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Land Sliding Zones Identification Using Remote Sensing And Gis: A Model Study From Pokhara To Kurintar, Prithvi Highway, Nepal

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Abstract

The term ‘landslide' includes all varieties of mass movements of hill slopes and can be defined as the downward and outward movement of slope forming materials composed of rocks, soils, artificial fills or combination of all these materials along surfaces of separation by falling, sliding and flowing, either slowly or quickly from one place to another. Although the landslides are primarily associated with mountainous terrains, these can also occur in areas where an activity such as surface excavations for highways, buildings and open pit mines takes place. Landslide is a general term for a wide variety of down slope movements of earth materials that result in the perceptible downward and outward movement of soil, rock, and vegetation under the influence of gravity. The materials may move by falling, toppling, sliding, spreading, or flowing. Some landslides are rapid, occurring in seconds. This study is useful for locating the vulnerable to landslide pockets along the highway within the study area and to prepare a land sliding risk zones map. Once prepare this type of information is useful for identification of risk zones, the decision makers would take sufficient care to avoid from possible risk of landslides. The present study area is world 7th riskiest highway in the world by the road safety and transport authority. The people lively wood and economy is depending on this highway keeping this in view. The study has taken to create the land sliding zones information using remote sensing technology.

Keywords: Land sliding zones, Remote Sensing & GIS, Highway, Natural disaster

Introduction

Nepal is landlocked country located in Southeast Asia in between India and China with an area of 1, 47,181 square kilometers. The kingdom of Nepal is situated in the central part of the Himalayan Arc separating the Gangetic plains of India from Tibetan plateau of china. The Himalayan belt extends over 2400km from the Punjab Himalayas, situated between 26° 15' to 30° 30' N latitude and 80° 00' to 88° 15' E longitude, stretch from over800km northwest to southwest. About 83% of the national land is covered by the rugged terrain of the hills and mountains and the land above 4,500 meters above sea level is approximately 14.7% of the total land. The rainfall pattern of Nepal is quite irregular and the most of the rainfall occurs on the monsoon season, so the mass movement and the related phenomenon are common. In Nepal, landslide and flood are main natural disaster which are responsible for huge social and economic loss in mountain region.Flood is a recurrent problem in the Terai as well as in the mountain regions. In the mountainous regions, rivers are in spates during the monsoon season. Bank undercutting, inundation of the flood plains are the results. But more disastrous are the floods in the high gradient tributary streams due to cloud bursts or high intensity rainfall concentrated usually in a small catchment. Such flash floods causes triggering of landslide, deep scouring of the stream bed and the side slopes and they rapidly develop into debris flows capable of transporting several cubic meter sized boulders. The causes of landslides in Nepal can be assigned to a complex interaction of several factors which are natural as well as human activity related. High relief, concentrated monsoon rainfall, withdraw of underlying as well as lateral supports by toe cutting and bank erosion, presence of weaker rocks, active non tectonic movements and a complex geological history, which has resulted in very intense faulting, folding and fracturation of the rocks, are the natural factors causing landslides in Nepal. But human activities are also responsible for the very high extent, and they add to the density of landslides in the country. Overgrazing of protective grassy cover, mass felling of trees leading to an unprecedented deforestation, disturbance of the hill slopes by road/canal construction, non-consideration of the geologic conditions in the corresponding location, planning or designs of infrastructures etc. are some of the important anthropogenic factors leading to landslides.

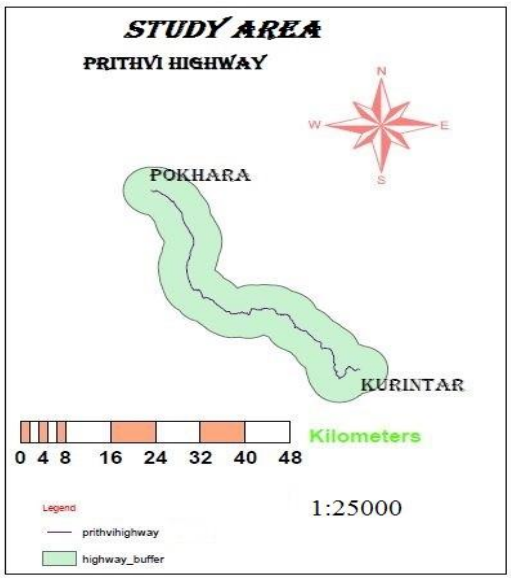
Prithvi highway is busiest highway in Nepal connects Pokhara and Kathmandu. The construction of highway was started with the aid of the Chinese government in 1967 and was completed 1974. This highway is named after King Prithvi Narayan Shah.

Study Area

Description of Study Area

The study area (Fig.1) is located along Prithvi Highway within the longitude $83^0$57'30" E to $84^0$37'30''E latitude of $28^0$15'00"N to $27^0$52'30"N which connects two major city of Nepal, Pokhara and Kathmandu. It is the busiest Highway of Nepal. It starts from 0Km (Pokhara) and ends at 95 km (Kurintar) along the stretch of

Pokhara to Kathmandu. The study area is buffered 350m on either side of the road. As the road is congested and from one side mountain runs and from other side river runs there is more prone to landslide during monsoon. This area having is highest rain fall. One of the more landslide area along the highway is Krishna Bheer. The Krishna Bheer is a cliff located in Dhading District by the side of Prithvi highway. The steep elevation of clip compounded with loose muddy constituent of the cliff creates vulnerability of landslide in monsoon. Young and the unstable geology, steep slope, rugged mountain topography, energetic river and streams with their steep gradient and the swift water flow, intense rainfall, and the frequent earthquakes contribute significantly to the process of the mass wasting. Kathmandu, Dhading, Chitwan, Tanahu and Kaski are the five districts which the highway passes. The hills that flank the 206 km stretch of the Prithvi Highway from Kathmandu to Pokhara contain some of the most important religious sites in Nepal. A 25 km road off the main highway connecting Pokhara and Kathmandu links to historical town of Gorkha. Apart from these historic points of interest, the highway is lined with modern townships that have sprung up around important road junctions and river crossings.



Importance of National Highway

The most frequently used road route by tourists in Nepal is more than 200km long Prithvi Highway leading from Kathmandu to Pokhara. Moreover, there are a number of important branches on the way .The highway follows a series of deep river valleys, passing's ancient stone villages, cascading rice terraces, rocky gorges and roaring rapid crosses. The country most vital hydropower project Marshyandi hydropower is located at Aanbukhaireni, Tanahu with installed capacity of 69 MW and annul design generation of 462.5GWh and it has three terminal upper, middle and lower. This hydropower plant is located beside the Highway.

Climate and Rainfall

Climatic conditions of Nepal vary from one place to another in accordance with the geographical features. In the north summers are cool and winters severe, while in south summers are tropical and winters are mild. Nepal has namely five major seasons: spring, summer, monsoon, autumn and winter. An average temperature drop of 6°C occurs for every 1,000 m gain in altitude. In the Terai, summer temperatures exceed 37° C and higher in some areas, winter temperatures range from 7°C to 23°C in the Terai. In mountainous regions, hills and valleys, summers are temperate while winter temperatures can plummet under subzero. The valley of Kathmandu has a pleasant climate with average summer and winter temperatures of 19°C – 35°C and 2°C – 12°C respectively. Eighty percent of the precipitation is received during the monsoon (June-September). Winter rains are more pronounced in the western hills. The average annual rainfall is 1,600 mm, but it varies by eco-climatic zones, such as 3,345 mm in Pokhara and below 300 mm in Mustang. An interesting fact is that there is no seasonal constraint on traveling in and through Nepal. Even in December and January, when winter is at its severest, there are compensating bright sun and brilliant views. Spring is the time for rhododendrons while the clearest skies are found after the monsoon in October and November. A brief view of the average temperatures and rainfall during peak summer and winter in three most popular tourists' areas Rainfall data of Pokhara from 2009 to 2013 given in below

Table 1:

Place	Summer (May, June, July)			Winter (Dec, Jan, Feb)		
	Max (°C)	Min (°C)	Rain (mm)	Max (°C)	Min (°C)	Rain (mm)
Kathmandu	28.1	19.5	312	19.3	3.0	15.4
Pokhara	29.7	21.3	829.7	20.3	7.7	26.3
Chitwan	33.0	25.3	404.0	24.1	8.3	13.8

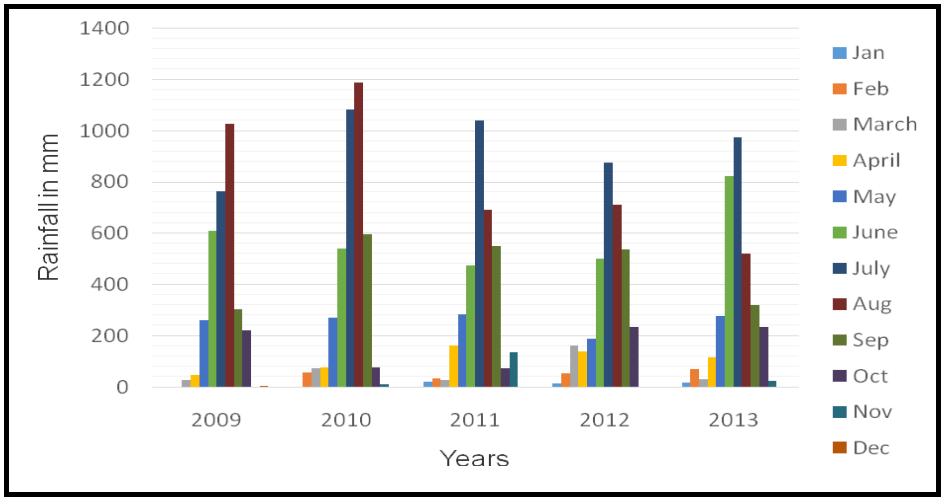


Figure 2: Graphical Representation of Rainfall

Socio-Economic Resources

Nepal Population and Housing Census 2011 (NPHC2011) marks hundreds years in the history of population census in Nepal. Population of Nepal as of the census day (June 22, 2011) stands at 26,494,504. The increment of population during the last decade is recorded as 3,343,081 with an annual growth rate of 1.35% Terai constitutes 50.27 %(13318705) of total population while Hill and Mountain constitutes 43 %(11,394,007) and 6.73(1,781,792) respectively. Among the five development regions, Central development region has the highest population (36.45%) and Far western development region records the lowest (9.63%). Nepal's gross domestic product (GDP) for 2012 was estimated at over $17.921 billion (adjusted to Nominal GDP). In 2010, agriculture accounted for 36.1%, services comprise 48.5%, and industry 15.4% of Nepal's GDP.

Methodology

Demarcation of Study Area

A buffer zone of 500m is delineated on the right and left sides of Pokhara to Kurintar,Prithvi national highway because it was observed that the landslides are only along the corridor which was due to unstable steep slopes and erosion due to river flow from buttoms, so on those areas which have landslide sand which can have landslides in future along the road corridor.

Data collection

The Survey of Nepal toposheets, Road network of highway, rain fall, metrological and demographic data has been collected from various related Government organizations.

Field Data Collection

Landslide zonation is procedure in which a lot of field investigation is needed. To collect the information about the geological and structural information we have to approach different agencies and we have to collect information about the area on which we are doing the work.

Data Input and Conversion

IRS-P6 satellite imageries collected from National remote Sensing Centre (NRSC) are geo-referenced using ground control points with Survey of Nepal (SON) toposheets as a reference and further merged to obtain a fused output in ERADAS software. The study area is then delineated based on the latitude and longitude values and a final hard copy output is prepared for further interpretation.

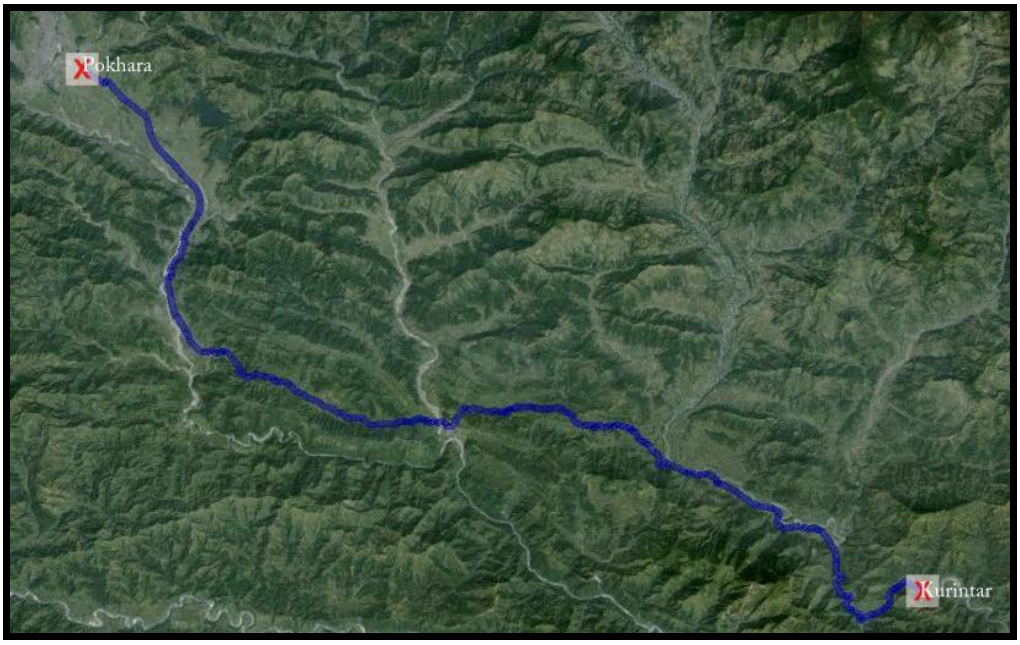


Figure 3: Satellite Image

Data Base Creation and Analysis

Database creation is a complex operation process, which involves data capture, verification and structuring processes. Raw geographical data are available in many different analogue and digital forms such as toposheets, aerial photographs, satellite imageries and tables. Out of all these sources, the source of satellite image and toposheet is of much concern to natural resources scientist and an environmentalist. In this study, different thematic layers viz, Land use/ land cover map, Geology, Slope, Soil, Drainage network etc. Maps are generated from topo sheet and satellite data using visual interpretation technique. The prepared map is converted to digital mode using scanning and automated digitization process.

Digitization

Digitization is the process of converting information into digital format. It is the representation of an object, image, sound, document or a signal (usually an analog signal) by a discrete set of its point. The toposheets map had been collected to digitize in order to develop and generate the required maps related to the aims and objectives of the study. Digitization is done either in Auto Cad or Arc GIS software. We had carried out the digitization work in Arc GIS. These maps are prepared to a certain scale and show the attributes of entities by different symbols or coloring. This digitized data is then exported for further processed in ArcView GIS software to create digital database for subsequent data analysis.

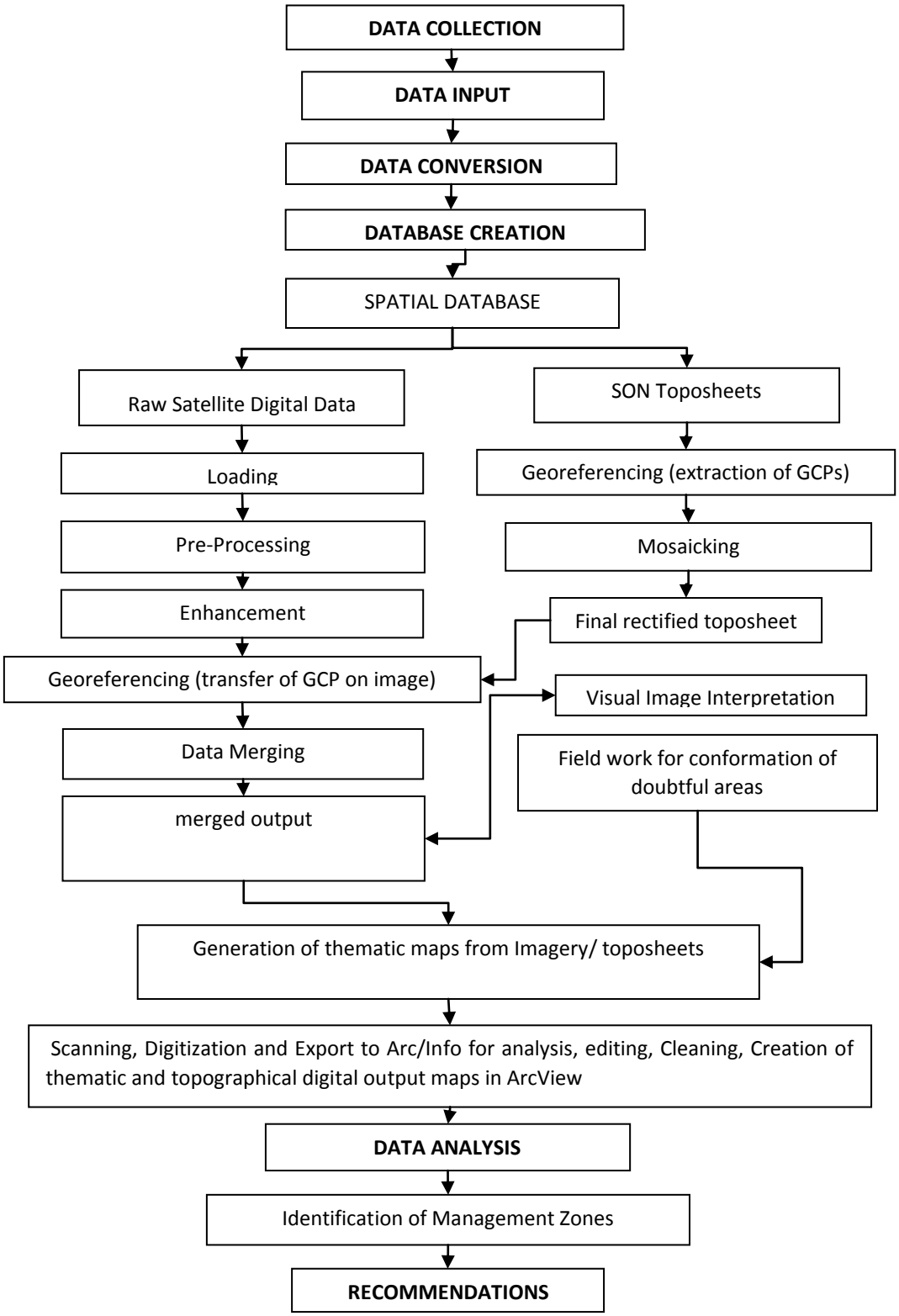


Figure 4: Flow chart showing the methodology adopted for the present study

Result and Discussion

Base map

The base map is prepared using survey of Nepal toposheets2883 16B, 2884 13A, 2884 13C, 2884 13D, 2784 01B, 2784 02A, 2784 02B, 2784 03A, 2784 03C and scale 1:25,000. A base map consists of various features like road network, rivers, streams, canals, settlement etc. which are delignated from toposheet. The map thus drawn is scanned and digitized using ArcGIS to get digital output. The major settlements and Prithvi national highway has been identified in this map. The major settlements are Muglin, Manakamana, Dumre, Sisa ghat, Kurintar, Khairenitar, Damauli and Pokhara.

Drainage Map and Morphometry Analysis:

The drainage map prepared from the toposheet and satellite image. All the rivers, tributaries and small stream channels are extracted to prepare the drainage map. In the study area dendrite drainage pattern and dense drainage density has been observed.

In the study area number of 1^{st} order stream=267,Number of 2^{nd} order stream =86,Number of 3^{rd} order stream =29,Number of 4^{th} order stream =12,Number of 5^{th} order stream =5.

Morphometry AnalysisRb= Nu/(Nu+1)

(Rb) 1st = 3.105,(Rb)2^{nd} = 2.97,(Rb)3^{rd} = 2.42,(Rb)4^{th} = 2.4

As per the above morphometry analysis the drainage is not much influence the geological formations.

Contour Map

Contour lines are imaginary lines which may be curved or straight lines on a map describing the intersection of a real or hypothetical surface with one or more horizontal planes. The configuration of these contours allows map readers to infer relative gradient of a parameter and estimate that parameter at specific places. In the study area minimum 300m and maximum 2000m contour has been observed.

Slope Map

Survey of Nepal toposheets on scale 1:25,000 helps in deriving the information. Contour map is useful in the preparation of the slope map. Closed space contours on the map reflect steepness when compared to widely spaced contours. The diff Closed space contours on the map reflect steepness when compared to widely spaced contours. The different classes of slopes have been categorized as per the guidelines suggested by NRSC. The study area has been categorized into three slope classes. The majority of study area comes under very steep class, very less area is representing steep slope class. In general, the elongated shape of the contours suggests the elongated morphology of the hills.

Geology Map

The geological structure presented in the map is a simplified view. Several stratigraphic groups in the relation to geology have been recognized. These groups are correlated to the probable geological ages which varies from recent period to the pre-

Cambrian era. Among the ecological regions the treai belt& a river basin are composed of most recent alluvium; the churiya arrange is formed out of mainly course fluvial deposits such as sandstones shale's and conglomerates. Then the midland hill are composed of plastic &carbonaceous rocks. The mountain belt, on the other hand, consist of highly metamorphosed complex rocks such as garnets gneisses, schists, etc. belonging entirely to the Precambrian period. The highway lies in lesser Himalayan, lesser Himalayan Meta sediments & sub Himalayan.

1. **Lesser Himalayan:** formed during plio-pleistocene&quaternary & contains fluvial /fluvioglacial gravels, conglomerates &lacustrine clay deposit with vertebrate fossils.
2. **Lesser Himalayan Meta sediments**: Tansen, Nuwakot& Kuncha groups are marked under the division and outlined to have been formed in the Precambrian to tertiary period.

A) Tansen Group:

1. Tertiary series

lower part: marine shale's & lime stones with Foraminifera.

Upper part: sand stones & shales of fluvial flood plain origin with plan remains.

2. Mesozoic series:

Lower part: continental fluvial sediments (conglomerates, sandstones, siltstones &shale's/ slates) with lava flows 7 plant fossils.

Upper part: partly marine (lime stones &shale's) dominantly fluvial sediments (sand stones, quartzites &shale's) with plant remains.

3. **Permo-carboniferous series:** partially glaciomarine & predominantly glaciofluvial & fluvial sediments (diamictites, shale's/ slates, sandstones & siltstones) with flora &fauna.

B. Nuwakot Group:

Precambrian to lower Paleozoic. Shallow marine sediments.

Lower parts: dominantly clastic (Phyllites, sandstones quartzites & calcareous sandstones).

Upper parts: stromatolitic lime stones & black slates. Basic sills & dykes present.

C. Kuncha Group

Precambrian mainly flyschoid sequence (bedded silts, Phyllites& Meta sandstones), locally shallow water quartzite beds & basic sills & dykes presents.

3. **Sub Himalaya:** Quaternary, alluvial deposits of Dun basins.

Soil Map

Being a mountainous country Nepal lacks fertile soil favorable for cereal crops. Instead, rocky and unfertile soils are found in abundant. The following type of soils found in the study area.

Rocky Soil:
Generally there is a profuse presence of rocks, red soil and other non-fertile in organic materials. Expect river and stream basins, bases of the hills and the vallies, with the increase in altitude the presence of rock increases.

Gravels
The composition of bhabar and churiya belts in between the main terai and inner terai contain gravels with no ability of letting grow crops expect bushes & trees & somewhere naked.

Land Use /Land Cover
In the past, Nepal was rich in forest resource. But due to rapid growth of population and lack of strong policy alarming rate of deforestation has been taking place. The forest of Terai, midhill, and the mountainous has been decreasing at great speed. According to the 1994 forest department information only 29% of total land are covered by forest. The rapid deforestation indicated by the decrease the resources to 35.9% in 1984 from 38% in 1978/1979 and to 29% in 1994. Due to elevation of land, there are more changes on climate and soil structures which in term causes to the variation of vegetation growth and its types. The following major classes has been identified in the study area Forest, Shrub land and Agriculture land.

Relief Map:
The Relief map has been prepared based on the contour and slope map as per the relief map the study area having altitude in between 500 to 1000 Meter is more along the highway. Few part is 1000 to 2000 meters very less part of the study area is below 500m along the Highway.

Population Density Map:
Population density is also one of cause of landside according to World Bank the Population density (people per sq. km) 208.99 in Nepal(2010), as per this data prepared the population density map in this the study area is coming two class that is less then 1000 people per sq. km (7.8%) and 100-200 people per sq. km(25.6%).

Land Sliding Zones Map:
As per the above analysis of different types of thematic data and collateral data information, 15 land sliding zones are identified, out of which 4 land sliding zones are identified in northeast side and 11 land sliding zones are identified in south west part of the study area.

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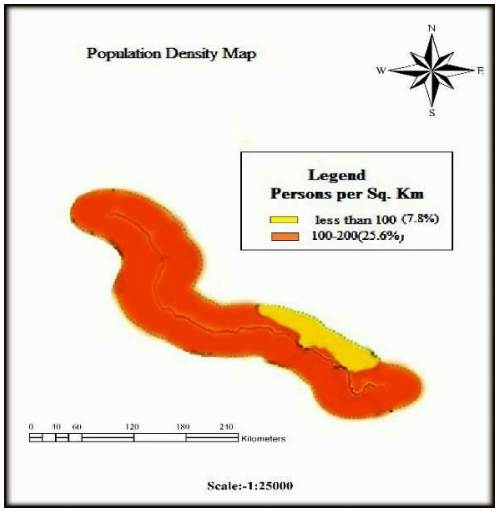
Population Density Map
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Legend
Persons per Sq. Km
less than 100 (7.8%)
100-200(25.6%)
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Kilometers
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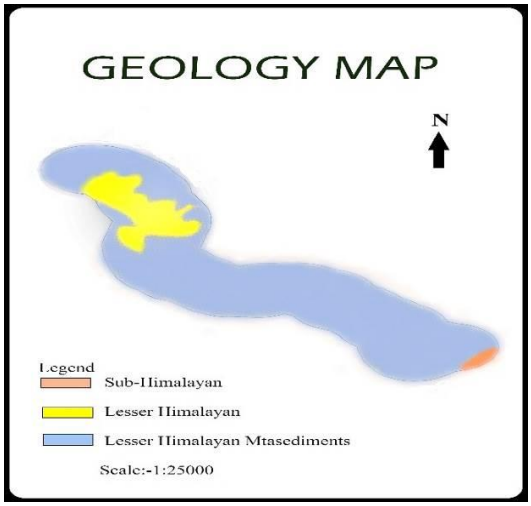
GEOLOGY MAP
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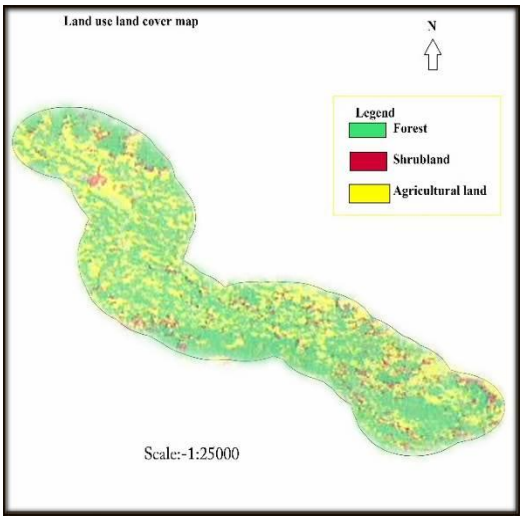
Land use land cover map
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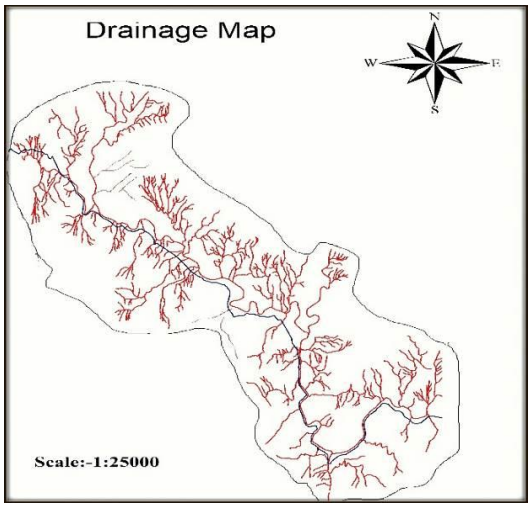
Forest
Shrubland
Agricultural land
Scale:-1:25000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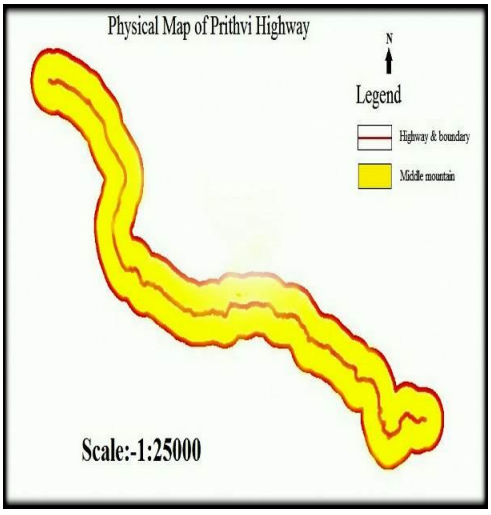
Physical Map of Prithvi Highway
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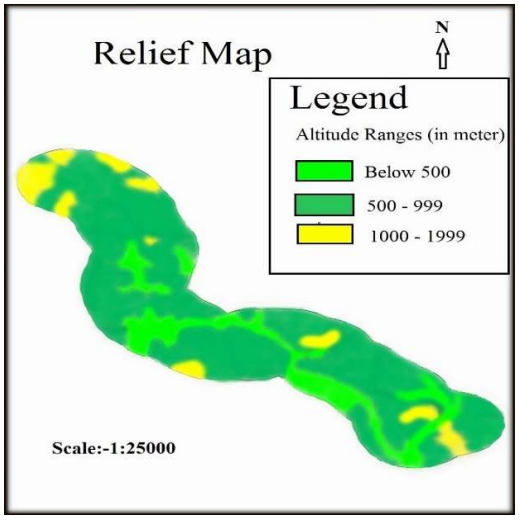
Highway & boundary
Middle mountain
Scale:-1:25000


Relief Map
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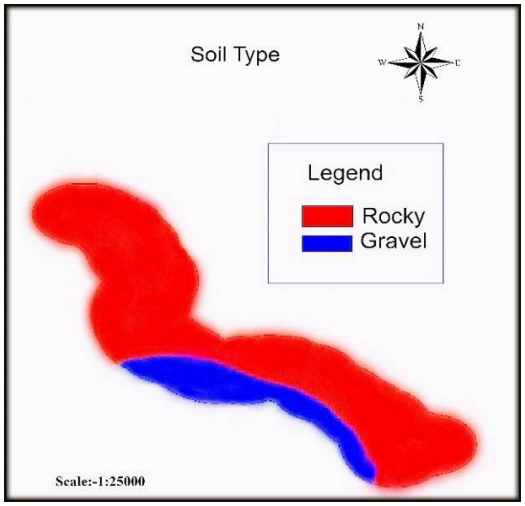
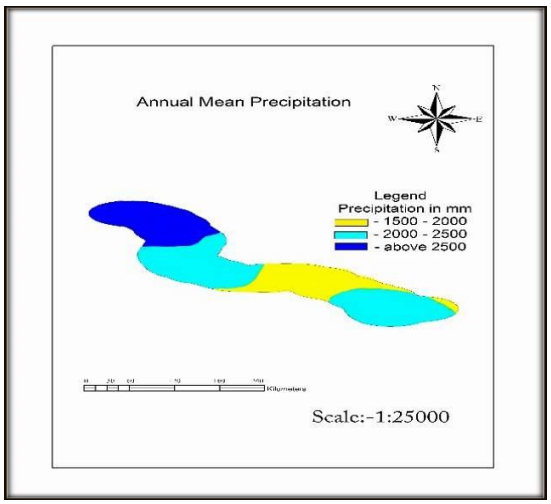
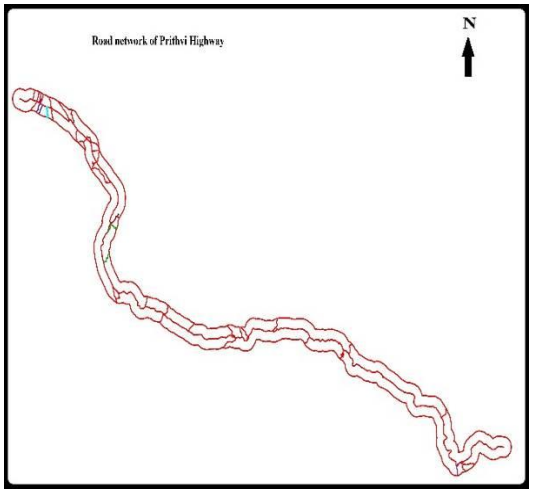
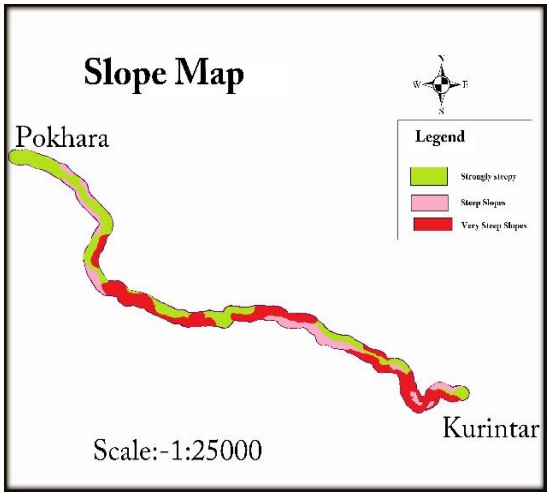
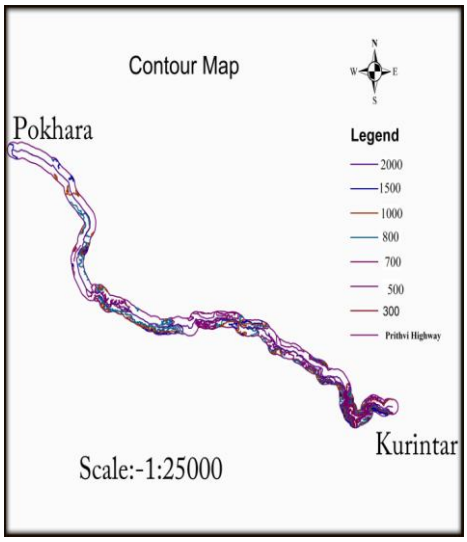
Legend
Altitude Ranges (in meter)
Below 500
500 - 999
1000 - 1999
Scale:-1:25000

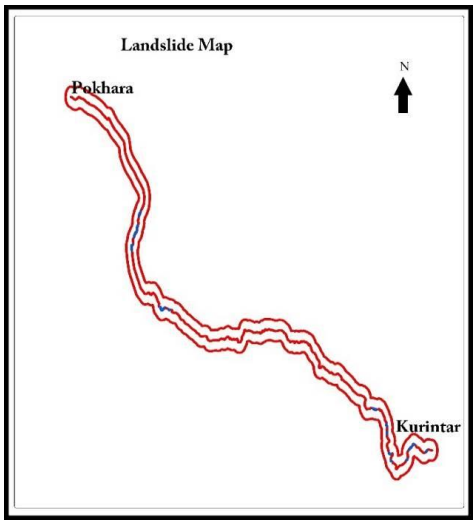

Soil Type
Legend
Rocky
Gravel
Scale:-1:25000


Annual Mean Precipitation
Legend
Precipitation in mm
- 1500 - 2000
- 2000 - 2500
- above 2500
Scale:-1:25000


Road network of Prithvi Highway
N


Slope Map
Pokhara
Legend
Strongly steepy
Steep Slopes
Very Steep Slopes
Kurintar
Scale:-1:25000


Contour Map
Pokhara
Legend
2000
1500
1000
800
700
500
300
Prithvi Highway
Kurintar
Scale:-1:25000


Landslide Map
Pokhara
N
Kurintar

Field Visit Along Prithvi Highway