

# STUDY ON LANDSCAPE PROCESSES WITH SPECIAL REFERENCE TO LANDSLIDES IN LELE WATERSHED, CENTRAL NEPAL.\*

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## ABSTRACT :

The study addresses Nepalese landscape ecology in general, and landslides within the Lele Watershed of Bagmati Drainage Basin in particular. The study primarily interpreted aerial photographs of the scale 1:25,000 and larger which were used for the purpose of studying landslide dynamics and slope instability of the catchment area. Measurements for morphometric analysis were obtained in the field. Local people were also consulted for their perceptions about the occurrence of landslides and their management. Several maps showing geomorphological hazards, the landuse, and a profile of landslide development between 1972 and 1986 were prepared. The study concluded that the major environmental problem was created by the process of modernization, and increasing poverty forced people to depend on forest land, which has led to the further degradation of the area.

## 1. INTRODUCTION

*"Santan bigriyo Lata, Gunda le*

*Ghar bigriyo Randi, Randa le*

*Ban bigriyo Ainselu, Chutro, Kanda le"* (Manadhar and Khanal, 1988)

In other words,

Due to deaf and dumb, generation degenerated

Due to widows and widowers, family disintegrated

Due to thorny bushes and berries, forest degraded"

About 83% of the total land of Nepal is occupied by mountain slopes. Being a mountainous as well as tectonically active country, it has a high energy environment in terms of transfer of mass and energy. Therefore, the geomorphic processes operating in this country are very active and rapid. Landslide is one of them. It has many examples of landslide hazard. Studies on landslides in Nepal indicate that nearly 600 people die and 1000 houses are affected annually by large landslides and debris flow. The total financial loss is estimated about 300 million dollars annually (Dixit, 1988).

Most of the watersheds of Nepal are naturally unstable due to physiographic conditions. Cultural factors have led to man-induced acceleration of the already existing rapid natural erosion and landsliding processes. The scientific study of management of landscape ecology therefore is an urgent need in Nepal particularly in the context of environmental protection.

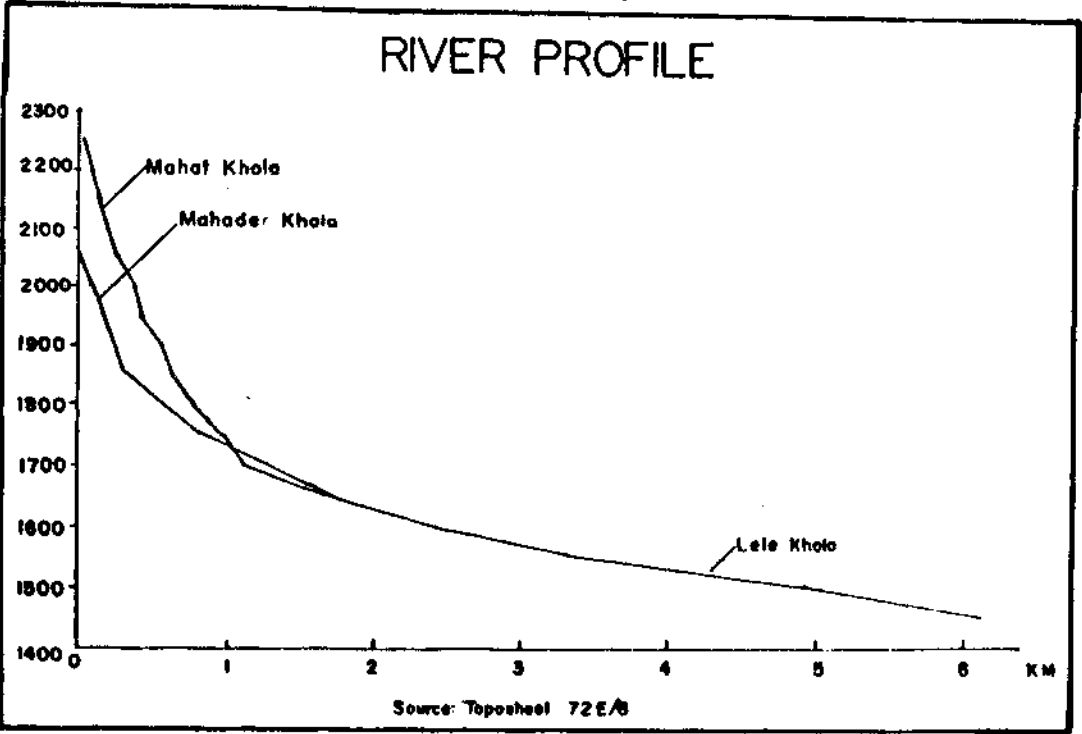
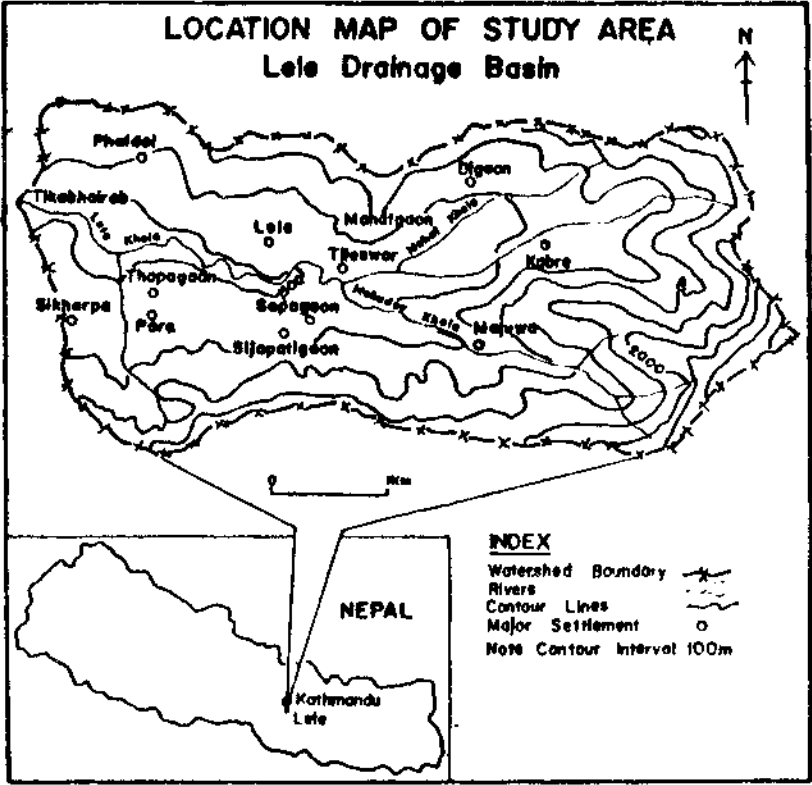
The present work attempts to study landscape ecology in general and specifically landslides within the Lele Watershed. This watershed is a severely affected by different types of landslides, is located near the densely populated region of southern Kathmandu Valley. Particularly, the exceptionally heavy rainfall in 1981 caused many landslides on the headward region of the watershed and deposited all the failure materials in the lower valley basin.

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of the total annual precipitation occurs in the monsoon period (June-Sept). Winters are comparatively dry months. Maximum 24 hour rainfall intensity recorded is 169 mm in September, 1981.

### 3.4 Natural Vegetation

Natural vegetation in Lele ranges from sub-tropical deciduous forest in the lower elevation (below 2000m) to temperate broad leaf forest above 2000 m. The major natural species of the lower region are Schinus Wallichii, Castanopsis Indica, Pinus Sp., Mirica Esculenta Sp., Michelia Champaca, Linn. Quercus Semicarpifolia Dentata, Quercus Lenuginosa Don, Rhodendron Sp., Myrsina Semicarpifolia, Quercus Spicata Smith are the major species of the moist temperate aera in higher altitude. More than 51 percent of the total forest area is covered by Pinus Sp. Due to the rapid rate of encroachment and emphasis of the plantation of Pinus Sp. in the area by the government, most of the previous natural species are being replaced by this species.

According to the local people, the forest was very dense in the past. Rapid forest encroachment started around 1955 and became more rapid 1961. The major causes are increase in the number of livestock, and commercial sale of timber and increase in fuelwood consumption. Even today, collection of Gol (charcoal) and sale of fuelwood is common. Timber is also sold illegally.

### 3.5 Landuse

Agriculture is by far the most important economic activity of the study area. Most of the flat lowland as well as the gentle hillslope is carved for agricultural purpose. According to the calculation based on the village Panchayat (now Village Development Committee) Record in 1985, the main landuse types in the Lele Catchment are given below: (Table 1)

Table 1

Types of Land use	Area in ha.	Percentages
1. Cultivated Land	327.6	52.8
a) Irrigated (Khet)	193.1	
b) Unirrigated (Pakho)	534.5	
2. Forest	585.0	42.4
3. Pasture and Grassland	7.7	0.6
4. Settlement	57.6	4.2
	1377.9	100.0

Source : Village Panchayat Records, 1985

More than 52 percent of the total land is under cultivation. The percentage of cultivated land derived from air-photo interpretation is 39.5 percent. The lower percentage of arable land derived from aerial photographs is mainly due to the distribution of unmapable size. Again, the higher percentages of arable land recorded in the tendency of the people to claim ownership of more land at the time of survey. More than 42 percent of the total land is under forest. The areas occupied by pasture and grass and settlements are 0.6 and 4.2 percent respectively.

### 3.6. Population

The study area currently is inhabited by 1,080 households with a total population of 6,063 (Panchayat Record, 1985). The annual growth rate of population between 1971 and 1981 is 1.75 percent. This rate is lower than the national average (2.66%) and slightly higher than mountain and hill area (1.65%). The density of population in this area is 422 person /km<sup>2</sup> which is higher than national average (102 Person/km<sup>2</sup>).

LAND USE MAP OF LELE DRAINAGE BASIN

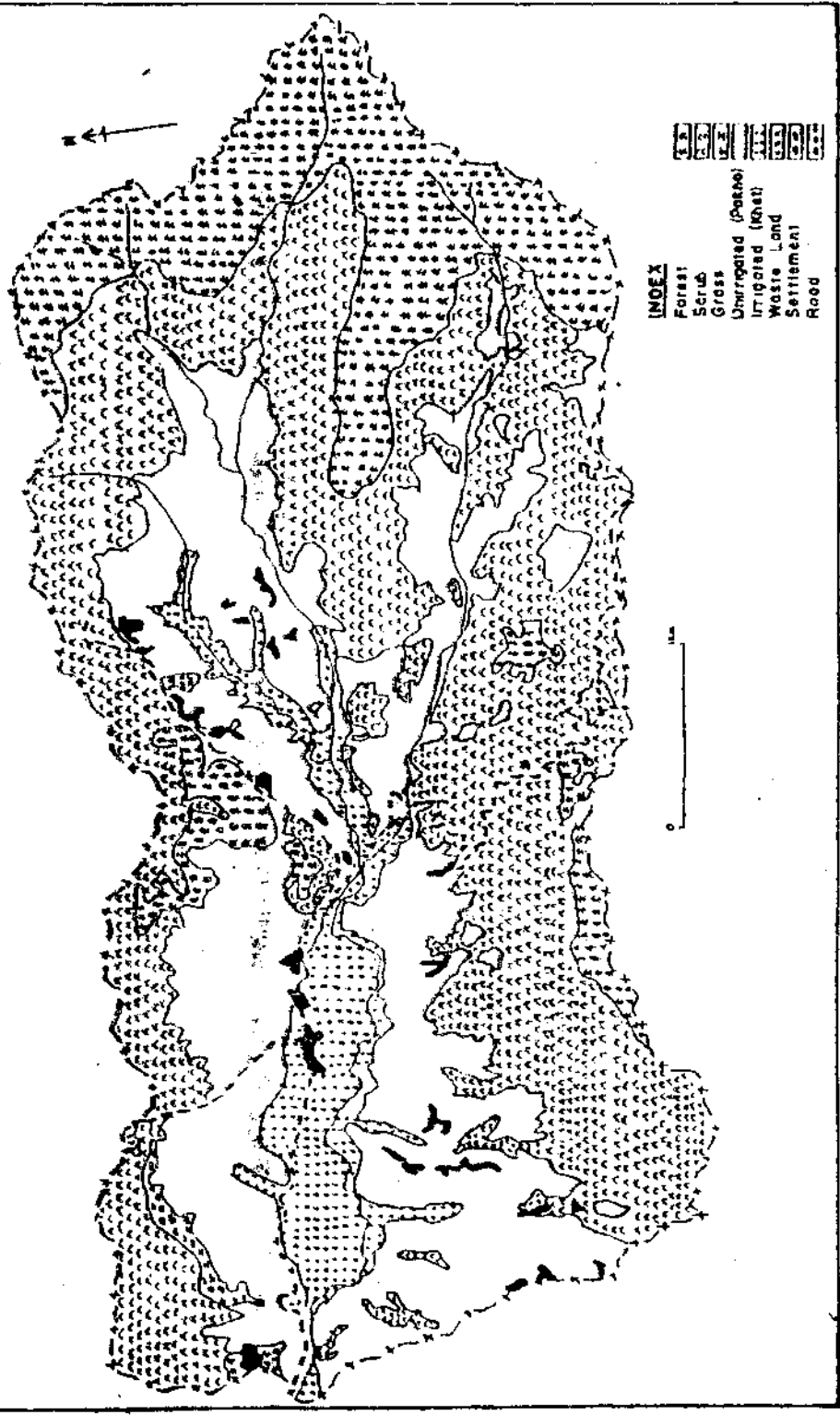


FIG - 3

The village population is composed of different caste and ethnic groups like Chhetri, Tamang, Newar and Nagarkote. The percentwise distribution of ethnic groups of population in the catchment area is given in Table 2.

Table 2

Ethnicity/Caste group	Population	Percentage
1. Chhetri	2800	46.2
2. Tamang	1900	31.3
3. Newar	700	11.5
4. Nagarkote	500	8.2
5. Others	163	2.7
Total	6063	100.0

Source : Lele Village Panchayat Records, 1985.

#### 4. GEOLOGICAL SETTING OF THE AREA

##### 4.1. Geological Formation

Lele catchment lies in the Central Mahabharat Region of Nepal. This region is structurally controlled by a syncline with an EW axis and controlling the alignment of principal mountain ridges and valleys of the study area. This range is thrust steeply southward over the Siwalik belt along the Main Boundary Thrust (MBT). The structure of the study area can be divided into two major divisions: a) Recent alluvium, and b) the Phulchoki Group of Palaeozoic sediments.

##### 4.1.1. Recent Alluvium

The recent alluvial deposits occupy the central zone of the catchment area. It covers a broad region of the lower river valley floors. This deposit consists of gravelly silt and sandy loam. Several levels of fluvial terraces have been developed in the basin. The upper parts of the fluvial terraces are mixed with gravelly and sandy footslope materials.

##### 4.1.2. Phulchoki Group

This group consists mainly of limestone and subordinate zones of shales and sandstones with the thickness of 3000 m to 4000 m (Mineral Exploration, 1981). This group can further be sub-divided into four units.

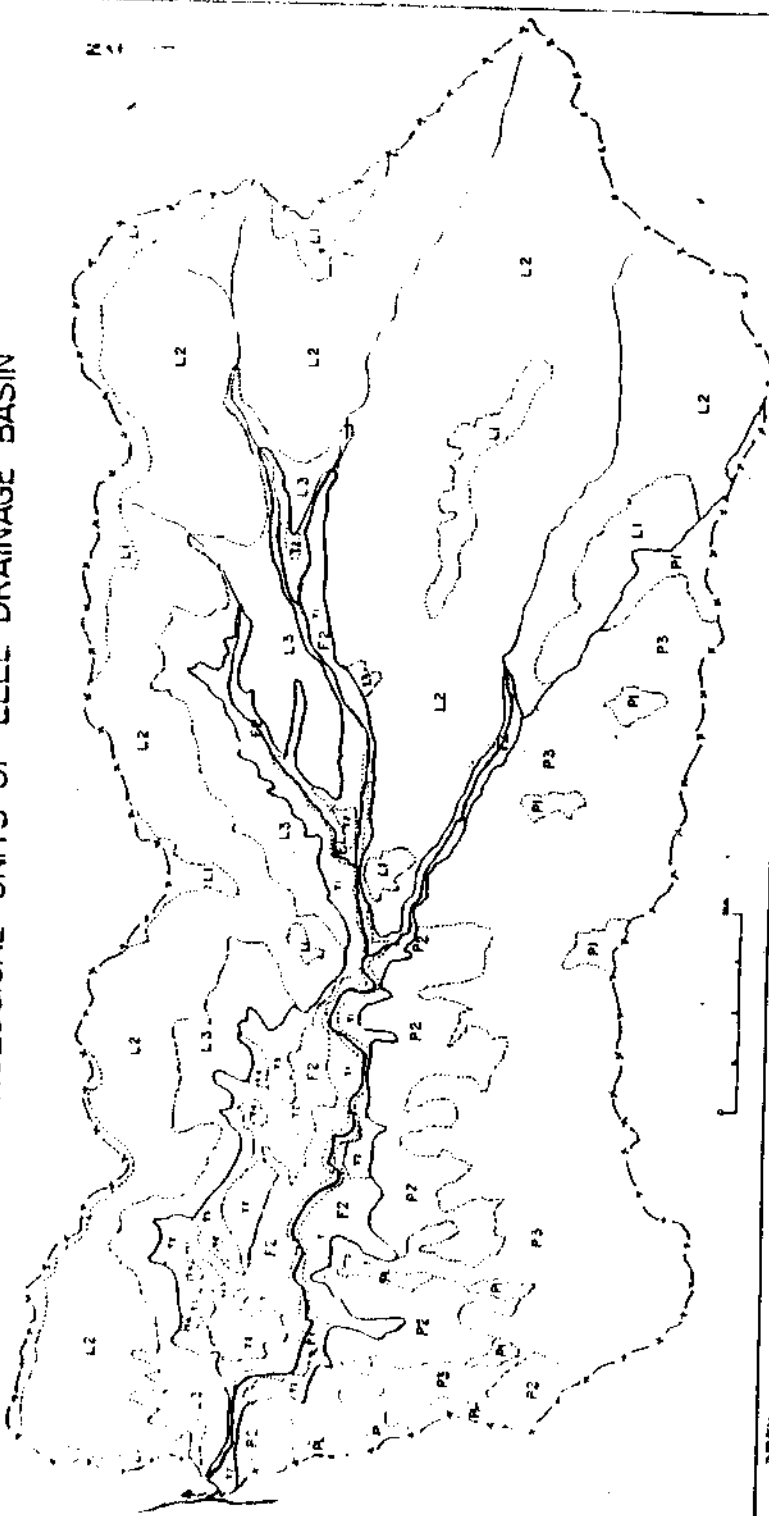
Chandragiri limestone formation is among the important ones of the Phulchoki Group. This unit is widely spread from west to east in the central parts of the study area. The main rock type is yellow or brown weathered limestone, partly silicious and dolomitic, containing decomposed pyrite. The colour ranges from white and yellow to plane green and pink. The lower layer limestone is more argillaceous and thinly bedded with the thickness of 2000 m to 2500 m.

The other three sub-groups like Sopyang, Chitlang Slate and Tistung formations are distributed in small areas in different regions of the watershed. Sopyang formation occupies a narrow belt in the south of the catchment. It is a transition between Chandragiri and Tistung formations with a mixture of the lithology of both formations. Rocks are soft and easily weathered phyllitic slates, argillaceous to marly in composition and thinly bedded with 100 m to 300 m thickness.

Chitlang Slate formation overlies the Ordovician Chandragiri limestone which forms the true core of the Chandragiri Syncline (Mineral Exploration, 1981). It consists mostly of dark, soft and weathered slates. It is concentrated only in the NE parts of the study area.

Tistung formation consists essentially of slates, phyllites and metasandstone. It is spread only in the NW ridges of the study area with the thickness of 3000m. The weathered rocks are mostly intense pink, blue, violet and purple in colour.

# GEOMORPHOLOGICAL UNITS OF LELE DRAINAGE BASIN



**INDEX**

- Forms Of Fluvial Origin (Recent Deposits)
- Flood Plain
- Fluvial Terraces T<sub>1</sub>, T<sub>2</sub>, T<sub>3</sub>, From Young To Old
- Forms Of Structural Origin Mainly In Limestones
- Undulating/Gently Sloping Round Crest Zone
- Steeply Sloping Zone
- Foot Slope Zone
- Forms Of Structure/Overthrust Origin, Mainly in Flysch
- Gently Sloping Round Crest Zone
- Moderately Sloping Zone (Moderate To Highly Dissected)
- Steeply Sloping Zone (Highly Dissected)

### 4.1.3. Lineaments

Lineaments are usually related to the bedrock geology. These are frequently observed in the phyllites, schists and impure quartzites of the study area. The processes of interpreting aerial photography has resulted in the identification and recording of five major lineaments in the study area. Most of these lineaments are in the NW-SE direction.

## 5. GEOMORPHOLOGICAL SETTING OF AREA

### 5.1 Geomorphological Units

The Lele Drainage Basin, on the basis of lithological units, has been divided into three major landscapes, such as Fluvial land forms coded as (F), Those of structural origin mainly in limestone (L) and those of structural/denudational origin mainly in phyllites (P). Sub-units of the main landforms are coded by numbers like L1, L2, L3 etc. A brief description of each landscape and its sub-units is as follows:

#### 5.1.1 Forms of Fluvial Origin (F)

The main valley bottom of Lele and its tributaries constitute the fluvial landscape. These are mainly related to areas of fluvial accumulation. Flood plains and river terraces are included under this unit. The lower basin of the western part of main Lele river is wider than the upper region in the east. The slope gradient is approximately 10 percent with the coverage of 2km<sup>2</sup> (nearly 12%) of the total study area. It can be divided into two sub-units.

a) Flood plain (F1) unit occupies the central zone of the fluvial landscape, which is regularly flooded during the monsoon period. The absence of grasses and bushes indicates high frequency of floods during summer. The relief is almost flat with the gradient 0-2 percent.

b) Fluvial Terraces (F2) developed along the both upper parts of the Lele river. It is generally characterized by nearly flat to gently sloping surfaces. These terraces are composed of alluvial materials carried down by Lele river. Sub-divisions like T1, T2, T3, etc. are made according to their elevation which also relates to the time of their formation. Lowest terrace T1 is sometimes affected by floods during heavy rainfall.

#### 5.1.2 Forms of structural Origin mainly in Limestone (L)

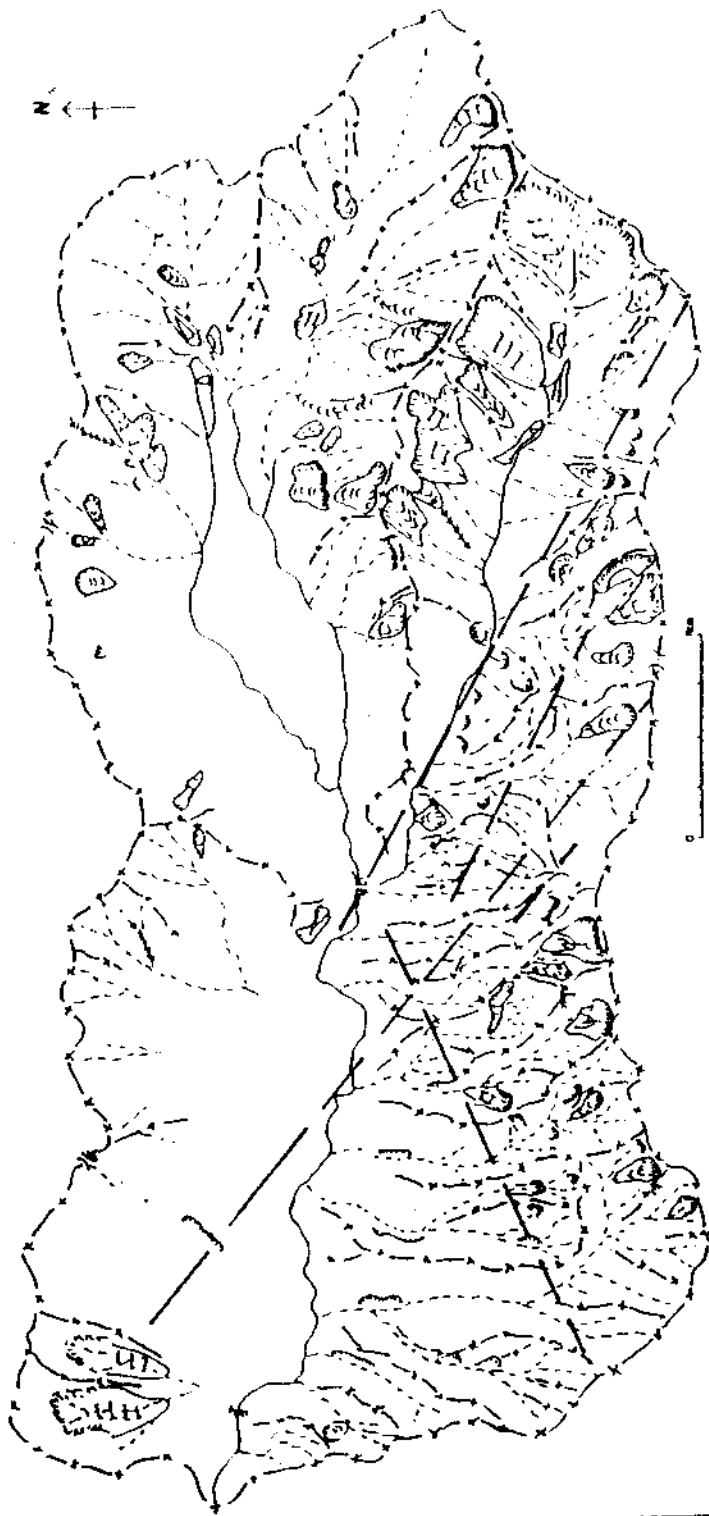
Structural landscape of limestone origin occupies an extensive area in the northern and eastern hills of the watershed. The lithology of this form is mainly of light-brown weathered limestone to argillaceous limestone. The altitude varies from about 160m to nearly 2400m above sea level. Due to the coverage of thick forest and bushes in most of this unit as well as the permeability of rock, the drainage density is relatively low. The area covered by this landform is 10.8 km<sup>2</sup> or nearly 61 percent of the total area. On the basis of slope and relief amplitude, this form is further sub-divided into three units (fig 4).

Undulating/Gently Sloping Rounded Crest zones (L1) unit occupies most of the crest zone of the limestone area. From the landslide hazards point of view, this is a relatively stable zone. The second unit, Steeply sloping zone (L2) is wide-spread within the limestone landscape. Due to the steep nature, many types of landslides developed especially after the heavy rainfall of the year 1981. The last unit Footslope zone (L3) occurs in the lower parts of the limestone area. It is characterized by gentle slopes with an average gradient of 14<sup>0</sup>. This Unit is formed by colluvial processes transporting materials from the upper parts of the limestone area.

#### 5.1.3 Forms of Structural/Denudational Origin, mainly in Phyllites (P)

This landscape occupies nearly 5 km<sup>2</sup> (27%) of the total area of the catchment. This unit covers almost the entire south-western parts of the catchment. The lithology is diversified and is of mixed nature with the dominance of phyllites and schists. The drainage density is very high in this region. The elevation ranges from 1600m to 2000m above sea

# GEOMORPHOLOGICAL AND SLOPE INSTABILITY MAP OF LELE DRAINAGE BASIN (1986)



## LEGEND

### Geomorphological Details

- Stream With Water
- Stream Without Water
- Foot Slope
- Lineament
- Head Scarp

- Gully
- Erosion
- Landslid (Rotational Slide or Slump)
- Planer or Rock Slids
- Debris Slide
- Debris Flow

### Topographical Details

- Watershed Boundary
- Bridge
- Dam
- Bhamiyang (Pass)
- Active Slide
- Inactive Slide



level. This unit can be sub divided into three groups (Fig 4).

Gently Sloping Rounded Crest Zone (P1) is wide-spread in several interfluvial regions of the Structural/Denudational Landscapes. This is the remaining part of the denuded areas. Most of this area is occupied by settlements and cultivated lands due to the nearly flat to gentle slope character. Moderately Sloping Zone (P2) is characterized by 15-20 percent slopes. The elevation ranges from 1600m in the fluvial parts of the lower basin upto 1800m above sea level. The drainage density is moderate to highly dissected, depending upon the rocks. The weathered zone is severely affected by laminar erosion. Steeply sloping zone (P3) is mostly located all over the higher parts of Structural/Denudational Landscapes. In steep to very steep slopes severe dissection has occurred in deforested and highly grazed lands.

## 6. LANDSLIDE FORMS AND PROCESSES

### 6.1 Landslide Morphometry

A total of 743 landslide scars were counted from aerial photographs of 1986 while there were only 93 in 1972 aerial photographs. The changes in the density of landslide scar between these two years are shown. Due to the unmapable size of many landslide scars the map does not show all of them.

Majority of landslides are shallow in nature. The average depth, width and length of the scars are 1.36m, 10m and 15m respectively. The longest landslide which was observed at the time of field work is 100m. The total aerial coverage of landslide scars is 9.7 ha. (0.74%) of the total area of the watershed contributing to a total soil loss of 131,429.27m<sup>2</sup>. This loss gives 10mm denudation of the hillslopes as a whole and 9mm for the single event of Sept. 30, 1981.

All materials from the landslide areas are transported to the lower valleys where the gradient of the channel decreases by 10 and less. The deposited materials ranges from silty sand, fine-grained sand-stone to cobbles and boulders up to a diameter of 3 meters. The major rivers are active in downward as well as lateral cutting of these previously deposited materials at the time of debris flow in its channel. The upper tributary stream has cut its channel bed vertically up to 2m below the level of flood plain after the 1981 event.

### 6.2 Types and Characteristics of Slope Movement

In this study the classification of mass movements is based on that followed by David J. Varns (1978). The main criteria in his classification were type of movement (primary) and types of materials (secondary). Several types of landslides and erosional features have been recognized in the study area. A brief description the characteristics of each type which is mapped is given below.

#### 6.2.1 Slides

Within this type are enclosed all those movements of coherent masses along one or more well defined shear surfaces. Two main kinds of slides can be recognized from aerial photographs, these are slides in rocks (translational), and slides in soils (rotational). The two kinds of slides are very easily distinguishable on aerial photographs of larger than 1:25,000 scale.

Rotational slides (slumps) are deep-seated consisting of weak material along a curved plane and have been found wide-spread in the catchment. Many large slumps are identified in 1986 photographs. The translational slides have generally occurred in large numbers over the hillslopes of the phyllites zone of the catchment.

#### 6.2.2 Flow

This includes mass movements in rocks and soils analogous to the movements in liquids. Flows usually occur in loose materials especially in clay-rich shales which become

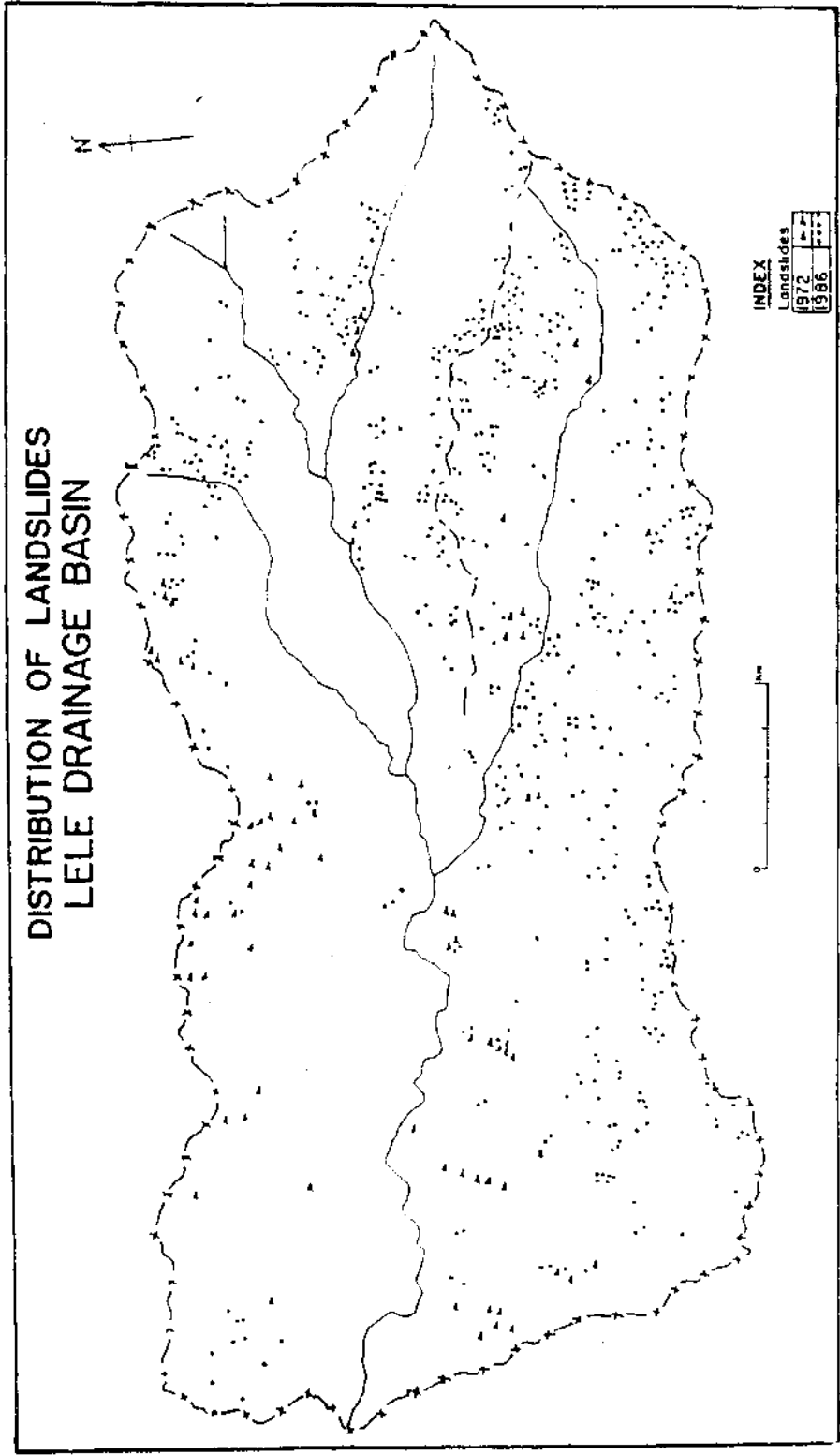


FIG - 6

saturated with viscous semi-liquid movement. These are found usually below rotational slides. According to the local people many big flows occurred during the time of heavy rainfall of 1981 in the catchment.

### **6.2.3 Creep**

This type includes long-term movement of non-increasing velocity without a well-defined sliding surface (Zaruba and Mencl, 1969). Creep process may lead to different types of mass movements if the creep is accelerated by any reason. Creep is restricted only to few areas of the catchment. Due to the difficulty in identification, preliminary interpretation of aerial photographs could not trace creep features but were noticed in the study area only after field work.

## **6.3 Types and Characteristics of Erosional Features**

The Lele catchment is not only affected by the landslide hazards but also has problems from various types of erosional processes. Among them gully, headward erosion and rill are notable. A brief description of some of the visible erosional features shown in the maps is given below.

### **6.3.1 Gullies**

Gullies are steep-sided ravines measuring several metres in width and depth. Although it is wide-spread in the study area only identifiable gullies are shown in the map.

### **6.3.2 Head Scarps**

Many head scarps are identified in the aerial photographs of the study area. They spread both on hill slopes as well as on the fluvial deposits. Most scarps are found in the upper parts of the slide features. Many elongated scarps are identified along the steep sides of the valley walls in the catchment.

### **6.3.3 Rills**

Rills are smallest erosional forms in the soil surface and regolith. These are wide-spread all over the catchment especially near the filling of the road cuts.

## **6.4 Causes of Landslides**

Landslides occur under the influence of various factors as evident in the Lele catchment. The mechanical properties of the deeply weathered metamorphic bedrock, the high relief characterized by very steep slopes, the increase in water pressure during and after heavy monsoon rains, tectonic movement etc. are major natural factors for initiating landslides in the study area. Anthropogenic factors such as agricultural grazing practices on hill slopes, excavation of stones, slates and clays, construction of dirt road on the steep slope area, etc. also accelerate already existing natural landslide processes.

Some prominent factors responsible for the occurrence of landslides in the study area, are discussed below.

### **6.4.1 Climate**

According to local people, very dry spring accompanied by heavy precipitation in late summer is a favourable climatic condition for the initiation of landslides in this area. For example, exceptionally heavy precipitation was experienced on 30<sup>th</sup> September, 1981 after the dry winter and spring months. Although the exact intensity of this precipitation event is not recorded, the heaviest rain started at 8.30 AM in the study area and continued only for 40 minutes and caused landslides and debris flow in this area. In addition the rise in water table at time of heaviest precipitation occurring in late monsoon seems to be another important cause of landslides initiation (Cane & Moof, 1982).

#### **6.4.2 Lithology and Structure**

Most of the hillslopes of the study area are composed of shale, gravels and weak sandstone. There are many horizons of carbonaceous shale containing pyrite in this area. These shales when exposed to the atmosphere turn into sulphuric acid. Chemical weathering of such rocks then generates landslides. All the large slides of this catchment occur on the slope of dip direction and plain of weakness also coincide with the occurrence of landslides in this area.

#### **6.4.3 Deforestation**

Many landslides are located on sparsely vegetated hillslopes either near the village of the crest region. Slopes near the villages are highly encroached by the people from Naldum (nearest neighbour) for the preparation of Gol (charcoal). Only few landslides are noticed in thickly vegetated area near Phulchoki Range. Location of majority of landslides on destabilizing hillslopes indicates the role of deforestation is destabilising will slopes in the study area.

#### **6.4.4. Mining and Quarrying**

Excavation of stones, clays and slates for building material and other construction purposes also contribute to slope failure in the catchment. For example, large scale quarrying of limestone in many parts of the catchment is one of the causes of active landsliding processes in the area. Excavation of limestone in this area started from the year 1980. Many landslides could be traced in the aerial photographs which are located on the upper parts of the quarrying area.

#### **6.5 People's Perception and Responses**

Local people are fully aware of the danger of landslides. Their perception about the causes of landslides ranges from God's wrath due to the increasing economic disparity, to heavy rainfall and deforestation in the area.

They perceive that environmental deterioration has accelerated in recent years. Their economy is based on subsistence agriculture and needs more labour force for the construction as well as the maintenance of already existing terraces on the hill slopes. But with the development of educational institutions in the village and motivation of local people to send their children for education, only a few children are engaged in agricultural activities. Due to this reason the problem of labour is increasingly being felt in the agricultural sector. At the same time agricultural production is decreasing while there has been a steady increase in population. Short term migration of economically active population in search of work has also created the problem of required labour force for maintenance of previously constructed terraces in the hills which has directly led to the increase in soil loss and further degradation of land. Due to the poor economic condition of the village, people have to depend heavily on forest resources. Besides, the collection of Gol (charcoal) by the poor by causing forest fires, especially Tamangs of the surrounding hills, has induced the rapid rate of deforestation and land degradation in the area.

Local people are anxious about the future growth of the forest, because the dense forest of the past has already degraded into thorny bushes and shrubs. They are trying hard to protect their whole forest strictly but the poor economic situation, the need of fuelwood and the lack of other alternatives has compelled them to encroach the forest land. In spite of prohibition, the local people have also used several illegal means to dry the trees so that they can use these wood later on for fuelwood. Villagers are trying hard to stabilize landslides scar areas by the construction of retaining walls and the plantation of trees in the susceptible zones. Due to the absence of appropriate environmental management practice their efforts seem futile in the study area.

Local people perceive that now a days not only the occurrence of landslides but also other forms of geomorphic processes have been increasing in their intensity. According to them the environmental deterioration in the study area includes the process of construction works, on the one hand, and increasing poverty which forces them to depend on forest land, on the other.

## 7. CONCLUSION AND RECOMMENDATION

### 7.1 Conclusion

The study area is naturally unstable due to physiographic, climatic, and geologic conditions. Socio-economic factors such as lack of the maintenance of terraces, construction of roads, mining and quarrying etc. have also led to man-induced acceleration of the already existing rapid landsliding processes.

There was a big jump in the number of landslide scars in 1986 aerial photographs compared to 1972. Both intrinsic factors like slope form, lithology and tectonic activities as well as extrinsic factors such as climate, especially heavy precipitation, and deforestation induced by human activities are responsible for land degradation in the study area.

Construction activities cannot be planned without avoiding potential hazard areas, which may damage lives and properties in near future. These potential hazard areas cannot be seen or observed easily in the field without using recent aerial photographs.

### 7.2 Recommendations

Based on the finding of the present study, the following recommendations have been suggested for further study on landscape processes :

a) The major environmental problem in the study area has been created by mismanagement of land resources. So management of resources is an urgent need of this area. For example, the illegal cutting of timber and Gol (charcoal making) collection should be strictly prohibited. Local people should be consulted at the time of selection of species for afforestation programme. Mining and quarrying in the area should be guided in such a way that there would be no adverse effect both on hillslope and downstream landscape.

b) Further research on landscape processes in hilly regions of Nepal will be helpful for a more comprehensive understanding of the environmental processes in the area.

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