Monitoring of Erosion-susceptible slopes in the Siwaliks of Nepal

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1. Introduction

Siwalik zone is located in the south of Himalayas, which separates the lowland of Indo-Gangatic plain and highland of Mahabharat hills in Nepal. Because of its weak geological formation, it is considered as the most erosion-susceptible and degraded zone. Sediment produced by active erosion in this region could be one of the causes of flooding due to sedimentation in lowland plain (Terai), which is the main crop production zone of Nepal. The Siwaliks is further degrading due to deforestation to meet the fuel need of increasing population. Being geologically and geomorphologically more homogeneous than other regions, methodologies leading to the measurement and process of erosion could be applied to other areas of the Siwaliks. Hence, the findings will be helpful in planning conservation works in the whole region. Main objective of this paper is to present the characteristics of erosion -susceptible slopes from Geomorphological perspectives and to document their development pattern with the help of field monitoring data.

2. Geomorphology of study area

The study area(Khajuri Stream) lies in one of the interior valleys(Dun) in eastern region of Nepal called Trijuga River(fig.1). Geology of the area comprises of monoclinal structure of north-dipping Middle Siwalik rocks represented by unconsolidated boulder conglomerates with thin layers of sandstone and mudstone. The hills stretch along northwest-southeast direction and the spurs (sub-ridge) stretch generally perpendicular to the main ridge. A number of dry streams that emerge from the hills join the river perpendicularly to its course. Based upon the aerial photo interpretation and field observations, four types of Geomorphological zones are recognized: 1. Uppermost hill slope (above 280m) 2. Upper fluvial terrace (200-280m) 3. Lower fluvial terrace and 4. Flood plain (below 200m).

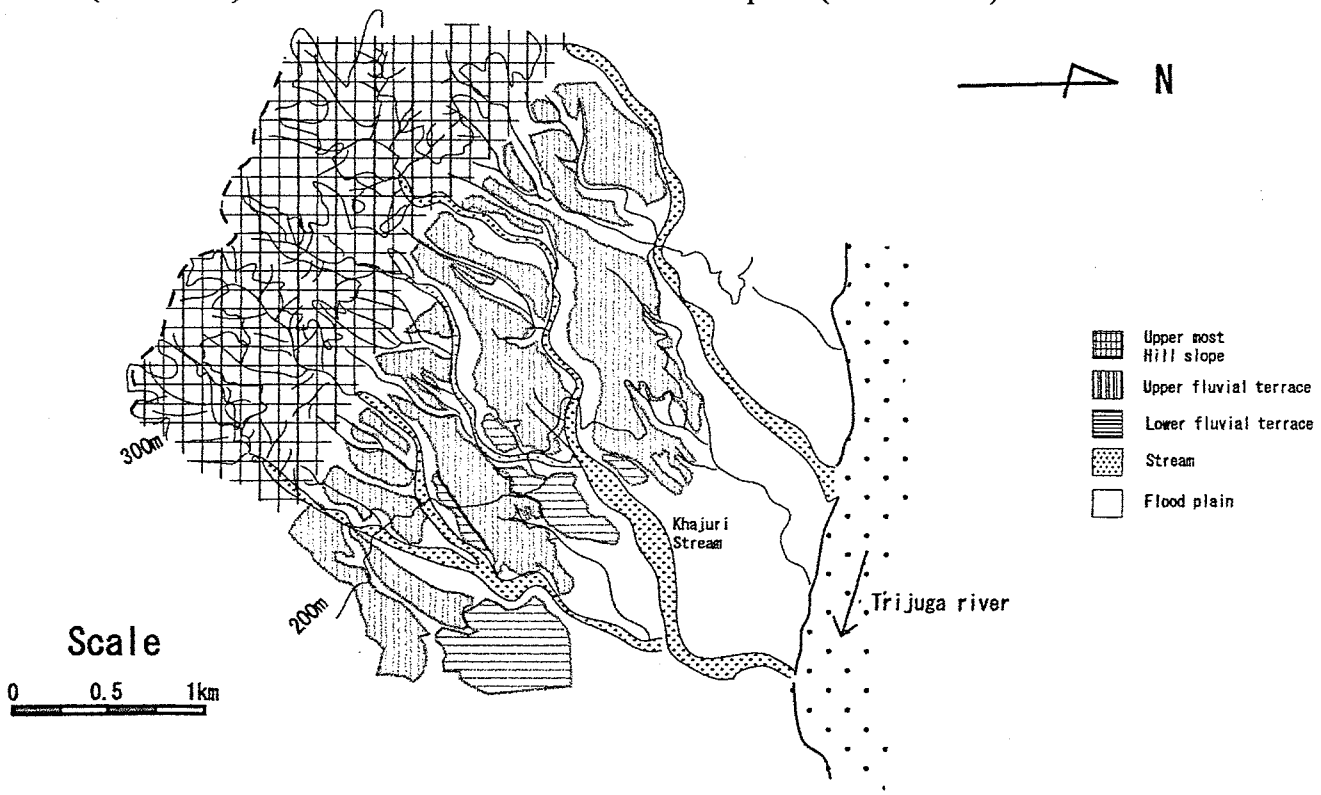
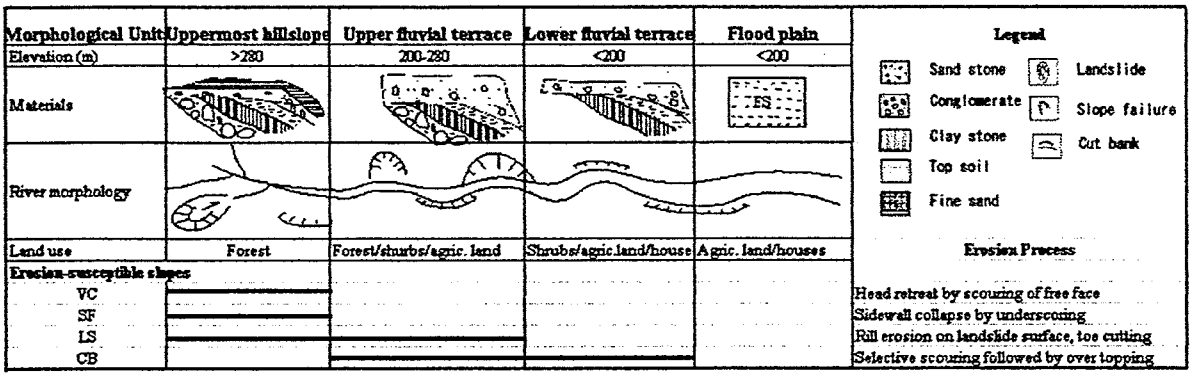


Fig. 1 Geomorphological Map of Khajuri

3. Types and distribution of erosion-susceptible slopes

Depending upon the forms and mechanics of development, erosion-susceptible slopes are categorized into four classes- 1.Vertical cliff eroded by rainwater (VC), 2. Slope failure (not vertical) triggered due to undercutting by gullies (SF), 3. Landslides and slope failures triggered due to undercutting by streams (LS), and 4. Stream cut banks (CB). Table 1 shows the types and distribution of these slopes.

Table 1. Types and distribution of erosion-susceptible slopes



The slopes VC and SF are typically developed in the head reach of tributary channels (gullies). They consist of mainly four essential elements: crest, free face cliff (VC), debris slope (SF), and pediment surface. Free face cliffs are dissected by tinny rills and are subjected to retreats. The debris slopes (minor gullies) are developed by bed scouring and undercutting of sidewalls. Most of the landslides, which are formed on the bottom of valley and triggered by the stream undercutting, are plane failure types. They are characterized by very steep slopes (above 70 degrees). Bank cutting occurs in the principle of selective scouring whereby more erodible layers of loosely bounded conglomerates are washed away first, following the less erodible layers of sandstones and mudstones. This results in an overhanging formation between the less erodible layers, which ultimately leads to failure by block collapse or overtopping.

4. Monitoring of erosion

Erosion susceptible slopes described above were monitored by two methods: (i) erosion pin and (ii) offset measurement. The first method was used to monitor the erosion rate of sidewalls of minor gullies (SF), and surface erosion from slope failures (LS), however, the second one was used to monitor head retreat of free face cliffs (VC) and stream cut banks (CB). Table 2 shows the average amount of erosion from different types of slopes occurred in the rainy season of 2002.

Table 2. Amount of erosion from erosion susceptible slopes (June-September, 2002)

Type of unstable slope	Erosion (Av. Value)	Remarks
Free cliff retreat (VC)	0.03-0.90 m	Retreat is more in case of overhanging cliffs
Gully Sidewall erosion (SF)	0.09-0.25 m	Erosion pins were located on the mid-slopes
Rill erosion of slope failures (LS)	0.02-0.07 m	Surfaces of slope failures develop tiny rills
Cut bank erosion (CB)	0.25-4.00 m	Depends on factors such as Geologic beddings, stream geometry etc.

5. Conclusion

Types, extents and processes of the erosion slopes are closely governed by the geomorphological development of the area. The method of Geomorphological classification and distribution of the slopes can be applied to other areas in the region as well, because of homogeneous geomorphology and topography. Monitoring data indicate the most active state of erosion in the region, which is about 10 times higher than in the Mahabharat and Midlands in Nepal.