Introduction

Background

Nepal is located in the very heart of the Himalayan arc and occupies nearly one third of the mountain range. About 83 per cent of the country is mountainous terrain, and the remaining 17 per cent in the south lies in the alluvial plains. Owing to the rugged mountain topography, complex and fragile nature of the geological structures, soft soil cover, high intensity rainfall in the monsoon season, and frequent earthquakes, the mountains are vulnerable to landslides, debris flows, soil erosion, and other mass wasting phenomena. The Himalayan rivers and streams, with their steep gradients and swift water flows, contribute significantly to the process of mass wasting.

In the Himalayan region, the damage caused by landslides was estimated to cost more than US$ one billion in economic losses, causing more than 200 deaths every year, which is about 30 per cent of the total of such losses worldwide (Li 1990). Landslides are very common occurrences in Nepal and are also one of the main natural hazards. Every year, especially during the monsoon season, a lot of damage to life and property is caused by them. For example, in 1968, a large slide occurred in Labu Besi and blocked the entire Budhi Gandaki River. The breaching of the dam severely damaged the settlement and bridges downstream (Sharma 1981). In 1985, a landslide dam in the Trishuli River caused great damage to the hydroelectric project and the settlement downstream (Galay 1987). Not all landslides, especially large ones, occur during the monsoon season. For example, in September 1978, a large rockslide in the Tinau River destroyed a newly-built bridge over the river at Butwal.

Many hill villages in Nepal are situated on or adjacent to unstable slopes and old landslides which are reactivated from time to time (Plate 1). In 1988, a huge landslide in Darbang (approximately 200km WNW of Kathmandu) killed 109 people and temporarily dammed the Myagdi *Khola*. About 62 years before this incident, the same landslide buried Darbang *Bazaar* and killed about 500 people (Yagi et al. 1990). In 1980, an earthquake with a magnitude of 6.5 on the Richter scale rocked Bajhang District and the adjacent areas of Far-western Nepal. It triggered several landslides on the mountain slopes. More than 3,700 houses were damaged and 178 people lost their lives (Sharma 1981). Floods and landslides alone claimed more than 4,200 human lives during the period from 1984 to 1993 (MOH 1994).

The rapidly increasing construction of infrastructure, such as roads, irrigation canals, and dams, without due consideration given to natural hazards, is contributing considerably to triggering landslides. Such infrastructures are also often damaged by mass movements. For example, in 1964, the Chisang *Khola* Hydroelectric Scheme, which was in operation for a few decades, was severely affected by a sudden slide in the balancing reservoir and the canal. Since then, the powerhouse has not been in operation (Sharma 1981). In recent years, cases of infrastructural damage caused by floods and landslides have increased steadily. The cost of rehabilitation has escalated and the economy of the country will be seriously strained if extensive rehabilitation work has to be carried out almost every year. Road failures as a result of rains and floods alone have necessitated more than 2.5 billion rupees (approximately US$ 50 million) worth of rehabilitation work from 1979 to 1993 (Deoja 1994). Moreover, landslides also seriously degrade the natural environment of the mountains and add an enormous load to the streams and rivers.

A systematic study of landslides, including hazard mapping and risk assessment on a larger scale, has not been undertaken in Nepal. Most landslide studies are confined either to individual cases or the hazard-prone sectors of linear infrastructures. Landslide studies in Nepal are carried out by professionals from government departments, non-government and international organisations, and academic institutions. The area of investigation, methodology applied, and classification scheme followed by these investigators differ considerably. This paper summarises the status of landslide studies in Nepal and focusses on the geomorphological, geological, hydrological, seismic, and other factors causing landslides in the Nepal Himalayas. A few case studies on landslides involving landslide inventory studies, hazard mapping, and mitigation are also given.

Physiography of Nepal

Nepal covers an area of about 147,181sq.km. and is bounded by the northern latitudes 26.22' and 30.27' and the eastern longitudes 80.04' and 88.12'. Its length is about 885km from east to west and the width varies from 130 to 255km.

Hagen (1969) was among the earliest workers to propose the physiographic subdivision of Nepal. The subdivisions discussed below are based on his suggestions with some modifications (Fig. 1 and Table 1).

Table 1: Physiographic Subdivisions of the Nepal Himalayas

Physiographic Unit	Width km	Main Geologic Unit
Terai (Indo-Gangetic Plain)	10-50	Northern part of the Indo-Gangetic basin, comprised of Recent Alluvium
Churia (Siwalik) Hills and Dun Valleys	10-50	Sub-Himalayas (foreland basin), comprised of sedimentary rocks of the Siwalik or Churia Group; the Dun Valleys, comprised of Recent sediments
Mahabharat Range	30-40	Lesser Himalayan unit, comprised of sedimentary, metamorphic, and igneous rocks
Midlands	40-60	Lesser Himalayan units, comprised of sedimentary, metamorphic, and igneous rocks with thrust sheets
Fore-Himalayas	10-50	Lesser and Higher Himalayan units
Great Himalayas	10-60	Higher Himalayan unit, comprised of high grade metamorphic rocks
Trans-Himalayas		Tibetan or Tethys Himalayan unit, comprised of fossiliferous sedimentary rocks

Terai

The northern continuation of the Gangetic Plain in Nepal is called the *Terai* (Fig. 1). This zone lies south of the Churia Hills and ranges in elevation from 100 to 200masl. The width varies between 10-50km and forms a nearly continuous belt from east to west. The *Terai* is generally flat with minor relief caused by river channel shifting and downwarping of the basin.

The *Terai* is divided into three parts: the Bhabar zone, middle *terai*, and southern *terai* (Sharma 1990). The Bhabar zone is made up of alluvial fan deposits sloping to the south, with its southern margin marked by a spring line that gives rise to many streams. The middle *terai* is an undulating terrain with isolated pockets of waterlogged and marshy conditions towards the southern part of the Bhabar zone. The southern *terai* stretches along the Nepal-India border, with an altitude of less than 90m.

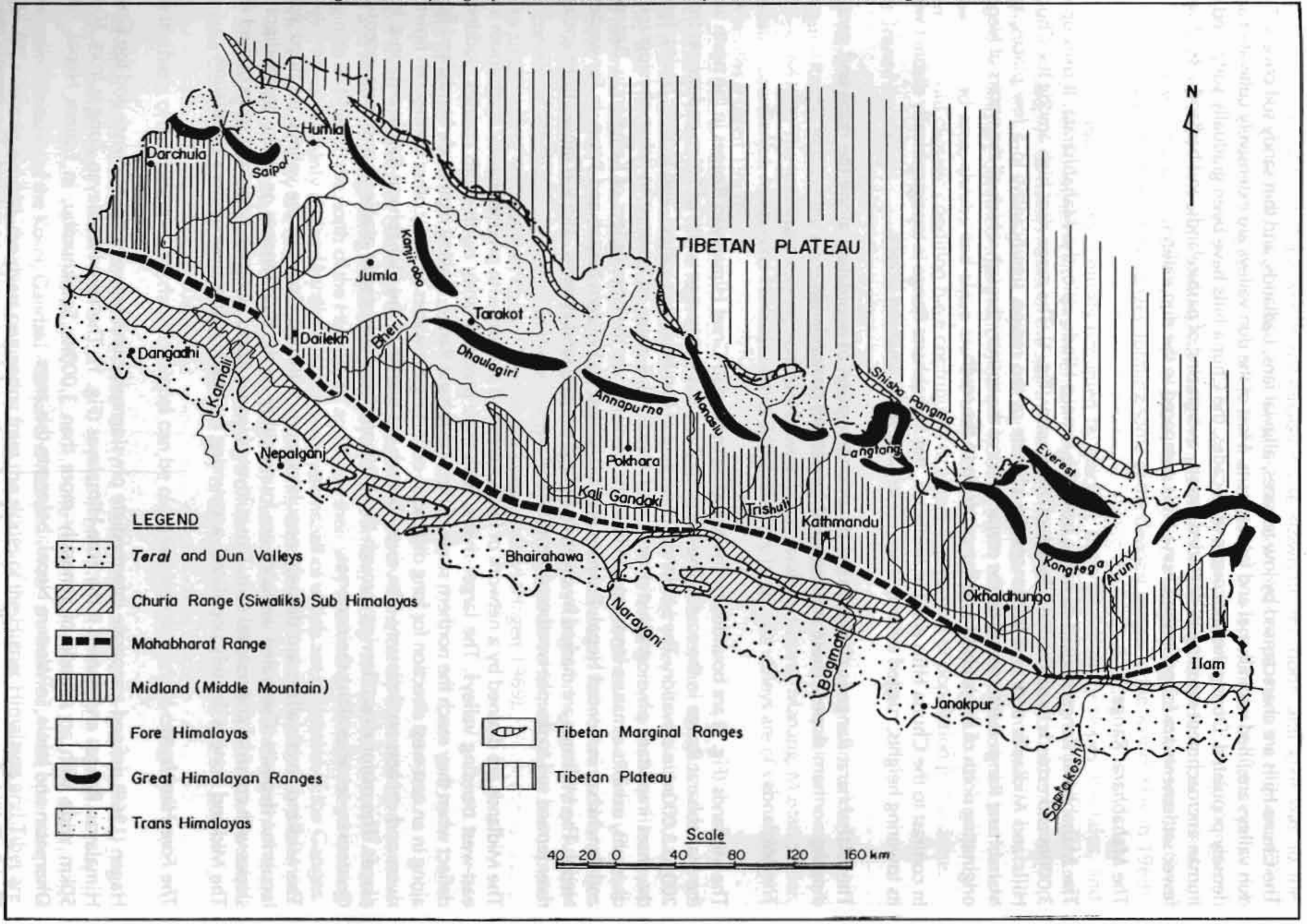
The land systems in the *Terai* can be divided into the flood plains of the rivers and recent and older river terraces. Generally, gravelly and bouldery soils prevail in the foothills, and sandy and/or silty soils are found in most of the remaining area. The region often suffers from devastating floods and droughts. The *Terai* has experienced massive deforestation since the control of malaria. Except for the 'protected forests', almost the entire *Terai* is cultivated.

The Churia (Siwalik) Hills and Dun Valleys

The Churia Hills or the Siwaliks (Fig. 1) are a unique topographic feature in the Himalayan region: the hills abruptly rise from the *Terai* and end with the beginning of the second topographic rise in the Mahabharat Range. They form the southernmost mountain range of the Himalayas.

The Churia Hills rise to altitudes of from 900 to 1,500m and show an arcuate face to the south. They form continuous east-west ranges all along the length of the country with steep escarpments towards the south. The Churia Hills have a young topography with numerous active gullies and escarpments.

Figure 1: Physiographic subdivisions of Nepal (modified after Hagen 1969)



There are several dun valleys within the Churia Hills. Some of the important ones are the Trijuga, East Rapti, Nawalpur, Deukhuri, Dang, and Surkhet valleys.

The Churia Hills are characterised by low terraces, alluvial fans, badlands, and thin sandy soil covers. The dun valleys are filled with alluvial and fan deposits. Most of the dun valleys are extensively cultivated and densely populated. During the last couple of decades, the Churia hills have been gradually subjected to human encroachment resulting in degraded forests, overgrazing of pasturelands, and badlands. Relatively fewer settlements are found in the Churia Hills compared to the dun valleys.

The Mahabharat Range

The Mahabharat Range derives its name from the famous Hindu epic, the *Mahabharata*. It rises up to 3,000m and extends throughout the length of the country (Fig. 1). The range rises high among the Churia Hills and Midlands and thus influences the climate of the region significantly. In a few places, the Mahabharat Range is intersected by the major rivers of the country through which all the waters of Nepal, originating north of the Mahabharat Range, drain to the south.

In contrast to the Churia Hills and the Midlands, the Mahabharat Range is topographically distinct with its towering heights, rugged terrain, sharp crests, and steep southern slopes.

The Mahabharat Range is characterised by a concentration of population along the ridge and gently-dipping northern slopes. There are degraded forests and pasturelands.

The Midlands

The Midlands (Fig. 1) are bounded by the towering snow-clad Great Himalayan Ranges in the north and the Mahabharat Range in the south. The Midland Zone has an average width of 60km and ranges from 200 to 3,000m in elevation. The Midlands, consisting of low hills, river valleys, and tectonic basins, form the most important physiographic province of Nepal. This zone, in contrast to other physiographic divisions, exhibits a mature landscape. Within the Midlands are the large valleys of Kathmandu, Banepa, and Panchkhal, in Central Nepal; Pokhara and Mariphant, in Western Nepal; and Patan, in Far-western Nepal. The Midlands are marked by diversity in land use and land systems. The soil ranges from ancient river terrace soil to deeply-weathered residual soil.

The Midlands are drained by a network of large rivers and streams with predominantly north-south and east-west trending valleys. The larger rivers, with their predominantly north-south courses, suddenly deflect when they reach the northern slope of the Mahabharat Range, making right angle bends, and flow along in an east-west direction for long distances, collecting the waters of many other north-south flowing rivers and streams on their way. The rivers breach the barrier of the Mahabharat Range only in a few places. The major rivers flowing through the Midlands have very gentle gradients and form extensive Quaternary terraces along their courses.

The Midland river valleys are densely populated and cultivated. Some of the valleys are filled with lacustrine deposits. Cultivated wetlands are found either on the river terraces or on the gently-dipping slopes with colluvial and residual soils. Dry cultivated land is found along the ridges and spurs of the hills. The Midland Zone is densely populated, accounting for nearly half of the country's population.

The Fore-Himalayas

Hagen (1969) defined a separate intermediate physiographic unit between the Midlands and the Great Himalayan Ranges and named it the Fore-Himalayas (Fig. 1). The Fore-Himalayan Zone is from 10 to 50km wide with an altitude of generally more than 3,000m. Solukhumbu, in Eastern Nepal, and Dhorpatan and Jumla, in Western Nepal, belong to this zone.

The Fore-Himalayas are generally covered by forests and are sparsely populated. The population is concentrated in river valleys.

The Great Himalayas

The hills of the Midland Zone and Fore-Himalayas rise slowly to the north and give way to the snowcapped ranges of the Great (or Higher) Himalayas. Not only does Nepal have the highest peak in the world, Mount Everest (Sagarmatha 8,848m), but it also has the greatest number of high peaks in the world. Unlike the other physiographic units, the Great Himalayas are not comprised of a single range but of several discontinuous and overlapping parallel ranges (Fig. 1). The trend of these ranges varies from E-W and NW-SE to NE-SW. The main north-south flowing rivers, originating from beyond the Great Himalayas, have dissected these ranges, forming some of the deepest gorges in the world (Hagen 1969).

The Great Himalayan Zone is mostly occupied by glaciers, snow peaks, rocky slopes and talus, and colluvial deposits. Topographically, this mountain range has an extremely rugged terrain with very steep slopes and deeply-cut valleys. Most of the soil in this zone is made up of landslide or talus material and glacial till with some fluvio-glacial deposits along the river banks. In the Great Himalayan Zone, taller species of plants are confined to elevations below 4,000m, while above 4,000m, below the permanent snow-covered area, shrubs and algae are the only vegetation. Lack of good agricultural land and an extremely cold climatic condition have contributed to a very low density of population in this zone.

The Trans-Himalayas

The Trans-Himalayas (Fig. 1) are situated to the north of the Great Himalayas and south of the Tibetan Marginal Range. Beyond the marginal range lies the Tibetan Plateau. It includes several Inner Himalayan valleys and hills. The important valleys, from east to west, are Rolwaling, Kutang, Manang, Mustang (Thak *Khola*), Dolpa (Sanju), Mugu, and Humla, some of which are very large. The valleys are of various lengths and widths (Hagen 1969).

As the Trans-Himalayas lie in the high altitude region and rain shadow zone, they are generally covered by talus and colluvial deposits, bare rocky slopes, snow, and ice. Though they lie within the Himalayan Zone, their climatic conditions and geomorphic features are quite different from those of the Himalayas and resemble those of the Tibetan Plateau. However, unlike the cold desert climate of the Tibetan Plateau, the Inner Himalayan valleys receive some rain (below 250mm on an average). Rain-bearing clouds enter these valleys through the deep gorges between the Higher Himalayan Ranges bringing rain that sustains the coniferous forests and agriculture in these valleys. In this zone, human settlements have been found up to an altitude of 4,300m (i.e., Phopa *Gaun* in the Langu Valley) (Hagen 1969).

Rivers of Nepal

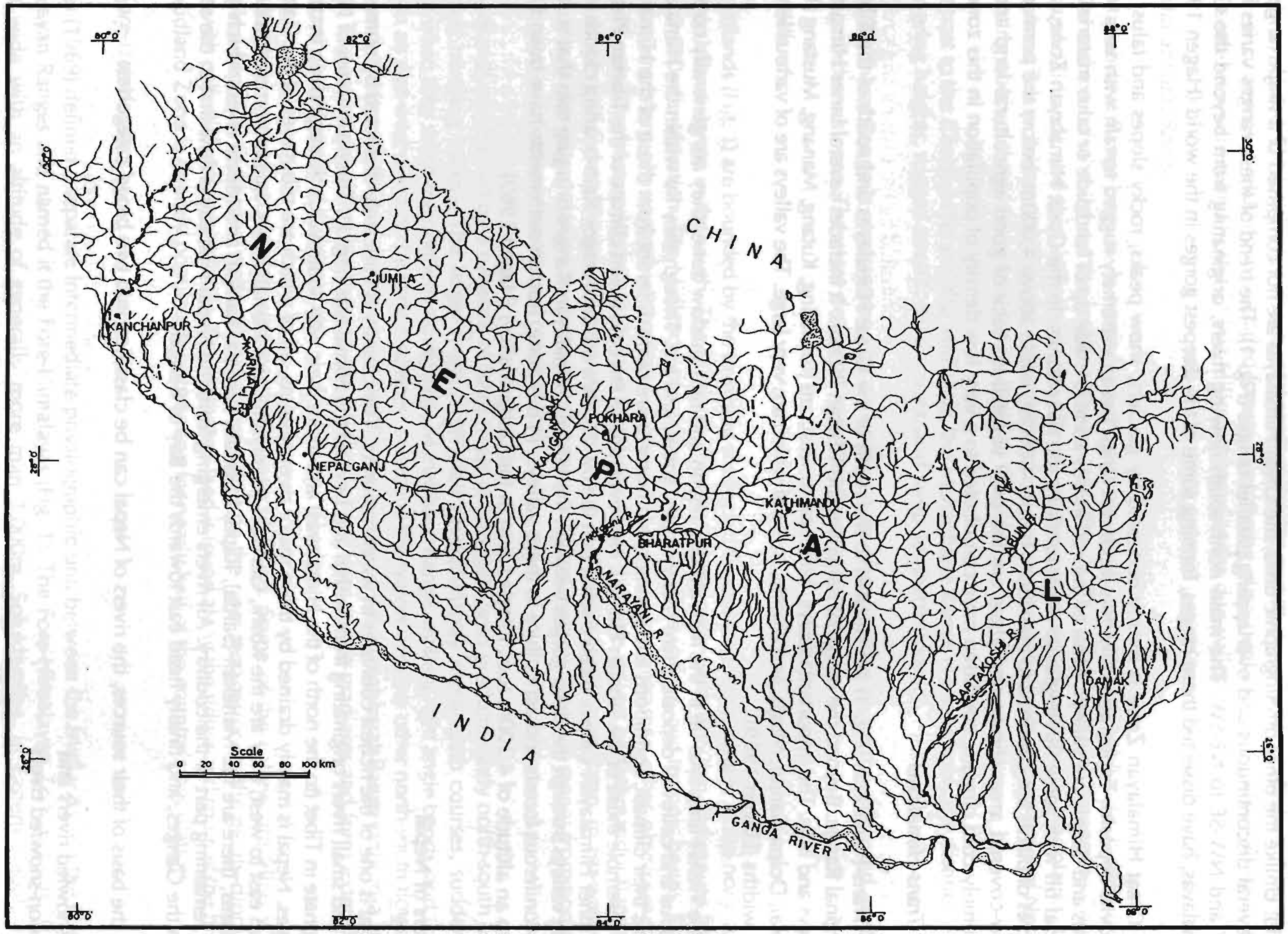
Nepal is one of the richest countries in water resources. The country is intricately dissected by numerous big and small rivers originating from within and beyond the Himalayas (Fig. 2). The main rivers of Nepal originate in Tibet (to the north of the Himalayas) and make their way southwards through deep incutting gorges. Nepal is mainly drained by three major river systems, all of which are tributaries of the Ganges. From east to west, they are the Koshi, Gandaki (Narayani), and Karnali rivers. In addition to these river systems, there are the Mahakali (Sarda), Rapti, Bagmati, Kamala, Kankai, and Mechi rivers which drain the remaining part of the country. All rivers emerging from the Nepal Himalayas flow first to the south, join the Ganges, and finally head east towards the Bay of Bengal.

On the basis of their sources, the rivers of Nepal can be classified into two broad categories:

a) snowfed rivers and
b) non-snowfed rivers

The main tributaries of the Koshi, Gandaki, Karnali and Mahakali rivers are snowfed, while others are non-snowfed rivers. In general, the rivers originating from the slopes of the Higher Himalayas and Tibet are snowfed, whereas those originating from the Midlands and the Churia Hills are non-snowfed. The river profiles of the main rivers show typically high elevations in the north and sudden drops while entering

Figure 2: Rivers of Nepal (modified after DPTC 1994)



the Midlands. In the Midlands, the rivers have moderate to low gradients, and they become steeper while crossing the Mahabharat and Churia Ranges.

Geological Framework of Nepal

Like the other parts of the 2,400km long Himalayan Range, the Nepal Himalayas are also geologically divided into the following five tectonic zones, from south to north respectively (Gansser 1964, Hagen 1969; Fig. 3).

Terai Zone
Sub-Himalayan Zone
Lesser Himalayan Zone
Higher Himalayan Zone
Tibetan-Tethys Zone

These east-west extending zones, which run almost parallel to each other, differ in their lithology, structure, and geological history. The Himalayan Ranges are tectonically very active and susceptible to frequent earthquakes. Generally, instabilities in the Himalayas are controlled by the textural and structural characteristics of the rocks and soils within the zone. There are also several active faults along which large landslides are often aligned.

The Terai Zone

This zone represents the northern edge of the Indo-Gangetic alluvial plain and is the southernmost tectonic division of Nepal (Fig. 3). Though physiographically this zone does not belong to the main part of the Himalayas, it is a foreland basin and owes its origin to the rise of the Himalayas; it is thus genetically related. To the north, this zone is often delineated by an active fault, the Main Frontal Thrust (MFT). Churia rocks are found to rest over the sediments of the *Terai* in many places along this thrust,

The *Terai* is covered by Pleistocene to Recent alluvium. The average thickness of the alluvium is about 1,500m. The basement topography of the *Terai* is not uniform. There appear to be a number of transverse ridges and valleys below the alluvium. The alluvial sediments were deposited over the Siwaliks, which in turn rest over Precambrians and Gondwanas or Eocene-Oligocene rocks (Tater et al. 1989, Sharma 1990).

The Sub-Himalayan Zone (Siwaliks)

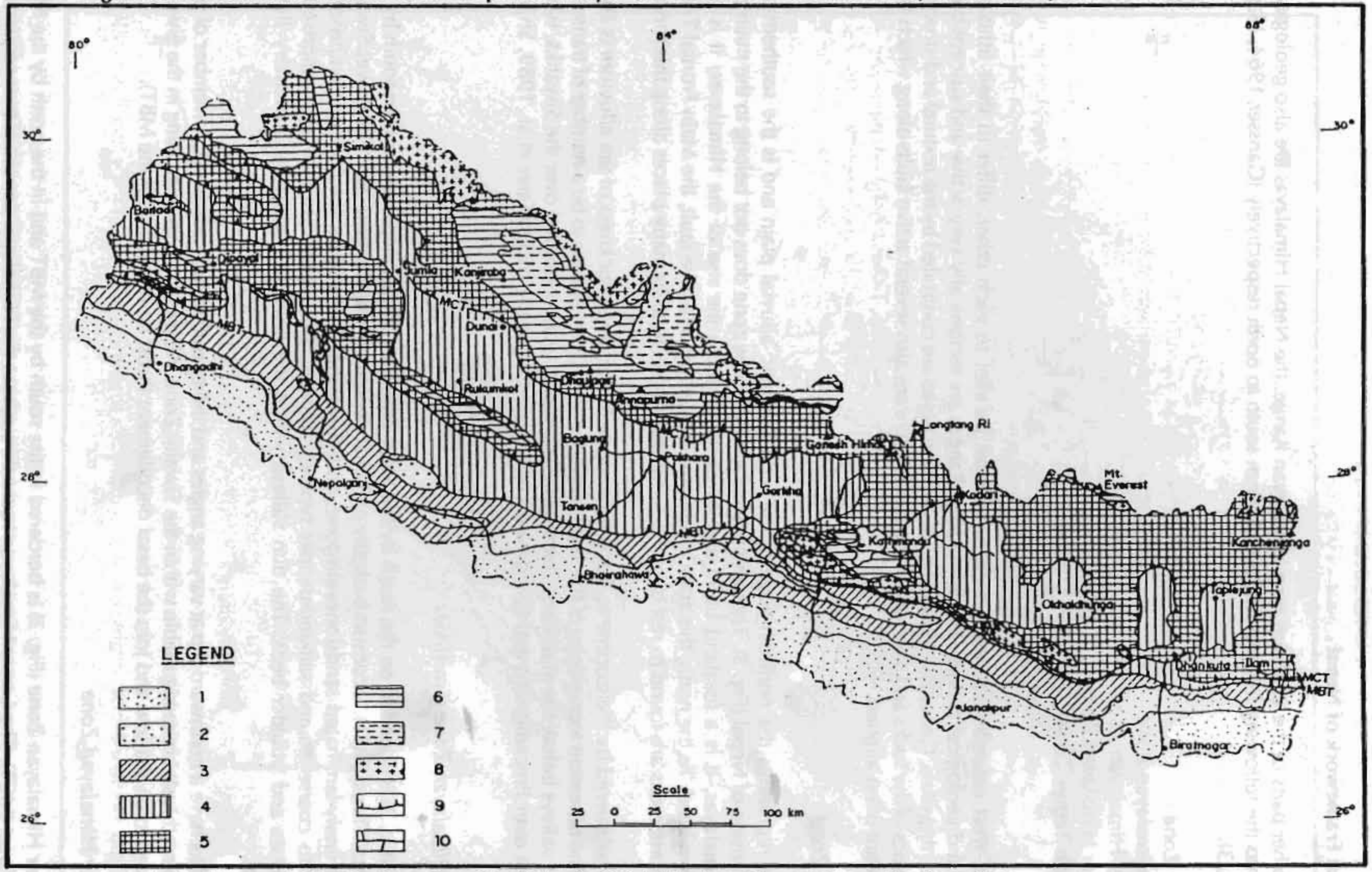
This zone (Fig. 3) is bounded on the north by the Main Boundary Thrust (MBT) and on the south by the Main Frontal Thrust (MFT). It consists basically of fluvial deposits of the Neogene age. The Lower Siwaliks consist of finely-laminated sandstone, siltstone, and mudstone. The Middle Siwaliks are comprised of medium- to coarse-grained salt-and-pepper type sandstones. The Upper Siwaliks are comprised of conglomerate and boulder beds. The dun valleys within the Siwaliks consist of Quaternary fluvial sediments.

The Siwaliks have a northward dip at varying angles and the overall strike is east-west. A number of east-west running thrusts are recognisable within the Siwalik Zone. All these thrusts originating in the Siwaliks are believed to be shallow and join the basal decollement thrust (continuation of the MBT).

The Lesser Himalayan Zone

The Lesser Himalayan Zone (Fig. 3) is bordered in the south by the MBT and in the north by the Main Central Thrust (MCT). The Lesser Himalayan rocks throughout the Himalayas consist of two sequences: allochthonous and autochthonous. The MBT itself is a fault zone that has brought older Lesser Himalayan rocks over the Siwaliks.

Figure 3: Tectonic subdivisions of the Nepal Himalayas (modified after Stocklin 1980, Kizaki 1988, and ESCAP/DMG 1993)



1. *Terai* Zone, 2. Sub-Himalayan Zone (Dun Valleys), 3. Sub-Himalayan Zone, 4. Lesser Himalayan Zone,
5. Higher Himalayan Zone and the Lesser himalayan Crystalline Rocks, 6. Tibetan Tethys Zone (Paleozoic Rocks),
7. Tibetan Tethys Zone (Mesozoic Rocks), 8. Granites, 9. Thrusts, 10. Roads

The Lesser Himalayas are mostly comprised of unfossiliferous, sedimentary, and metasedimentary rocks such as slate, phyllite, schist, quartzite, limestone, dolomite, etc, ranging in age from Precambrian to Eocene. There are also some granitic intrusions in this zone.

From east to west, the Lesser Himalayas of Nepal vary in stratigraphy, structures, and magmatism. Eastern Nepal is characterised by the development of extensive thrust sheets of crystalline rocks (gneiss and schist) that have travelled southwards. There are large tectonic windows which expose the low-grade metamorphic rocks below the cover of the crystalline thrust sheets. They are the Taplejung, Arun, and Chautara-Okhaldhunga windows. In Central Nepal, a large thrust sheet called the Kathmandu Nappe covers a wide area around the Kathmandu region. West of Kathmandu, between the Budhi Gandaki and Bheri rivers, crystalline rocks are restricted to the north of the MCT. West of the Bheri River, up to the western border of Nepal, crystalline nappes reappear and cover much of the terrain (Fig. 3).

The Higher Himalayan Zone

Ever since Heim and Gansser (1939) identified and described the 'Central Crystalline Zone' in the Kumaon Himalayas, this zone has been mapped and traced along the entire Himalayan region and has been given different names in different places. Geologically, the Higher Himalayas include the rocks lying north of the MCT and below the fossiliferous Tibetan-Tethys Zone.

The northern or upper limit of this zone is generally marked by normal faults. This zone consists of an approximately 10km-thick succession of crystalline rocks, also known as the Tibetan Slab (Le Fort 1975). The crystalline unit of the Higher Himalayas extends continuously along the entire length of the country, and its width varies from place to place. The high-grade, kyanite-sillimanite-bearing gneisses, schists, and marbles of the zone form the basement of the Tibetan-Tethys zones. Granites are found in the upper part of the unit (Fig. 3).

The Tibetan-Tethys Zone

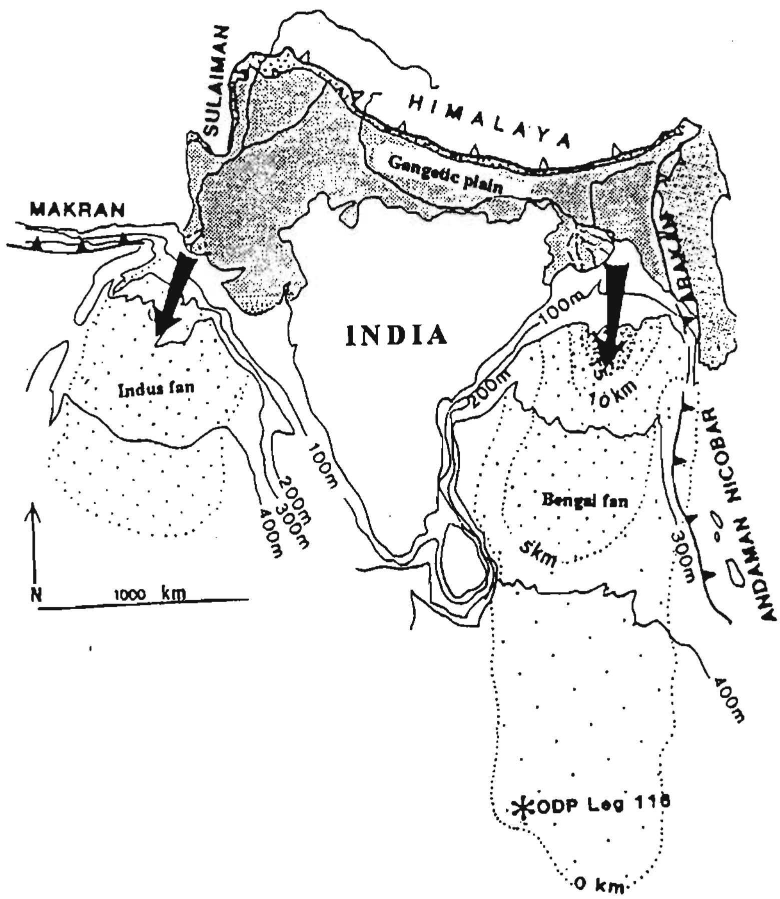
The Tibetan-Tethys Zone begins at the top of the Higher Himalayan Zone and extends to the north in Tibet. In Nepal, the fossiliferous rocks of the Tibetan-Tethys Zone are well-developed in Thak *Khola* (Mustang), Manang, and Dolpa. Most of the Great Himalayan peaks of Nepal, including Mt Everest, Manaslu, Annapurna, and Dhaulagiri, belong to the Tibetan-Tethys Zone (Fig. 3). This zone is composed of sedimentary rocks, such as shale, limestone, and sandstone, ranging in age from Lower Palaeozoic to Palaeogene.

Erosion and Sediment Yield in the Himalayas

The erosional history of the Himalayas can be deciphered by studying the submarine fan in the Bay of Bengal. The Bengal Fan (Fig. 4) came into existence through the accumulation of sediments from the rising Himalayas. It is the world's largest submarine fan, extending to about 3,000km south from Bangladesh into the Indian Ocean (France-Lanord et al. 1993). The sediments constituting the fan have a maximum thickness of approximately 22km, and the mass of the sediments derived from the collision of India and Asia is about 22.9×10^{16} tonnes (Curry 1991). The Bengal Fan is fed by the Ganges and the Brahmaputra rivers, which currently drain both the northern and southern slopes of the Himalayas (Figs. 2 and 4). The high relief, intense precipitation during the monsoon season, and extensive glaciation are responsible for the world's highest erosion rates. The Ganges-Brahmaputra River system (with approximately 1.4 million square kilometres of watershed area) produces 12 per cent of the river particulate flux in the world's oceans, while providing less than three per cent of the water flux (Milliman and Meade 1983).

The isotopic study of the sediments from the Bengal Fan indicates that the Higher Himalayan Crystallines (HHC) have been the predominant source of sediment supply to the Bengal Fan at least since the last 17Ma (France-Lanord et al. 1993). This situation has still not changed significantly. The presence of a large volume of the sediment derived from the HHC has significant implications for the tectonic history

Figure 4: Sketch map of Bengal and Indus fans (France-Lanord et al. 1993)



of the Himalayas. It implies that the Himalayan Range had already achieved an elevation of the same order as the present day by 17Ma (France-Lanord et al. 1993).

Today, the Ganges and Brahmaputra rivers are the second and third largest sediment carriers in the world (Fig. 5), and the average annual suspended load carried by them to the Bay of Bengal is more than $1.6x10^9$ tonnes and $0.8x10^9$ tonnes respectively (Holeman 1968). If we calculate the average rate of sedimentation in the Bengal Fan from the total post-collisional sediment deposits in the fan for 17Ma, it is about $2.9x10^{10}$ tonnes per year.

Studies on the annual sediment load of the Koshi River (one of the tributaries of the Ganges), from 1948 to 1981, have shown that the total average annual sediment load at Barahakshetra is $94.95x10^6m^3$ (about 190 million tonnes per year) (RONAST/CWRC 1994). The same river further downstream at Baltara, India, has only $57.35x10^6m^3$ (about 115 million tonnes) of sediment load. The measurements of annual sediment load at Barahakshetra and Baltara are shown in Table 2, and the monthly sediment load in the Koshi River at Barahakshetra is given in Table 3.

Table 2: Annual Sediment Load at Barahakshetra and Baltara (RONAST/CWRS 1994)

Location	Annual Sediment Load in million m^3			
	Coarse	Medium	Fine	Total
Barahakshetra	17.978	23.858	53.114	94.95
Baltara	4.70	11.36	41.29	57.35

Figure 5: The sediment load of selected South Asian rivers compared to the world average (Ferguson 1984)

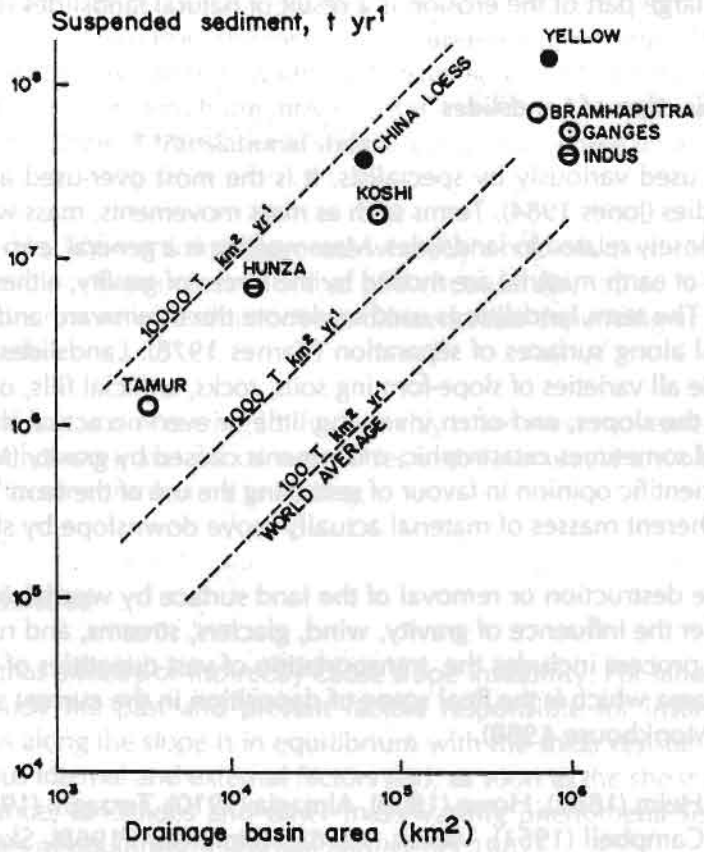


Table 3: Monthly Sediment Load in the Koshi River at Barahakshetra (RONAST/CWRS 1994)

Month	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec	Total
Sediment Load (x106m³)	0.099	0.074	0.12	0.44	2.82	14.02	26.90	29.01	15.13	5.82	0.71	0.20	94.99
Total between July and October													90.88

The annual sediment load and sediment yield per km² of the tributaries of the Koshi River are presented in Table 4 (RONAST/CWRC 1994).

Table 4: The Annual Sediment Load and Sediment Yield of the Tributaries of the Koshi River (RONAST/CWRC 1994)

Tributary	Annual Sediment Load (given in $x10^6m^3$)	Annual Sediment yield (given in m^3/km^2)
Sunkoshi	54.2	2818
Arun	34.6	947
Tamur	29.6	5016
Total	118.4	8781

The sediment load of the Karnali River has been estimated at between 93.5 and 170 million tonnes per year. Similarly, the sediment load of the Narayani River at Bhainsalotan is estimated at 170 million tonnes per year (Sharma 1988). From Nepal's 147,181sq.km. of land, about 240 million cubic metres of eroded per year (Sharma 1988). From Nepal's 147,181sq.km. of land, about 240 million cubic metres of eroded soil is transported each year by the country's four major rivers and over 6,000 tributaries (DSWC 1977). It is estimated that the soil loss range is between 20-50tonnes/ha/year and may increase locally to 200-500tonnes/ha/year. A large part of the erosion is a result of natural landslides (DSWC 1977).

Definition and Classification of Landslides

The term landslide is used variously by specialists. It is the most over-used and loosely-defined term employed in slope studies (Jones 1984). Terms such as mass movements, mass wasting, slope movement, slope failure, etc, are closely related to landslides. Mass wasting is a general term for a variety of processes by which large masses of earth material are moved by the forces of gravity, either slowly or quickly, from one place to another. The term landslide is used to denote the downward and outward movements of slope-forming material along surfaces of separation (Varnes 1978). Landslides are quick mass-wasting processes. They include all varieties of slope-forming soils, rocks, artificial fills, or combinations of these, moving out and down the slopes; and often involving little or even no actual sliding over a long period of time, or sudden, and sometimes catastrophic, movements caused by gravity (Monkhouse 1988). There is a growing body of scientific opinion in favour of restricting the use of the term 'landslide' to cover those situations in which coherent masses of material actually move downslope by sliding (Jones 1984).

On the other hand, the destruction or removal of the land surface by weathering, corrasion, corrosion, and transportation under the influence of gravity, wind, glaciers, streams, and running water are termed 'erosion'. The erosion process includes the transportation of vast quantities of weathered rock, usually downhill, towards the area which is the final scene of deposition in the current sequence; transportation is an essential phase (Monkhouse 1988).

Many authors, such as Heim (1882), Howe (1909), Almagia (1910), Terzaghi (1925), Ladd (1935), Sharpe (1938), Ward (1945), Campbell (1951), Varnes (1958), Hutchinson (1968), Skempton and Hutchinson (1969), Záruba and Mencl (1969), Crozier (1973), and Varnes (1978) have tried to classify landslides. Here, the classification by Varnes (1978) is followed. The International Association of Engineering Geology (IAEG) has also suggested the same nomenclature (IAEG 1990).

Varnes classified landslides on the basis of the types of movement and material. Movement types are divided into five main groups: falls, topples, slides, spreads, and flows. A sixth group, complex slope movements, includes combinations of two or more of the other types of movement (Table 5). Similarly, materials are divided into two classes: rocks and engineering soil. Soil is further subdivided into debris and earth, based on the grain size (Varnes 1978). A short description of the various landslide types is given below (Varnes 1978).

Table 5: Classification of Landslides (Varnes 1978)

Type of Movement			Type of Material		
			Bedrock	Engineering Soil	
				Predominantly coarse	Predominantly fine
Falls			Rockfall	Debris Fall	Earth Fall
Topples			Rock Topples	Debris Topples	Earth Topples
Slides	Rotation	Few units	Rock Slump	Debris Slump	Earth Slump
	Translation	Many units	Rock Block Slide Rockslide	Debris Block Slide Debris Slide	Earth Block Slide Earth Slide
Lateral Spread			Rock Spread	Debris Spread	Earth Spread
Flows			Rock Flow (Deep Creep)	Debris Flow	Earth Flow
				(Soil Creep)	
Complex			Combination of two or more principal types of movement		

Falls are masses of rock and/or soil that move downslope by falling or bouncing through the air. They are most common on steep road cuttings.

A Topple denotes the overturning or tilting of a block of rock on a pivot or hinge. Finally, it separates from the main mass resulting in a fall or slide.

The term **slide** is applied to a mass movement process in which a distinct surface of rupture or zone of weakness separates the slide material from the more stable, underlying material. The slide materials can be broken up and deformed or they can remain fairly cohesive and intact. A cohesive landslide is called a **slump.** A **rotational slide** is one in which the movement is more or less rotational about an axis that is parallel to the contour of the slope. A **translational slide** is a mass movement on an approximately planar surface.

Spreads are failures caused by liquefaction: the process whereby water-saturated sediments transform into a liquid state. The movement of **flows** resembles that of a viscous fluid; slip surfaces are almost absent. Flow can take place as one or more lobes that move at different rates depending upon the viscosity of the material and the slope angle.

The most common natural hazards occurring in the Himalayas are mass movements (landslides, debris flows, and mud flows), earthquakes, and floods. Landslides in the Himalayas are often complex, as there is usually more than one factor contributing to sliding.

Factors Causing Landslides

There are several factors that directly or indirectly cause slope instability. For landslide assessment, it is necessary to carefully study the past and present factors responsible for instability. Under normal conditions, the shear stress along the slope is in equilibrium with the shear resistance of the slope. But it is often modified by various internal and external factors and, as soon as the shear stress along the slope exceeds the shear resistance, landslides and other mass-wasting phenomena set in and the slope is modified to the new values of equilibrium (Záruba and Mencl 1982).

Factors that are more or less long-lasting and inherent in the constituent rock and soil can be called the primary causes of failure. The basic factor is the force of gravity. There are also many other factors. Some of the important ones are: rock and soil type and strength, rock structure (folding, faulting, jointing, foliation, bedding (Hoek and Bray 1981), soil depth, porosity, and permeability.

The factors that are either variable or very short-lived can be called the secondary causes or triggers. They are seismicity, intensity of precipitation, land use, natural slope conditions, rock and soil weathering conditions; presence or absence of gullies, streams, and rivers; and groundwater conditions.

A short description of the important landslide-causing factors common in the Nepal Himalayas is presented below.

Geology

Lithology

Lithology is one of the primary factors causing landslides. The rocks in the Himalayas range from granite, gneiss, and schist in the Higher and Lesser Himalayas to soft sandstone, mudstone, and conglomerate in the Siwaliks. The most common types of mass rock movement in the Himalayas are rockslides, rockfalls, rock toppling, and wedge failure. Short descriptions of the common rocks are given below (Dhital 1991).

Fractured Slate: This type is found in a large portion of the Midlands and breaks easily into long pencil-shaped or small flat polygonal chips which cleave off the bed even in the dry season. Slate is susceptible to wedge failure, gully erosion, and toppling.