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Paudel, Prem P.

Joshi, Jaqannath

Laboratory of Forest Conservation, Division of Forest Environment and Management Sciences,
Department of Forest and Forest Products, Graduate school of Bioresource and Bioenvironmental
Sciences, Kyushu University

Omura, Hiroshi

Laboratory of Forest Conservation, Division of Forest Environment and Management Sciences,
Department of Forest and Forest Products, Faculty of Agriculture, Kyushu University

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Erosion in the Western Middle Mountain Watersheds of Nepal: A Review

Prem P. PAUDEL*, Jagannath JOSHI* and Hiroshi OMURA**

Laboratory of Forest Conservation, Division of Forest Environment and Management Sciences,
Department of Forest and Forest Products, Faculty of Agriculture,
Kyushu University, Fukuoka 812–8581, Japan
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Soil erosion and mass movement are the major causes of the middle mountain environmental degradation in Nepal. The middle mountain region comprises about 30% of the country area, which ranges between the elevations of 300 m to 3000 m above the sea level. The number of landslide distribution per 100 ha area in 5 different watersheds varies from 0.89 to 3.20. The number of landslides by land use type per 100 ha is largest at grassland with 6.98, followed by non-irrigated cultivated land with 1.90 and least at irrigated cultivated land with 0.85. The shallow landslides are greater in number at above 30° slope angle. The estimated soil loss from grassland and farmland is more than 170–180 ton/ha/year. The onsite significance of surface erosion is reduction of the productivity. While its off-site significance is in causing siltation, water pollution etc. in the downstream areas.

Key words: Landslide, bank erosion, surface erosion, Nepalese middle mountain

INTRODUCTION

Nepal is a mountainous country, situated between the latitude of 26° 22' to 30° 27' N and longitude of 80° 04' to 88° 12' E. The physical environment of Nepal is dominated by a major mountain-building process and situated in the central part of the great Himalayan arc, which extends for about 2400 km from the Punjab Himalaya located at India in the west to the north eastern frontier area or Assam Himalaya in the east. The middle strip of 820 km constitutes Nepal. The physiographic north-south cross section is similar throughout the Himalaya, therefore a simple geo-tectonic zonation is applicable for Nepal, too. As a result of northward movement of Indian plate, it has been drawn downwards and thrust below the Eurasian plate. The collision of these two plates creates problems of frequent occurrence of natural disasters along the Himalayan region. It is estimated that about 20% of Indian Himalayan region is in degraded conditions (Bahadur 1998).

Broadly the country is divided into five different physiographic regions namely: High Himal (elevation 4000 m–8848 m), High Mountain (2300 m–4000 m), Middle Mountain (300 m–3000 m), Siwalik (300 m–1500 m) and Terai (70 m–300 m) (LRMP 1986). The characteristics of each region vary significantly. In High Himal valley glaciers are

* Laboratory of Forest Conservation, Division of Forest Environment and Management Sciences, Department of Forest and Forest Products, Graduate school of Bioresource and Bioenvironmental Sciences, Kyushu University

** Corresponding author (Email: HYPERLINK "mailto:homura@agr.kyushu-u.ac.jp" homura@agr.kyushu-u.ac.jp)

common, while on the densely populated middle hill large number of slope failure occur frequently. The Siwalik region is unstable due to fragile geology, and the Terai region has flat plain with flood and sedimentation problem. Thus mountain slopes rarely achieve a truly straight profile because of above mentioned different features as well as variations of rock type, structure and weathering environment. The history of Himalayan geo-morphology is one of a continuous succession during periods of rapid adjustment towards a more stable state i.e. slope angle have been reduced. In the present landscape of the middle mountains five different principle slope elements are identified and they are ridge top of 15° – 45° , upper slope of 15° – 25° , mid slope of 20° – 30° , lower slope of 30° – 45° , and river valley of 0° – 15° (Howell 1999). The schematic cross section of a typical mountain valley slope of the middle mountain is shown in Figure 1.

Due to the geological conditions as well as different geomorphological characteristics, the mid mountain watersheds are under the conditions of increasing state of surface erosion and mass wasting. In the midlands of Nepal, shallow landslides are common due to cultivation, deforestation and cutting at outer side of river wherever it turns a course. In the eastern part of middle mountains, phylites, shales and schists showed no significant difference in the degree or type of mass wasting. Major factors contributing to the natural instability and resulting mass movements in the middle mountains are: structure and inclination of slope; number and density of natural fracture planes; type of rock or mineral, state of weathering, and the presence of water (Shiwakoti 2000).

To study the state of erosion from the middle hill region of western Nepal, the five watersheds from two districts i.e. from Kaski and Parbat districts were studied in 1994 (Figure 2) jointly by the multidisciplinary team of Japan International Co-operation Agency (JICA) and His Majesty's Government of Nepal (HMG/N). This review paper analyze and presents some important information regarding soil erosion in Nepalese

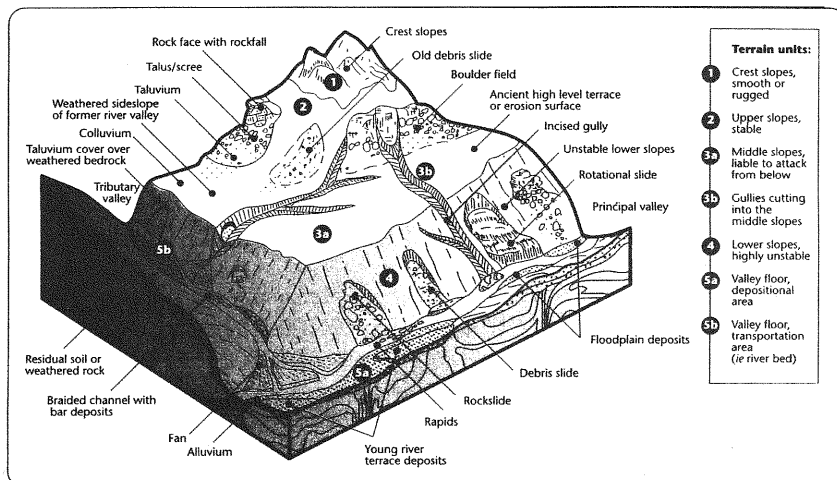


Fig. 1. Schematic cross-section of a typical mountain valley slope in the middle mountain (After Fookes *et al.*; 1985 and Transport Research Laboratory 1997).

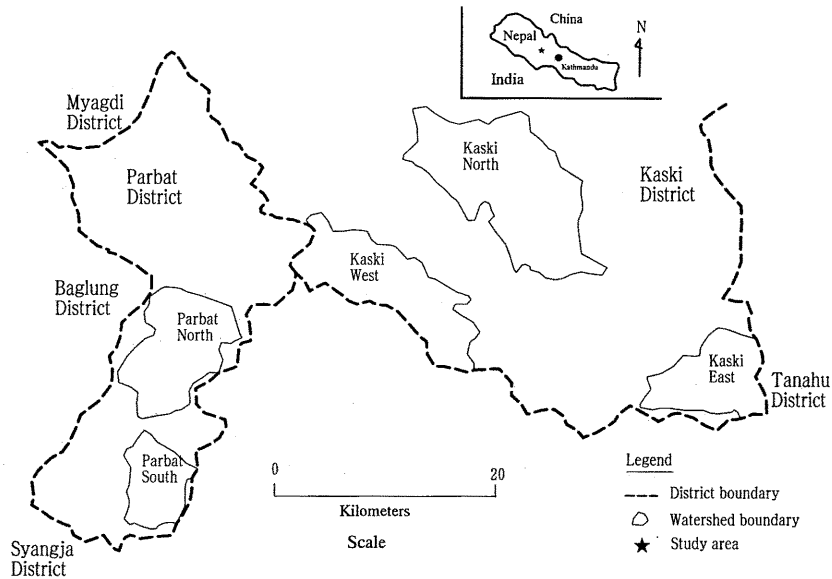


Fig. 2. Location map of the study area.

Middle Mountain watersheds through incorporating information obtained from such an inventory.

NATURAL CONDITIONS OF WATERSHEDS

The climate of the watersheds is subtropical to warm temperate. The annual precipitation at Parbat North watershed during monsoon season is up to 2518mm (Lumle agriculture center rainfall station) and about 5377mm at Kaski North watershed (Near Pokhara airport rainfall station). About 85% of the total annual precipitation falls only in the monsoon season that lasts from June to September.

Large rivers in the watersheds are Seti and Madi. Both rivers originate from the Annapurna range in the Himalayas and flow north-south and finally join each other into Narayani river. All other streams around the watersheds like Kalikhola, and Lamaya khola are the tributaries of these two rivers. The stream discharge of Seti river during dry and monsoon season is $2.1 \text{ m}^3/\text{sec}$ and $383.8 \text{ m}^3/\text{sec}$ respectively. Similarly that of Madi river is $2.8 \text{ m}^3/\text{sec}$ and $523.0 \text{ m}^3/\text{sec}$ (HMG/JICA 1998a).

These watersheds belong to the lower Himalayan zone (Matsuura 1997). The inner lesser Himalayas are characterized by a mature topography and extensive development of soil originated from slate, phyllite and schist. Sedimentary rocks like sandstone and shale are more common in the southern part while metamorphic rocks like phyllite and crystalline schist are common in the northern part of the watersheds area. A major thrust named as main central thrust, accompanied with Phalebas thrust runs in the watersheds

area with strikes in the WNW–ESE direction (Matsuura 1997). Besides these thrust a large number of small to medium fault exists causing intensive deformation, and fracturing rocks. The soil texture distribution around watersheds are of sandy loam, clay loam and sand. The total area of the watersheds is about 41143 ha, of which about 46% is occupied by forest land, 28% by non- irrigated Bari land, 11% by irrigated Khet land, 6% by grassland and 9% by others. The vegetation is dominated by tropical mixed hardwood species and also found deciduous mixed broad- leaved species together with pine and alder.

EROSION

The landslides occurred in the watersheds are classified as shallow type and deep seated one. The former one has a scale within a depth of 1.0 m to 3.0 m and affected area size is 100–3000 m². The latter is deeper than 3.0 m and of more than 3000 m². Landslides in each watershed is listed in Table 1. Concerning about the density per 100 ha by land use type is the largest at grassland with 6.98, followed by Bari land with 1.90, shrub with 1.63,

Table 1. Density of landslides in different watersheds.

Location	Area (ha.)	Shallow landslide (Number)	Deep seated landslide (Number)	Total (-)	Density (No./100 ha)
Kaski North	14068	235	58	293	2.08
Kaski East	5471	35	14	49	0.89
Kaski West	9886	87	25	112	1.13
Parbat North	7877	79	38	117	1.48
Parbat South	3841	101	23	124	3.199
Total	41143	537	158	695	1.68

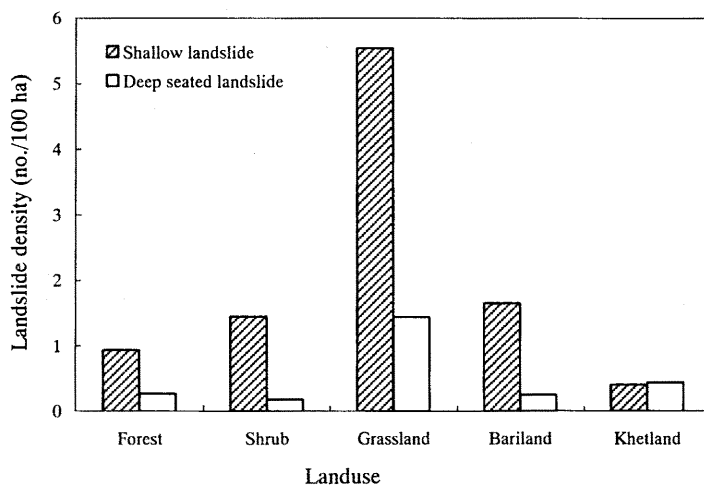


Fig. 3. Density of landslides by landuse type.

forest with 1.20 and Khet land with 0.85 (Figure 3). In terms of slope, the density is greatest at more than 30° slope category (Figure 4). One of the probable reason for higher number of landslide density in grassland is due to thick soil cover, low vegetation coverage and shallow rooting system. The density of landslide in Parbat south watershed is highest among others. This might be due to deeply weathered bed rocks eroded by undercutting effect of Argaudi stream. An example of a deep seated landslide is shown in Photo 1.

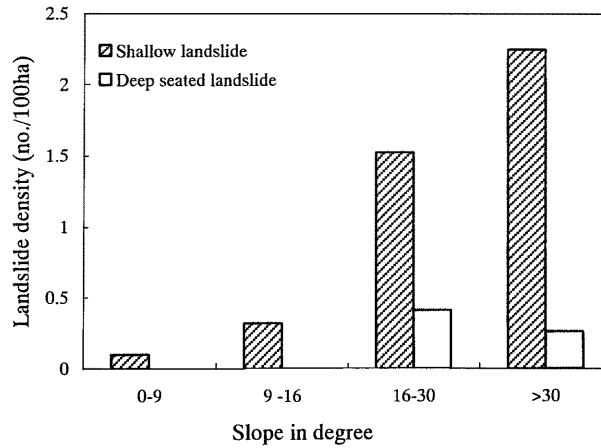


Fig. 4. Density of landslides by slope category.



Photo. 1. Toe cutting of a deep seated landslide and side erosion by a stream in Parbat North watershed.

The gully erosion has occurred mainly due to an increase of surface run-off because of over-grazing, improper farmland management, construction of trails and rural roads without side drainage. It looks more serious in cultivated land. There are so many gullies in the watersheds most prominent areas are in Kaski North and Parbat south area. The conditions of gullies are presented in Table 2, where the shape of gullies depends on soil properties and direction of flow of water in the ground. The U shape gully is formed if the resistance of the subsoil against erosion is equals with that of the top soil. On the contrary V shape gully is formed if the subsoil is more resistive than the top soil (HMG/JICA 1998a). The view of gully formation in filled bank slope is shown in Photo 2.

Each watershed in the study area is not an unit watershed discharging surface stream flow through only one outlet but also has, relatively small sub-watersheds. During high flows in the monsoon season, generally there are problems of bank erosion and over flowing related with flood. The upper layer of most banks has soils overlaying a loose sediment layer composed of sand and gravel, which is easily eroded and washed away

Table 2. Gullies in Kaski North and Parbat South.

Location	Length (m)	Depth (m)		Width (m)		Gradient (°)	Type
		max.	min.	max.	min.		
Kaski North	36	6.0	4.5	10.0	6.5	26	U shape
	200	3.4	2.9	10.0	6.5	6.5	U shape
	105	6.5	3.7	21.0	13.5	7	V shape
Parbat South	150	2.2	2.0	13.5	12.0	15	V shape



Photo. 2. V shape gully formation on filled bank slope formation below the road.

mainly during monsoon season. The bank erosion on both sides of the streams of each watershed is shown in Figure 5. The erosion in Kaski North watershed is highest. It might be due to activities of major tributaries like Bijayapur stream, Kali stream, and Bhoti streams. A typical example of bank erosion is shown in Photo 3.

A sustainable use of land without progressive deterioration can be achieved when the

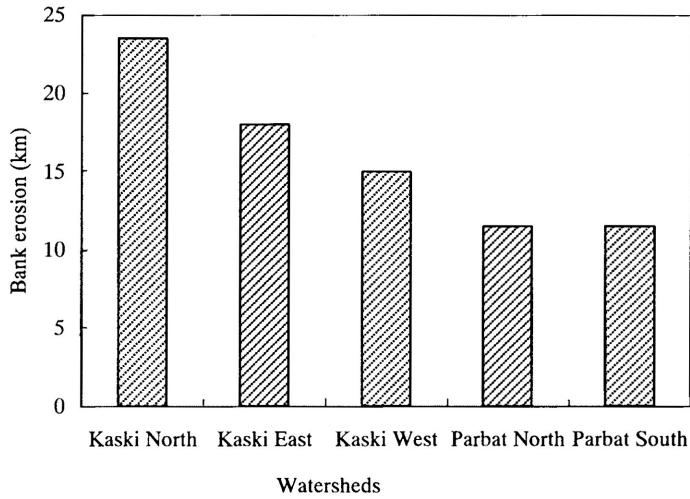


Fig. 5. Condition of bank erosion at both sides of streams.

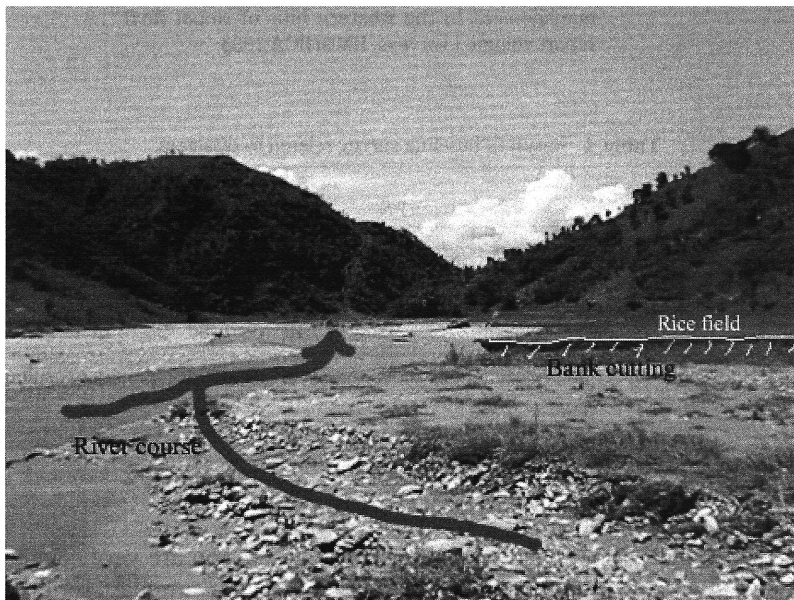


Photo. 3. View of Bank cutting by Bijayapur stream in Kaski North Watershed area.

rate of soil loss is no greater than the rate of soil formation. However it can not be precisely measured, but when the disturbances, aeration and leaching actions are accelerated by tilling the land, it will take some 100 years to form 25mm of soil (HMG/JICA 1998a). According to Nepal Agriculture Research Council, bulk density of soils in the middle mountains of Nepal vary from 1.0 to 1.4 gm/cm³. Assuming the bulk density of 1.2 gm/cm³, soil formation is approximately 3.0–10.0 ton/ha/year (HMG/JICA 1998a). The rate of soil loss by surface erosion in different land use type is classified in Table 3. Severe surface erosion occurs in overgrazed grassland due to surface run-off caused by poor vegetation as a result of overgrazing, where surface run-off is as much as 53% of the total annual precipitation (HMG/JICA 1998a). The average population of cow and goat per household in Parbat North (PN), Parbat South (PS), Kaski East (KE), Kaski North (KN), and Kaski West (KW) is 2.4, 2.8, 4.0, 2.5, and 2.6, respectively so that the grazing pressure to the top soil seems to be high.

Further, the people living in the watersheds area are frequently affected by soil erosion. To find out the condition of disaster there, the household survey was conducted in 1996. Result of problem related to disaster in watersheds mentioned above is cited in Table 4.

Table 3. Soil loss from surface erosion by landuse type.

Land use type	Soil loss (ton/ha/year)
Slopping terrace	60–70
Home garden	3
Overgrazed grassland	110

Source: The development study on Integrated watershed management in the western hills of Nepal final report volume I surveys, HMG/JICA 1998.

Table 4. Result of baseline survey related to disasters.

Disaster	Items	Watershed area				
		PN	PS	KE	KN	KW
Landslide	Frequently affected household (%)	33	31	9	12	12
	Flood					
	Frequently affected household (%)	10	10	30	14	12

Source: Household survey and household member survey, JICA/multidisciplinary consultants 1996.

CONCLUSION

Landslides, gully erosion, bank erosion and surface erosion are very common in the middle mountain watersheds of Nepal where natural disasters are most serious problem to conservation of resources (Joshi *et al.*; 1998) and also damage to infrastructure,

farmland and lives & property of local people. Therefore nation takes the attention.

Gully erosion was found mostly in bare slopes, and it has triggered landslides through undercutting the foot of a slope. The possible causes of landslides may be due to geological factors inherent to the mountains such as fractured, deeply weathered rock, which allows water penetration. Similarly the diversified geomorphological features of the mountain slopes are equally responsible. Further human activities such as degradation of forest and grassland by over exploitation, improper farmland management, construction of trail, canals for irrigation and roads without any proper drainage. The landslides in grassland were highest due to presence of thick soil layer, poor vegetation coverage besides having weakened geological settings.

Considering the above erosion state in the middle mountain region some integrated management programs are essential to mitigate the problems. Such as conservation of forest resources, mitigation of landslide, flood management and soil conservation, increase of fuel-wood, fodder and timber production, improving the living conditions of villagers through increasing food production, protection of downstream area while constructing some infrastructure in the upstream side, protection and improvement of existing water source areas are some activities to reduce the existing problems.

Thus detail studies on mechanism, cause and preventive measures on landslide, surface erosion and bank erosion are essential in the middle hills of Nepal in order to mitigate the problems.

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