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Naturally Induced Hazards in the Agra Khola Watershed, Central Hills, Nepal

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Abstract

Mountain watersheds are fragile and susceptible to landslide and erosion. However, the occurrence of landslides is controlled by various physical parameters viz., elevation, degree of slope, drainage density, geology, land-use /land-cover etc. This paper attempts to analyse the relationship between these physical parameters and landslide occurrence in the Agra Khola watershed by using geographic information system (GIS). In the study area, the landslides were found to occur mostly between 1500 - 2000 meters from AMSL, from 60 - 100 percent slope area, in less drainage density area, quartzite and schist rock type area and in sloping terrace area.

Keywords: *GIS, landslide,natural hazards, geology elevation, slope, drainage density.*

Introduction

Mass movements probably constitute the most common and dreaded hazards to the mountain people all over the world. Natural hazards occur as an inherent phenomenon in the mountain region of Nepal which with its massive mountain has always faced the problem of landslides. The watersheds of Nepal have fragile ecosystem and a great contrast in climatic condition over a short physical distance. Elevation, slope, drainage density, land-use/land-cover, etc are considered as important parameters in Nepal which directly cause landslide hazards at varying degree.

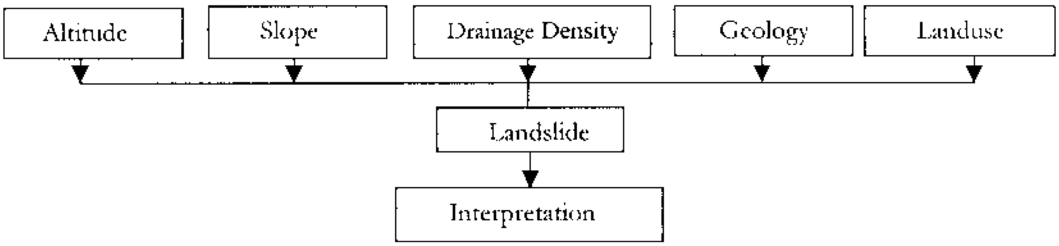
Analysis of landslide hazard assesses land damages, land depreciation and sedimentation problem which are important to know because they affect hydro-electric dams, flood control structures, bridges, roads and irrigation channels etc. Mitigation of landslide disasters can be successful only when a detailed survey of frequency, character and magnitude of the mass movement of an area is known before the next hazard of similar nature. The zonation of landslide hazards would provide a basis for landslide mitigation, which should be available to planners and decision-makers. A reliable hazard map depicting such information is considered an important tool. In this context, the present study analyses different parameters that cause to occur the landslide hazar in the Agra Khola watershed. This watershed is one of the most affected area of the 1993's landslide hazard. It is expected to provide a basis for the planners to design measures to mitigate the land degradation in the hills of Nepal.

Methodology

The analysis is based on Geographic Information System (GIS) using ARC/INFO Software. The main attributes used include altitude, slope, drainage, geology and land-use/ land-cover (Maps 1-8). The analysis is based on overlaying of each of the physical layers onto the landslide coverage. These data layers were captured from the aerial photo (1:50000), topo-map (1:25,000), Land Resource Mapping Project (LRMP) map (1:50,000) and geological map (1:50,000) of the study area. These base maps were analysed through using computerised Geographical Information System (GIS) tool. The mapping analysis of each of the parameters considered is interpreted in terms of table information. The field verification in the study area was carried out in September 1995 (Fig. 1).

Fig. 1

Relation between landslide and different parameters



Study Area

Location

The Agra Khola watershed is located in the Mahabharat hills, Central Hill Region of Nepal. It occupies 112.6 km² in the drainage basin of the Agra Khola, and is located within 27°38' N to 27°46' N latitudes and 84°56' E to 85°7' E longitudes. The elevation of the watershed ranges from 600m in the northern end at Mahadevbesi to 2504m in southern end. The major tributaries of the Agra khola are the Chalti Khola, the Lapse Khola, the Hakarti Khola, the Liti Khola, the Narayan Khola, the Bahun Khola and the Bhasme Khola. The pattern of the Agra Khola drainage system is dendritic. The total length of all streams is 32.57 km. The mean length of the stream segment is 0.54 km with maximum length of 2.22 km and minimum length of 0.94 km.

The Agra Khola basin forms a part of the western closure of the Mahabharat synclinorium in the western central sector having SE to NW trading axis and controlling the alignment of principal mountain ridges and valleys. The basin is composed of soft rocks, namely phyllite, schists, limestone and quartzite that account for its subdual topographic form, lower relief and deeper weathering horizon. Cultivated land, forest, shrubland and grazing land are dominant types of land units in this watershed. The climate varies from sub-tropical to temperate.

Magnitude of Landslide

Dhital et al (1993) indicated that several landslides had occurred in the watershed area due to heavy rainfall. The first of such hazard took place in 1954. Similar events took place in 1970 and 1974. In July 1993, huge amounts of debris was accumulated in the valley floor. This resulted into a great loss of life and property and severe damages to the roads and bridges along the Tribhuvan and the Prithivi highways. The most strategically located bridge at the Mahadevbesi was swept away and the Prithivi highway was interrupted for four months. This heavy downpour had swept away several mills, water turbines and houses and more than 45 people of the Agra Khola watershed were killed.

The field survey carried out in 1995 showed that the total landslide area had covered 270.87 hectare, making up 2.41 percent of the total watershed area. The major landslides were concentrated in Chisapani, Chaubas, Dandabas and Chhap areas (Fig.9). Large landslides were common especially in the north facing dip-slopes. The depth of the landslide in the study area ranged from 0.5m to 20m. Major mass movement types included debris slide, debris fall, debris flow, complex slide and deep rotational slide. The mass moved out of the slide from the steep slopes of the mountains containing a huge amount of sediments from the high flood. The toe cutting along the bank of the khola also accelerated the landslides and debris. It increased the sediment outflow. The heavy rainfall (540mm on 20 July 1993) and high floods also caused sheet erosion, rill erosion and gully erosion, which contributed substantial amount of sediments into the stream. The volume of the sediments produced from the landslide in the basin was estimated to be 21.00 million m^3 (Thapa, 1995).

The Parameters and the Landslide Relationship

The parameters observed in the analysis of landslide included geology, land use/land cover, slope, drainage density and elevation. Each parameter was classified into different groups and their spatial coverage was computed. Each of the parameter coverage was overlaid on the landslide coverage and the result was obtained.

Altitude and Landslide

The distribution of the existing landslides in different altitude zones is not even. (Table 1). Almost sixty percent of the landslide area is found to be between 1500 - 2000 m altitude zone. The intensity of the landslides has increased along with the increase of altitude. But over 2000 meter, the landslide area has decreased which may be due to the relatively flat topography on the top of the hill.

Table 1
Landslide and Altitude zone

Altitude Zone (meter)	Area (ha)	Percent	Area of Landslide (ha)	Percent
Below 1000	1633.59	14.51	0.79	0.29
1000 - 1500	4427.57	39.31	69.84	25.79
1500 - 2000	3918.70	34.79	160.05	59.09
2000 and above	1282.50	11.39	40.18	14.83
Total	11262.36	100.00	270.86	100.0

Source: Based on altitude zonation and landslide map, Department of Survey, 1994.

Slope and Landslide

The largest landslide area has occurred on the gentle steep slope zone (Table 2). The steeper slope class is generally more liable to higher landslide process because the energy of gravitational pull increases with the steepness of the slope. The highest proportion of landslides has occurred on the steep slope class of 60-100 percent while the valley slope class below thirty percent has the least proportion of area.

Table 2
Landslide and Slope Class

Slope Class	Slope in Percent	Area (ha)	Percent	Area of landslide (ha)	Percent
Valley slope	Below 30	231.65	2.06	7.83	2.89
Mid-hill slope	30 - 60	3237.32	28.74	74.41	27.47
Gentle steep slope	60 - 100	6230.16	54.43	166.20	61.36
Very steep slope	100 and above	1663.22	14.77	22.42	8.28
Total		11262.35	100.00	270.86	100.0

Source: Based on slope class and landslide map, Department of Survey, 1994

Drainage Density and Landslide

Table 3 shows that existing landslides in different drainage density classes are not evenly distributed. The landslide areas have increased towards the lowest drainage density. On the highest drainage density zone, the rivers are long as well as meandering and the load of sediment discharged is very low. On the other hand, in the lowest drainage density zone, observation showed that the rivers are short and have originated in the hill-slope and have discharged sediment.

Table 3
Landslide and Drainage Density

Drainage Density (in m\25 ha)	Area (ha)	Percent	Area of landslide (ha)	Percent
Below 250	4997.66	44.37	129.08	47.6
250 - 500	2338.77	20.77	59.30	21.9
500 - 750	2070.40	18.38	40.06	14.8
750 and above	1855.52	16.48	42.42	15.7
Total	11262.35	100.00	270.86	100.0

Source: Based on landslide and drainage density map, Department of Survey, 1994.

Geology and Landslide

Table 4 shows that the maximum share of landslide area was confined to the quartzite and schists area whereas there was no landslide on the granite rock. Landslide was largely concentrated in areas with, the quartzite and schists belonging to the Kulekhani group (88 percent).

Table 4
Landslide and Rock Types

Rock Type	Area (ha)	Percent	Area of Landslide (ha)	Percent
Granite	1187.42	10.5	0	0
Quartzite, Schists	3724.52	33.1	237.66	87.7
Quartzite, Phyllites	2788.48	24.8	9.93	3.7
Sopyang Slate, Calc Phyllites	858.13	7.6	1.38	0.5
Chandragiri Limestone	1552.94	13.8	0.2	0.1
Massive Marble	658.61	5.8	15.77	5.8
Phyllites with Marble Bands	492.27	4.4	5.93	2.2
Total	11262.35	100.0	270.89	100.0

Source: Computed from the Geological Map and Landslide Map, Department of Mines and Geology, 1994.

Landuse and Landslide

Table 5 shows that slopping terrace and shrubland areas were the most vulnerable in terms of landslide which accounted for 42 percent and 36 percent respectively.

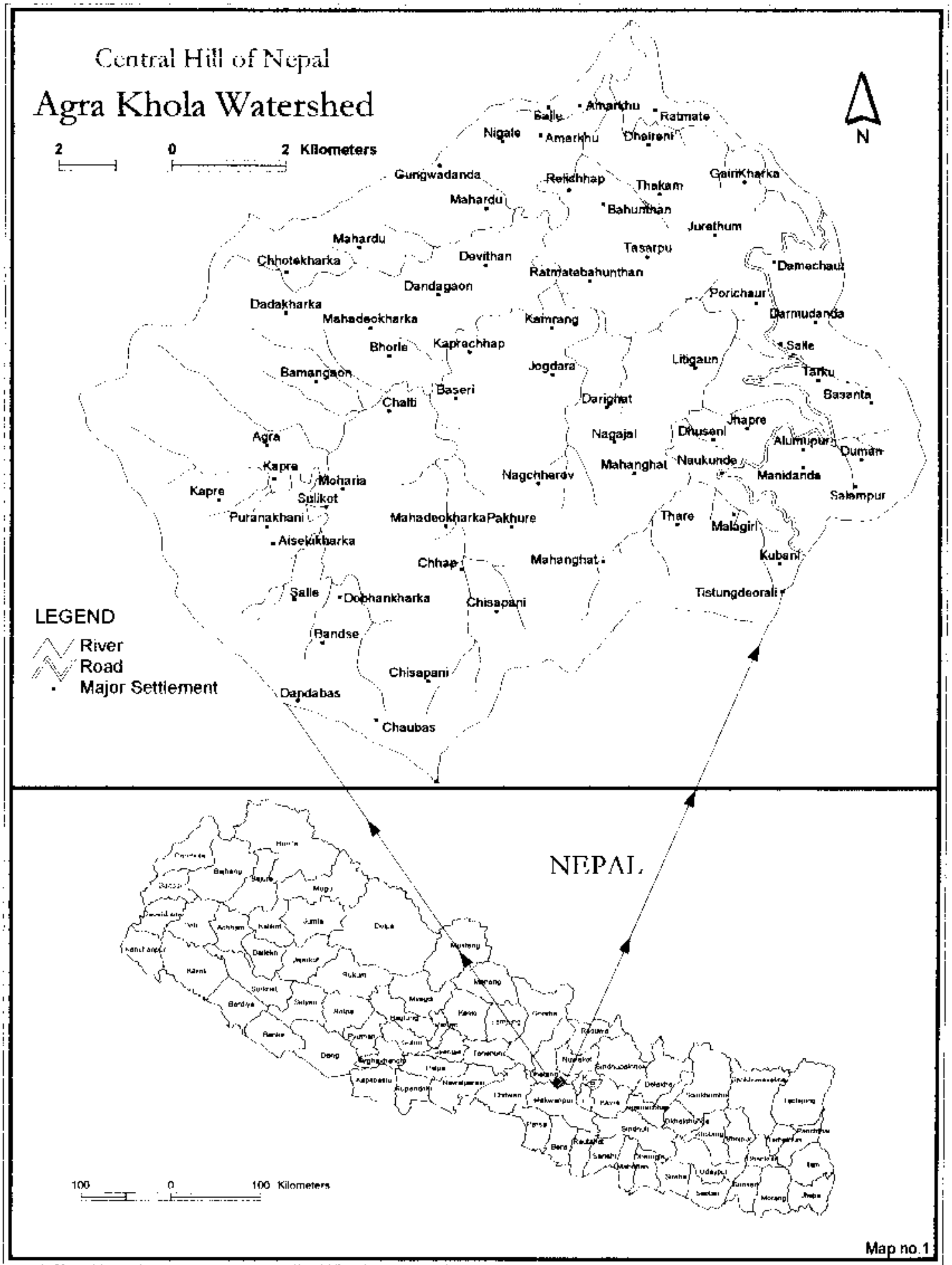
Table 5
Landslide and Land Use/Land Cover

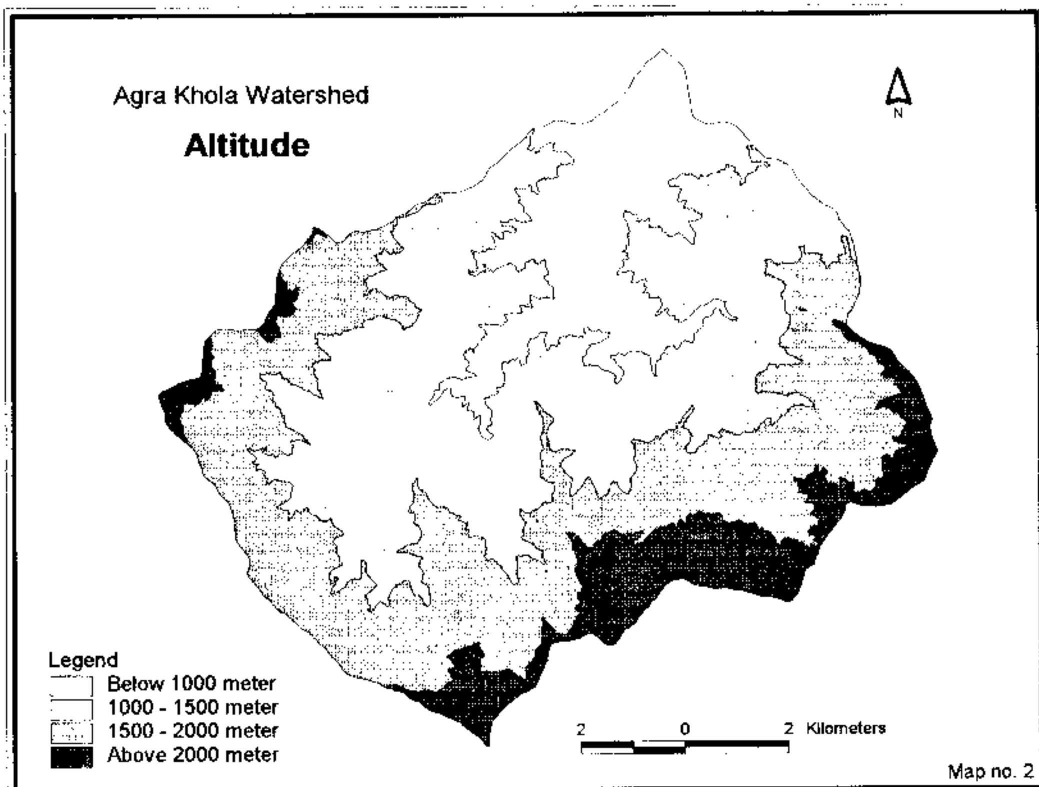
Land Use Types	Area (ha)	Percent	Landslide area (ha)	Percent
Dense forest (>40% crown density)	828.13	7.36	11.07	4.09
Sparce forest (<40% crown density)	1466.82	13.02	96.26	15.90
Shrubland	1829.13	16.24	3.69	35.54
Grazing land	1386.77	12.32	112.59	1.36
Sloping terrace	4410.73	39.16	43.07	41.57
Level terrace	1340.21	11.90	4.19	1.54
Total	11262.36	100.00	270.87	100.00

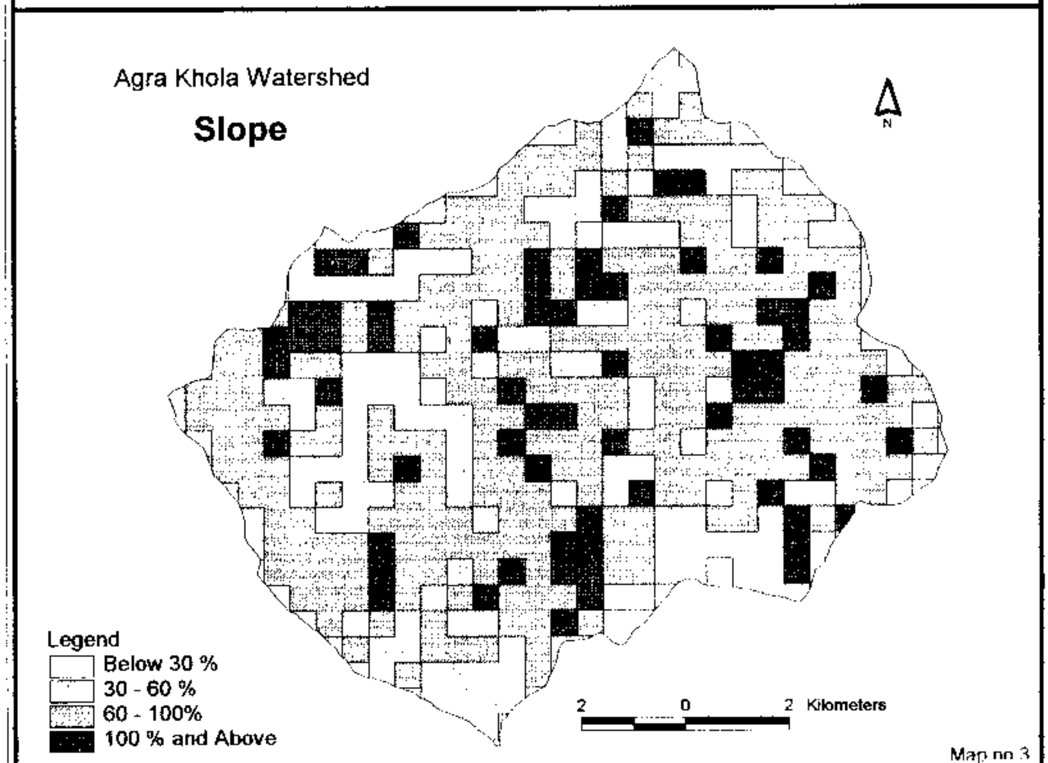
Source: Based on land utilization and landslide map, Department of Survey, 1994.

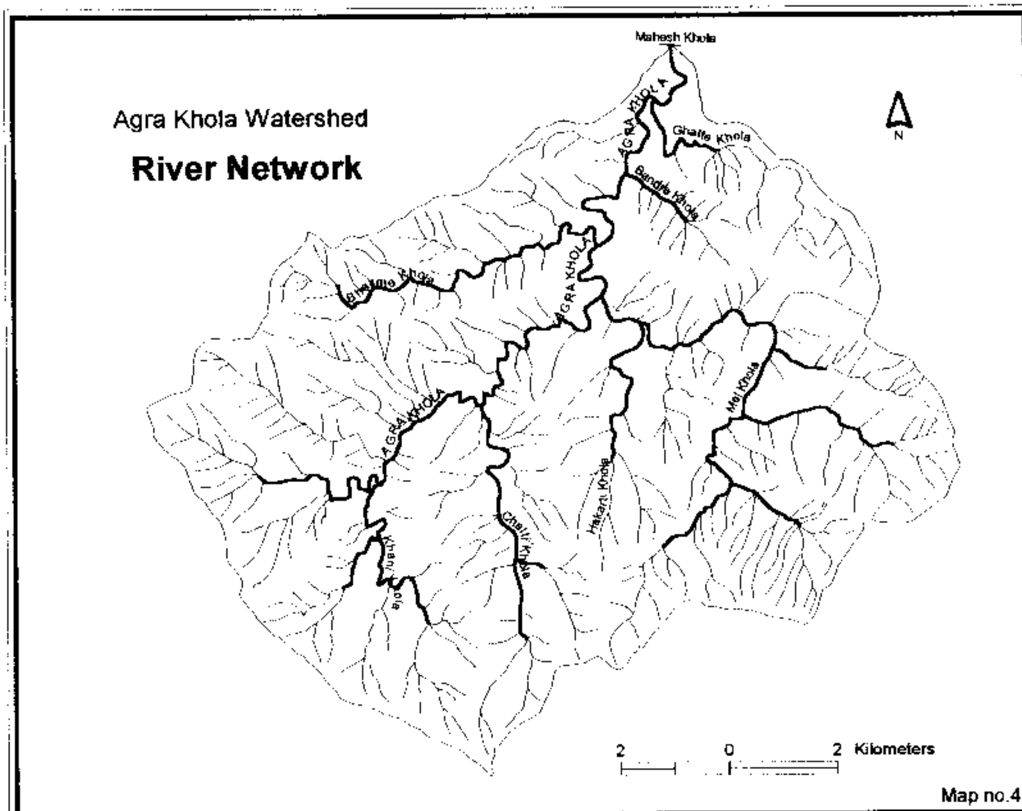
Conclusion

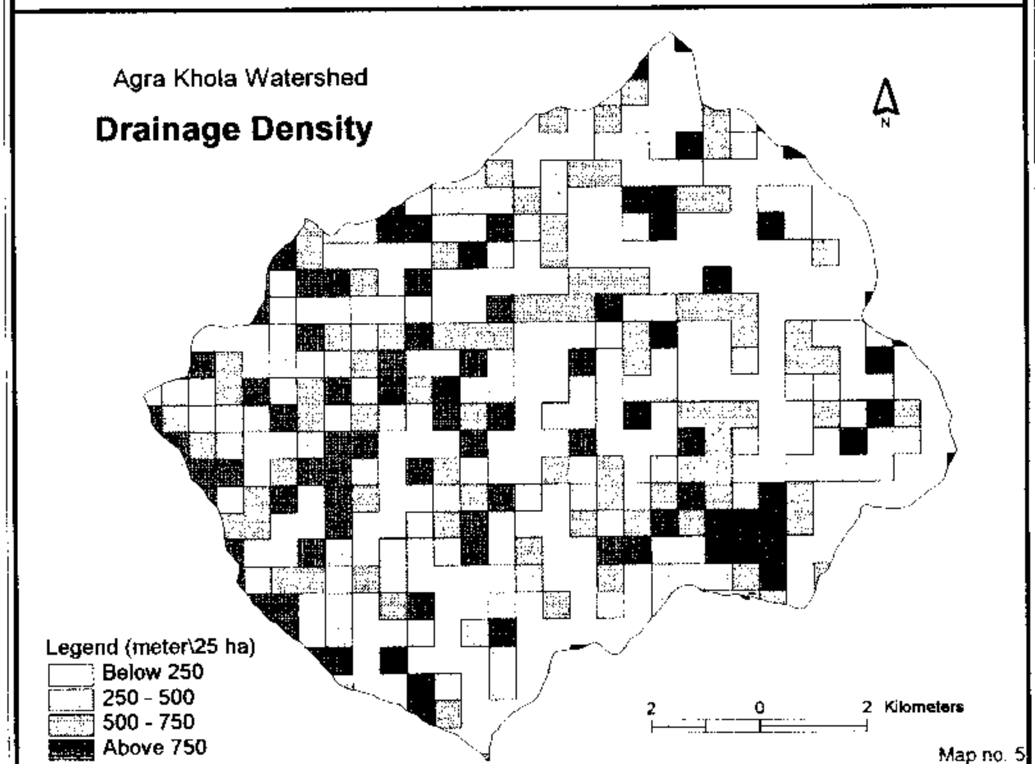
The parameters including altitude, drainage, rock type and landuse were considered important to describe the intensity of landslide in the study area. High altitude, moderate slope, low drainage density, rocks consisting quartzite and schists and slopping terrace were found most vulnerable to landslide. The temporal concentration of rainfall is proved to be the single most factor to cause landslide at greater extent in the study area. A careful landuse planning is required to mitigate the landslide hazards in such hilly area of Nepal. This study would provide a basis for the composite analysis of different layers over one-to-one coverage analysis of landslide.

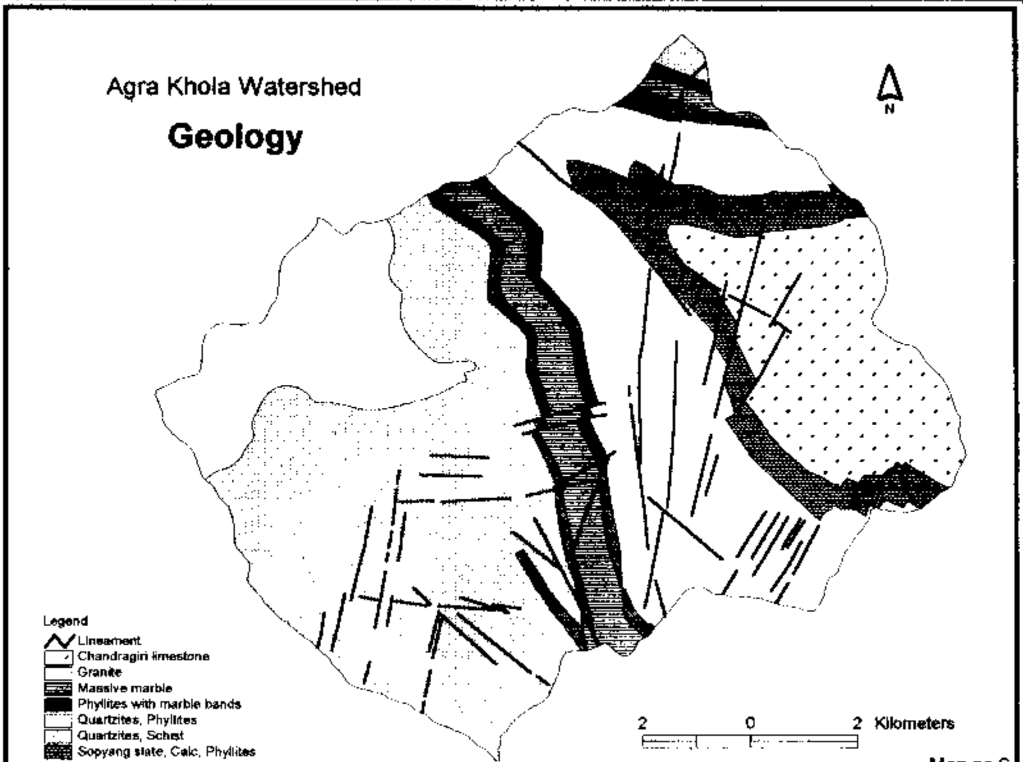

Central Hill of Nepal
Agra Khola Watershed
2 0 2 Kilometers
N
LEGEND
River
Road
Major Settlement
Salle
Amarkhu
Ratmate
Nigale
Amarkhu
Dhalreni
Gungwadanda
Relidhhap
Thakam
GairiKharka
Mahardu
Bahunthan
Jurethum
Mahardu
Tasarpu
Chhotekharka
Devithan
Ratmatebahunthan
Damechaur
Dandagaon
Dadakharka
Porichaur
Darmudanda
Mahadeokharka
Kamrang
Bhorle
Kaprechhap
Salle
Litigaun
Bamangaon
Jogdara
Tarku
Baseri
Chalti
Darighat
Basanta
Jhapre
Agra
Nagajal
Dhuseni
Alumupur
Duman
Kapre
Mahanghat
Naukunde
Moharia
Nagchharev
Manidanda
Kapre
Sulikot
Salempur
Puranakhani
MahadeokharkaPakhure
Thare
Malagiri
Aisekikharka
Chhap
Mahanghat
Kubani
Salle
Dobhankharka
Tistungdeorali
Chisapani
Bandse
Chisapani
Dandabas
Chaubas
NEPAL
100 0 100 Kilometers
Map no.1


Agra Khola Watershed
Altitude
N
Legend
Below 1000 meter
1000 - 1500 meter
1500 - 2000 meter
Above 2000 meter
2 0 2 Kilometers
Map no. 2

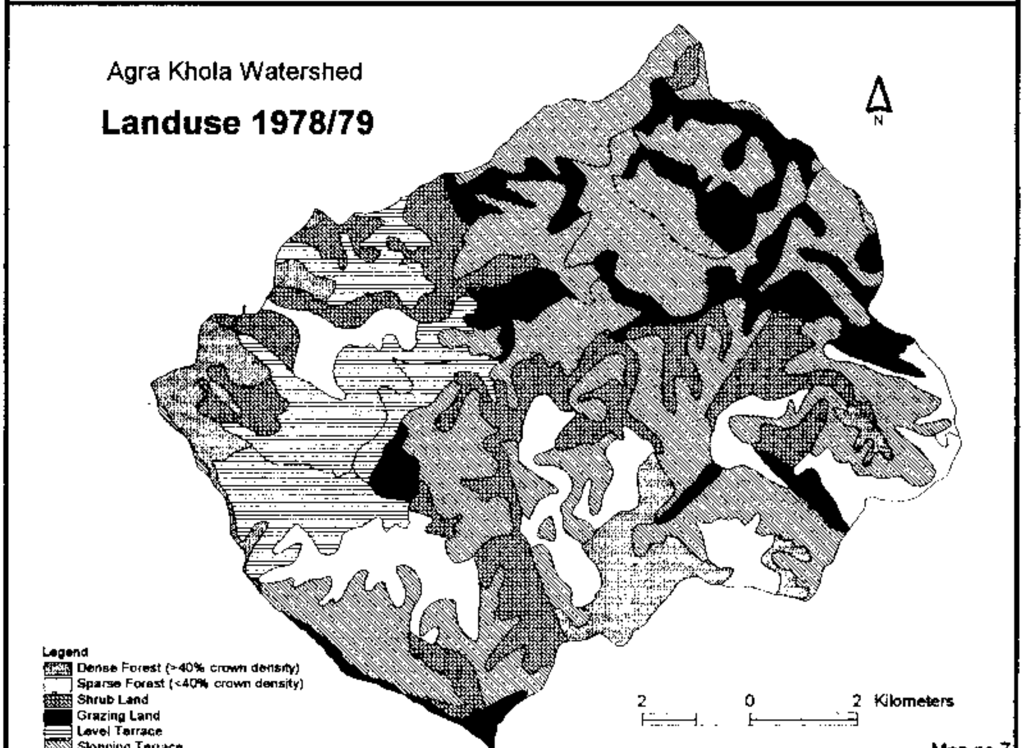

Agra Khola Watershed
Slope
N
Legend
Below 30 %
30 - 60 %
60 - 100%
100 % and Above
2 0 2 Kilometers
Map no 3


Agra Khola Watershed
River Network
Mahesh Khola
AGRA KHOLA
Hakari Khola
N
2 0 2 Kilometers
Map no.4


Agra Khola Watershed
Drainage Density
N
Legend (meter\25 ha)
Below 250
250 - 500
500 - 750
Above 750
2 0 2 Kilometers
Map no. 5



Map no.6



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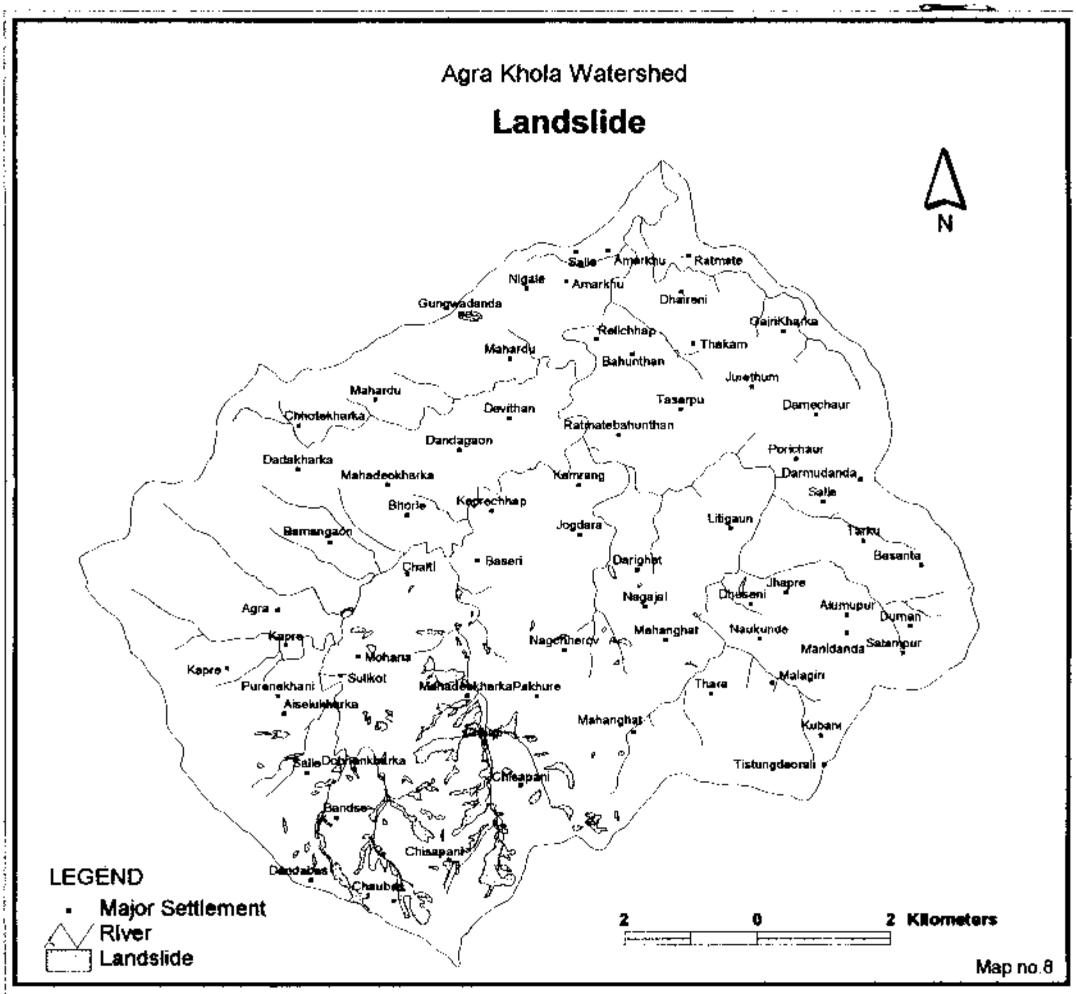
Agra Khola Watershed
Landslide
N
LEGEND
Major Settlement
River
Landslide
2 0 2 Kilometers
Map no.8

References

Dhital, M.R., Khanal, N.R., Thapa, K.B. 1993: *The Role of Extreme Weather Events, Mass Movements, and Land Use Change Increasing Natural Hazards*, ICIMOD., Occasional Paper No. 10, Kathmandu, Nepal.

Thapa, P. B. 1995: *Engineering Geological Studies of Landslides Induced by Dissaster of July 19-21, 1993.* The Agra Khola Basin, Central Nepal Lesser Himalaya. Unpublished M.Sc. Thesis, Central Department of Geology, Tribhuvan Univesity, Kathmandu, Nepal.

Sharma, P. 1996: *A Study on Landslide Hazard in Agra Khola Watershed,Central Hill Region, Nepal, Using GIS.* Unpublished M.A. Thesis, Central Department of Geography, Tribhuvan University, Kathmandu, Nepal.