Landslide Hazards and Sustainable Development in Himalayan Region

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1 Introduction

Landslides are commonly reported in mountainous region around the world. Many of these landslides are caused mainly because of improper planning related to construction of roads and buildings. Since these activities have increased manifold in the recent times in Himalaya, the number of incidences has also increased relatively. The Himalayan mountain eco-system is generally characterized by fragile geological setting in addition to steep rock slopes and adverse hydro-geological conditions, which are mainly responsible for large scale landslides. All these parameters bring out a need for systematic planning incorporating adequate geological inputs in addition to other relevant parameters. It is essential that research and development regarding landslide analysis and their control should be planned in a more systematic way based on the principles of sustainable development.

The sustainable development in mountainous region refers to implementation of development schemes taking into account existing instabilities of the terrain so that the resultant geo-environmental hazards are minimized. In this context, landslide hazard zonation (LHZ) mapping and landslide risk assessment techniques provide basic data related to stability of hill slopes in the initial stages for proper planning. A landslide hazard zonation map depicts division of land surface into zones of varying degree of stability based on an estimated significance of causative factors in inducing instability. This mapping technique is based on the basic inherent causative factors which are responsible for incidences of landslides. These factors include lithology, structure, slope morphometry, relative relief, land use and land cover and hydro-geological conditions. These parameters are studied within individual slope facets and the facets are categorized into very low to very high hazard. The LHZ maps prepared on regional scales are useful for preliminary planning of development schemes to avoid hazard prone areas. Even if unavoidable, their recognition in the initial stage of planning will help to evolve better preventive measures.

The landslide risk assessment (LRA) mapping refers to estimation of the extent of damage likely to occur if the landslide occurs. The risk assessment factor, R, is a function of hazard probability (hp) and damage potential (dp)

\[ R = f (Hp,Dp) \]

The LRA maps can be used for environmental planning by identifying priority areas of environmentally degraded zones.

Examples of systematic investigations have been illustrated for route planning and development of terraces for buildings in hilly regions. The systematic investigations for route locations involve four stages, namely a) Preliminary investigations, b) Detailed investigations, c) Design investigations and d) construction investigations. Similarly different criteria for development of terraces and geological factors for the design of cut slopes have been indicated.

2 Methodology

Sustainable development in view of landslides problems can be addressed in Himalaya by preparing accurate landslide hazard and risk map.

Fig 1. Landslide Hazard Zonation map of part of Nainital town (Modified after Anbalagan et. a., 2008)
LHZ maps can be produced using LHEF method by considering inherent causative factors of landslides and hill slope facet. A slope facet is a topographic unit which contains uniform slope condition and can be distinguished from other facet by natural boundary such as ridges, spars, and rivers. LHEF rating technique is an empirical approach which takes into consideration individual and net effects of all inherent causative factors of a landslide. Maximum value of rating for individual parameter is assigned by keeping in view its estimated significance in slope failure. Maximum LHEF rating for lithology, structure, slope parameter (slope morphometry and relative relief), land use and land cover is assigned 2, whereas value of maximum 1 is assigned for hydro-geological condition and external factors (.5 each for seismicity and rainfall). The Total estimated hazard (TEHD) is calculated by adding LHEF rating obtained for individual inherent parameters and later applying suitable corrections for external parameters namely: Rainfall, Seismicity. The final TEHD value is manifestation of stability condition and it is calculated for each slope facet. Fig 1 is an example of LHZ map on meso-scale based on LHEF scheme.

Based on hazard probability model a landslide risk map can be prepared to estimate the damage. LRA map is based on risk assessment factor and it takes account hazard probability and damage potential.

**Conclusion**

In Himalaya, thrust on infrastructure developments have resulted in a number of landslides incidences. Geo-environmental frame work of the region is seriously damaged due to unplanned construction of roads, urban townships, tunnels and dams. Sustainable development of the Himalayan region in view of landslide problem requires large scale (1:5000) LHZ mapping based on a model which could correctly predict the vulnerable zones. LHEF rating technique of required scale (micro, meso) shall be a great benefit for planners to sustainably develop infrastructure projects.

**References**