

Masters Program in **Geospatial Technologies**



**LAND USE/LAND COVER CHANGE AND ITS IMPACT ON
SOIL EROSION PROCESS IN BEGNAS TAL RUPA TAL
WATERSHED USING GEOSPATIAL TOOLS, KASKI
DISTRICT, NEPAL**

Saroj Koirala

Dissertation submitted in partial fulfilment of the requirements
for the Degree of *Master of Science in Geospatial Technologies*

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Dissertation Supervised By

Professor Pedro Cabral, Ph.D

Dissertation Co-Supervised By

Professor Edzer Pebesma, Ph.D

Professor Filiberto Pla, Ph.D

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LAND USE/LAND COVER CHANGE AND ITS IMPACT ON SOIL EROSION PROCESS IN BEGNAS TAL RUPA TAL WATERSHED USING GEOSPATIAL TOOLS, KASKI DISTRICT, NEPAL

ABSTRACT

The spatial-temporal analysis of changes in land use/land cover between 1988 and 1999 at Begnas Tal Rupa Tal Watershed, covering an area of about 50.94 km² in Kaski District, Nepal, reveals the changing scenario of land use/land cover and their consequent effect on soil erosion. The geo-spatial analysis of database generated from the satellite images, ancillary database and socio-economic information critical/vulnerable areas of land degradation are identified. Visual interpretation technique is carried out for land use/land cover by comparing satellite images of Landsat TM from 1988 to 1999 using GIS tools. Datasets of moderate spatial resolution (Landsat TM) have been processed. The geo-spatial analysis results show an increase in major land use/land cover such as agricultural land, dense mixed forest and settlement whereas there is decrease in barren land and open forest. The main land cover such as open forest and barren land are converted both into agricultural land and settlement. This change in land use indicates that the mountain land use is changing rapidly in the Himalayan region. It has not only disrupted ecological balance of the watershed but also reduced ground water recharge, increased run-off and soil erosion as well. Changing land uses/land covers have accelerated the process of soil erosion, loss of top soil and leaching of nutrients in upstream area on the one hand and sedimentation in lakes, reservoirs and river channels on the other. The rain-fed agriculture is contributing maximum to soil losses. High soil erosion is found in sloppy areas where unscientific farmland management practices are prevailing. Most of woody vegetated lands fall on low soil erosion areas. Information obtained using remote sensing techniques can help decision makers to prepare resource map accurately in less time and cost. For the estimation of soil loss by using Morgan approach, the various factor maps can be generated. The lower soil losses are recorded under forest cover and irrigated agricultural land.

KEYWORDS

GIS

Land Use Change

Mountain

Soil Erosion

Watersheds

ACRONYMS

ANSWERS – Areal Non-Point Source Watershed Environment Response

Simulation

AGNPS – Agricultural Non-Point Source Pollution Model

CBS – Central Bureau of Statistics

CF – Community Forest

DDC – District Development Committee

FAO – Food Agriculture Organization

ILWIS – Integrated Land and Water Information System

LUCC – Land Use Land Cover Change

SLEMSA – Soil Loss Estimation Equation for Southern Africa

USLE – Universal Soil Loss Equation

VDCs – Village Development Committees

WEPP – Water Erosion Prediction Project

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1. INTRODUCTION

1.1 Background

The high intensity of land use and the fast rate of change in land cover are the characteristic features of developing countries whose economy is based on primary production. The human impacts upon land are very high because of increasing human population. The land use land cover is defined as the observed physical layer including natural and planted vegetation and human constructions, which cover the surface of the Earth. A watershed is a structural and functional unit of a landscape consisting of various environments and sustaining a certain biodiversity. Land Use Land Cover Change (LUCC) around the world has been altering natural ecosystem. Land use from a watershed perspective, is a watershed characteristics influenced by human activities and plays a significant role in delivering sediment and modified water yield (quantity, quality and regime) in the river. Due to anthropogenic activities, the Earth surface is being significantly altered in some manner and man's presence on the Earth and his use of land has had a profound effect upon the natural environment thus resulting into an observable pattern in the land use/land cover over time. The land use/land cover pattern of a region is an outcome of natural and socio-economic factors and their utilization by man in time and space. Land is becoming a scarce resource due to immense agricultural and demographic pressure.

The land use/land cover pattern of a region is an outcome of natural and socio – economic factors and their utilization by man in time and space. Hence, information on land use / land cover and possibilities for their optimal use is essential for the selection, planning and implementation of land use schemes to meet the increasing demands for basic human needs and welfare. This information also assists in monitoring the dynamics of land use resulting out of changing demands of increasing population. Knowledge of land cover and land use change is important for many planning and management activities (Lillesand and Kiefer, 1994).

Land use and land cover change has become a central component in current strategies for managing natural resources and monitoring environmental changes. The advancement in the concept of vegetation mapping has greatly increased research on land use land cover change thus providing an accurate evaluation of the

spread and health of the world's forest, grassland, and agricultural resources has become an important priority. Viewing the Earth from space is now crucial to the understanding of the influence of man's activities on his natural resource base over time. In situations of rapid and often unrecorded land use change, observations of the earth from space provide objective information of human utilization of the landscape. Over the past years, data from Earth sensing satellites has become vital in mapping the Earth's features and infrastructures, managing natural resources and studying environmental change.

Remote Sensing (RS) and Geographic Information System (GIS) are now providing new tools for advanced ecosystem management. The collection of remotely sensed data facilitates the synoptic analyses of Earth - system function, patterning, and change at local, regional and global scales over time; such data also provide an important link between intensive, localized ecological research and regional, national and international conservation and management of biological diversity.

Satellite data interpretation followed by field verification from several time points allows the creation of land cover maps over greater spatial extents and more frequent time steps (Nagendra, 2001). Because these classifications are spatially explicit, they not only provide information on percent changes in land cover, but also allow for evaluation of the spatial location of these changes and their association with environmental and biophysical landscape parameters that may be critical associates of this change (Nagendra *et. al.*, 2004).

1.2 Statement of the Problem

Watershed management has become an increasingly important issue in many tropical countries including Nepal as government agencies and non-governmental groups struggle to find appropriate management approaches for improving production of natural resource systems. Principles, concepts and approaches related to watershed management have experienced a vast change during the past few years but yet there is no universal methodology for achieving effective watershed management (Naiman *et al.*, 1997; Bhatta *et al.*, 1999). Mountain watersheds in Nepal occupy an important geographical setting of the country which possesses the significant role in the resource utilization and management policies. Nowadays, the world is facing the

conflict of increasing population, resource degradation and resource depletion (Joshi *et al.*, 2001). Over exploitation of watershed resources by the growing population has resulted in its degradation in the most parts of the world (FAO, 1985). Watershed conditions have been further deteriorating due to improper land use practices such as deforestation, uncontrolled and excessive grazing, use of unsuitable land for agriculture, and infrastructure development. The degradation in watershed conditions has severely affected the natural resources base of the country. Accelerating pressure on forests and agricultural lands for meeting the basic human needs of fuel, fodder and food have resulted in forest and farmland degradation. Resources are the basis of human beings' living and development, while these are limited. After a period of depletive exploitation, the speedy vanish of forest, the degradation of the land, the shortage of energy and its consequential impact on the micro as well as global environment not only decreases the living standard of human beings but also threat to their development and survival.

In Nepal forestry and land use change alone contribute about 85% of national account of greenhouse gases emission. Total CO₂ emission from land use change and forestry sector in 1994 was about 8.1 million tones. Involvement of wide range of stake-holder's interest objectives and needs makes the process complex and multidimensional in nature. These complexities necessitate a systematic approach to find out the proper utilization techniques and sustainable management plans. This study attempts to analyze Land use Land cover change and its impact on Soil Erosion process in Begnas Tal Rupa Tal Watershed using geospatial tools. Some of the potent questions related to research problems are as follows:

- What are the drivers for the changes in land use land cover occurred during the years 1988 and 1999?
- What is the impact of forest resource utilization pattern on soil erosion process?
- Are there any inherent conservation practices so far?

1.3 Objectives of the Study

This study attempts to analyze land use land cover change and its impact on soil erosion process by applying and adopting commonly used satellite remote sensing and GIS techniques at Begnas Tal Rupa Tal Watershed in Nepal. Specific objectives of the study are set as follows:

- To prepare land use/land cover maps using satellite data;
- To create spatial and non-spatial database of the area of study;
- To detect land use/land cover changes based on 1988 and 1999 satellite; imageries; and
- To prepare soil erosion map by analyzing changing impacts of resource utilization on soil erosion process.

1.4 Organization of the study

The study is organized into five chapters. Chapter I deal with the background, statement of the problem, objectives and organization of the study. Chapter II explores the study area. In Chapter III provides literatures related to land use/land cover change, an overview on theoretical concept regarding resources utilization and losses incurred, methods and procedures applied in research are presented. This chapter deals with visual interpretation and spatial database creation techniques. The chapter IV provides spatial and non-spatial analysis of data and interpretation of results. Finally, Chapter V is a discussion chapter which provides a brief insight on the subject matters as well as conclusion and recommendations.

2. STUDY AREA

2.1 The Study Area

The Begnas Tal Rupa Tal Watershed is located between 28°07'30"N to 28°18'00"N latitudes and 84°00'00"E to 84°20'00"E longitudes covering 50.94 km² area of Kaski District in western Nepal (Fig.1). The land use practice in watershed can be characterized a semi agricultural watershed in mid-hill belt (600-1420 meter) of a mountain ecosystem. It is rich in biodiversity on the one hand and represents mountain characteristics in the Nepal Himalayas on the other. The elevation ranges from 600 meter to 1420 meter which has provided habitat of sub-tropical species of vegetation.

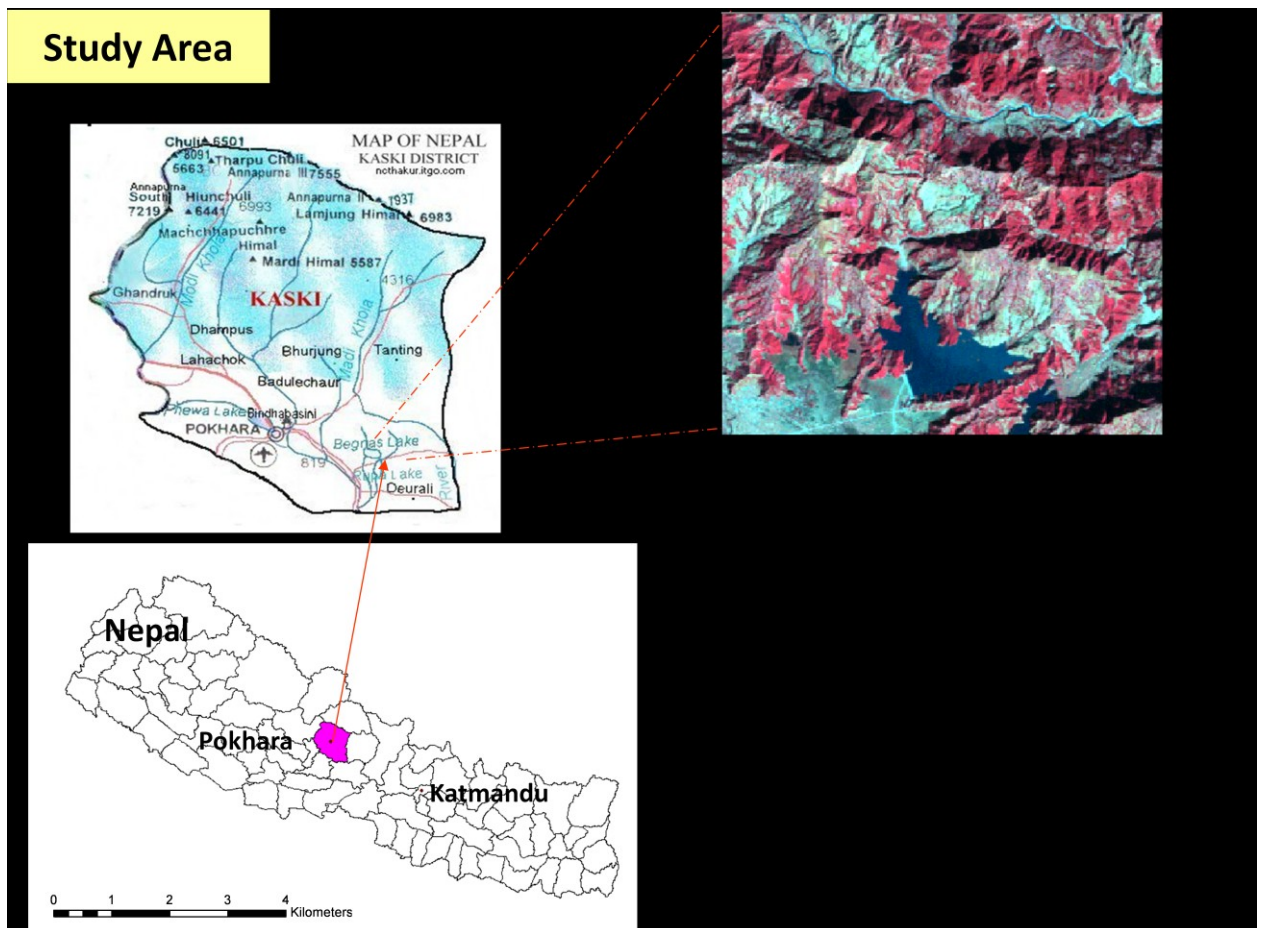


Figure 1: Location of the Study Area

2.2 Land Use

Forest, agriculture, open forest and barren lands are the main land use categories of the Begnas Tal Rupa Tal Watershed. The forest land use basically consists of community forestry whereas agriculture land use consists of field crop cultivation. The most common gregarious natural vegetation types under tropical to sub tropical monsoon climates are *Schima wallichii*, *Castanopsis indica*, *Alnus nepalensis* and *Shorea robusta* (Department of Forest, 2002). However, the watershed is interspersed by a number of patches of rural settlement and agricultural fields. Agricultural lands are allotted to wet and dry crops cultivation depending upon prevailing local climatic conditions.

2.3 Livestock

Raising livestock is an important economic activity in the watershed area. In spite of the time involved in collecting fodder and looking after the livestock and other social costs, raising livestock is profitable. Livestock is also the main source of manure for improving soil fertility and of draft power for plugging. The availability of forest and water resources encourages the farmers to raise livestock.

2.4 Socio-economic conditions

The watershed inhabitants are of many ethnic groups and castes and practice Hinduism, Buddhism and Islam. Due to economic, social and ecological pressures, the local people are forced to leave their villages for short and long-term employment. The lower castes often work as seasonally paid lab ours. A socio-economic study carried out in 1990 indicated that about 2% of the population was landless, and that 60% of the farmers own less than one hectare of land. Only an average of 3.8% own above 1 ha of cultivated land (Poudel, 1985).

2.5 Natural Vegetation

Plant associations of tropical to sub tropical forests are found in different elevation zones of the watershed. *Shorea robusta* occur in the tropical belt and *Schima wallichii*, *Castanopsis indica*, *Alnus nepalensis* predominate on the sub-tropical hills. In the sub-tropical belt forests are most vulnerable to destruction due to human encroachment. Mostly forests have been left only on the steeper slopes.

2.6 Climate

The climate of the watershed varies from tropical to sub-tropical monsoon types depending upon the altitude. Local convection hailstorms in autumn and strong winds during the dry spring are the limiting factors to certain crops. The seasonal cycle is cool-warm and dry winter and warm-hot and wet summer. The agricultural activity conforms to the seasonal rhythm and the vagaries of monsoon affect the farmer's poverty or prosperity (Gurung, 1965).

2.7 Sunshine

Begnas Tal Rupa Tal Watershed Area gets nearly six hours sunshine on an average round the year. The minimum hour is found in June when monsoon cloud covers the entire sky. Until September the sunshine hours slowly increase indicating the cloud stay for shorter period before the precipitation (Sharma 1975).

2.8 Wind

Wind is one of the important climatic parameter. In general wind is not very strong with average annual wind speed of 2.2 km per hour. Moreover south-west north-east and south-east winds also blow in the valley.

2.9 Evapotranspiration

The minimum evaporation is 2 mm/per day in January and maximum is 6.2 mm in May and June. The gap between evaporation and monthly precipitation is not much. But watershed areas lies in the city area being porous like honey-comb structure the percolation rate is abnormally high; hence a wide gap is created between the water requirement and water available for the plants.

2.10 Location and Extent

Begnas Tal Rupa Tal Watershed lies in the mid-hill belt of Nepal. Administratively the watershed confine covers four Village Development Committees (VDCs) and some parts of Leknath city in Kaski district. Begnas Tal Rupa Tal Watershed has city area as well as village area. This watershed has been categorized into two parts, first is upstream area and second part is downstream area. In upstream parts most of the area belongs to village and in downstream parts belongs to urban area.

2.11 Ecosystem Condition

The Begnas Tal Rupa Tal Watershed has different ecosystems viz., aquatic, wetland and terrestrial ecosystems. The aquatic ecosystem constitutes two distinct zones: Limetic (deep open water central zone) and littoral (shallow depth peripheral / shoreline zone). The wetland ecosystem consists of swampland and marshlands located along the floodplain. The terrestrial ecosystem consists of different land use types: forest grazing land and agricultural land. Urban and rural settlements are located along Lake Shoreline and gentler hill slopes as well. Villages are interspersed into agricultural lands. The common species include *Schimia wallichii*, *Castonopsis indica*, *Alnus nepalesnsis*, *Shorea robusta*, *Bombax ceiba* and *Ficus spp.* economically important and commercially threatened species under IUCN Red data book include: *Swerita chirayita*, *Bergenia ciliata*, *Choreospondias axillares*, *Elaeocarpus sphaericus*.

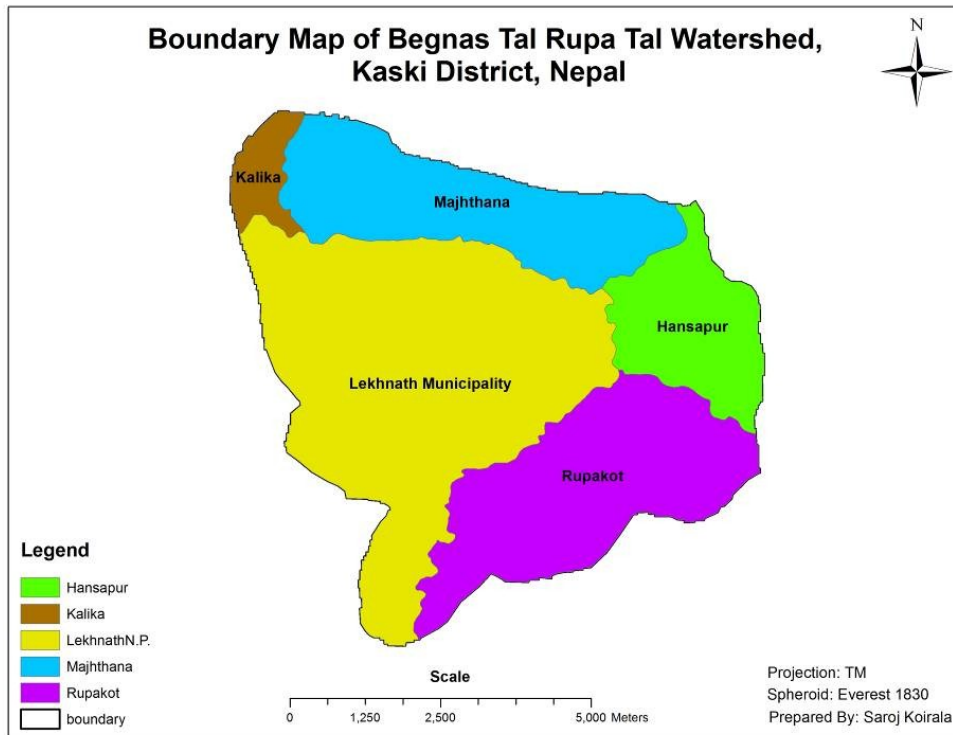


Figure 2: Boundary Map of Begnas Tal Rupa Tal Watershed

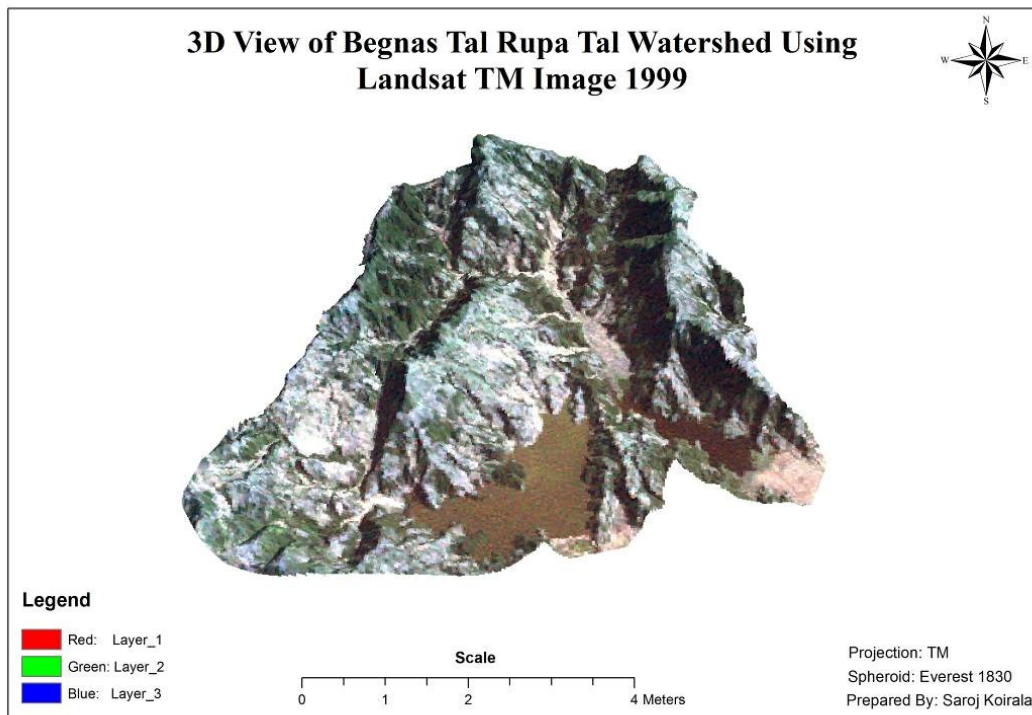


Figure 3: 3D View of Begnas Tal Rupa Tal Watershed

3. METHODOLOGY

3.1 Introduction

Land use land cover change and its impacts on soil erosion process is an explanatory type of research. The database is generated from the satellite images and published and unpublished records supported by primary data obtained from field observation and household survey. Geometry and topology of landforms pattern of forest resource uses and change in land use/land cover (1988 to 1999) and soil mapping are designed as the dimensions of spatial analysis.

3.2 Conceptual Construct

Begnas Tal Rupa Tal Watershed area is very rich in forests and species diversity. Different kinds of herbs and shrubs are found in this study area. Forest based small industries can be developed in these areas particularly where these forests are found. The term watershed is not restricted to surface water run-off but includes interactions with sub-surface water. Ecologically a watershed is a mosaic interacting abiotic components *viz.*, soil, land, topography, climate, and biotic component *viz.*, flora and fauna. The functions and values provided by natural features are included in the development of a watershed system. Administrative boundaries such as a block, village, town, city, district, and country are part of a watershed where the size of the watershed or basin in each case becomes a determining factor. Therefore, it helps in any conservational, economical and developmental activities to be planned and managed ensuring long-term sustainability.

3.3 Studies in Land Use/Land Cover Change

Different studies on land use/land cover changes, application of tools and techniques in estimating changes and assessment of the impacts on soil erosion have been the topics of interest of most environmentalists and ecologists. By using remote sensing satellite imagery different researchers and institutions have tried to measure out the changing pattern of land use land cover and came with different results.

S.N.	Studies in Land Use/Land Cover Change
1.	<p>Khanal and Bastola (2005) studied land use/land cover changes in Phewa Lake Watershed where watershed area has changed drastically due to opening of highways and urban facilities of sub-metropolitan Pokhara city. They found that most of the changes have occurred on agricultural land, forest area and built-up-area and minor changes have been found in different land cover. The study shows that land use change is a continuous process of change from one aspect to another aspect. The natural factors and human beings are the major agents for the change in cultural landscapes of nay region of the country. Finally they conclude that the country should develop an integrated land use policy for the overall economic and environmental development.</p>
2.	<p>Chaudhary <i>et al.</i> (2008) studied land use/land cover changes in Northern Part of Gurgaon District, Haryana, India and found that there is tremendous pressure on the natural resources due to increasing population, maximum increase in the area under settlements, which has increased almost four times over this period. The wasteland has also decreased drastically due to its conversion to settlements and other categories. The expansion of Gurgaon City is due to increasing population and Industrial/Infrastructural development pressure of National Capital, as Guragon is the most preferred and favorable destination.</p>
3.	<p>Tiwari (1999) studied land use changes in Indian Himalaya. The rapid growth of population has brought about extensive land-use changes in the region, mainly through the extension of the Himalayan watersheds through reduced groundwater recharge, increased run-off and soil erosion.</p>
4.	<p>Kammerbauer <i>et al.</i> (1999) used aerial photographs and GIS in to see land use dynamics and landscape change pattern in a typical watershed in the hillside region of central Honduras where he found during the last 40 years, forest cover has been reduced drastically with increasing population pressure and agricultural activities. Limiting physical and ecological factors were assessed, as well as the socio-economic and policy forces that caused these</p>

S.N.	Studies in Land Use/Land Cover Change
	changes in natural resource management practices and the resulting land use patterns.
5.	Weng, Q., (2001) used satellite remote sensing, GIS and stochastic modeling to find out land use change analysis in the Zhujiang, his results indicated that there has been a notable and uneven urban growth and a tremendous loss in cropland between 1989 and 1997. The land use change process has shown no sign of becoming stable. The technologies of satellite remote sensing, GIS and stochastic modeling are combined to address land use and land cover changes in the Zhujiang Delta, China, during the period 1989-1997. It was found that urban or built-up land and horticulture farms have notably increased in area, while cropland has decreased. The integration of satellite remote sensing, GIS, and Markov modeling provides a means of moving the emphasis of land use and land cover change studies from patterns to processes.
6.	Giri <i>et al.</i> , (2001) analyzed the multi-temporal and multi-seasonal NOAA AVHRR Satellite data of 1985/86, and 1992/2000 in Continental Southeast Asia to prepare historical land cover maps and to identify areas undergoing major land covers transformations (called “hot spots”). The identified “hot spots” areas were investigated using high-resolution satellite data such as Landsat and SPOT supplemented by intensive field survey. Shifting cultivation, intensification of agricultural land were found to be the principal reasons for land use land cover change in Oudomxay provience of lao P.D.R, Mekong Delta of Vietnam and Loei provience of Thailand respectively. The rapid rate of economic development, demographics and poverty are believed to be the underlying forces responsible for the change in this region.
7.	Ghosh <i>et al.</i> , (1996) studied the land use/ land cover change in a mountainous region of Himalayas using remote sensing and GIS. He derived the changes from aerial coverage under major land-use and land-cover types by spatial intersection of 1963 and 1993 data. He found out significant increase in cultivated area as a result of conversion of previously forest or

S.N.	Studies in Land Use/Land Cover Change
	pastures land to agriculture. However, some areas revealed an opposite trend where previously agriculture areas were afforested.
8.	Pfaff (1999) combined aggregated forest cover change from remote sensing data and included both population and economic variables in his analysis of deforestation in the Amazon. The major empirical finding was the importance of land characteristics (soil quality and vegetation density) and factors affecting transportation costs (distance to markets and own and neighboring county road networks) in determining deforestation rates.
9.	Pereira (2004) grouped the possible causes for land use change into two categories: a) real changes in land cover; b) differences observed due to other factors. It includes occurrence of floods and population growth. He suggested the changes induced by the growth of settlements can have different origins like the excessive utilization of natural fuel wood, cattle overgrazing or conversion of land to agriculture.
10.	Xiaomei Y. and Rong Qing L.Q.Y., (1999) noted that information about change is necessary for updating land cover maps and the management of natural resources. The information may be obtained by visiting sites on the ground and or extracting it from remotely sensed data.
11.	Barret <i>et al.</i> (2009) carried out case study of carbon fluxes from land change in the Southwest Brazilian Amazon and found land change is responsible for one-fifth of anthropogenic carbon emissions. In Brazil, three-quarters of carbon emissions originate from land change. They produced land-cover maps of pasture, forest, and secondary growth from 1993, 1996, 1999, and 2003 using an unsupervised classification method (overall accuracy = 89%). They presents new methods for estimating emissions reductions from carbon stored in the vegetation that replaces forests (e.g., pasture) and sequestration by new (> 10-15 years) forests, which reduced gross emissions by 16%, 15% and 22% for the period of 1993-1996, 1996-1999 and 1999-2003 respectively.
12.	Vadjunec <i>et al.</i> (2009) used geospatial tools to analyze land use/land cover change among rubber tappers in the Chico Mendes Extractive Reserve,

S.N.	Studies in Land Use/Land Cover Change
	<p>Brazil and found rubber tapping plays a less important role in livelihood strategies, as welfare is linked to non-extractive activities. Households pursue diverse livelihood activities including extractives, small-scale market cultivation, animal rearing, and cattle production. The overall results suggest that land use/land cover change is highly dynamic in the reserve.</p>
13.	<p>Millette <i>et al.</i> (1995) examined three villages in the Kathmandu valley of Nepal for pathways to criticality, which they define as a regional situation in which the rate or extent of environmental degradation precludes the continuation of current human use systems or levels of human well being, given feasible adaptations and societal capabilities to respond. They conclude that despite the difficulties of analyzing remote sensing imagery in a mountainous area where high slope angles and shadows complicate image analysis, remote sensing imagery in combination with ground-based data can "provide information highly germane to the analysis of changing nature society relations, including trajectories toward endangerment and criticality."</p>
14.	<p>Gautam <i>et al.</i> (2003) provided important insights into the dynamics that occurred in forested area and other major land use of the Upper Koshi Watershed in between 1976 and 2000 and provides a solid quantitative foundation for forest policy and institutional analysis.</p>

Table 1: Literature Review on Land Use/Land Cover Change

3.4 Studies on Soil Erosion

There are lot of models (empirical and physical) are available to assess soil erosion. Some models, applicable to a particular area, may not be directly applicable to other areas as they were designed for specific applications. The Universal Soil Loss Equation, (USLE) (Wischmeier and Smith, 1965), allows assessing soil loss from agricultural fields in specific conditions. It has been adapted to other conditions through modified versions such as MUSLE (Williams and Berndt, 1977) and RUSLE (SWCS; 1993) for sediment yield estimation. SLEMSA, the Soil Loss Estimation

Equation for Southern Africa (Stocking, 1981) was developed in Zimbabwe on the basis of the USLE model. There are some other models such as ANSWERS (Areal Non-point Source Watershed Environment Response Simulation, Beasley et.al., 1980), and AGNPS (Agricultural Non-Point Source Pollution Model, Young et.al., 1987), these models are based on grid cells and were developed to estimate runoff quality, with primary emphasis on sediment and nutrient transport. Although USLE has been widely used through various modified versions, its application in mountainous terrain with steep slopes is still questionable. Some models, such as AGNPS or ANSWER, may not be suitable in the Nepalese context because of very high data demand and AGNPS in particular is not adapted well enough to the Nepalese mid-hill belt mountain conditions (Kettner, 1996). Considering all these, the model developed by Morgan, Morgan and Finney (Morgan et al., 1984) is used in the present study to assess soil loss from hill slopes in the mid-hill belt of Nepal. Due to its simplicity, flexibility and strong physical base it was selected.

S.N.	Studies on Soil Erosion
1.	Awasthi <i>et al.</i> (2002) have carried out accurate measurement of land use/land cover and watershed analysis based on GIS in Mardi and Phewa Lake Watershed using aerial photographs of 1978 and 1996. In these watersheds there was a net increase in forest cover with a corresponding decrease in shrub and rain-fed agriculture. A significant area under agriculture in 1978 was found abandoned in 1996 in both watersheds most likely due to increased out migration of the labour force.
2.	Bakker <i>et al.</i> (2004) carried out test in the western part of Lesvos, Greece where they analyzed that soil erosion as a driver of land-use change; erosion has a strong impact on land-use. Abandonment of arable land due to declining productivity is a land use change that may result from soil erosion. Lesvos has experienced accelerated erosion on marginal soils over the last century during which important land-use changes have taken place. Erosion was modeled backwards for the period 1886-1996 and soil depths reconstructed for the time when the land-use was assumed to have changed (the mid-1950s). A logistic regression was performed with soil depth, erosion and slope as explanatory

S.N.	Studies on Soil Erosion
3.	<p>variables and land-use change as the response variable. They analyzed that based on the logistic model, it is anticipated that cereal cultivation in western Lesvos will probably be abandoned in the near future.</p> <p>Shrestha (1997) He analyzed that soil erosion is a crucial problem in Nepal where more than 80% of the land area is mountainous and still tectonically active. Results provided by running Morgan Morgan and Finney model in a GIS environment show that annual soil loss rates are the highest (up to 56 tonnes/ha/yr) in the areas with rain fed cultivation, which is directly related to the sloping nature of the terraces. The lowest soil losses (less than 1 tonne/ha/yr) are recorded under dense forest. In the degraded forest, the soil loss varies from 1 to 9 tonnes/ha/yr and in the grazing lands it is estimated at 8 tonnes/ha/yr. Erosion rates are higher on the south facing sub watershed than on the north facing one. Finally, his study shows that soil erosion can be modeled in the mountainous region.</p>

Table 2: Literature Review on Soil Erosion

3.5 Materials

The study is based on both remote sensing and ancillary data. The details of different hardware and software used during analysis and field observations are given below.

Details Used

The details of satellite data used in study are given table 3.

Data Used	Path/Row	Spatial Resolution (m)	Spectral Resolution (μm)	Spectral Bands Used (μm)	Band	Swath (km)	Date of Acquisition
Landsat TM	142/040	30	Band 1: 0.450 - 0.515	Band 1: 0.450 - 0.515	Blue	185	December 13, 1999 & November 20, 1988
			Band 2: 0.525 - 0.605	Band 2: 0.525 - 0.605	Green		
			Band 3: 0.630 - 0.690	Band 3: 0.630 - 0.690	Red		
			Band 4: 0.760 - 0.900	Band 4: 0.760 - 0.900	NIR		
			Band 5: 1.550 - 1.750	Band 5: 1.550 - 1.750	SWIR		
		120	Band 6: 10.40 - 12.5	Band 6: 10.40 - 12.5	Thermal IR		
		30	Band 7: 2.080 - 2.35	Band 7: 2.080 - 2.35	SWIR		

Table 3: Satellite Data Used for the Study

Ancillary Data

Topography sheet developed by department of survey Nepal is used in present study. Scale is 1:25,000 (Sheet No. 2884: 13A 13B). Same as Land Systems Map of scale 1:50000 (Sheet No. 62 P/15, 62 P/16) is used developed by department of survey Nepal. Socio-economic data from household survey as well as from Village Secretary and District Development Cooperation. Community forest operational plan from District Forest Office (DFO) Kaski. Annual Report of Nepal Agriculture Research Council (NARC). District Profile Kaski district, Nepal. Meteorological data from Department of Meteorology and Demographic data of the Central Bureau of Statistics Nepal.

Instruments / Field Equipments

Global Positioning System Garmin 12 Channel, Magnetic Rangers compass, Binocular, Camera are used for collecting data in field.

Ground Truth Data

Field Performa: It was designed to collect the ground data (Annexure 1).

Hardware

The computer hardware used during the study is given table 4.

Hardware	Uses
Laptop <i>hp</i> (4 GB RAM)	Data storage, software and internet support.
Plotter	To print hardcopy, paper maps and poster.
Scanner	To convert pictures or maps to digital form.
Printer	To produce high quality hardcopy, computer output viz. literature, thesis and report.

Table 4: Hardware Used for Study

Software

The software used in the study is in table 5.

Software	Uses
Arc View GIS 3.2a	Digitizing Mapping
ERDAS IMAGINE 9.1	Registration and processing of topographic map and satellite data change detection Image Classification
Arc Info 8.0	Topology (cleaning and building)
ILWIS 3.3 Academic	Morgan Morgam Finney Soil erosion modelling
Microsoft office	Data entry Non-Spatial Data Analysis Thesis Compilation and Presentation
Arc Map	To Prepare Map Composition

Table 5: Software Used for Study

3.6 Methods

The total research activities were set into pre-fieldwork, fieldwork and post-fieldwork stages. Description of work in each stage is as below:

3.6.1 Pre Field Stage

Pre-field work consisted initiation of project followed by downloading and pre-processing different satellite data and creation of base map. Project planning pre-processing and database creation are major works performed in this stage.

Project Planning

The study was proposed and planned in view of the problems in resource conservation and their sustainable use in Begnas Tal Rupa Tal Watershed of Kaski district, Nepal. On the basis of literature review and the knowledge gained during the study period, it was felt that the remote sensing along with GIS could be useful to detect changes in land use/land cover between 1988 and 1999. Project planning includes

- Collection of literature pertaining to the research topic;
- Study of topographic maps and
- Procurement of remote sensing data products followed project planning.

Pre-processing

Pre-processing of data includes radiometric and geometric corrections are made before data base creation. The procedures of corrections are discussed as follows:

Radiometric Correction

Raw data was not directly possible for using. In this type of data there is a lot of distortion which must be corrected before using by different methods. First order corrections were done by dark pixel subtraction technique (Lillesand and Kiefer, 1999) where the water leaving radiance in the near infrared is assumed to be zero and the signal received at the satellite is thus entirely due to atmospheric effects. The effect of air molecule scattering can be calculated and removed, leaving the radiance due to aerosol scattering. It is then possible to produce ratios relating the effects of aerosol scattering in the near infrared to the aerosol scattering at other wavelengths,

and thus to remove atmospheric effects from visible wavelength data. The corrected radiance values can be related to physical properties such as concentrations of chlorophyll and sediments in the water. The “darkest pixel” technique can also be used in land studies, provided that an area of deep (and hopefully unpolluted) water is available somewhere within the study image.

Geometric Correction

Geometric correction addresses errors in the relative positions of pixels. It is undertaken to avoid geometric distortions from a distorted image. Raw digital image usually contains geometric distortions so significant that they cannot be used as maps. The sources of these distortions range from variations in the altitude and velocity of the sensor platform to factor such as panoramic distortion, earth curvature, atmospheric refraction, relief displacement and non-linear ties in the sweep of a sensor’s IFOV. To carry out the geometric correction in image which we are going to be used for analysis of the proposed study area. We need to rectify those images with the reference map e.g. corrected topo sheet (Produced by Survey Department of Nepal) map on 1:25,000 scales. For getting better accuracy during geometric corrections common well distributed ground control points necessary. A sub-pixel accuracy of control points was obtained for all satellite images by geo-referencing. The images used were then re-sampled by cubic convolution method. The data sets were then co-registered for further analysis.

3.6.2 Field Work Stage

Entire study area was visited in the month of September 2009. From the field different necessary information was obtained.

Ground Truth Collection

Different land uses are identified on the FCC Map. The land uses type was recorded as well as major plant species were enumerated. The tonal variation representing the different land uses were correlated with various features. From the whole study area, collection of coordinates pertaining to various features using GPS in the field was carried out. Different type of statistical data and other important information was

taken from forest department. Based on the preliminary reconnaissance survey and visual interpretation of the satellite data, land use in the study area was classified as below (Table 6):

S.N.	Land Use/Land Cover	Description
1.	Dense Mixed Forest	Forest composed of trees of two or more species intermingled in the same canopy forming 40-70% dense canopy and consisting at least 20% canopy other than principle species. The main species are <i>Schima wallichii</i> , <i>Castanopsis indica</i> , <i>Alnus nepalensis</i> , <i>Dendrocalamus hamiltonii</i> , <i>Cinnamomum zeylanicum</i> , <i>Syzygium cumini</i> , <i>Myrica esculenta</i> , <i>Rhus javanica</i> etc.
2.	Sal Forest	Sal (<i>Shorea robusta</i>) occurs in the tropical belt at an altitude below 1000 meter. Some small area of sal forest occurs in Southern hills.
3.	Open Forest	Forest consist less than 40% in the canopy composition.
4.	Agricultural Land	In the downstream of study area mainly variety of paddy is growing and irrigation also good but in the upstream of the study area water sources and soil are not good. The major crops are Wheat (<i>Triticum spp.</i>), Paddy (<i>Oryza sativa</i>), Millet Soybean, Maize (<i>Zea mays</i>) etc.
5.	Barren Land	Without vegetation and agricultural crops, soil is very poor in this land. Almost all the cultivation activity is zero. Most of these lands are unproductive.
6.	Settlement	Very Dense population with compare to past eleven years.
7.	Water Body	The land covered under natural drainage system like river streams as well as manmade linear drainage system like canals (used or unused) and natural or manmade linear reservoir or ponds and lakes.

Table 6: Land Use/Land Cover Classification Scheme for Mapping

Other Data Collection

Rainfall, Temperature and Humidity data was collected from Metrological Department of Nepal. Forest plantation, compartment map and timber production data are taken from Forest Department in Kaski, Pokhara, Nepal. Soil map and other important documents related to soil is taken from Soil Conservation Department of Kaski, Pokhara, Nepal.

Road Network Development

Due to some parts of watershed area located in city there is black road where most of the villages have only village road which is not well constructed. Most of the rural people use these types of village road for their daily livelihood requirements.

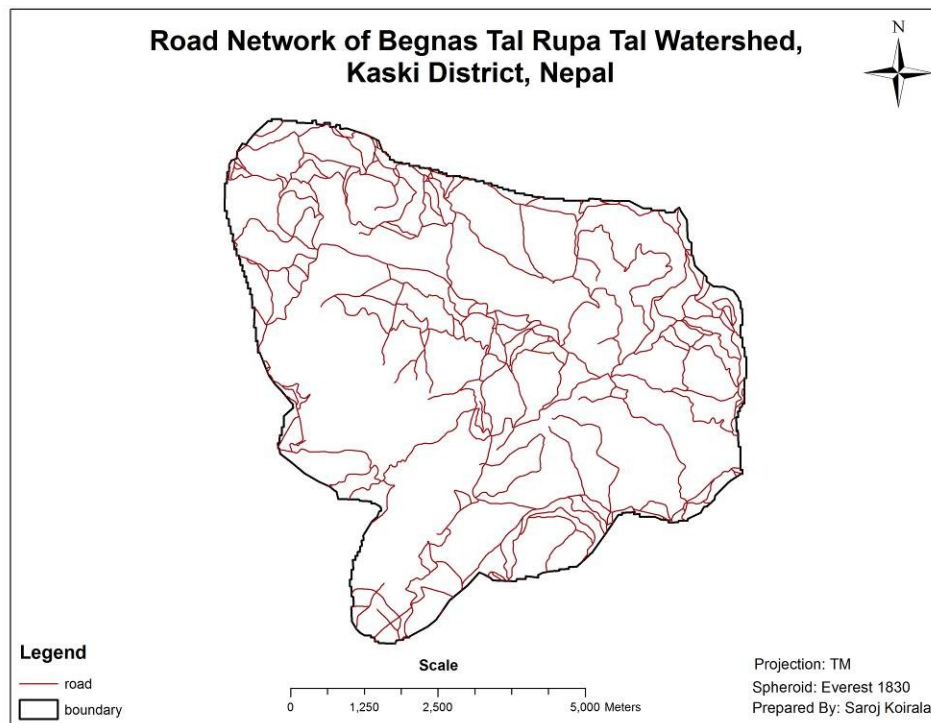


Figure 4: Road Network of Watershed

3.6.3 Post Fieldwork Stage

Preparation of Land Use/Land Cover Map

Procedure of on screen visual interpretation of satellite data was carried out to find out different land use/land cover classes in conjugation with information from maps and ground truth. Land use/land cover map of Landsat TM 1988 image and Landsat TM 1999 image was prepared. The identification and delineation of all classes along with other cover types was done by following the standard visual interpretation technique (Browden and Pruitt, 1983).

Preparation of Slope, Aspect, Drainage and Contour Maps

Contour map was prepared in 20 meter intervals from 1:25,000 scale topographic maps of Department of Survey (Nepal) in ArcView GIS 3.2a software. Similarly

drainage map was prepared from the same topographic maps. With the help of contours DEM was generated in ArcView GIS 3.2a software. Slope and aspect maps were derived from DEM in same software.

Land Used Cover Map along the Slope

Slope is the gradient of the surface of the ground expressed in either degrees or in percent (Gulati, 1986). Slope plays important role in distribution of land use/land cover. In the present study the slope map is recoded into 5 classes (Table 7). The land use/land cover map was then intersected with slope index map to assess land cover distribution along slope categories.

S.N.	Classes	Slope (Degree)
1	Flat/almost Flat	0~2
2	Gentle slope	2~6
3	Moderate slope	6~13
4	Moderate to steep slope	13~25
5	Steep slope	25~55

Table 7: Slope Classes Used in the Study

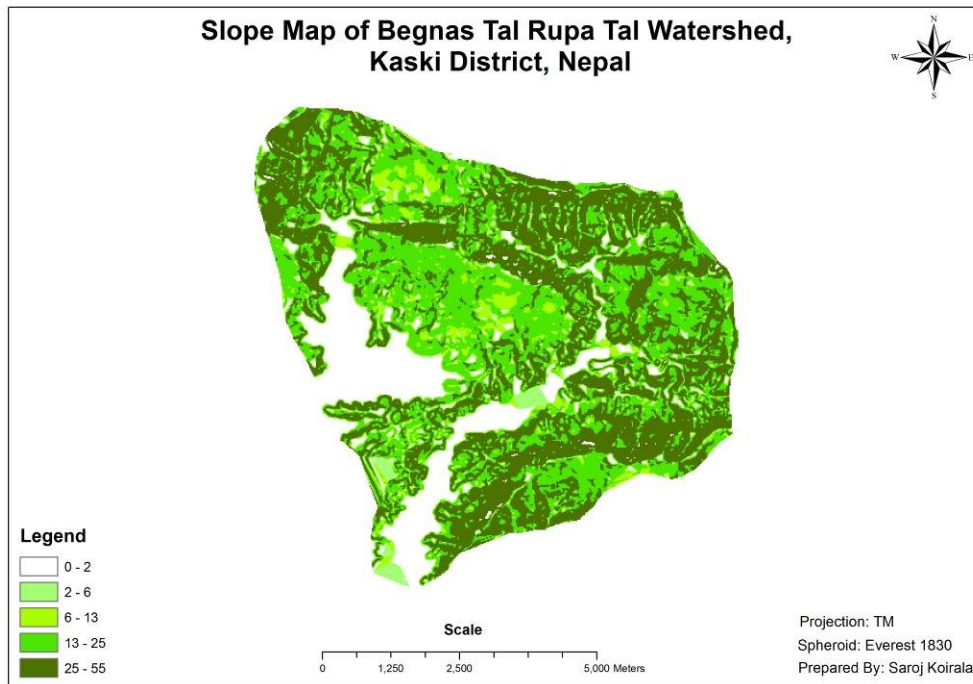


Figure 5: Slope Map of Watershed

Land Used Cover Map along the Aspect

Aspect is the direction towards which the slope faces (Gulati, 1986). The aspect map which was derived from DEM was recorded into 8 classes and each land use/land cover map was intersected with recorded aspect map (Table 8).

S.N.	Classes	Aspect (Degree)
1	North	0-22.5 337.5-360
2	North-East	22.5-67.5
3	East	67.5-112.5
4	South-East	112.5-157.5
5	South	157.5-202.5
6	South-West	202.5-247.5
7	West	247.5-292.5
8	North-West	292.5-337.5

Table 8: Aspect Classes Used in the Study

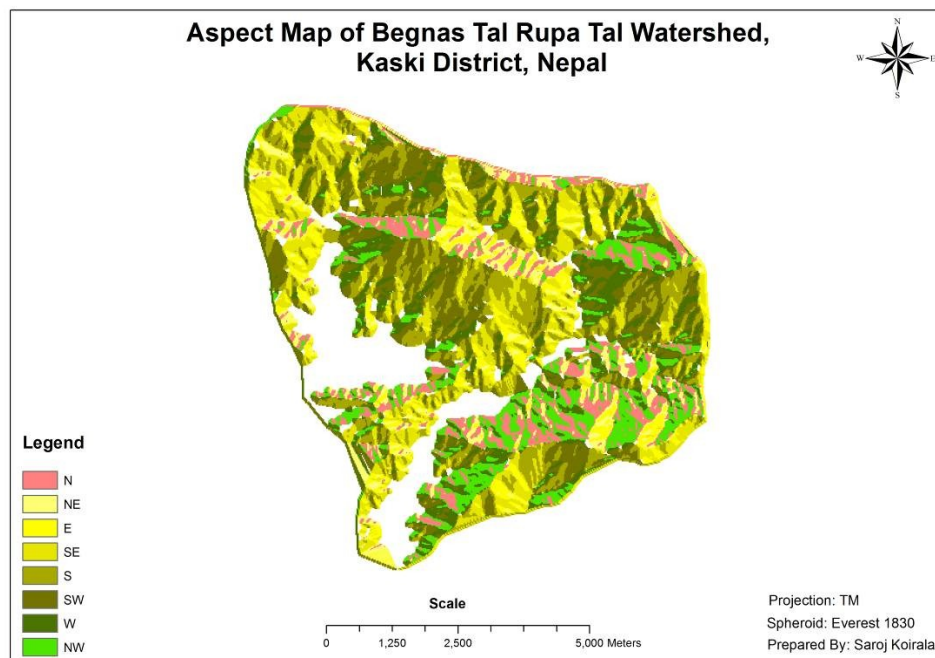


Figure 6: Aspect Map of Watershed

Land Used Cover Map along the Altitude

Altitude is the elevation from a known level or datum (msl). Altitude greatly affects on land cover distribution. Total three altitude classes (Table 9) were made by

recording in the original DEM. The recorded DEM was then intersected with each land use/land cover map.

S.N.	Classes	Altitude (Meter)
1	Lower Tropical Zone	620 - 800
2	Tropical Zone	800 - 1000
3	Sub-Temperate Zone	1000 - 1420

Table 9: Altitude Class Used in the Study

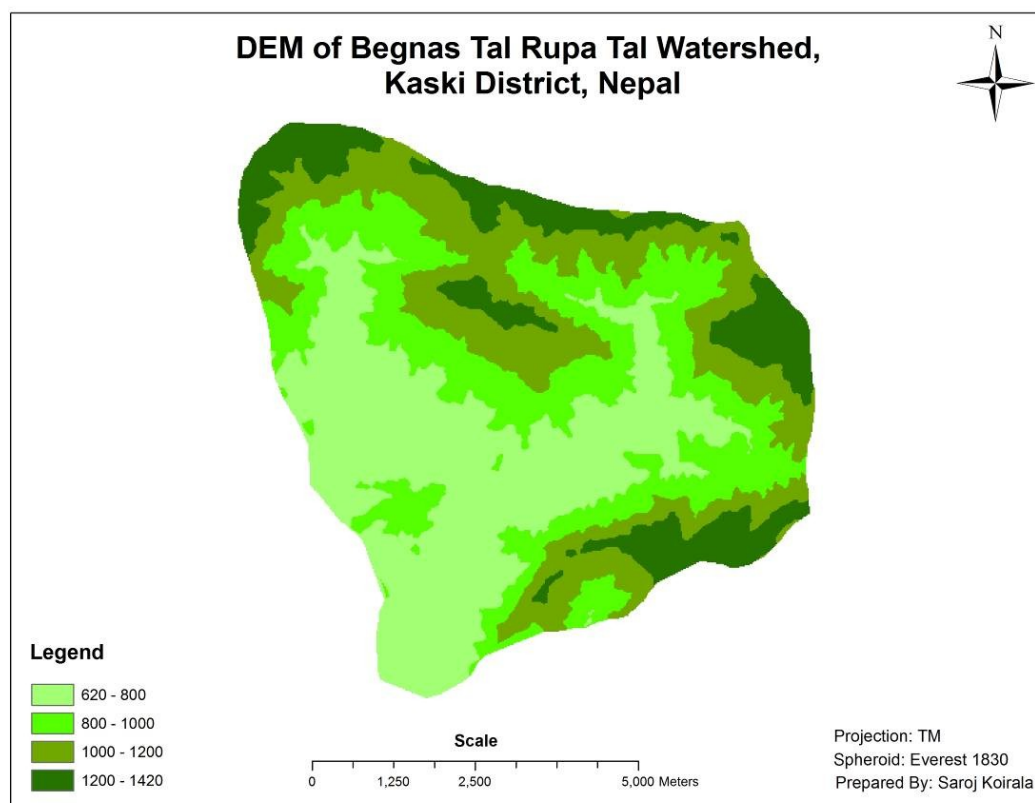


Figure 7: DEM of Watershed

3.7 Land Use/Land Cover Map Preparation

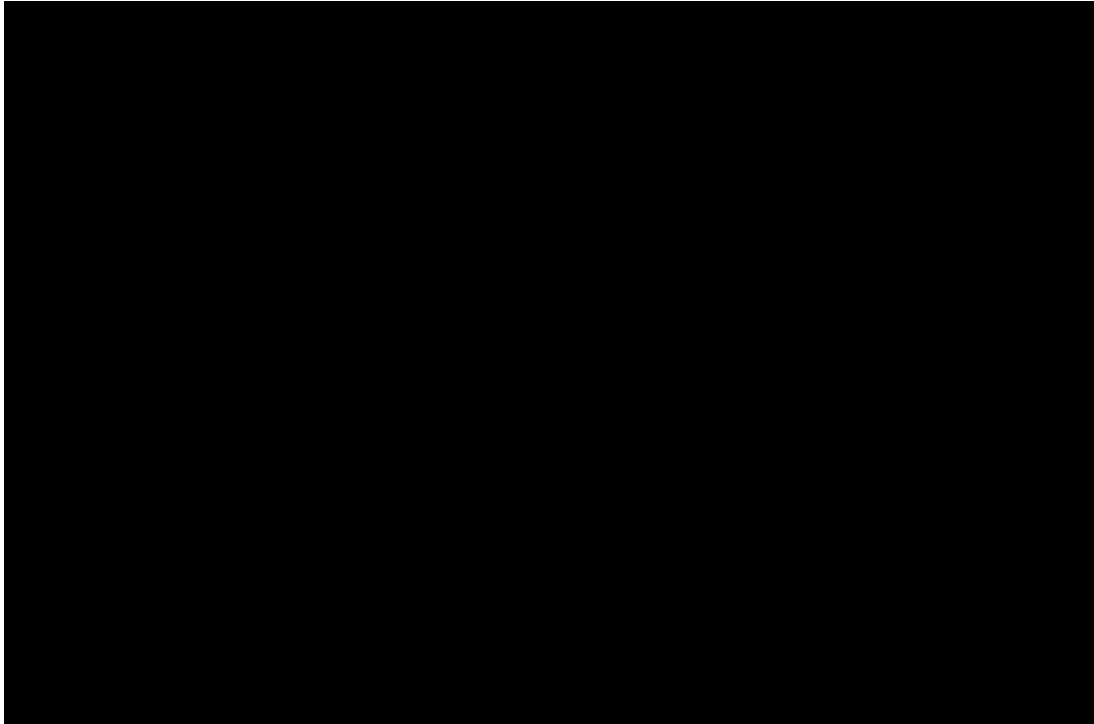


Figure 8: Methodology in Land Use/Land Cover Map Preparation

Satellite images Landsat TM of 1988 and 1999 are used for land use land cover map, raw images of this year was taken and did radiometric/geometric correction; radiometric correction was done by dark pixel subtraction after that geometric correction. It was done by providing sufficient ground control points in permanent features such as road, canal etc. Preliminary Visual Interpretation was carried out, from topography map boundary was created according to that boundary satellite image was subset. Final interpretation was carried out by sufficient information from ground truth. Finally, land use land cover map was created by digitizing satellite image.

3.8 Land Use Change during (1988-1999) Period

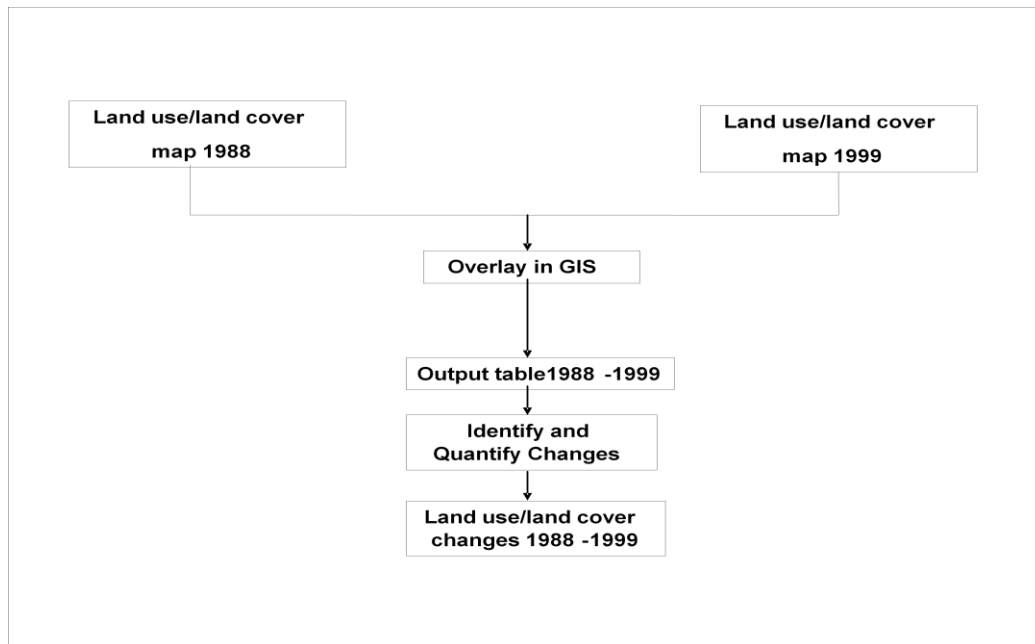


Figure 9: Methodology to detect Land Use/Land Cover Change from 1988-1999

The detection of change over time is one activity that can be performed more efficiently with digital remotely sensed imagery than by almost any other means. A change in digital values between two dates of imagery of the same area can result from real change of surface cover, or from atmospheric or solar elevation differences. Remote Sensing is a valuable data source from which land use/land cover change information can be extracted efficiently. To assess the change in Land use of Begnas Tal Rupa Tal Watershed Satellite data of 1988 and 1999 were selected. The land use polygon themes for these two years obtained from the visual interpretation were converted into grid format and imported to ERDAS as image file for further analysis. Then 1988 and 1999 maps were overlaid respectively using matrix option in ERDAS IMAGE 9.1 to find changes. Change and no-change matrix were made from attribute table of the overlaid 1988-1999 images. The area of change and no-change and percent change were also calculated using Excel. On the basis of these matrices, the results and conclusion were derived.

3.9 Pressure Index Map

It is very essential to find out the areas which are highly on pressure and which are least pressure from resource extraction point of view. Pressure Map has been prepared taking settlement, road and slope index into the consideration. Following table shows the parameters and their respective weights for pressure zone mapping.

Parameters	Criteria	Weight
Settlement buffer	<200m	0.25
	200-400m	
	>600m	
Road buffer	<200m	0.25
	200-400m	
	400-600m	
Slope index	<15°	0.50
	15-30°	
	>30°	

Table 10: Input parameters and their weights for pressure zone mapping

Pressure index map = $0.5 \times (\text{slope index}) + 0.25 \times (\text{road buffer}) + 0.25 \times (\text{settlement buffer})$

3.10 Soil Erosion Modeling

Revised Morgan Morgan and Finney Model (MMF) with the aid of Remote Sensing and GIS are used in present study. This model was selected because of its simplicity, flexibility and strong physical base. Morgan *et al.* (1984) presented a simple empirical model for predicting annual soil loss from field-sized areas on hill slopes. The MMF model used the concepts proposed by Meyer and Wischmeier (1969) and Kirkby (1976) to provide a stronger physical base than the Universal Soil Loss Equation (Wischmeier and Smith, 1979).

The model was designed to separate the erosion process into a water phase and a sediment phase. The MMF model simplified the erosion processes into two: detachment of soil particles from the soil mass by raindrop impact and the transport of those particles by runoff. The ability of rainfall to transport soil particles down slopes and of runoff to detach soil particles were ignored. The results obtained by the model are most sensitive to changes in annual rainfall and soil parameters when erosion is transport-limited and to changes in rainfall interception and annual rainfall

when erosion is detachment-limited. Thus good information on rainfall and soil is required for successful output (Morgan *et al.* 1984),

Factor	Parameter	Definition and remarks
Rainfall	R	Annual or mean annual rainfall (mm)
	Rn	Number of rain days per year
	I	Typical value for intensity of erosive rain (mm/h); 10 for temperate climates 25 for tropical climates and 30 for strongly seasonal climates e.g. Mediterranean type and monsoon
Soil	MS	Soil moisture content at field capacity or 1/3 bar tension (w/w)
	BD	Bulk density of the top soil layer (Mg/m ³)
	EHD	Effective hydrological depth of soil (m); depend on vegetation/crop cover presence or absence of surface crust presence of impermeable layer within 0.15 m of the surface.
	K	Soil detachability index (g/J) defined as the weight of soil detached from the soil mass per unit of rainfall energy.
	COH	Cohesion of the surface soil (kPa) as measured with a torvane under saturated conditions.
Landform	S	Slope steepness (°).
Land Cover	A	Proportion between 0 and 1 of the rainfall intercepted by the vegetation or crop cover.
	Et/Eo	Ratio of actual (<i>Et</i>) to potential (<i>Eo</i>) evapo-transpiration
	C	Crop cover management factor; combines the <i>C</i> and <i>P</i> factors of the Universal Soil Loss Equation.
	CC	Percentage canopy cover expressed as a proportion between 0 and 1
	GC	Percentage ground cover expressed as a proportion between 0 and 1
	PH	Plant height (m) representing the height from which raindrops fall from the crop or vegetation cover to the ground surface

Table 11: Input Parameters (Morgan *et. al.* 1995) for soil erosion modeling

R = Rainfall; Rn = Number of rainy days per year; I = Intensity of erosive rain (mm/h); MS = Soil moisture content at field capacity (w/w); BD = Bulk Density (Mg/m³); EHD = Effective Hydrological depth of the soil (m); K = Erodibility of the soil (g/J); COH = Cohesion of the surface soil; S = Slope steepness (°); A = Proportion between 0 and 1 of the rainfall intercepted by the vegetation; Et/Eo = Ratio of actual (*Et*) to potential (*Eo*) evapo-transpiration; C = Crop cover management factor; CC = Percentage canopy cover; GC = Percentage ground cover; PH = Height of the plant canopy (m).

3.10.1 Soil Erosion Modeling Database Creation

Creation of Maps based on Attributes

Attribute values (Table 12) were assigned based on remote sensing data, ground truth and ancillary data for each parameter of the land use/land cover, soil and the rainfall

maps. Attribute maps of each parameter was created. Finally the erosion model was run in the Integrated Land and Water Information System (ILWIS) a raster based GIS software package capable of combining conventional GIS procedures with image processing and using a relational database (Valenzuela, 1988) applying following steps.

Step1. Estimation of rainfall energy

The procedure for calculating the energy of rainfall is partitioned during interception and the energy of the leaf drainage. The model takes the annual rainfall total (R; mm) and computes the proportion (between 0 and 1) which reaches the ground surface after allowing for rainfall interception (A) to give the effective rainfall (ER):

$$ER=RA$$

Where,

R = Annual rainfall (mm)

A = Proportion of rainfall which reaches the ground surface after allowing for rainfall interception (according to Morgan it should be between 0 to 1).

(a)

Forest/Land Use Type	A	GC	CC	PH	Et/E0	C	EHD
Dense mixed forest	0.40	0.45	0.45	18.0	0.85	0.004	0.16
Sal Forest	0.38	0.38	0.29	14.0	0.88	0.003	0.18
Open forest	0.20	0.30	0.20	15.0	0.60	0.002	0.13
Agriculture	0.15	0.15	0.15	1.0	0.50	0.002	0.11
Barren land	0.10	0.10	0.05	0.05	0.65	0.001	0.05
Settlement	0	0	0	0	0	0	0
Water body	0	0	0	0	0	0	0

(b)

Rainfall	R1988	Rn1988	R1999	Rn1999	I
Pokhara	3274.4	160	4686.6	148	15

(c)

Soil Texture	MS	BD	K	COH
Fragmental sandy	0.08	1.5	1.2	2.0
Loamy	0.20	1.3	0.8	3.0
Loamy bouldery	0.15	1.2	0.3	2.0
Loamy skeleton	0.10	1.3	0.8	3.0

Table 12 (a-c): Attribute Values assigned for creating input layers in soil erosion modeling

A = Proportion between 0 and 1 of the rainfall intercepted by the vegetation; GC = Percentage ground cover; CC = Percentage canopy cover; PH = Height of the plant canopy (m); Et/Eo = Ratio of actual (Et) to potential (Eo) evapo-transpiration; C = Crop cover management factor; EHD = Effective Hydrological depth of the soil (m); R = Rainfall; Rn = Number of rainy days per year; I = Intensity of erosive rain (mm/h); MS = Soil moisture content at field capacity (w/w); BD = Bulk Density (Mg/m³); K = Erodibility of the soil (g/J); COH = Cohesion of the surface soil.

The effective rainfall (ER) is then split into that which reaches the ground surface as direct through fall (DT) and that which is intercepted by the plant canopy and reaches the ground as leaf drainage (LD). The split is a direct function of the percentage canopy cover (CC):

$$LD = ER \times CC$$

$$DT = ER - LD$$

Where,

LD = Leaf drainage

ER = Effective rainfall

CC = Percentage canopy cover

DT = Direct through fall

The kinetic energy of the direct through fall (KE DT; J/m²) was determined as a function of the rainfall intensity (I; mm/h) using a typical value for the erosive rain of the climatic region i.e.10.

Kinetic energy of the direct through fall was calculated using following standard formula.

$$KEDT = DT (11.9 + 8.7 \log I)$$

Where,

DT = Direct through fall

KEDT = Kinetic energy of the direct through fall (J/m²)

I = Intensity of erosive rain (mm/h) i.e. 15 for subtropical climates

(Morgan et. al.; 1995)

The kinetic energy of leaf drainage (KELD; J/m²) is dependent upon the height of the plant canopy (PH; m). Following formula was used to calculate KELD.

$$KE LD = (15.8 \times PH^{0.5}) - 5.87$$

where,

KELD = Kinetic energy of leaf drainage (J/m²)

PH = Height of the plant canopy (m)

The total energy of effective rainfall (KE; J/m²) was then obtained by summing up KEDT and KELD.

$$KE = KEDT + KELD$$

Step 2. Estimation of runoff

The procedure for estimating the annual runoff (Q; mm) remains unchanged. It assumes that runoff occurs when the daily rainfall exceeds the soil moisture storage

capacity (R_c ; mm) and that daily rainfall amounts approximate an exponential frequency distribution. The annual runoff is obtained from:

$$Q = R \exp(-R_c/R_o)$$

where,

$$Q = \text{Annual Runoff (mm)}$$

$$R = \text{Annual Rainfall (mm)}$$

$$R_c = \text{Soil moisture storage capacity i.e. } 1000 \times MS \times BD \times EHD \left(\frac{Et}{E_o} \right)$$

where,

$$MS = \text{Soil moisture content at field capacity (w/w)}$$

$$BD = \text{Bulk density (Mg/m}^3\text{)}$$

$$EHD = \text{Effective Hydrological depth of the soil (m)}$$

$$Et/E_o = \text{Ratio of actual (Et) to potential (E_o) evapotranspiration}$$

$$R_o = \text{Mean rainfall per rain day (R/R}_n\text{)}$$

where,

$$R = \text{Annual rainfall (mm)}$$

$$R_n = \text{Number of rain days per year}$$

Step 3. Soil particle detachment by raindrop impact

In the revised MMF model, rainfall energy can be estimated using rainfall interception. It is therefore, removed from the equation used to describe soil particle detachment by raindrop impact (F ; kg/m²) which then simplifies to:

$$F = K \times KE \times 10^{-3}$$

where,

F = Raindrop impact (kg/m²)

K = Erodibility of the soil (g/J)

KE = Kinetic energy of the effective rainfall (J/m²)

Step 4. Soil particle detachment by runoff

Soil particle detachment by runoff was estimated using following formula

$$H = ZQ^{1.5} \sin\alpha (1-GC) \times 10^{-3}$$

where,

H = Soil particle detachment by runoff

Z = Resistance of the soil i.e. 1/(0.5COH)

Q = Annual Runoff (mm)

Sin α = It was obtained from slope map of the study area by using formula i.e. SIN (DEGGRD) \times Slope map

GC = Percentage ground cover

Step 5. Transport capacity of runoff

It was calculated by using following formula

$$TC = CQ^2 \sin\alpha \times 10^{-3}$$

where,

TC = Transport capacity of runoff (kg/m²)

C = Crop cover management factor

Q = Annual Runoff (mm)

Step 6. Estimation of total annual detachment

Total annual detachment (AD; kg/m²) = F + H

where, F = Soil particle detachment by raindrop (kg/m^2)

H = Soil particle detachment by runoff (kg/m^2)

Step 7. Estimation of total annual soil erosion

It was calculated by comparing annual detachment (AD) to annual transport capacity (TC). The lesser of the two values indicates annual soil erosion rate (Meyer and Wischmeier 1969).

$$\text{Annual Erosion (kg/m}^2\text{)} = \text{if (AD < TC AD TC)}$$

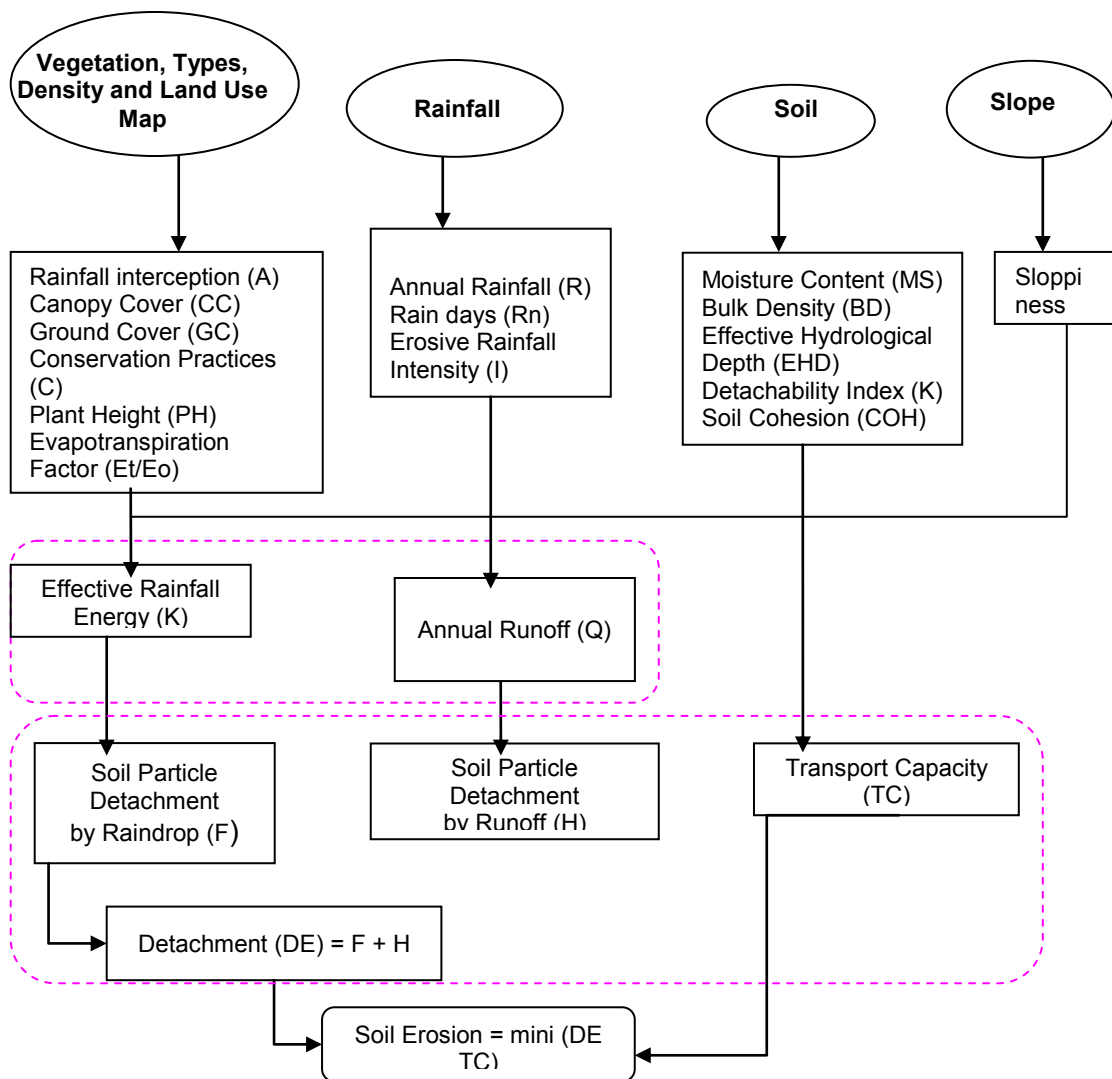


Figure 10: Soil Erosion Modeling (Revised Morgan-Morgan-Finney-Model)

A = Rainfall interception; CC = Canopy Cover; GC = Ground Cover; C = Conservation Practices; PH = Plant Height; Et/Eo = Evapotranspiration Factor; R = Annual Rainfall; Rn = Rain days; I = Erosive Rainfall Intensity; MS = Moisture Content; BD = Bulk Density; EHD = Effective Hydrological Depth; K = Detachability Index; COH = Soil Cohesion; K = Effective Rainfall Energy; Q = Annual Runoff; F = Soil Particulate Detachment by Raindrop; H = Soil Particle Detachment by Runoff; TC = Transport Capacity; DE = Detachment.

3.11 Hydrology

The source of water for Begnas Tal Rupa Tal watershed is surface water through rivers and rivulets. These are contributed by surface runoff and groundwater recession. There is high density of rivulets. There is both low water table and coarse texture. Such steep slopes are susceptible to erosion. Lowland area is vulnerable to flood havoc during heavy rains.

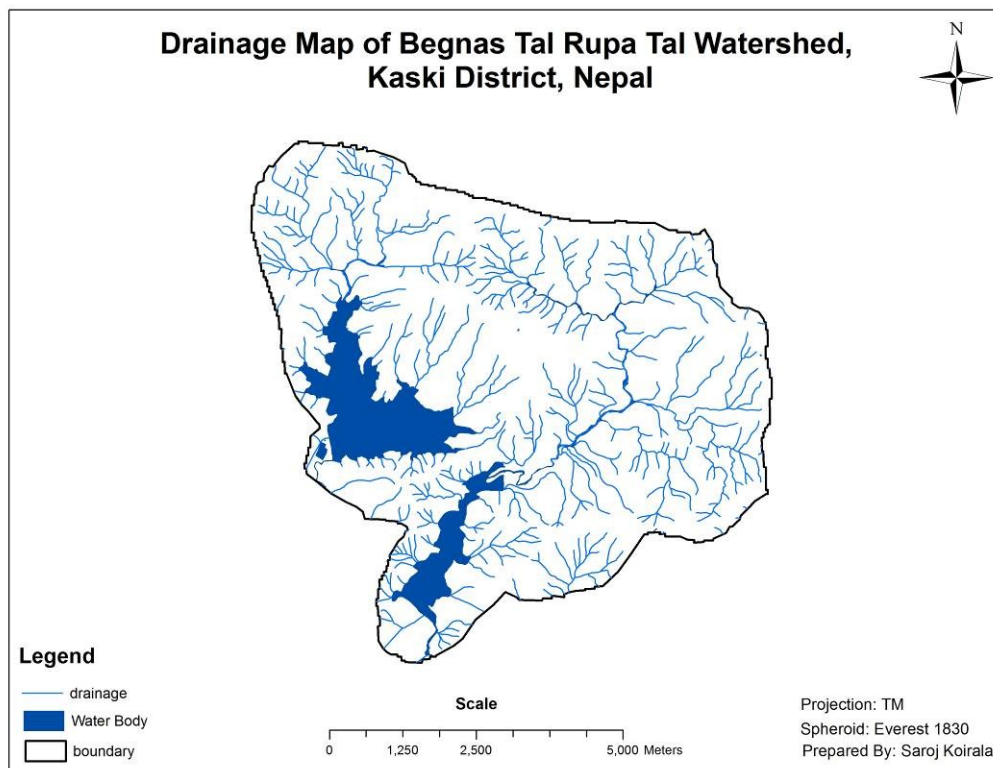


Figure 11: Drainage Map of Begnas Tal Rupa Tal Watershed

3.12 Precipitation

The wet months are July to September, while October to December is dry months. From January the rain starts and the maximum precipitation is received in the month of July. The monsoon starts in mid-June and reaches its maximum intensity in July and falls down slowly in October.

Year	January	February	March	April	May	June	July	August	September	October	November	December
1988	1.6	26.1	73.4	135.6	241.9	782.6	1093.5	810.5	793.9	15	3.6	55
1989	68	14.2	65.5	11.7	518.3	594.1	973.9	871.6	807.2	58.4	44.4	42.9
1990	0	59.6	114.7	44.8	361.1	931.5	732.5	742.5	530.2	99.7	0	2.9
1991	9.9	22.4	77.6	64.2	358.3	497.5	797.7	602.9	994.1	53	0.8	35.2
1992	10.5	24.7	0.5	53.9	247	469.1	793.6	798.7	396.5	246.5	2.4	26.2
1993	9.7	20.2	55.7	205.2	358.4	652.1	965.6	1168.5	478.5	294.7	0.6	0
1994	34.7	49.5	73.2	59.6	380.7	686.9	1020.3	794.4	523.8	97.8	1.8	0
1995	16	43.4	72.5	75.8	282.4	1391.3	1372.1	745.5	560	202.8	80.8	3.9
1996	59.7	75.4	94.6	38.5	371.9	687.5	939.8	857.4	703.4	131.7	0	0
1997	62.5	11.8	45.6	224.6	308.7	545.8	1113.5	604.1	327.4	115.8	30	133.9
1998	0	24.8	107.6	238.9	415.3	769.7	917.2	1493.5	740.3	158.7	9.6	3.4
1999	7	22.6	0	20.6	899.7	979.6	950.5	899.7	730.7	176.4	0	0
Total	279.6	394.7	780.9	1173.4	4743.7	8987.7	11670.2	10389.3	7586	1650.5	174	303.4
Mean	23.3	32.89	65.08	97.78	395.31	748.98	972.52	865.78	632.17	137.54	14.5	25.28

Table 13: Annual Rainfall (mm) in Begnas Tal Rupa Tal Watershed, Pokhara,

Nepal (Source: The Office of the Meteorological Station, Pokhara, Nepal)

3.13 Temperature

Temperature its intensity and duration is important in the mountainous country for the agriculture purpose checking the last 11 years data it is seen that the maximum recorded mean monthly temperature is 30.35° C in the month of May and minimum recorded mean monthly temperature is 7.04° C in the month of January (Table 15 and 16).

Year	January	February	March	April	May	June	July	August	September	October	November	December
1988	8.2	9.7	12.4	16.1	19.3	21.2	22.3	22.2	21.3	16.5	10.2	9.3
1989	6.9	7.4	11.9	14.5	19.1	20.6	21.4	21	20.7	15.9	11	7
1990	8.6	9.3	10.6	15	18.2	21	21.8	21.4	20.6	15.6	11.1	7.6
1991	6.1	8.9	12.6	15.3	19	21.3	22.3	22.1	20.7	16.5	11.2	7.1
1992	7.1	7.9	12.8	15.5	17.2	20.3	21.6	21.9	20.7	16.5	11.2	7.1
1993	8.1	9.8	10.2	14.6	18.5	21.2	22.4	22	20.4	17.4	13.2	8.9
1994	7.4	8.1	14	14.8	18.8	21.4	22.3	22.3	21.4	15.7	9.4	6.4
1995	5.5	6.5	12	15	20	21.9	21.9	22	22.1	17.6	12.1	8.8
1996	7.1	9.4	14.3	15.9	18.1	20.9	22.2	22	20.7	16.5	12.3	7.3
1997	6.2	7.8	12.5	14.5	17.1	20	22.3	22	20.8	14	11.8	7.7
1998	6.8	9.7	11.9	16.3	19.6	22.2	22.6	22.6	21.3	19.3	13.5	8.2
1999	6.5	10.7	13.2	18.7	19.1	20.8	21.7	21.4	21.4	17.4	12.7	9.1
Total	84.5	105.2	148.4	186.2	224	252.8	264.8	262.9	252.1	198.9	139.7	94.5
Mean	7.04	8.77	12.37	15.52	18.67	21.07	22.07	21.91	21.01	16.58	11.64	7.88

Table 14: Minimum Temperature of Begnas Tal Rupa Tal Watershed, Pokhara, Nepal

(Source: The Office of the Meteorological Station, Pokhara, Nepal)

Year	January	February	March	April	May	June	July	August	September	October	November	December
1988	20.4	22.9	25.6	30	30	30.5	29.8	29.4	29.5	28.2	25.3	21.4
1989	18.2	20.9	25.8	30.9	31.2	30.3	28.2	29.9	29.2	28	23.5	19.8
1990	21.3	21	23.7	28.3	29.5	31.2	29.7	30	29.5	27.2	25.5	21.5
1991	19.7	23.9	26.9	29.5	30.1	29.8	30.4	29.9	29.8	28	23.7	20.5
1992	19	19.8	28.3	33.1	29.6	31.3	29.8	30	29.8	26.8	24.3	20.1
1993	18.8	23	25	28.7	29.1	30.4	30.5	29.4	28.1	27	23.7	21.4
1994	19.9	20.7	26.1	29.2	31	30.1	30.5	30.4	28.7	26.9	24.1	20.7
1995	18.7	21.2	26.2	30.4	32.2	29	29.5	30.1	29.5	27.6	23.7	19.8
1996	18.6	21.3	26.6	30.3	31.1	29.3	29.8	29.9	29.3	26.2	24.6	21.7
1997	18.9	20.2	26.4	26.5	29.9	30.4	30.5	30.2	29	25.7	22.9	18.3
1998	18.4	22.1	24.2	28.8	30.5	31.5	29.8	29.2	30	28.6	24.7	21.5
1999	20.6	25.3	29.4	33.6	30	30.1	29.3	29.1	29.9	27.6	24.4	21.5
Total	232.5	262.3	314.2	359.3	364.2	363.9	357.8	357.5	352.3	327.8	290.4	248.2
Mean	19.38	21.86	26.18	29.94	30.35	30.33	29.82	29.79	29.36	27.32	24.2	20.68

Table 15: Maximum Temperature of Begnas Tal Rupa Tal Watershed, Pokhara, Nepal

(Source: The Office of the Meteorological Station, Pokhara, Nepal)

4. ANALYSIS OF RESULTS AND INTERPRETATION

4.1 Land Use/Land Cover Map using Landsat TM 1988

Land use/land cover map for 1988 is prepared from the Satellite Image of Landsat TM by applying onscreen visual interpretation technique. According to land use/land cover map seven land use classes are identified. Forests and Agricultural Land were dominant land uses in 1988. Proportional share of each land use categories are shown in (Table 17; Fig. 12).

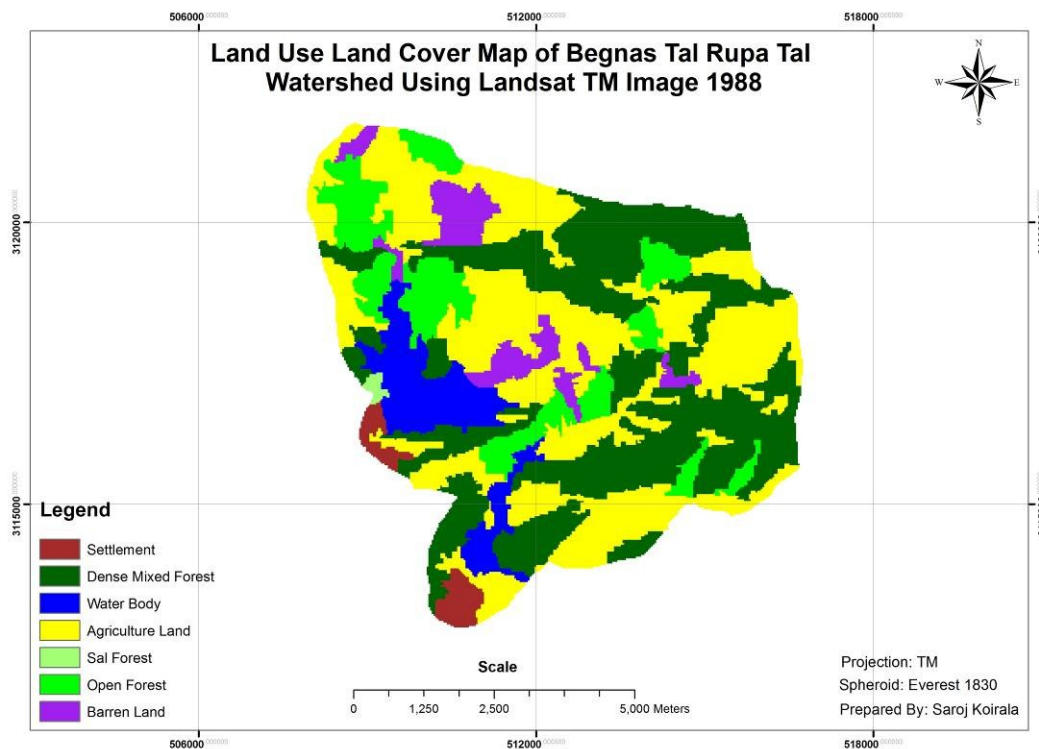


Figure 12: Land Use Land Cover Map of Watershed

S.N.	Particulars	Area (ha)	Percentage
1	Settlement	105.48	2.07
2	Dense Mixed Forest	1756.71	34.48
3	Water Body	394.47	7.74
4	Agriculture Land	1918.71	37.66
5	Sal Forest	14.76	0.29
6	Open Forest	626.76	12.3
7	Barren Land	277.92	5.45
Total		5094.81	100

Table 16: Area Statistics of Land Use/Land Cover Map of Watershed (November 1988)

4.2 Land Use/Land Cover Map using Landsat TM 1999

Land use/land cover map was prepared of December 1999 Satellite image Landsat TM using onscreen visual interpretation technique. According to land use/land cover map 7 land use classes were identified. In land use/land cover map of Landsat TM 1999 image total area in Settlement 173.84 ha, Dense Mixed Forest 1907.26 ha, Water body 416.07 ha as well as in Agriculture land 2040.99 ha, Sal forest 26.19 ha, Open forest 467.37 ha and Barren land 63.09 ha respectively (Table 18; Fig. 13).

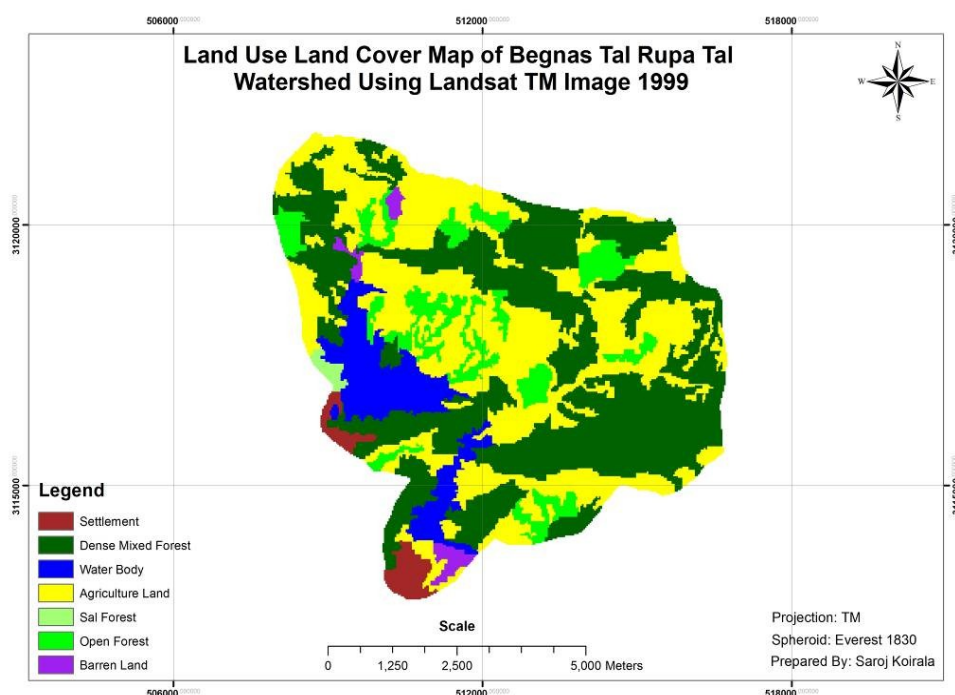


Figure 13: Land Use/Land Cover Map of Watershed

S.N.	Particulars	Area (ha)	Percentage
1	Settlement	173.84	3.41
2	Dense Mixed Forest	1907.26	37.44
3	Water Body	416.07	8.17
4	Agriculture Land	2040.99	40.06
5	Sal Forest	26.19	0.51
6	Open Forest	467.37	9.17
7	Barren Land	63.09	1.24
Total		5094.81	100

Table 17: Area Statistics of Land Use/Land Cover Map of Watershed (December 1999)

4.3 Land Use/Land Cover Change 1988-1999

The land use maps for 1988 and 1999 are presented in Fig. 12, 13 and the area under the seven land use classes during the two periods is shown in Table 4.3. Results show that from 1988 to 1999 land uses such as Dense mixed forest, Agricultural land, Water body, Sal forest, Settlement area are increased and Open forest, Barren land are decreased in Begnas Tal Rupa Tal Watershed. There has been remarkable growth in Agriculture land (40.06%) and Dense Mixed Forest (37.44%) during this period. During the same period open forest (9.17%) and barren land (1.24%) have remarkably decreased.

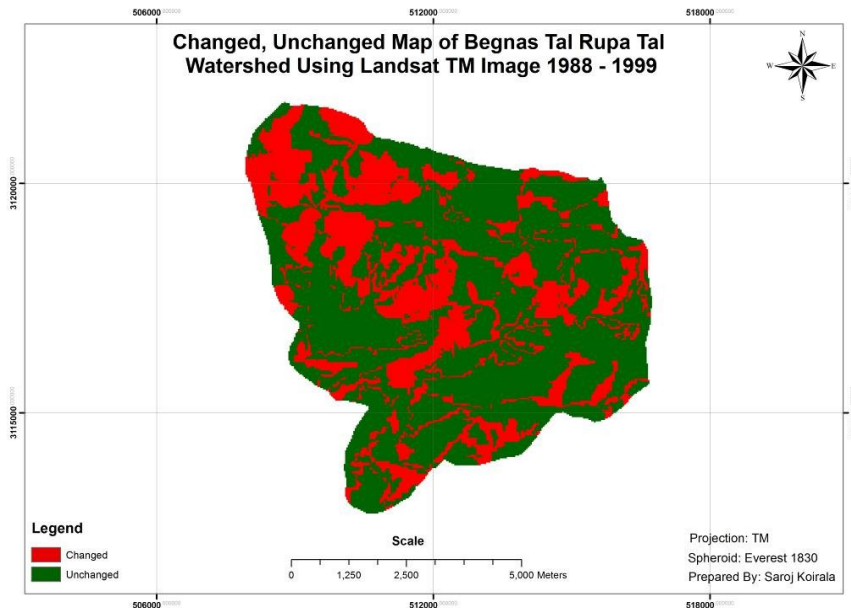


Figure 14: Land Use/Land Cover Change Map (1988-1999)

4.4 Land Use/Land Cover Change from Major Land Use to Different Land Uses

The data reveals that fallow land changed into different land use classes from 1988 to 1999. The major land use changed from fallow land to agricultural land which covers about 200.79 ha. Same as dense forest changed into agricultural land which covers about 183.33 ha, Open forest changed into agricultural land 626.13 ha, Agricultural land changed into settlement 242.19 ha, Dense mixed forest changed into open forest 275.58 ha in 1999-2006. Fairly dense mixed forest changed into dense mixed forest which covers about 1372.23 ha of land in 1999-2006 (Table 19).

S.N.	Land cover changes		1988 – 1999		Annual
	From	To	Area(ha)	%	%
1	Settlement	Dense Mixed Forest	5.94	36.26	3.30
		Water Body	4.86	29.67	2.70
		Agriculture Land	5.58	34.07	3.10
		Total	16.38	100.00	9.09
2	Dense Mixed Forest	Settlement	8.46	3.22	0.29
		Water Body	10.29	3.92	0.36
		Agriculture Land	198.69	75.65	6.88
		Sal Forest	10.62	4.04	0.37
		Open Forest	34.92	13.30	1.21
		Degraded Land	1.08	0.41	0.04
		Total	262.63	100.00	9.14
3	Water Body	Dense Mixed Forest	5.23	14.44	1.31
		Agriculture Land	23.21	64.10	5.83
		Open Forest	2.52	6.96	0.63
		Degraded Land	5.85	16.16	1.47
		Total	36.21	101.66	9.24
4	Agriculture Land	Settlement	20.46	7.41	0.67
		Dense Mixed Forest	100.78	36.52	3.32
		Water Body	13.32	4.83	0.44
		Open Forest	112.16	40.64	3.69
		Degraded Land	29.25	10.60	0.96
		Total	275.97	100.00	9.09
5	Sal Forest	Settlement	2.36	2.36	0.21
6	Open Forest	Dense Mixed Forest	315.57	61.62	5.60
		Water Body	5.86	1.14	0.10
		Agriculture Land	185.23	36.17	3.29
		Degraded Land	5.44	1.06	0.10
		Total	512.1	100.00	9.31
7	Degraded Land	Dense Mixed Forest	16.11	6.40	0.58
		Agriculture Land	218.53	86.81	7.89
		Open Forest	17.1	6.79	0.62
		Total	251.74	100	9.09

Table 18: Area statistics of Land use land cover change from major land use to different land uses in Begnas Tal Rupa Tal Watershed

4.5 Soil Erosion Mapping

A revised version of the Morgan-Morgan-Finney model has been carried out for doing soil erosion modeling. This model has proved that it is simple to use, and is able to give reasonable estimates of annual runoff and erosion. The erosion processes

is carried out in two steps: detachment of soil particles from the soil mass by raindrop impact and the transport of those particles by runoff. The model was designed to evaluate erosion where rates are likely to be accelerated by human impact and incorporated in the model is Geographical Information System domain using Remote Sensing. Different vector maps such as land use/land cover map, soil/soil texture and digital elevation model/slope map have been prepared. All these vector maps have been converted into raster map by using Integrated Land and Water Information System (ILWIS) a raster based GIS software. Attributes values were assigned based on remote sensing data, ground truth and ancillary data for each parameter of the land use/land cover, soil and the rainfall maps by applying different steps: (a) First effective rainfall has been calculated by multiplying total annual rainfall and rainfall interception, (b) After this calculation of leaf drainage has been done by multiplying effective rainfall and percentage canopy cover, (c) In the third steps calculation of direct through fall by subtracting effective rainfall from leaf drainage. (d) The kinetic energy of the direct through-fall was determined as a function of the rainfall intensity, using a typical value for the erosive rain of the climatic region. The kinetic energy of the leaf drainage is dependent upon the height of the plant canopy. These steps have been carried out to estimate rainfall energy. (e) Estimation of runoff is based on the method proposed by Kirkby (1976) which assumes that runoff occurs when the daily rainfall exceeds the soil moisture storage capacity and that daily rainfall amounts approximate an exponential frequency distribution. Rainfall energy can be estimated using rainfall interception. (f) Soil particle detachment by raindrop impact was calculated by multiplying by erodibility of the soil and kinetic energy of the effective rainfall, (g) similarly soil particle detachment by runoff was calculated by multiplying resistance of the soil and annual runoff. It occur only where the soil is not protected by ground cover, (h) After this method transport capacity of runoff was calculated by multiplying crop cover management factor and annual runoff, by adding soil particle detachment by raindrop and soil particle detachment by runoff, the product was estimation of total annual detachment. (i) Finally estimation of total annual soil erosion was calculated by added soil particle detachment by raindrop impact and by runoff, this is then

compared with the annual transport capacity and the lesser of the two values is the annual erosion rate.

4.5.1 Soil Erosion Map of November 1988

Soil Erosion Map was carried out of watershed area using satellite image Landsat TM 1988, where erosion was characterized by low, medium, high and very high. In 1988, high and very high erosion area was occurred in rain fed area, barren land as well as some agriculture land. Medium and Low erosion occurs in open forest and dense mixed forest.

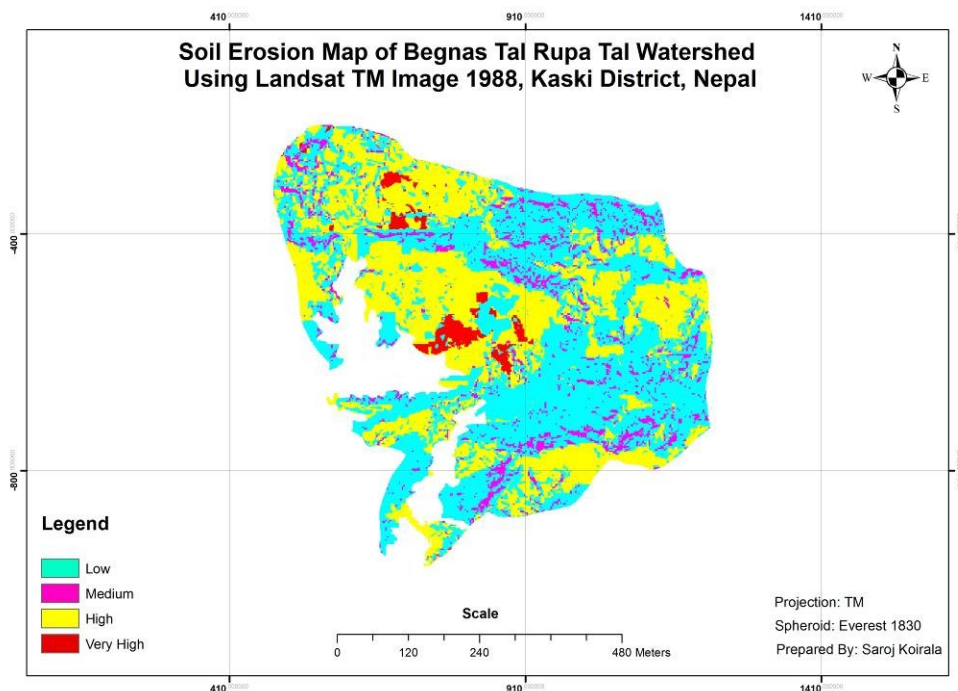


Figure 15: Soil Erosion Map of Begnas Tal Rupa Tal Watershed

S.N.	Types of Erosion	Area (ha)	Ton/Ha/Yr
1	Low	2089.26	0 - 5
2	Medium	156.24	5 - 10
3	High	2090.97	10 - 15
4	Very High	84.51	15 - 20

Table 19: Area statistics of Soil Erosion of Begnas Tal Rupa Tal Watershed, 1988

4.5.2 Soil Erosion Map of December 1999

Soil erosion map was carried out for the watershed area using satellite image Landsat TM 1999, being erosion characterized by low, medium, high and very high. In 1999, high and very high erosion area occurred in rain fed area, barren land as well as in

some agriculture land. Medium and low erosion occurred in open forest and dense mixed forest. In 1988, high and very high erosion occurred in rain fed area, agriculture area and barren land. In 1999 these high and very high erosion areas suffered low erosion due to new conservation practices in the watershed area.

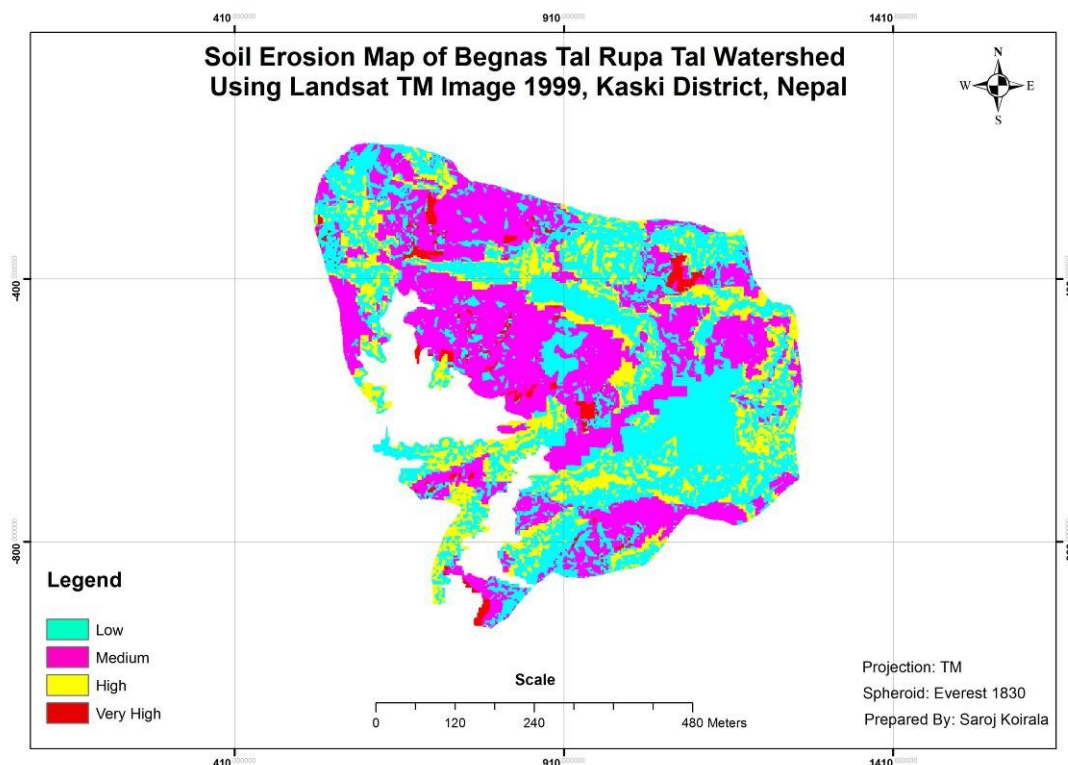


Figure 16: Soil Erosion Map of Begnas Tal Rupa Tal Watershed

S.N.	Types of Erosion	Area (ha)	Ton/Ha/yr
1	Low	1852.92	0 - 5
2	Medium	1841.94	5 - 10
3	High	665.01	10 - 15
4	Very High	76.59	15 - 20

Table 20: Area statistics of Soil Erosion of Begnas Tal Rupa Tal Watershed, 1999

4.5.3 Area Statistics of Soil Erosion with relation to Land Use Land Cover Maps

The table below shows that high erosion class 1988 contains a larger area when compared to high erosion class in 1999. This also happens with, very high erosion class in 1988 which contains a larger area when compared to 1999 very high erosion class; Medium erosion was higher in 1999 when compared to 1988 and low erosion area was also higher in 1988 when compared to 1999.

Statistical data of erosion maps shows that very high erosion and high erosion areas decreased when compared to 1988 due to conservation practice during this period. Awareness campaigns about erosion were put into practice for the local people. These resulted in the adoption of methods that prevented erosion. Different local NGO and INGO'S were involved in these activities during this period. Maximum erosion area was found in rain fed area in watershed. Medium and low erosion area slightly increased in 1999 with compare to 1988, due to some unscientific cultivation practices, deforestation and settlement expansion.

Area Distribution of Soil Erosion Map to Land Use Land Cover Map of November 1988				Area Distribution of Soil Erosion Map to Land Use Land Cover Map of December 1999				Total Erosion Area Change from 1988 - 1999
S.N.				S.N.				Absolute Area (ha)
	From	To	Area(ha)		From	To	Area(ha)	
1.	Very High Erosion	Dense Mixed Forest	0.45	1	Very High Erosion	Dense Mixed Forest	1.98	-1.53
		Agriculture Land	68.76			Agriculture Land	12.33	56.43
		Open Forest	8.19			Open Forest	58.77	-50.58
		Barren Land	6.93			Barren Land	1.08	5.85
		Total	84.33			Total	74.16	
2.	High Erosion	Dense Mixed Forest	460.89	2	High Erosion	Dense Mixed Forest	271.5	189.39
		Agriculture Land	1233.18			Agriculture Land	358.59	874.59
		Open Forest	320.04			Sal Forest	22.7	22.7
		Barren Land	46.62			Open Forest	7.83	312.21
		Total	2060.73			Barren Land	1.53	45.09
3.	Medium Erosion	Dense Mixed Forest	50.03	3	Medium Erosion	Total	662.15	
		Agriculture Land	48.62			Dense Mixed Forest	65.43	-15.4
		Open Forest	7.56			Agriculture Land	1300.13	-1251.51
		Barren Land	50.03			Open Forest	177.13	-169.57
		Total	156.24			Barren Land	293.49	-243.46
4.	Low Erosion	Dense Mixed Forest	1457.4	4	Low Erosion	Total	1836.18	
		Agriculture Land	473.49			Dense Mixed Forest	1499.76	-42.36
		Sal Forest	21.24			Agriculture Land	323.82	149.67
		Open Forest	123.93			Open Forest	99	24.93
		Barren Land	1.71			Barren Land	1.17	0.54
	Total	2077.77		Total	1923.75			

Table 21: Change area data of Soil Erosion (1988 – 1999)

4.6 Pressure zone mapping

The area is classified into three zones in terms of anthropogenic pressure; the proximity to road; settlement and slope gradient has been taken into consideration to assess the pressure zone. Pressure map being characterized by low, medium and high. Statical data shows that high pressure area contains maximum in watershed which means people around watershed area highly depends upon the resources mainly in forest. Followed by medium and low pressure which contains 1403.46 ha and 460.3 ha respectively.

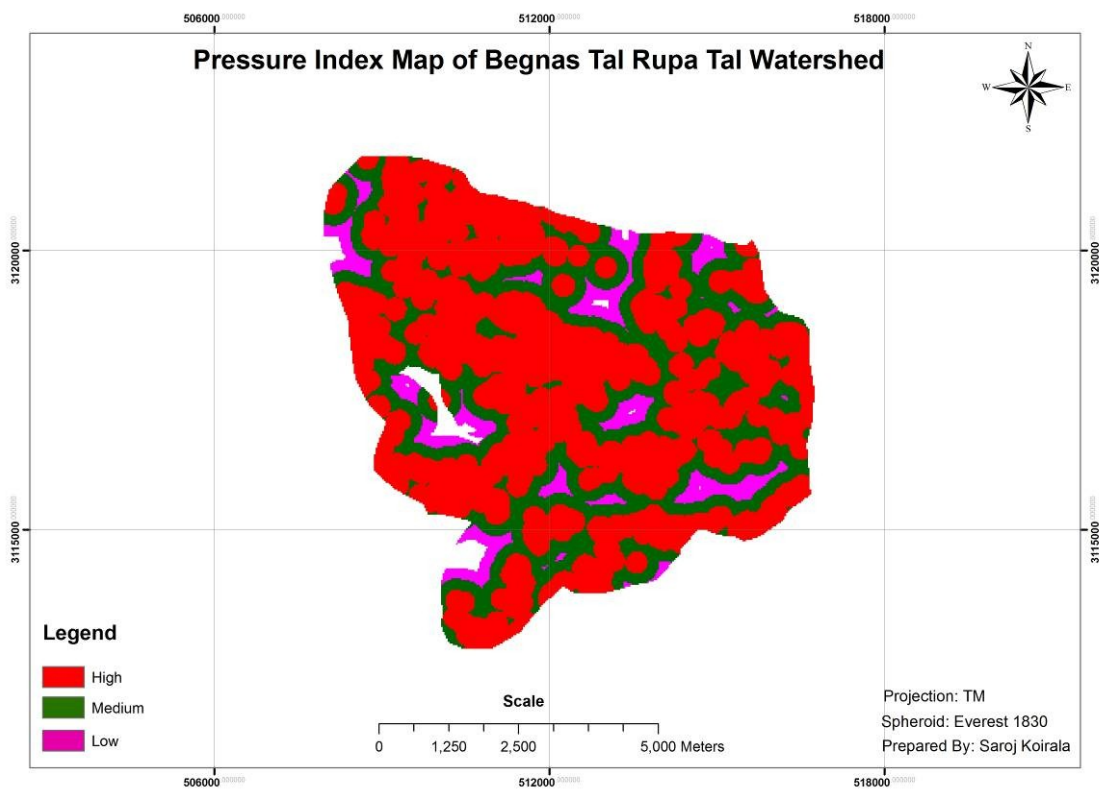


Figure 17: Pressure Index Map of Watershed

S.N.	Types of Pressure	Area (ha)	Percentage
1	High	3230.82	63.41
2	Medium	1403.46	27.55
3	Low	460.53	9.04
	Total	5094.81	100

Table 22: Area of Pressure Index Map

4.6.1 Area Statistics of Pressure Index with relation to Soil Erosion Map

The table below shows that high pressure class 1999 contains a larger area when compared to high pressure class in 1988. This also happens with, medium pressure class in 1999 which contains a larger area when compared to 1988 medium pressure class; low pressure area was higher in 1988 when compared to 1999.

Statistical data of pressure index maps shows that high pressure and medium pressure class areas increased with compared to 1988 due to increase in population. Maximum pressure area was found in near by dense settlement area with resources and low pressure was found in far way from settlement area where extraction of resources is less.

Area Distribution of Pressure Index Map to Soil Erosion Map December 1988				Area Distribution of Pressure Index Map to Soil Erosion Map December 1999			
S.N.	From	To	Area(ha)	S.N.	From	To	Area(ha)
1	High Pressure	Very High Erosion	133.01	1	High Pressure	Very High Erosion	102.99
		High Erosion	1743.29			High Erosion	413.49
		Medium Erosion	109.07			Medium Erosion	1642.62
		Low Erosion	1207.07			Low Erosion	1041.76
		Total	3192.44			Total	3200.86
2	Medium Pressure	Very High Erosion	70.73	2	Medium Pressure	Very High Erosion	102.25
		High Erosion	377.9			High Erosion	309.79
		Medium Erosion	144.08			Medium Erosion	304.3
		Low Erosion	793.87			Low Erosion	732.79
		Total	1387.07			Total	1449.13
3	Low Pressure	Very High Erosion	60.02	3	Low Pressure	Very High Erosion	44.83
		High Erosion	119.06			High Erosion	95.86
		Medium Erosion	82.34			Medium Erosion	68.59
		Low Erosion	253.88			Low Erosion	235.54
		Total	515.3			Total	444.82

Table 23: Area distribution Pressure Index Map (1988-1999)

5. DISCUSSION

5.1 Conclusion

The study provides a basis that the remote sensing technique can be an effectively used for land use/land cover mapping and land cover change monitoring. Land use/Land cover change pattern presents a distinct relation to different topographical factors: altitude, slope and aspect. This owes to both natural environmental and human activities. The change analysis shows three important changes: increase in agriculture land, decrease in barren land, dense mixed forest and settlement area expansion. Dense Mixed Forest increases and Open Forest shrinking. There's a net increase in dense mixed forest during 1988 to 1999 due to the protection activity while agriculture land expansion, forest resources extraction, increasing human and livestock population pressure and other human interference leads to the continuously decreasing of open forest and barren land. Dry season is for mapping better due to the better contrast; however soil reflectance is more prominent. The results from this study appear practically useful for management of natural resources in the study area. The study concludes that Remote Sensing and GIS can be effectively utilized for understanding the distribution and utilization pattern of resources. Satellite remote sensing can play a useful role in understanding the nature of changes in land use/land cover where they are occurring and projecting possible or likely future changes. Such information is essential to planning for development and preserving our natural resources and environment and is needed by rural planners and citizens. Satellite remote sensing approaches provide a cost-effective alternative where more information is needed. Information obtained using remotely sensing techniques can help decision makers to prepare resource map accurately in less time and cost. It also helps in linking those maps with other information related to geographic location and helps modeling analyzing and solving complex problems. Erosion map was generated to understand the actual situation of erosion in watershed area, where Morgan Morgan and Finney model was used. This model is very good to estimation soil erosion particularly in hilly watershed area. From the above soil map it shows that most of the soil erosion was happening in rain fed area, deforestation area, unscientific cultivation land and low erosion was occurred in dense mixed forest

area. Over-all statistical analysis shows that erosion was more controlled in 1999 when compared to 1988 due to different conservation practice in the watershed area.

5.1.1 Land Use/Land Cover Mapping

Preparing forest/land use land cover map using satellite remote sensing is an established technology (Mulders, 2001). As such Land use/Land cover Map was prepared by visual interpretation technique with sufficient ground truth. Different data set such as Toposheet, Land System Maps, Google Earth, Different statistical data obtained from the Forest and Soil Conservation Department and published/unpublished literatures are used for land use/land cover mapping. Two time series data of Landsat TM image was taken into consideration. However, it is attributed with some of the inherent issues while interpreting the classes. Due to medium resolution satellite image it's difficult to classified the images due to mixing pixels in same spectral reflectance land use classes. Total seven land cover classes were discriminated from Landsat TM image on the basis of spectral values and textural characteristics. The analysis of temporal Landsat images (1988-1999) shows that the other land use classes conversion into agriculture, dense mixed forest and settlement is notable during the assessment period.

5.1.2 Change Detection Analysis

Transformation in the traditional lifestyle due to changing socio-economic condition leads to transition in the resource use. Pattern of resource and land use by human beings bring about alteration of the vegetation structure and composition. In the present study, we have observed that one of the major causes of land use land cover change is the expansion of agricultural land, intensification of agriculture and increase in livestock population under the influence of population growth coupled with biophysical limitations. The increased livestock population has increased pressure on the available forest resources. On the other hand increased in population has lead expansion of agricultural lands in the form of deforestation. These factors have increased pressure in the existing forest leading to decrease in availability of forest resources.

This study acquires accurate bio-physical data (i.e. land use/land cover change vectors) from the Landsat TM images at different time scenes through Remote Sensing and GIS analyses. Though the detection methods and the quality of remote

sensed data may affect the accuracy level this method definitely fills a gap in studying land use/land cover changes resource distribution and their utilization as well. The Nepalese statistical data on land use/land cover changes is very questionable (Shrestha *et al.* 2004). The present data shall certainly help to update the information and create a baseline database for future data collection. Spatial and Temporal databases were used to assess the changes in land use and land cover patterns in the eleven-year period. Technological institutional and natural resource policy forces also play an important role in changing land use pattern. Land use change is therefore often modeled as a function of a selection of socio-economic and biophysical variables that act as the so-called 'driving forces' of land use change. At different scales of analysis different driving forces have a dominant influence on the land use system. Driving forces are most often considered exogenous to the land use system to facilitate modeling. However, in some cases this assumption hampers the proper description of the land use system. Population pressure is often considered to be an important driver of land use/land cover changes.

5.1.3 Resource Distribution Mapping

The Begnas Tal Rupa Tal Watershed is very rich in natural resource endowment consisting Dense Mixed Forest (mostly *Schimia wallichii* and *Castanopsis indica*), Open Forest, Sal Forest and Water Body. Forests being the dominant natural resource covered an area of 2398.23 ha in 1988 and 2400.82 ha in 1999.

5.1.4 Soil Erosion Modeling

The study shows the effect of land cover changes on soil erosion that and can directly be quantified by Remote Sensing and GIS technology. It makes the building information for land use planning decision possible with GIS as a nuclear and remote sensing system as an input data system.

5.2 Recommendations

This study contributes to answer “when and how much” the land cover changes. To have a better understanding, a more comprehensive study that includes more socio-economic factors, cultural context, farming traditions and political policies related to land use, the interaction between land use and land cover change is recommended.

- Improving the living standard of local people is of importance in protecting forest.
- Scientific grazing system is needed for livestock management.
- Forest conservation should be considered as an important issue in development aspect.
- Development Planner must focus for Technology and Sustainable Development to upgrade rural arena and rural populace.
- The approach developed in this study especially those for the land use/land cover changes can be used as reference information for managers/decision makers in defining their management strategies.
- Community forests of this range need to be managing effectively for economic benefit for the rural populace.
- This study tried to briefly describe the impact of land use/land cover change in soil erosion processes. The need for a more thorough study on change process and information sharing mechanism to the local stakeholders is strongly felt. This step would be very helpful in bringing more scientific information from producers to users.
- Irrigation management is must necessary in this watershed area for better agricultural production.
- Infrastructure development is must necessary for Begnas Tal Rupa Tal Watershed area to upgrade rural populace (such as road, construction, water supply, electricity, telephone etc.)
- Scientifically managed all resources in watershed area for people will be one of the big assets for development. Participation as well as equality in every

development activities will be the new approach for sustainable development in Begnas Tal Rupa Tal watershed.

- The understanding of land cover change processes in the area e.g. a study to test the hypothesis whether the changing socio-economic development in the region leads to changes in the relationship between population density and land use land cover change. Another possible study is to investigate the effect of spatial resolution or spatial scale on logistic models for land cover changes in the study area.

BIBLIOGRAPHIC REFERENCES

- Awasthi, K.D., Sitaula, B.K., Singh, B.R., Bajacharaya, R.M., 2002, Land-Use Change in two Nepalese Watersheds: GIS and Geomorphometric Analysis. *Land Degradation and development* **13**(6): 495-513.
- Beasley, D. B., L. F. Huggins, E. J. Monke, 1980, ANSWERS: A Model for Watershed Planning. *Transactions of the ASAE*, 23(1980)4, pp. 938-944.
- Bhatta, B.R., 1999, Recent Concepts, Knowledge, Practices, and New Skills in Participatory Integrated Watershed Management: *Trainers Resource Book*. ICIMOD, PWMTA-FAO, and Department of Soil Conservation and Watershed Management, Nepal.
- Browden, L.W. and Pruitt, E.L., 1983, Manual of Remote Sensing. *American Remote Sensing Agency*, USA.
- Chaudhary, B.S., Saroha, G.P., Yadav, M., 2008, Human Induced land Use/Land Cover Changes in Northern Part of Gurgaon District, Haryana, India: Natural Resources Census Concept. *Journal of Human Ecology*, **23**(3): 243-252.
- Dept. of Meteorology, Nepal, 1984, *Climatological records of Nepal*, 1971-1982, vol. 1, HMG, Kathmandu, Nepal.
- FAO, 1985, *Tropical Forestry Action Plan*, Committee on Forest Development in the Tropics, FAO, UN, Rome.
- Gautam, A.P., Webb, E.L., Shivakoti, G.P., and Zoebisch, M.A. (2003). Land use dynamics and landscape change pattern in a mountain watershed in Nepal. *Agriculture, Ecosystems and Environment* **99**: 83-96.
- Ghosh, S., Sen, K.K., Rana, U., Rao, K.S., Saxena, K.G., 1996. Application of GIS for land use/land covers change analysis in a mountainous terrain. *Journal of Indian Society of Remote Sensing*, **24**: 193-202.
- Giri, C., Shrestha, S., and Levy, M., 2001, Assessment and Monitoring of Land Uae/Land Cover Change in Continental Southeast Asia. Prepared for

- presentation at the Open Meeting of the *Global Environmental Change Research Community*, Rio de Janeiro, 6-8 October, 2001.
- Government of Nepal, 1999, Buffer zone management guidelines. Ministry of Forests and Soil Conservation and Department of National Parks and Wildlife Conservation, Kathmandu.
- Gulati, N.K. (1986). *A Glossary of Forestry Terms*, International Book Distributors, Dehradun, India, p 172.
- Gurung, B. S., 1985, *Pokhara: A study of Urban Geography*, Ph.D dissertation, Submitted to Ranchi University, PP 174.
- Gurung, H. B., 1970, *Pokhara Valley: A Study in Regional Geography*, Ph.D dissertation, University of Edinburgh, Edinburgh.
- Joshi, P.K., Gairola, S., 2003, Land cover dynamics in Garwal Himalayas – A case study of Balkhila Sub-watershed, Journal of *Indian Society of Remote Sensing* **32** (2): 199-208.
- Kammerbauer, J., Ardon, C., 1999, Land Use dynamics and Landscape Change pattern in a typical watershed in the hillside region of Central Honduras. *Agriculture, Ecosystems and Environment* **75**, 93–100.
- Kettner, A., 1996, *Simulated man-induced erosion in the Middle Mountains of Nepal, a case study on the relation between land use, land tenure and erosion with the use of the AGNPS-model in the Mahadev Khola watershed*. Master dissertation (unpublished), Dept. Of Soil and Water Conservation and Irrigation, Agricultural University, Wageningen, Netherland.
- Khanal, T.R. and Bastola, K.R., 2002, Land Use/ Land Cover Changes in Phewa Lake Watershed Area in Pokhara, Nepal. Paper Presented in *Map Asia*, Jakarta, Indonesia.
- Lillesand, T. M., Kirfer. J. W., 1999, *Remote Sensing and image interpretation. (4th ed.)*. John Wiley & Sons, New York.

- Meyer, L.D. and Wischmeier, W.H., 1969, Mathematical simulation of the process of soil erosion by water. *Transactions of the American Society of Agricultural Engineers* **12**: 754–758 and 762.
- Millette, T.L., Tuladhar, A.R., Kasperson, R.E., Turner, B.L., 1995, The use and limits of remote sensing for analysing environmental and social change in the Himalayan Middle Mountains of Nepal. *Global Environmental Change* **5**(4): 367-380.
- Morgan, R.P.C., 2000, A simple approach to soil loss prediction: a revised Morgan–Morgan–Finney model. *Catena* **44**: 305-322.
- Morgan, R.P.C., Morgan, D.D.V., Finney, H.J., 1984, A predictive model for the assessment of soil erosion risk. *J. Agric. Engng. Res.*, **30**: 245-253.
- Mulders, M.A., 2001, Advances in the application of Remote Sensing and GIS for surveying mountainous land, Wageningen Agriculture and Research centre, Wageningen, The Netherlands, *JAG*, **3**(1): 3-10.
- Nagendra, H., 2002, Tenure and forest conditions: Community forestry in the Nepal Terai. *Environmental Conservation* **29**:530–539.
- Nagendra, H., Munroe, D., Southworth, J., 2004, Introduction to the special issue: From pattern to process: Landscape fragmentation and the analysis of land use/land cover change. *Agriculture, Ecosystems and Environment* **101**:111–115.
- Naiman, R.J. (1997). Approaches to management at the watershed scale. *The science of ecosystem management* pp 240-251
- Naiman, R.J., 1997, Approaches to management at the watershed scale. *The science of ecosystem management* pp 240-251.
- Pereira, H.M., Daily, G., Roughgarden.J., 2004, A framework for assessing the relative vulnerability of species to land use change, *Ecological Applications*, **14**: 730-742.

- Pfaff, A.S.P., 1999, What Drives Deforestation in the Brazilian Amazon? Evidence from Satellite and Socio-economic Data. *Journal of Environmental and Economic Management* **37**: 26-43.
- Poudel P. C., 1982. *A study of Urban Land Use in Pokhara Town*, Research Report 20, Tribhuvan University, Nepal.
- Shrestha, D.P., Zinck, J.A. and Ranst, E.V. (2004). Modelling land degradation in the Neplease Himalaya, *Catena* **57**: 135-156.
- Stocking, M., 1981, *A working model for the estimation of soil loss suitable for underdeveloped areas*. Development studies, occasional paper No. 15, University of East Anglia, Norwich (UK).
- SWCS, 1993, User's guide. Revised Universal Soil Loss Equation, version 1.03. *Soil and Water Conservation Society*, Iowa, USA.
- Tiwari, P.C., 2000, Land use changes in the Himalaya and their impact on the plains ecosystem: need for sustainable land use. *Land use policy* **17**: 101-111.
- Tiwari, P.C., Joshi, P.K., 2006, *Resource utilization pattern and its impact on the biodiversity in the Lake region of District Nainital, Kumaon Himalaya using Remote Sensing and Geographical Information System*. Technical Report, Indian Space Research Organization, India.
- Vadjunec, J.M., A.Gomes, C.V., Ludewigs, T., 2009, Land-use/land-cover change among rubber tappers in the Chico Mendes Extractive Reserve, Acre, Brazil. *Journal of Land Use Science*, iFirst, 2009, 1-26.
- Valenzuela, C.R., 1988. ILWIS overview. *ITC Journal* **1**:4-14
- Weng, Q., 2002, Land Use Change analysis in the Zhujiang Delta of China using Satellite remote sensing, GIS and Stochastic modelling. *Journal of Environmental Management* **64**, 273–284
- Williams, J. R., H. D. Brendt, 1977, Sediment Yield prediction based on watershed hydrology. *Transactions of the ASAE* vol. 20, p. 1100-1104.
- Wischmeier W. H. and D. D. Smith, 1978, Predicting rainfall erosion losses. *A guide to conservation planning*. USDA Agricultural Handbook, No. 537.

- Wischmeier W. H., D. D. Smith, 1965, Predicting rainfall erosion losses from cropland. A guide for selection of practices for soil and water conservation. USDA Agri. Handbook no 282, Washington DC., USA.
- Xia Li, Anthony Gar-on Yeh, 2003. Analyzing spatial restructuring of land use patterns in a fast growing region using remote sensing and GIS. *Journal of Landscape and Urban Planning*, **69**, (2004): 335-354.
- Young R. A. et. al., 1987, *AGNPS, Agricultural Non-Point-Source Pollution Model*, Agricultural Research Service, Conservation Research Report 35, USDA, USA.

APPENDICES

4	Others			
Grand Total				

c. Service Income:

No.	Items	Employee no.	Per year income	Total Amount
1	Government service			
2	Pension			
3	Private service			
4	Business			
5.	Daily wages			
Grand Total				

20. Expenditures:

No	Items	Rs/month	Rs/year	Total Amount
1	Household expenditure			
2	Education expenditure			
3	Agricultural expenditure			
4	Other expenditures			
Grand Total				

21. Means of irrigation.....

22. Source of drinking water.....How far? Is it enough.....

23. Major problems.....

24. Suggestions.....

25. Anything you want to tell at last?

2 - Field Performance

Date:	Place:	Topo sheet:
Geo coordinates: Latitude:		Longitude
Distance from habitation:		
General land use type:		
Physiographic conditions:		
Altitude:	Aspect:	Terrain:

Soil:

Soil type	Stoniness

Forest:

Forest type	Forest density	Major species

Evidence of human intervention:

Lopping		Pollarding		Tree Stump		Wood Collection	
Forest Cutting		Browsing		Digging		Quarrying	

Any other information:

Diagrammatic representation surrounding features: