Landslide monitoring in part of Uttarakhand using satellite imageries.

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Abstract:
Since last four decades, remote sensing tools have become integral part of landslide studies. Remote sensing imageries captured from Arial, space borne and ground-based sensors in addition to digital elevation model (DEM) are frequently used by planners, researchers and mitigators. Active remote sensing tools such as LiDAR, RADAR, SAR etc., are being commonly used in landslide study. This work has been aimed to examine the capability of open source remote sensing imageries in monitoring landslides in Part of Uttarakhand Himalaya. Open source remote sensing imageries available on google earth has been used in this study. From the Google Earth archives, imageries were captured and compared in GIS software as well as at the Google Earth platform itself. Using the archive images, historical landslide information, active landslide areas and potentially vulnerable area were identified. Visual image interpretation techniques such as color, contrast, shape, size pattern, texture etc., were used to identify present and past landslide scraps. Dimension of landslides were estimated using the vector tools available on the Google Earth platform. For few landslides, estimated dimensions were verified during the field observation. Landslide dimensions estimated using google earth was found to be matching with the measurements carried out in the field.

Key words: Landslide, Remote sensing, Uttarakhand

Introduction
The Uttarakhand Himalaya is represented by complex landscape such as steep slopes, high ridges/spurs, deep valleys and a complex network of streams. Inherent weak terrain of Uttarakhand Himalaya in combination with human interference is mainly responsible for the landslide incidences. Above all, the Himalaya is a young and very long mountain range which is witnessing various geodynamic activities such as folding, faulting, shearing and earthquakes. Successive phases of orogeny have produced structurally deformed rocks, which are subjected to severe erosion by toe cutting of deeply dissecting rivers and streams. All these
adverse phenomena of the Himalayan terrain contribute to the landslide susceptibility. The Himalaya is receiving high precipitation during monsoon season and most of the landslides are triggered during this period. Most of the Indian Himalaya falls under high seismic hazard zone (Zone-IV & Zone-V, BIS 2002) owing to the high level geodynamic activities in this region. A number of landslides were reported due to earthquakes namely, Uttarkashi earthquake (1991), Chamoli earthquake (1999) and Sikkim earthquake (2011). Many landslides are also reported from the areas where large scale infrastructure development activities such as hydro-electric projects, roads, towers, ropeways etc., are being carried out.

**Study Area and data used**

Landslide monitoring using passive remote sensing techniques has been carried out for the Part of Tehri Garhwal area. The area lies in longitude 78.42 E and latitude 30.41 N. The area is part of Tehri and Koteshwar reservoir rim region along a road stretch (Fig: 1). A number of landslides are reported from that particular road section. Due to landslides, the road network used to get obstructed and that led to blockade. In order to understand the

![Figure 1: Study area – Tehri Koteshwar road section](image-url)

recurrent landslides along the road stretch, remote sensing tool was used for multitemporal image analysis of the slope faces on which landslide was seen. Remote sensing data available on Google Earth platform has been used for the monitoring of the
landslides (Figure 2). From the google earth archive, data of year 2005, 2007, 2010, 2013, 2015, 2017 and 2019 has been captured. These data are very high-resolution multispectral imageries having spatial resolution ranging between 2.5m to 0.5 m. Most of the imageries belong to World view 2 sensor which is having spatial resolution in multispectral band of 1.84m and panchromatic band of 0.5m. In this work multispectral imageries in visible range were analysed (Fig: 2).

Method
Landslides were identified in each slope face adjoining the road section. Temporal Google Earth images of various years mentioned in previous section has been visually interpreted. Visual interpretation keys such as contrast, pattern, shape, size, texture, association etc., has been used for the extraction of present as well as past landslides. Once the landslides were identified on the basis of visual interpretation keys, they were polygonised in order to estimate the dimensions of the landslides. There is a ‘Add Polygon’ tool in the google earth, which facilitate GIS layer (in this case vector layer) creation that further allows area estimation. Length of the base of the landslide was also estimated by using Add Path tool of the platform.

Result and Discussion
Using the Google Earth image, landslides along the road section in Tehri Garhwal area, has been identified. Visual interpretation key were successfully used in identifying and estimating the landslide area. Figure 3 shows, the landslides identified on the Google Earth image. A, B and C in figure 3 represent the landslides, that has been captured using Add Polygon tool of the Google Earth. At A, landslide has been identified using
the association feature. In Himalaya, landslides are most commonly associated with the roadcut slopes. Roads are generally constructed by cutting the slope faces and they are left untreated quite often. These cut slopes often fail during the monsoon season and they typically form an association with road network. The area of landslide A was found to be 2100 m². At location B, landslide was identified using shape. Generally, landslides take a typical arcuate shape along the roads. Dimension of landslide at the site B was found to be 22000 m². At site C, landslide was identified using the contrast key. The slopes of Himalayan terrain are covered with moderate to thick vegetation. Any landslide in these terrains led to removal of top soil vegetation and exposure of bare soil. That phenomenon lead to development of contrast in the image. Landslides are often identified using contrast key.

Conclusions

This work has shown the capability of web GIS tool such as Google Earth in landslide monitoring. Landslide along the Tehri-Koteshwar road section has been identified using the Visible range imageries available on the Google Earth. Visual interpretation keys such as colour, contrast, shape, size, pattern and association has been optimally used in identifying landslides. This work can be further broadened by incorporation temporal imageries from the archives. That will give the broad prospective of the global landslide conditions existing in the area.
References