2. STUDY AREA

2-1 LOCATION

The study area is the Kulekhani watershed (124 km^2) located in the Lesser Himalayan region of the Himalayan belt in the central region of Nepal. The area lies between 27° 34' N and 27° 42' N latitudes and between 85° 1' E and 85° 12' E longitudes (Figure 2-1), with elevation ranging from 1,500 m to 2,600 m. This region of Himalayan belt (Figure 2-2) in Nepal is highly populated and most prone to landsliding. In terms of political division of the country, it falls in the Makawanpur district of the central development region. The aerial distance from Kathmandu is about 30 km. The Kulekhani reservoir located in the study area received a tremendous amount of sediments (thirty times the average annual) during the landslide/debris-flow disaster of July 1993 (Figure 2-3 (A-E); Dhakal, 1995). This is the only reservoir in Nepal and supports one third of the total electric power generation of Nepal; consequently landslide hazard assessment is critical for effective watershed management.

2 -2 . TOPOGRAPHY

The Lesser Himalayan region in which the Kulekhani watershed is situated is one of the four tectonic zones of the Himalayan belt. The Himalayan belts from South to North respectively are divided as Sub Himalaya or Siwaliks, Lesser Himalaya, Higher Himalaya, and Tibetan Tethys zone (see Figure 2-2). The main frontal thrust (MFT), the main boundary thrust (MBT), and the main central thrust (MCT) are three active thrusts, which separate various physiographic regions. The MBT separates Lesser Himalaya from Sub Himalaya, and the MCT separates Higher Himalaya from Lesser Himalaya. The Lesser Himalaya region consists of Mahabharat zone and Midland zone. Mahabharat zone is located just north of MBT, and a wide depressed zone further north is Midland.

The elevation of the study area ranges from 1,500 m at the dam site to 2,600 m on the southern hills of the watershed called Simbhanjyang. East -West aerial length is about 17 km and that of North-South is about 11 km. The watershed possesses comparatively gentler slopes. About seventy six percent of the area falls in the region of slope gradient less than 30°. Elevation map, slope gradient map, and slope aspect

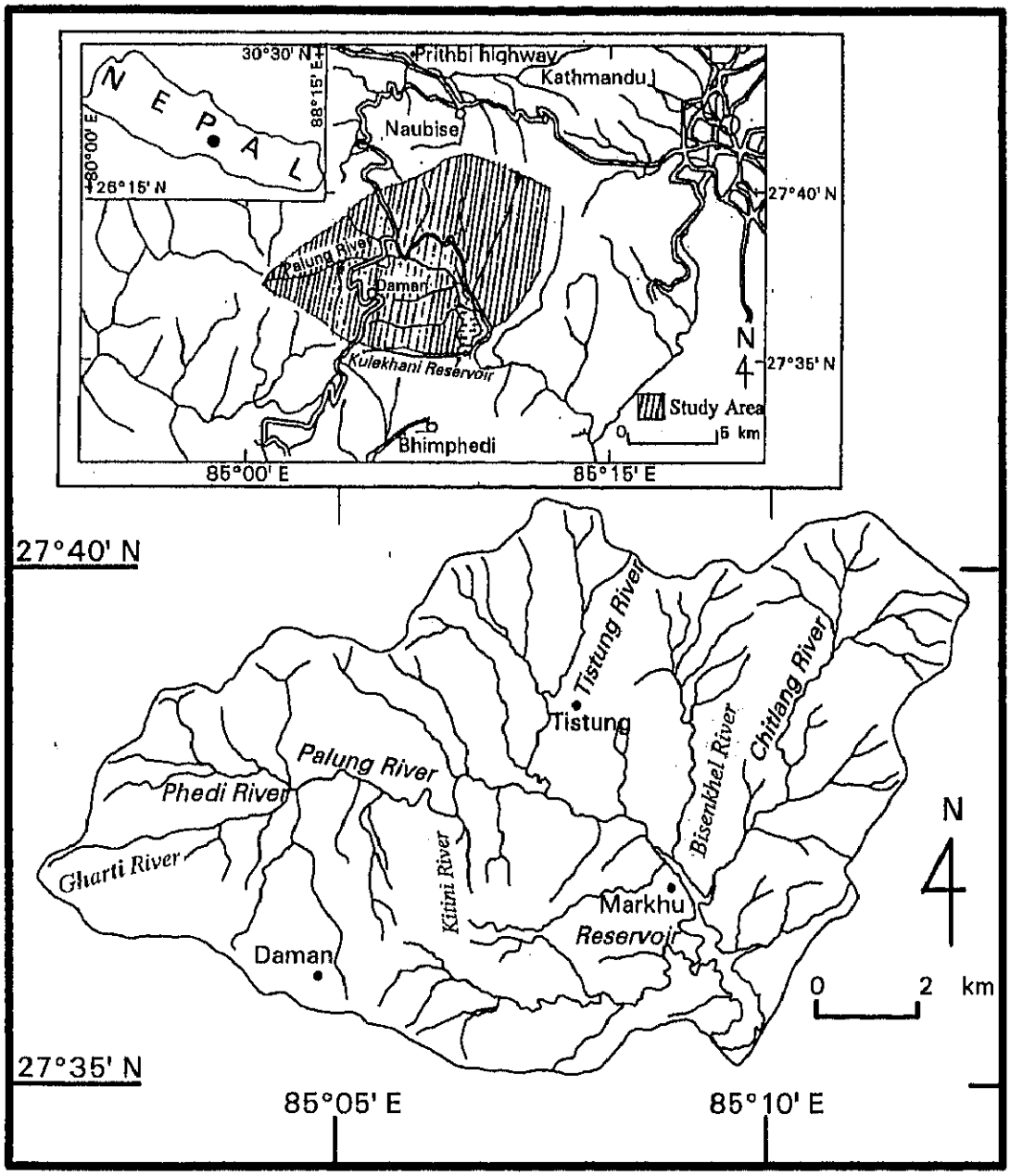

Figure 2-1 The study area Kulekhani watershed, Nepal.

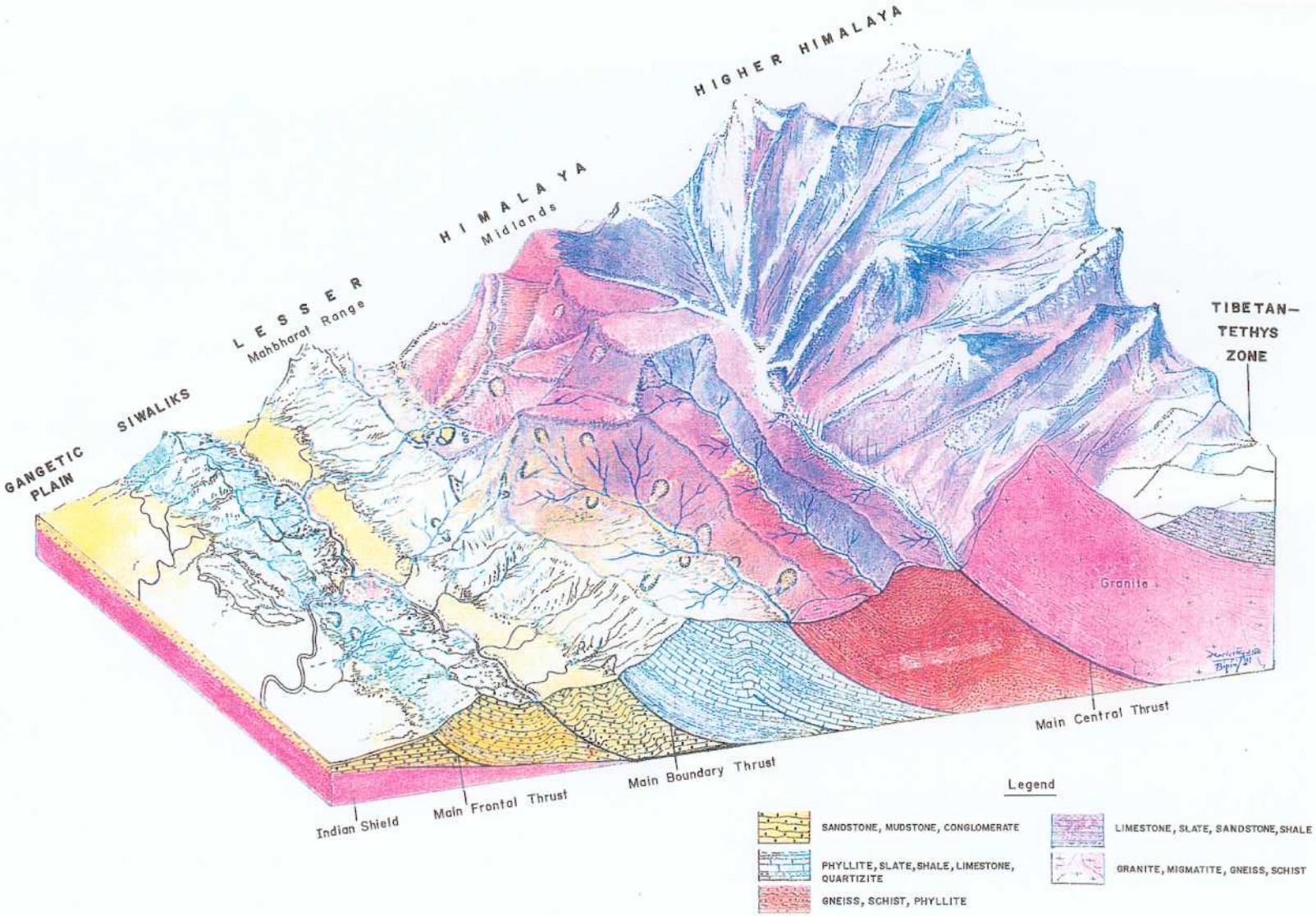

Figure 2-2 Block diagram of the Himalaya (modified after, ICIMOD, 1991).

Figure 2-3(A) Landslides in the study area, around the hills of Palung and Daman (Top), and upper catchment of the Phedi river (Bottom).

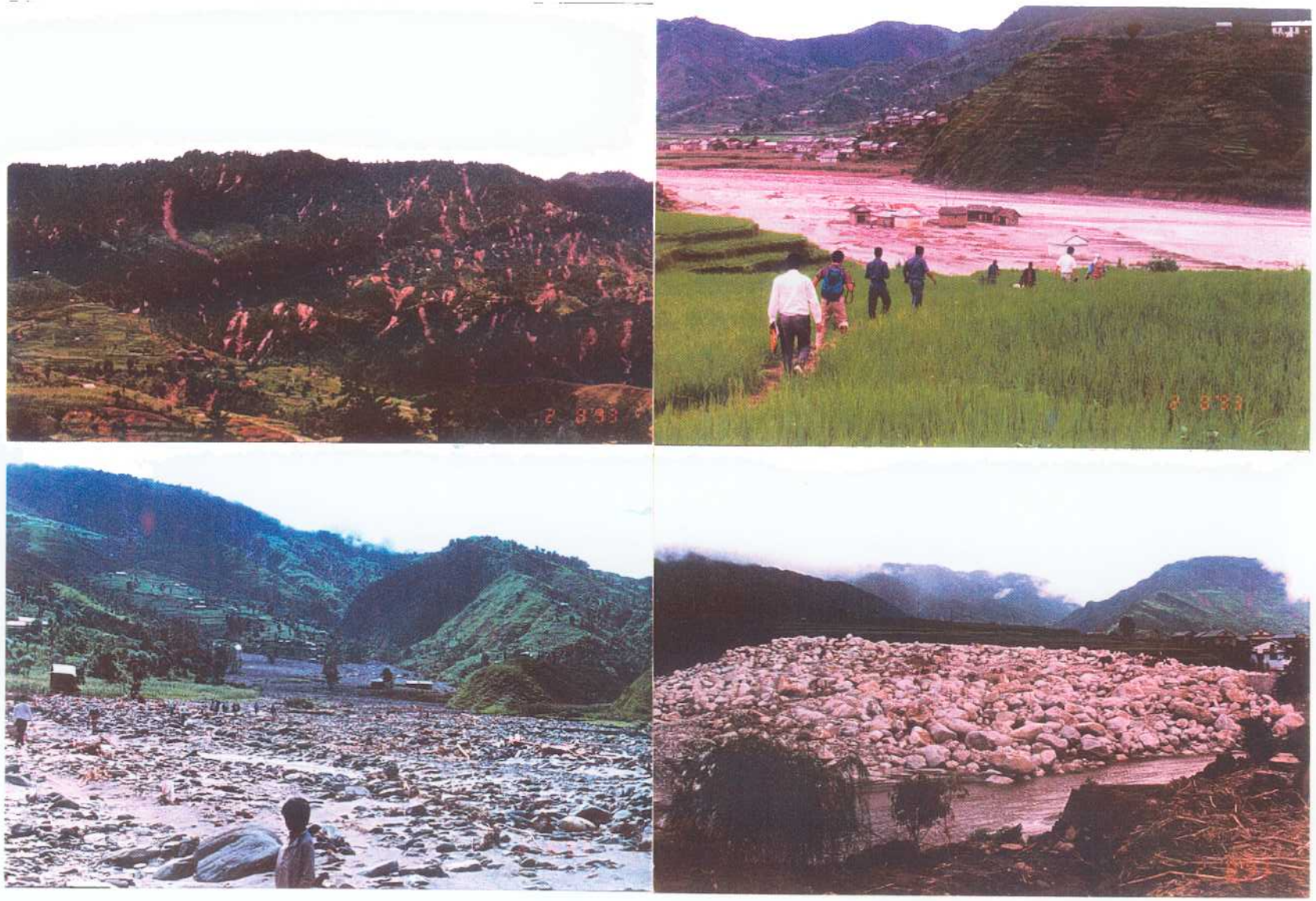

Figure 2-3(B) Different forms of "landslide affected areas"; slope failures and sand deposited area, Plaung river (Top), and cobble and boulder type debrisflow deposition areas in Phedi and Kitini rivers (Bottom), respectively.

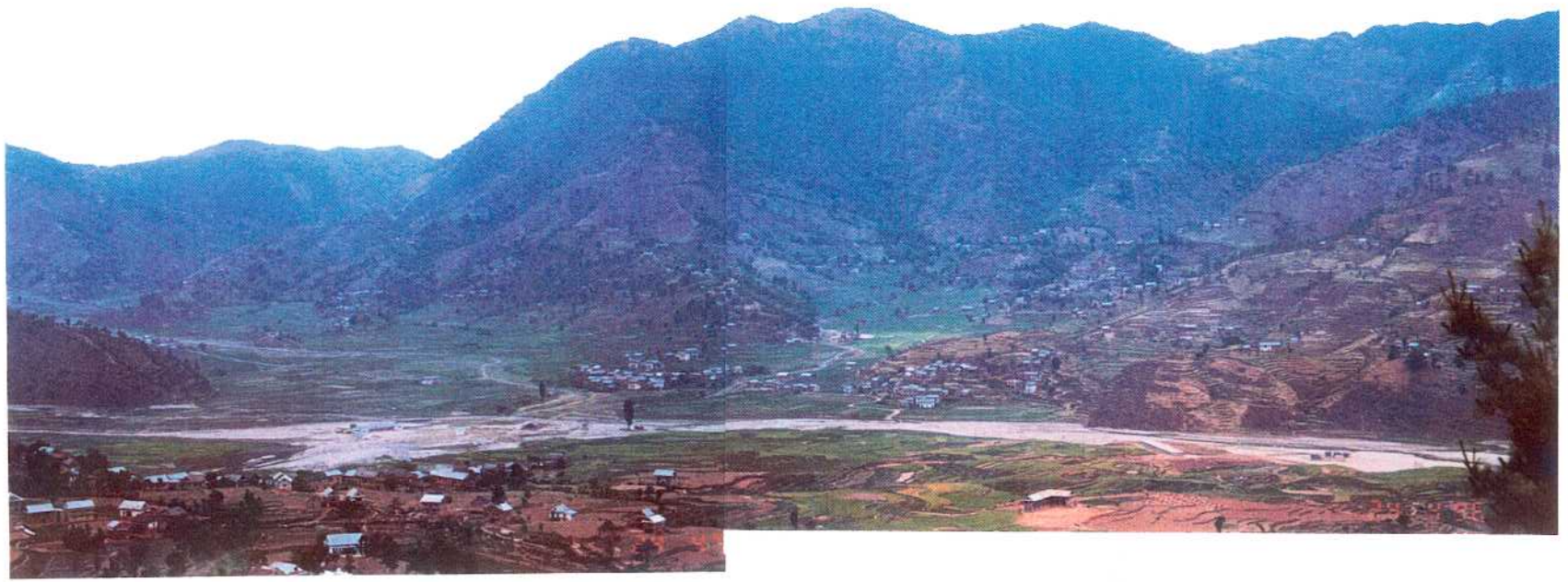

Figure 2-3 (C) Sand deposited areas due to flooding or debris flow in the upper catchment in the Palung river, near Palung village. Cluster of houses in the middle of the photograph is Palung village.

Figure 2-3 (D) Cobble type debris deposition area and the surrounding land use in Phedi river. The debris flow occurred on the night of 19 July 1993. It claimed 58 lives and destroyed 45 houses.

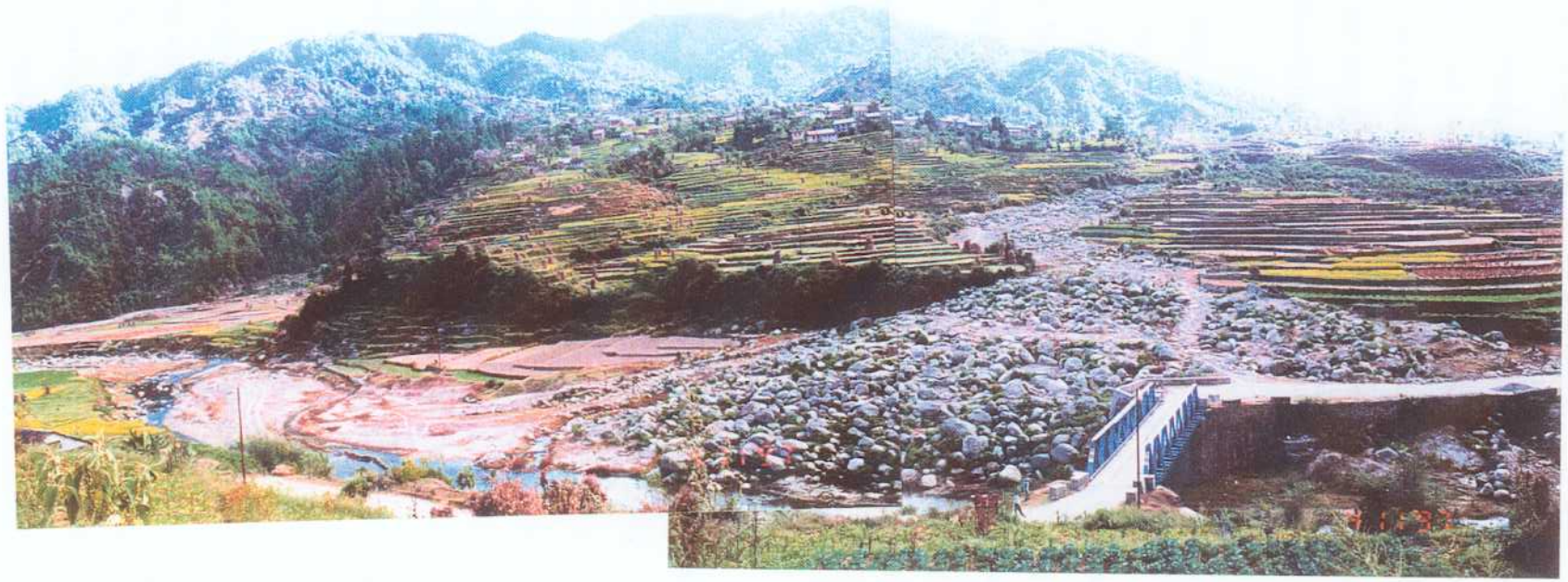

Figure 2-3 (E) Boulder type debris deposition area and the surrounding land use in Kitini river. The debris flow occurred on the morning of 20 July 1993 and claimed 10 lives.

map, are shown in Figure 2-4 (A, B, C). The watershed consists of various small valleys such as Palung valley, Tistung valley, Bishenkhel valley, and Chitlang valley (see Figure 2-1). These valleys are located in the middle and eastern part of the watershed. These valleys possess very fertile land and are famous for the production of large amount of vegetables and are densely populated. The vegetables produced here are basically brought to Kathmandu.

2-3 CLIMATE AND RIVERS

Climatic region can be divided into the warm temperate (15° C - 20° C) and the cool temperate (10° C - 15° C). The average annual rainfall of the watershed, varies from about 1500 mm at Sarbang to about 1700 mm at Daman. Among the five rainfall stations in the watershed, Daman was established in 1968, and is the oldest one. Tistung was established in 1991. Figure 2-5 shows the maximum and minimum temperature for 1993 observed at Markhu (Simlang) and monthly average rainfall between 1982-1992 observed at Daman.

2-3-1 Drainage Network

The watershed is drained by the Palung river, which originates as the Phedi river and runs about 25 km with an average gradient of 1: 25 and empties into the reservoir (see Figure 2-1). It meets the Gharti and Kitini rivers on the right bank, and the Tistung, and Bisenkhel rivers on the left bank before emptying into the reservoir. Fig. 2-4 (D) shows the drainage network and the drainage basin orders. The total area from which the first order stream drains out is about 60 percent of the total study area. The reservoir occupies the area of about 1.6 Km^2.

2-4 GEOLOGY

The Lesser Himalaya region is composed of medium to low grade metamorphic rocks, and some igneous and sedimentary rocks. The rocks of the study area fall in the Phulchawki group or the Bhimphedi group of the Kathmandu complex of the Lesser Himalaya with granite intrusions (Figure 2-4 (E); Stocklin and Bhattarai, 1981). The Bhimphedi group contains high grade meta sedimentary rocks, where as the Phulchowki group is characterized by sedimentary or weakly metamorphosed rocks. The rocks

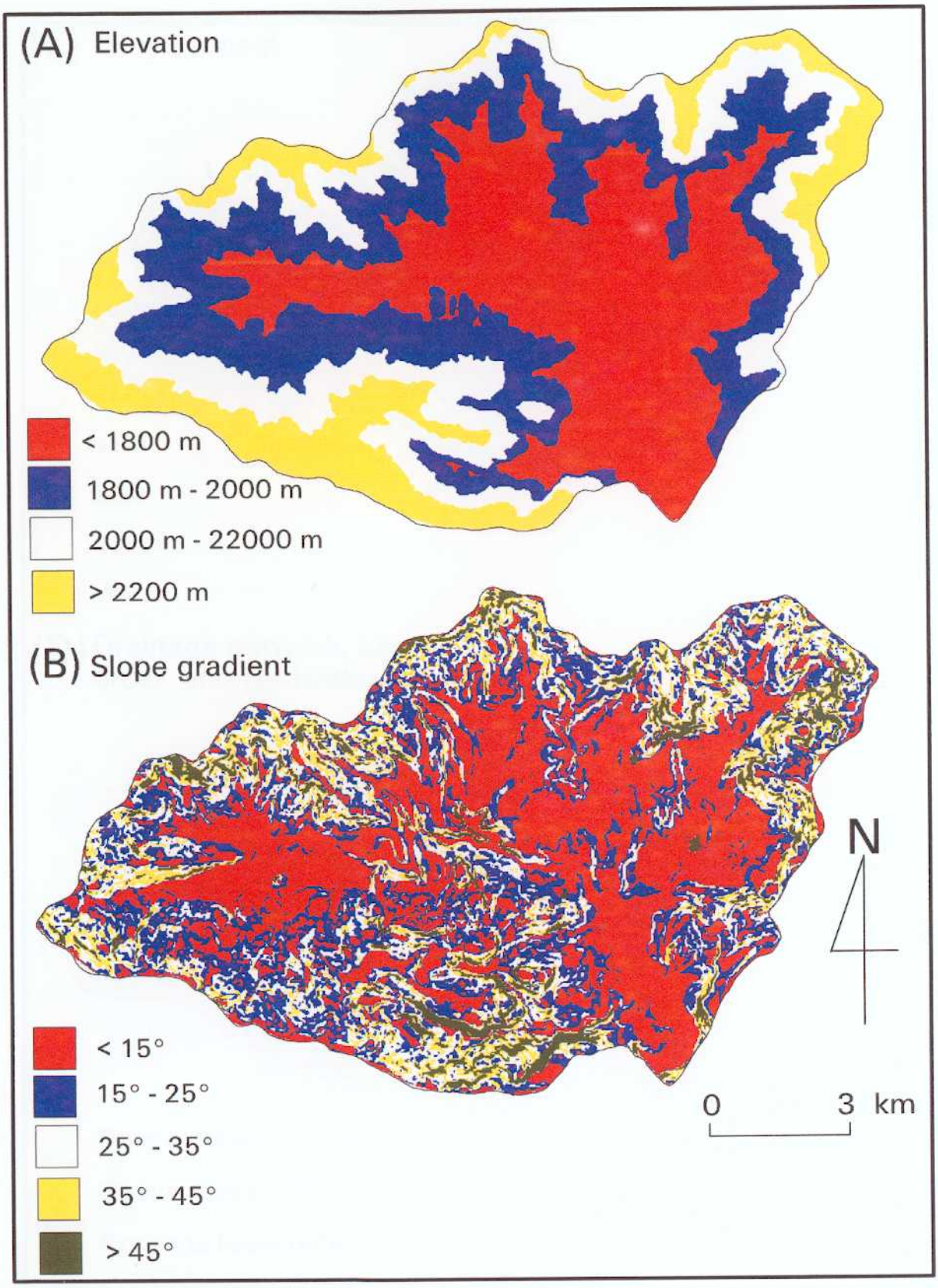

Figure 2-4 (A-F) Maps showing topographical, geological and land use/cover characteristics of the Kulekhani watershed.

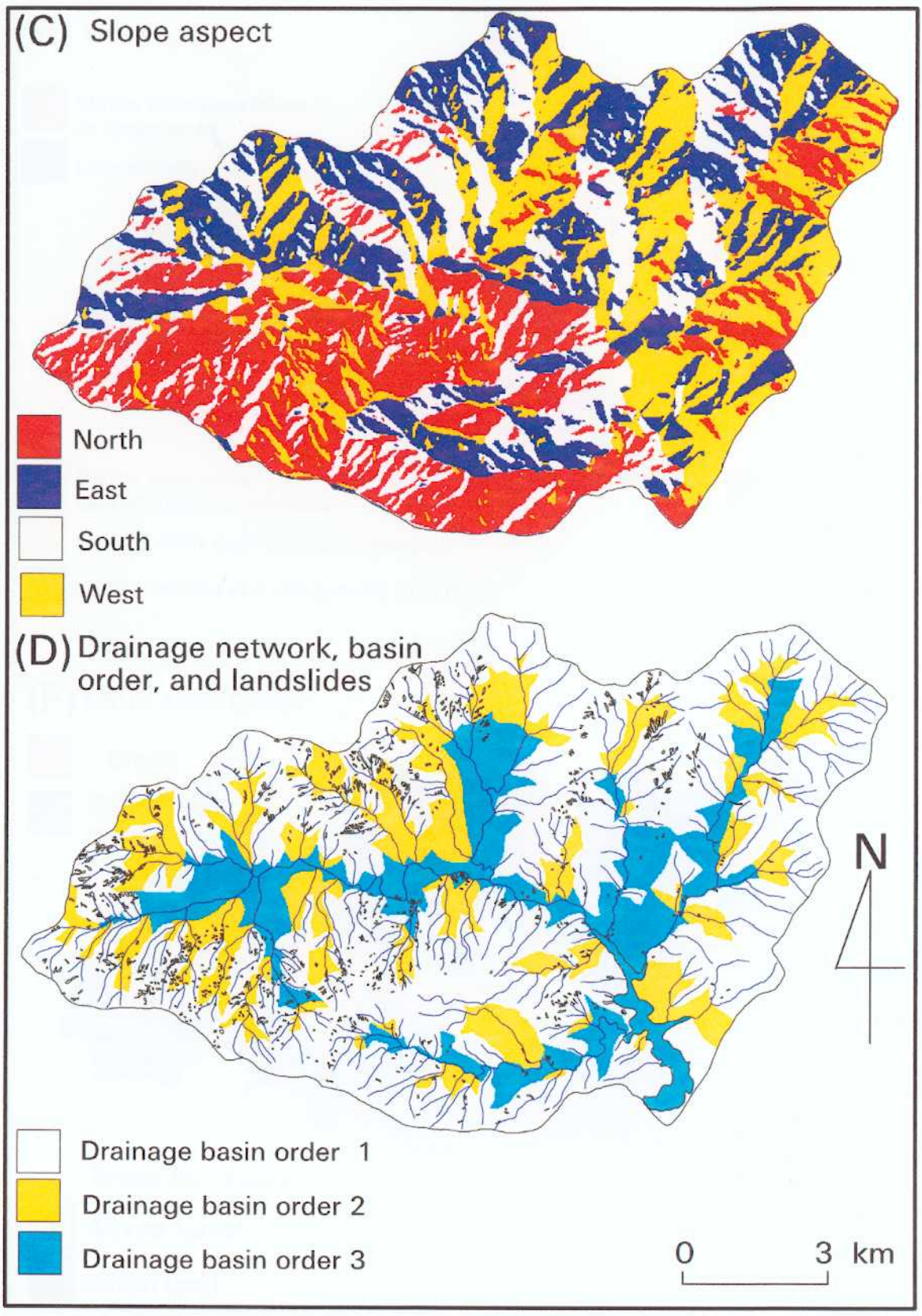

Figure 2-4 (continued; black spots in the bottom Figure are landslides).

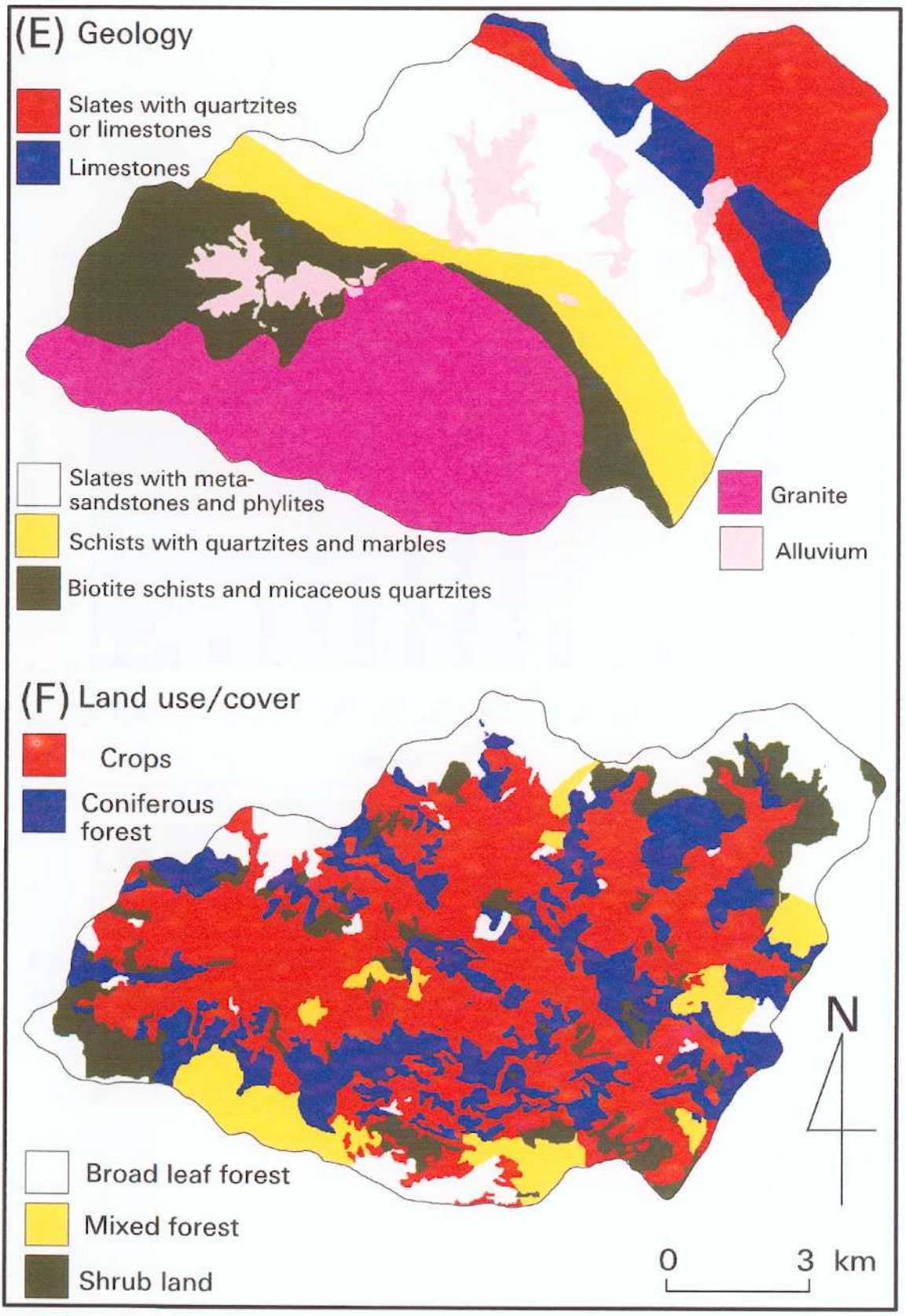

Figure 2-4 (continued).

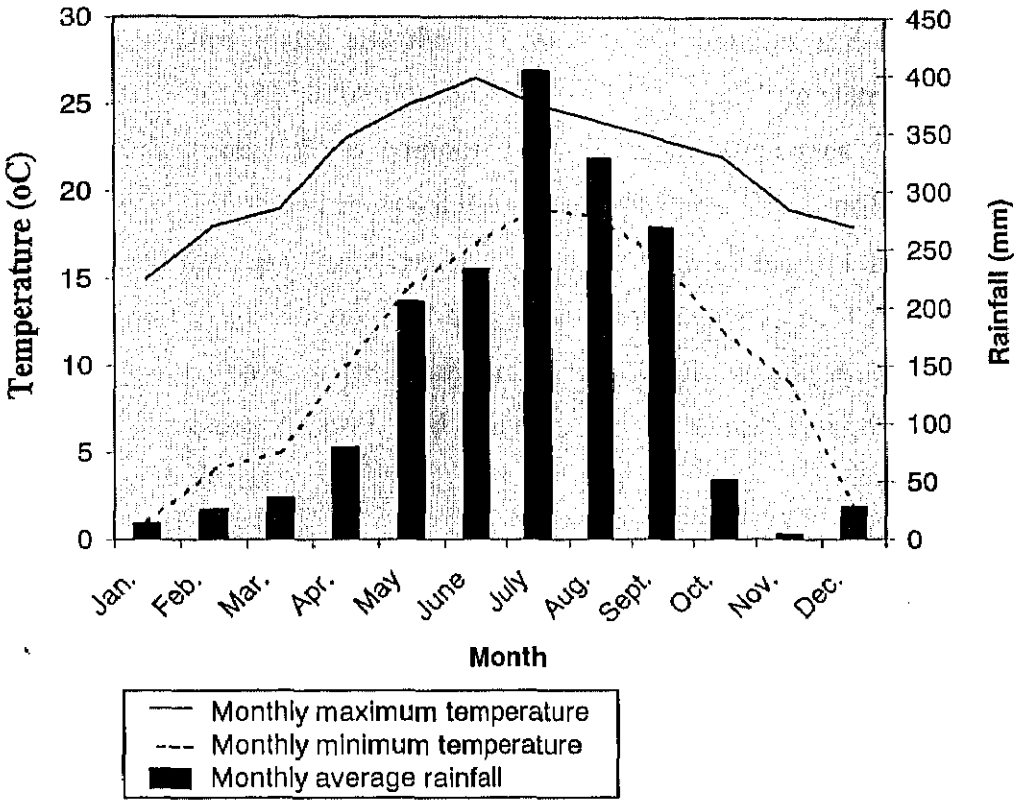

Figure 2-5 Monthly maximun and minimum temperature (1993), and monthly average rainfall (1982-1992) of Kulekhani watershed.

exposed in the study area on the northern part falls in the Bhimphedi group (with the exception of the granite area) and the southern part falls in the Phulchowki group. Phulchowki group can be divided into Chitlang formation, Sopyang formation, and Chandragiri limestone. Similarly Bhimphedi group can be divided into Tistung formation, Markhu formation and Kulekhani Formation. Chitlang formation (CF) is composed of phylitic slates and the intercalation of quartzites and calcareous bands. Sopyang formation (SF) is composed of soft weathered phylitic slates and limestones. Chandragiri limestone (CL) is composed of weathered limestones. Tistung formation (TF) is composed of slates, meta-sandstones and phylites. Markhu formation (MF) is composed of schists, phylites, quartzites and marbles. Kulekhani formation (KF) is composed of fine grained biotite schists and micaceous quartzites. Palung granite (GR) is the only igneous rock of the study area. It is deeply weathered and permeable. It contains sand, gravels, cobbles, and boulders derived from weathering of granite and decomposition of mica.

2-5 LAND USE/COVER

. The modified land-use/cover map of the study area (Department of Forest, Nepal, 1991) shows five categories of land use/cover (see Figure 2-4 (F)). They are crops coniferous forest, broad leaf forest, mixed forest, and shrub land. Crop occupies 43 percent of the total area, which consists of sloping cultivation, alluvial fan and terrace field. Among 44 percent of the total land being forest, coniferous species comprises 41 percent, broad leaf species 32 percent, mixed forest 18 percent. In total, crops (slope cultivation) occupies 35 percent of the total area, coniferous and broad-leaf forest occupies 18 percent and 14 percent, respectively.

The topographic characteristics for land use types are often important in the mountainous area from the viewpoint of mountain hazard. Distribution of the major land use/cover classes in slope gradient, slope aspect and elevation was calculated using land use/cover map, elevation map, slope gradient map and slope aspect map (Table 2-1). Eighty four percentage of the Crops (sloping cultivation) area falls in the region of slope gradient less than 30° and is concentrated in the lower elevation. In contradictory to the general trend of other watersheds in Nepal, crops (slope cultivation) are distributed slightly higher in North slopes. In Nepal, usually the percentage of slope

Table 2-1 Distribution of major land use classes in slope gradient, slope aspect, and elevation.

Land use classes	Area of land use classes in slope gradient (%)		Area of land use classes in slope aspect (%)		Area of land use classes in elevation (%)	
	$< 30^0$	$> 30^0$	South facing	North facing	< 2000 m	> 2000 m
Crops (slope cultivation)	84	16	44.7	55.3	82.1	17.9
Coniferous species	70.7	30.3	38.2	61.8	54.6	45.4
Broad leafed species	54.4	45.6	60.2	39.9	17.5	82.5

cultivation is greater on the south facing slopes because of the increased availability of sunlight. Broad leaf species are predominant on the higher ground.

2-6 LANDSLIDES IN THE STUDY AREA

The landslide distribution map produced from the interpretation of large-scale aerial photographs (1:20,000; discussed in section 5-1-1) is shown on the top of drainage basin order map (see Figure 2-4 (D)). Most of these landslides were triggered by the rainfall of July 1993, during which the Kulekhani watershed received the average rainfall of 385 mm. In Nepal, the landslide events are often encountered when an average daily rainfall exceeds 300 mm. These landslides had also caused debris flows on various streams. Among them the debris flows in Phedi and Kitini rivers were the worst in terms of human lives and property loss.

As the aerial photographs were taken during dry season, the landslides were distinct without vegetation cover. Altogether 1,246 landslides were finalized after vigorous field checking during which about 400 landslides plotted on the landslide distribution map was confirmed for their location. The minimum size of these landslides is 600 square meter, which was the size that could be surely identified on the aerial photographs in this case.

About one hundred thirty landslides were surveyed in detail for which basic parameters such as slope gradient, slopes aspect, land use/cover were measured. There were very few landslides in the southeast part of the watershed whereas a large number of landslides were located in the northwest part. Figure 2-6 shows the distribution of landslides in slope gradient measured in the field. Landslides are concentrated at 25°-45° with the highest concentration at 35°-45°. A large number of smaller landslides are located in the granite area, which is highly weathered and permeable. Most of these landslides are of transnational type in the engineering soil (Varnes, 1978). Larger landslides are located in the catchment of Phedi and Bisenkhel rivers. Field survey shows the large number of landslides in the south facing slopes. Sparsely vegetated coniferous forest showed greater number of landslides. As shown in the Figure 2-4 (D), landslides were concentrated in first order drainage basin.

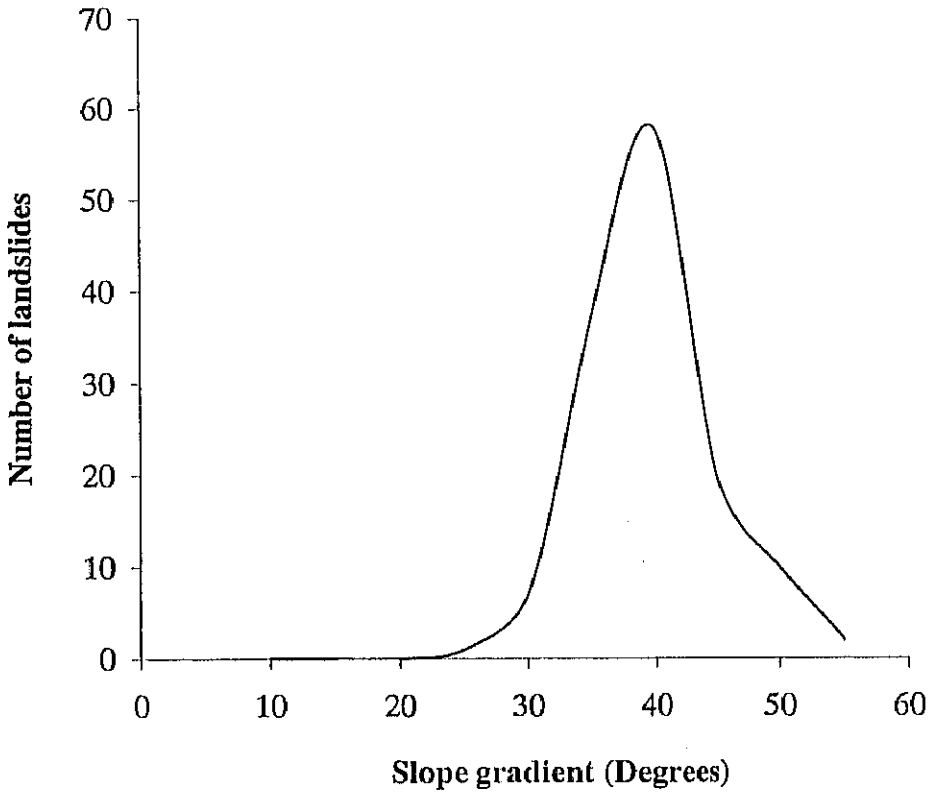

Figure 2-6 Distribution of landslides in the slope gradient measured in the field.