Recent landslides in Uttarakhand: nature's fury or human folly

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Hill slopes in the Himalaya are known for their instability due to ongoing tectonic activity. However, increasing anthropogenic intervention in the recent times appears to be contributing to terrain instability in addition to natural factors, as observed by increasing frequency and magnitude of landslides since 1970.

During August and September 2010, Uttarakhand Himalaya witnessed large-scale slope destabilization, particularly along the roads where widening work was in progress (Figure 1). The landslides killed about 220 people in the entire rainy season of 2010, while 65 lives were lost, 6 persons went missing, 21 people were injured, 84 livestock died, 534 houses were fully damaged and 2138 houses were partially damaged due to heavy precipitation within 4 days from 18 to 21 September[1], which virtually brought the state to a grinding halt for several days. The cause of regional-scale landslides has been attributed to exceptionally high rainfall in the region during September. When the average rainfall for the month of August and September from 2000 to 2009 is compared with rainfall data of the same period of 2010, it was found that in September 2010, 336% higher rainfall was received by the area (Figure 2). However, the question that arises is: was it unusual rainfall-induced calamity or a result of human intervention? Here we present our preliminary observations along Rishikesh–Mana National Highway (NH-58) that runs along the Ganga–Alaknanda Valley (Figure 1). Our observations suggest that inadequate consideration of geology and geomorphology during the road alignment and poor, faulty engineering techniques were major factors responsible for the recent landslides.

Experts hold the view that while tampering with the Himalayan slopes, one needs to be extra careful as the slopes which have evolved by exogenic and endogenic processes are precariously balanced[2]. It would be unjust to say that our planners and policy makers are not aware of the sensitivity of the Himalayan ranges, but it seems that the awareness is masked by the pressure of utilizing the Himalayan resources for national growth

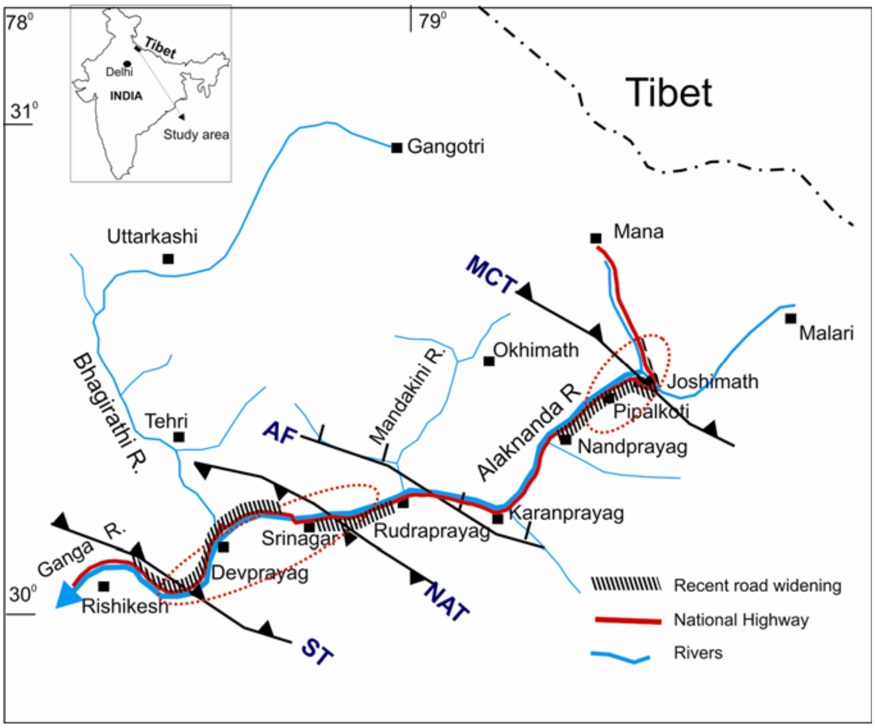

Figure 1. Map of the Upper Ganga and Alaknanda valley. Red dotted circles show the areas that suffered maximum damage during August and September 2010. MCT, Main Central Thrust; AF, Alaknanda Fault; NAT, North Almora Thrust; ST, Saknidhar Thrust.

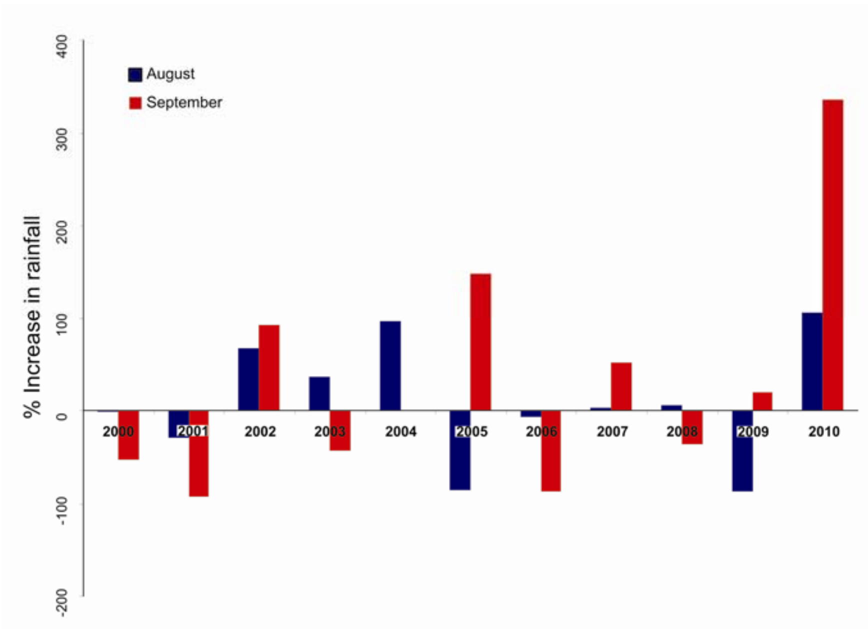

Figure 2. Bar diagram showing rainfall variability in percentage during August and September (summer monsoon) for the past 10 years. Exceptionally high rainfall in September 2010 can be observed.

and providing easy and fast accessibility by developing road networks. Our surveillance indicates that a majority of the landslides along NH-58 occurred in areas where the road-widening work was either in progress or had just been completed without adequate remedial measures (Figure 1).

Studies carried out by various governmental and non-governmental organizations in Uttarakhand Himalaya provide a reasonable insight into the environmental fragility of the slopes, particularly in areas traversed by major and minor tectonic structures (weak zones). Way back in the mid nineties a major project pertaining to landslide mapping in Uttarakhand was launched by Indian Space Research Organization. This project was aimed at providing the geodynamic status of the slopes along major pilgrim roads so that any future work, particularly that involving widening of the existing roads must take into account the finding of these studies so that appropriate engineering measures can be employed. Appreciating the chronic problem of landslides, the Department of Science and Technology, Government of India, generously supported and is still supporting projects related to landslide studies in the Himalaya. In addition, geologists and environmental scientists are persistently pleading for a detailed geomorphological, structural and lithological mapping of the slopes along the proposed roads so that our engineers know exactly what kind of treatment strategies need to be employed. Considering the ever-increasing incidences of landslide-induced tragedies in the Himalaya, time has come to put the findings of these studies not only in the public domain, but devise a methodology so that the same can be implemented on the ground level, particularly in road construction projects.

Landslides are the geomorphic expression of the slope instability that occurs when the shear stress in a part of the slope exceeds the shear strength, and this condition can be achieved: (i) by the increase in pore water pressure, which eventually decreases the frictional forces and/or (ii) by slope steepening[3]. Slope instability is accelerated by abrupt changes in the otherwise graded slope profile by anomalous vertical cut during road construction/widening. In addition, frequent dynamite blasting during road construction activities causes the widening of the fractures and joints[4] of already fissile lithology in the vicinity of shear zones associated with major and minor structures. Conventionally, major landslides in the Himalaya are located in the transitional zone between the Lesser and Higher Himalaya. The reason being that this zone is dominated by steep slopes, focused rainfall (cloud bursts) and frequent seismicity. According to Valdiya[2], slopes in this zone are precariously balanced and even a small disturbance is capable of inducing changes that can rapidly assume alarming proportions. Some of the major landslides in the recent times in this zone are: (i) the 1970 landslide that induced flash floods in the Alaknanda Valley; (ii) the 1978 Kanodiya Gad landslide in the Bhagirathi Valley; (iii) the 1998 Malpa and Okhimath landslides in Kali and Madhyamaheswar river valleys; (iv) the 2003 Varunavat Parvat landslide in Uttarkashi and (v) the 2009 Munsiyari landslide[5–9]. The above catastrophic landslides and associated flash floods mainly occurred in July and August, and claimed many human lives, except the Varunavat Parvat landslide of 23 September 2003, in which no human life was lost. However, during September 2010 for the first time the lesser Himalaya witnessed such a large-scale slope mobilization either along the roads or around the towns with accelerated and unscientific construction over unsafe slopes in the last few years (Figure 3). It was observed that around 300 landslides of various dimensions riddled NH-58 in September 2010. Majority of them occurred south of the Main Central Thrust between the Alaknanda Fault (AF) and Saknidhar Thrust (ST; Figure 1). In addition, 20 urban settlements located along the highways were severely damaged. The chronic Kaliyasaur landslide which had been dormant for a few years due to the efforts of various government agencies has now been reactivated (Figure 4). Based on the nature of distribution of landslides in the Alaknanda Valley, it can be suggested that this time the Lesser Himalaya had to bear the brunt of slope instability.

Under normal climatic conditions, a majority of the valley slopes are in the state of geomorphic equilibrium[10]. Rain normally triggers the landslide by raising the water table and water pressure, which ultimately leads to slope failure[11]. This phenomenon is a part of the natural process of hill slope erosion. Nevertheless, the present scenario of devastation in Uttarakhand could not be the spontaneous response of rainfall, unless the slope stability is disturbed in the recent times. A rapid assessment of the type and nature of distribution of landslides, particularly between AF and ST (Outer Lesser Himalaya) shows that: (i) a majority of the landslides were shallow. Here we have defined 'shallow landslide' wherein considerably small thickness of overburden experiences movement over the bedrock.

Figure 3. Slope destabilization around Devprayag caused due to the widening of NH-58. Yellow dotted line indicates the recent activation of the slope. House circled by yellow dots was partially buried under the debris. (Inset) A house damaged due to disturbance of slope during road widening.

Figure 4. ***a***, Kaliyasaur landslide (along NH-58) reactivated due to heavy rainfall in September 2010. It has become a major bottleneck for vehicular traffic on the Rishikesh–Badrinath road. ***b***, Road widening work in progress along NH-58. Note the massive debris that has slided down after the angle of repose was disturbed during road-widening work followed by heavy precipitation in September 2010 along NH-58.

Figure 5. ***a***, Disaster in the making – defying all safety norms, a school was allowed to be constructed on old landslide debris on the bank of a seasonal stream. ***b***, Shops and houses constructed along the bank of an ephemeral nala. Shops seen buried under debris from upslope due to heavy rain in September 2010.

Such cases are more frequent during monsoon when impervious bedrock creates favourable conditions for creeping of saturated overburden. Such conditions are common on cut slopes along the highways. Shallow landslide may also be initiated due to under-cutting of ephemeral streams on hill slopes activated due to prolonged or heavy rainfall that also facilitates soil erosion. (ii) They were associated with former debris flows, talus cones and sheared rocky slopes. (iii) They seem to be concentrated along shear zones. A combination of factors such as degraded forest cover, change of moderate debris-laden slopes into near vertical slopes during road widening and building construction without adequate and appropriate engineering measures made the slopes vulnerable to the onslaught of torrential rainfall in the region. In the urban clusters obstruction of natural drainage was responsible for slope destabilization and diversion of the debris-laden waters into the habitation areas (Figure 5 *b*). The unscientific urban development speaks volumes about the poor governance and lack of urban development policy. According to Barnard *et al*.[12], approximately two-thirds of the landslides in the Alaknanda Valley were accelerated by anthropogenic intervention, mostly by the removal of slope toes at road cuts.

There is no denial that the existing roads in Uttarakhand are unable to cope with the increase in vehicular traffic (both domestic and commercial). As a result, during the last few years, excavation of slopes for road-widening is a common sight in the state. According to an estimate, during the pilgrim season nearly 200,000–300,000 vehicles ply between Rishikesh and Badrinath; similar is the case on the Gangotri route. In addition, innumerable hydropower projects which have mushroomed in various river valleys require wider roads to transport heavy machinery. In a terrain where roads are unscientifically planned and their construction is badly executed[5] without considering proper measures at the base of road cut slopes, if the slopes of such roads are tampered with, it is bound to create fresh landslide zones. Additionally, after the creation of Uttrakhand, a significant increase in the built-up areas in the Alakanda River has taken place. Particularly, there has been a quantum jump in the built-up areas around Srinagar, Devprayag, Rudraprayag, Karnprayag, Nandprayag and Joshimath. Since the safe-habitation slopes are scanty in these towns, unsafe slopes have been modified for house construction and a school building was also found constructed on the old landslide along an ephemeral stream course (Figure 5).

We have competent scientific and engineering institutions capable of devising methods for mitigating the magnitude of destruction caused by the frequent landslides during the monsoon. Unfortunately, the lack of coordination between the scientific/academic institutions and the field implementing agencies contributes to such devastations. Let us make a beginning by developing a module which should have the provision for ascertaining the terrain stability/instability using the standard geological and ecological criteria. Further, similar to earthquake zonation, valley slopes should be categorized based on the degree of stability.

With the advent of satellite remote sensing technology, it is now possible to gather information both in spatial and temporal domain. Such data provide an opportunity to ascertain the nature and magnitude of change witnessed by a particular valley slope, so that an appropriate slope treatment strategy can be evolved.

Also, State Departments like the Disaster Mitigation and Management Centre and the Uttarakhand Space Application Centre (USAC) should be proactive in their approach. Uttarakhand has dedicated centres of remote sensing and disaster management. It is expected that these centres should cater to the need of the state which suffers destruction every year from landslides and debris flows. In the inaccessible Himalaya, the remote sensing technique has proved quite effective for mapping and monitoring of terrain status. Having witnessed the unprecedented landslides during the monsoon, we hope that USAC in association with other departments will work towards generating a scientific database on spatial and temporal changes in the terrain characteristics. This information may not prevent, but will at least help in devising methodologies by the concerned departments in order to minimize the severity of landslides in future.

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