is required to enhance the user interface.

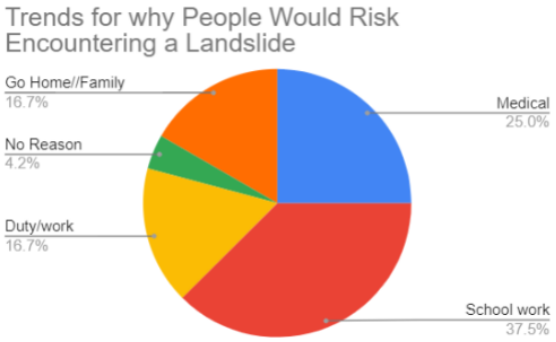
Extensive Surveys of people of Kamand Region


What do you think the chances of encountering a landslide during the monsoon season on the North-South road are in a week?
n = 25
Before Seeing the Data
After Seeing the Data
Count
Percentage
0
1
2
3
4
5
6
0
10
20
30
40
50
60
70
80
90
100


Count of How Likely if Heavy Rain
Count Pre
Count Post
Count
How Likely 1-5
0
2
4
6
8
10
1
2
3
4
5


Count of How Likely if Recent Landslide
Count Pre
Count Post
Count
How Likely 1-5
0
2
4
6
8
10
12
14
1
2
3
4
5


Trends of Peoples Experiences with Landslides
Not Affected
8.3%
Last season w...
12.5%
Scary/Concer...
20.8%
Inconvenience
29.2%
Classes, Food...
29.2%


Trends for why People Would Risk Encountering a Landslide
Go Home//Family
16.7%
Medical
25.0%
No Reason
4.2%
Duty/work
16.7%
School work
37.5%

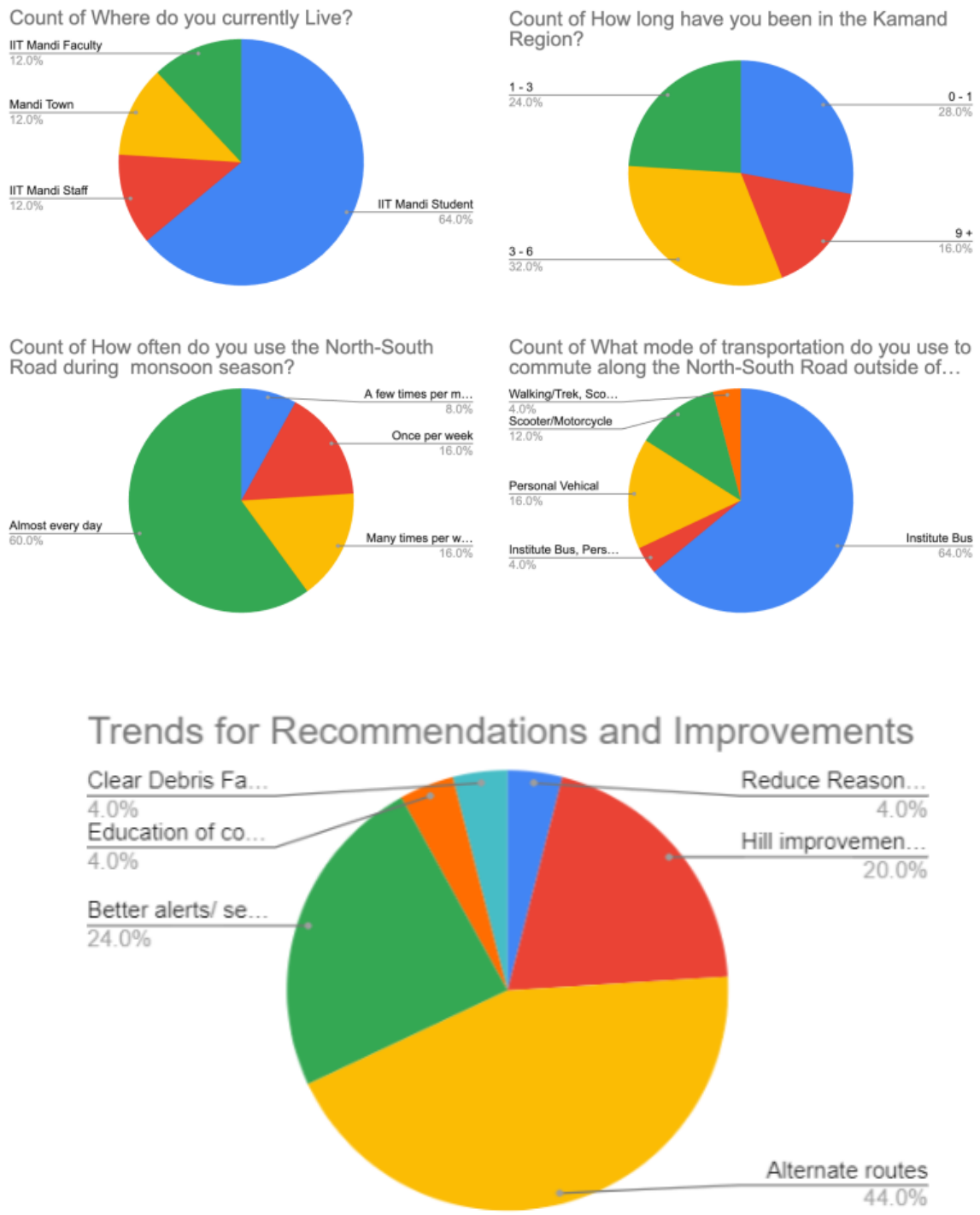


Fig 10 : Graphical representation of the findings from the surveys

The poll also showed that the respondents may be divided into two different categories. One group voiced caution, avoiding travel during periods of severe rain or perceived risk, and assessed that there was a 10% probability of running into a landslip. The other group had a higher likelihood estimation (about 70% or more), and

thus were more willing to travel despite the possible risks. The different perspectives on risk that exist within the Kamand Valley community are shown by this difference.

It was interestingly learned during the interviews that the IIT campus was building a new road to directly connect the North and South campuses. According to the respondents, establishing a second route connecting the schools would lessen reliance on the North–South motorway and improve safety. It is crucial to keep in mind, though, that the development of this new road may result in the creation of more landslide-prone regions, necessitating the expansion of the current sensor network to include the new route.

The respondents' propensity to use the North-South road was significantly influenced by their reasons for travelling along it. Undergraduate students in particular showed a more cautious attitude and were less likely to risk travelling during periods of heavy rain or landslides. Respondents who had more compelling justifications, such as crucial appointments, work commitments, lab work, or family visits, displayed a higher level of readiness to accept the risk posed by landslides. PhD candidates, faculty, and employees from IIT made up the majority of this group.

In addition, it was noticed that PhD and Masters students specifically stated a need to commute for their lab work because their academic dissertations largely relied on it. They had to travel frequently during the rainy season to move their offices from the South Campus to the North Campus, which presented new difficulties and risks.

Overall, these data highlight the Kamand Valley community's landslip knowledge and flexibility. The survey results showed that descriptive data did not significantly influence decision-making, highlighting the significance of taking into account the community's first-hand knowledge and experience when creating risk mitigation methods. The disparate risk perceptions within the community and the possible impact of infrastructure development on landslide risks indicate the need for additional study and all-encompassing approaches to manage the shifting patterns and risks related to landslides in the area.

Recommendations and Suggestion

The recommendations from our project, which were customised for different stakeholders like the IIT Mandi community, the Mandi Public Work Departments, and our IIT mentors, are listed below. We also make recommendations for potential ISTP projects that could help advance our study.

Supporting a safer campus community:

1. The administration of IIT Mandi should think about developing a strategy to group faculty and students close to their particular labs and classrooms. By minimising the need for students to commute between campuses during dangerous weather, dangers and disruptions will be reduced.
2. Master's and PhD students who now go to the North Campus for their coursework should have priority in funding for new lab spaces on the South Campus. Through this approach, the risk of travelling during the rainy season will be reduced, and the interruption of instruction brought on by road closures will be at a minimum.

Supporting more resilient infrastructure:

1. The Mandi Public Works Department should complete the construction of the new North-South road, incorporating retaining walls along the entire length. Ideally, this should be accomplished before the next monsoon season, ensuring that the road remains unaffected by landslides.
2. Constructing retaining walls along the main road in known landslide-prone areas is crucial. This measure will prevent the collapse of entire road sections during heavy rainfall and mitigate the occurrence of road blockages.

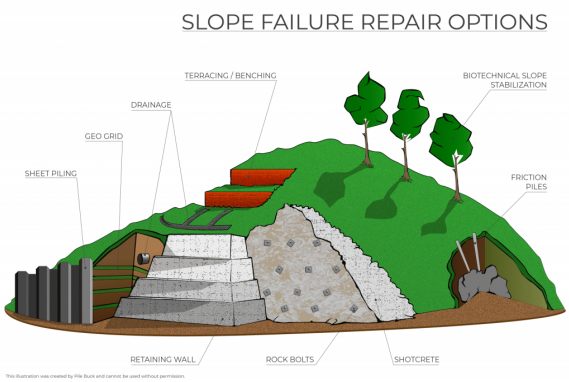


Fig 11 : Depiction of retraining walls to avoid Landslides

Advancing research threads for Mentors:

1. The current sensor system for landslip detection needs to be improved. The majority or all of the sensors should be placed underground, and battery packs rather than solar panels should be used. Further research is also required to decrease false alarms and enhance sensitivity or data filtering skills.

2. The effectiveness of descriptive data in altering people's landslip risk behaviour is limited. Instead, we advise investigating the usage of VR landslip simulations in Unity. The effectiveness of VR as a teaching tool and its possible impact on risk perceptions can be better understood by conducting surveys prior to and after participants engage in the VR simulation.

Informing future ISTP projects and student research:

1. Continue and finish a VR landslip simulation project in Unity that focuses on the route that connects the North and South IIT Campuses. This project can be used as a teaching tool to improve understanding of the risks posed by landslides and to elicit more interesting replies.
2. Future ISTP projects should build on the existing work and suggestions, given the significance and complexity of the topic. Planning the construction of retaining walls beside old and new roadways, optimising campus layout to lower landslide risks, and creating teaching materials regarding landslides and alarm systems for nearby communities are a few suggestions.

By implementing these recommendations and encouraging further research, we aim to bring about meaningful changes and address the challenges posed by landslides in the IIT Mandi and Kamand communities.

Conclusion

The goal of our investigation was to comprehend how the Kamand Valley community perceived risk and made decisions in response to landslip dangers. We have gathered crucial insights that have inspired a number of significant recommendations through surveys, interviews, and data analysis.

The first step in promoting a safer campus community is to reduce academic travel across campuses when dangerous conditions are present. We suggest grouping instructors and students close to their labs and classrooms to cut down on travel time and reduce dangers and disturbances. The need to commute to the North Campus during the monsoon season will be lessened by the addition of lab space on the South Campus.

We propose finishing the new North-South road construction with retaining walls over its whole length to create more robust infrastructure. To further avoid road collapses and lessen obstructions, retaining walls must be built alongside the major route in regions that are known to be landslide-prone.

The sensor system for landslip detection can be improved by burying sensors and using battery packs, according to research threads being advanced by mentors. Additionally, the utilisation of VR landslip simulations might be a useful educational tool to improve the IIT community's perceptions of risk and comprehension of it.

We stress the significance of carrying out and broadening the scope of our programme through subsequent ISTP projects. Retaining walls should be built, campus design should be optimised, and neighbouring residents should be educated about landslides and alert systems.

We want to make the IIT Mandi and Kamand region a safer and more resilient place by putting these suggestions into practise and encouraging more research. Our findings highlight the need of mitigating landslip threats and guaranteeing the community's welfare. We can reduce the effects of landslides and create a more secure future by working together.

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