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FOREST COVER CHANGE IN GODAWARI KHOLA SUB-WATERSHED, LALITPUR

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DECLARATION

I hereby declare that the work presented in this thesis has been done by myself and has not been submitted elsewhere for the award of any degree. All sources of information have been specifically acknowledged by reference to the author(s) or institution(s).

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LETTER OF RECOMMENDATION

Date:

This is to recommend that the thesis entitled "**FOREST COVER CHANGE IN GODAWARI KHOLA SUB-WATERSHED, LALITPUR"** has been carried out by "Prerana Mishra" for the partial fulfillment of Master's Degree in Environmental Science with special paper "Mountain Ecology". This is her original work and has been carried out under my supervision. To the best of my knowledge, this thesis work has not been submitted for any degree in any institutions.

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This dissertation presented by **Ms. Prerana Mishra** entitled, "**FOREST COVER CHANGE IN GODAWARI KHOLA SUB-WATERSHED, LALITPUR**" has been approved for partial fulfillment of the requirements for the completion of Master's degree in Environmental Science.

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ABSTRACT

The land-use/land-cover (LULC) pattern of a region is an outcome of natural and anthropogenic process. Land-use/land-cover change has become a central component of current strategies in managing natural resources and monitoring environmental changes. The present study was carried out with an integrated approach using Remote Sensing and GIS techniques for land cover change detection. Landsat TM of 1989 and 2011 and ETM+of 1999 imagery were used to evaluate forest cover dynamics during 1989 to 2011 in the Godawarikhola Subwatershed, Lalitpur, Nepal. The aims of the study were to quantify and map the spatio-temporal pattern of forest cover change in term of landuse changes between1989-2011 and to explore the proximate cause behind those processes. Supervised classification was used to prepare landuse maps using the maximum likelihood algorithm. Image classification was carried out by emphasizing six main categories. Ground verification was done in February, 2014.

The study revealed that there is decrease in forest cover from 1989 to 2011. In 1989 forest coverage area was 80%, where in 1999 it was 53.9% and in 2011 it was 50.7%. This shows that there is a rapid decrease in forest cover from 1989 to 2011 with the rate of changes 16.48% and 9.6% from 1999 to 1999 and 1999 to 2011 respectively. This compensates to increase in agricultural area where in 1989 its coverage was 11.5% of the total study area, which increased to 27.9% in 1999 and in 2011 to 36.66%. The overall accuracy was 78% for both year maps.

For a clear comparison between the landuse/ landcover changes in total and in a managed community forest, Diyale Dada community forest having total area of 224.71 was selected. And accordingly, its landuse/ landcover map was developed using GIS. During 20 years period from 1988 to 2009, forest area is increased by 4.80%. The cultivation land is decreased by 14.26 %. The increment of shrub land is the highest and indicated that the cultivated land has transformed to shrub and forest land. The status of Diyale Danda Community Forest shows the total species richness of 26 in which tree density was found to be 1785 individuals per hectare.

Keywords: *density, forestcover, GIS and remote sensing, landuse/landcovcer change, species richness, supervised classification*

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LIST OF ABBREVIATIONS AND ACRONYMS

AOI	Area of Interest
ºC	Degree Celsius
CBS	Central Bureau of Statistics
CDES	Central Department of Environmental Science
CF	Community Forest
CFUGs	Community Forest User Groups
DFO	District Forest Office
DHM	Department of Hydrology and Meteorology
ETM+	Enhanced Thematic Mapper
FAO	Food and Agriculture Organization
GIS	Geographic Information System
GPS	Geographic Positioning System
Ha.	Hectare
HOD	Head of Department
IPCC	Intergovernmental Panal on Climate Change
Km.	Kilometer
LULCC	LandUse/Landcover Change
MEA	Millennium Ecosystem Assessment
RRN	Rural Reconstruction Nepal
RS	Remote Sensing
S.N	Serial Number
TAL	Terai Arc Landscape
TM	Thematic Mapper
USGS	United States Geological Survey
UTM	Universal Transverse Mercator
VDC	Village Development Committee
WWF	World Wildlife Fund for Nature

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CHAPTER I

INTRODUCTION

Background

The land-use/ land-cover pattern of a region is an outcome of natural and anthropogenic process. Land-use /land-cover change has become a central component of current strategies in managing natural resources and monitoring environmental changes. Studies have shown that there remain only few landscapes on the Earth that is still in their natural states anthropogenic activities have altered the Earth's surface significantly and are associated with profound effect upon the natural environment. This has resulted in an observable pattern of change in context of land use/ land cover over time. Rapid population growth and subsequent demand of agricultural land and forest products such as fire wood, fodder, timber and lumber accelerated deforestation process in many developing tropical countries. Scientific interest in the tropical deforestation and its impact on livelihood has focused largely in countries like Brazil (Brondizio *et.al*., 1996) to explore the cause of deforestation and such study needed to understand how agrarian rural population, that depends on limited natural resources, responds to increasing resource scarcity with technological advancement as envisioned by Ecological Modernization Theory (Ehrarat *et.al*., 2002). Around 75% of the natural forested areas across the world have either been cleared or dominated by human activity since the last ice age (Huston, 1993). The global rate of forest loss is currently reported to be 0.6% per year (Hunter, 2000). Forest degradation as a result of resources extraction, and conversion of forested areas to cropland, settlement and other land use types is leading to forest fragmentation, a decrease in productivity (Geist, *et.al*. 2001), an increase in forest isolation , and changes in community composition. Studies have shown that, if not controlled, natural old-growth forests can be critically fragmented to the point at which they can neither maintain viable populations of flora and fauna, nor maintain their ecological integrity (Namaalwa *et.al*., 2007). Forest fragmentation, in which the forest is reduced to patches, can have a marked detrimental impact on biodiversity.

Studies have shown that there remain only few landscapes on the Earth that is still in their natural states. Anthropogenic activities have altered the earth's surface significantly and are associated with profound effect upon the natural environment. This has resulted in an observable pattern of change in context of land use/land cover over time. Rapid population growth and subsequent demand of agricultural land and forest products such as firewood, fodder, timber and lumber had accelerated deforestation process in many developing tropical countries. Scientific interest in tropical deforestation and its impact on livelihood have focused largely in countries like Brazil (Brondizio *et.al.*, 1996).

Similar research has also been done in countries like Nepal (Tokola *et. al*., 2001) to explore the cause of deforestation and such study needed to understand how agrarian rural population, which depends on limited natural resources, responds to increasing resource scarcity with technological advancements envisioned by Ecological Modernization Theory

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(Ehrarat-Martinez *et. al*., 2002). Understanding changes in landscapes pattern requires in-depth knowledge of both biophysical and socio-economic patterns and processes. Human use and management of land, i.e., how people use landscape as a source of livelihood, shelter, recreation and/or industry, are powerful forces shaping patterns and dynamics inhuman occupied landscapes (Turner *et. al*., 1995). Many human activities, especially those related to agriculture and natural resources extraction, are dependent on existing biotic and abiotic pattern and processes and to some extent by the natural Environment (Huston, 1993; Meyer, 1995).

Land use/Land cover

The pace, magnitude and spatial reach of human alteration of the Earth's land surface are unprecedented. The Land use/Land cover pattern of a region is an outcome of natural and socio-economic factors and their utilization by men in time and space. Changes in land cover (biophysical attributes of the Earth's surface) and land use (Human purpose or intent applied of these attributes) are among the most important (Turner *et.al*., 1990; Lambin *et. al*., 1999). Land use/Land cover changes are so pervasive that, when aggregated globally, they significantly affect the key aspect of Earth system functioning. They directly impact biotic diversity world-wide (Lambin *et. al*., 2000); contribute to local regional climate change. Land cover is defined as the observed biophysical cover on the earth's surface whereas land use as the arrangements, activities and inputs that people undertake on a certain land cover type (FAO, 2000). Thus, land cover corresponds to the physical condition of the ground surface, e.g. forest, grassland, agriculture land etc. while land use reflects human activities such as the use of land for different purposes as industrial zones, residential zones, and agricultural fields. This definition establishes a direct link between land cover and the action of people in their environment, i.e. land use may lead to land cover change (Phong, 2004).

Land use/land cover is a hybrid category. Land use denotes the human employment of the land and is studied largely by social scientists. Land cover denotes the physical ad biotic character of the land surface and is studied largely by natural scientists. Connecting the two are proximate sources of change: human activities that directly alter the physical environment. These activities reflects human goal that are shaped by underlying social driving forces. Contemporary global environmental change is clearly unique. The human reshaping of the earth has reached a truly global scale, is unprecedented in its magnitude and rate, and increasingly involves significant impacts on the biogeochemical systems that sustain the biosphere (Meyer, 1992). The Land use/Land cover pattern of a region is an outcome of natural and socio-economic factors and their utilization by men in time and space. Land is becoming scarce resource due to immense agricultural and demographic pressure. 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 or basic human needs and welfare. Land cover changes take two forms: conversion form and category of land cover to another and modification of condition within a category (Meyer, 1992). It is regarded as the single most important

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variables of global change affecting ecological systems (Vitousek, 1994) with an impact on the environment that is at least as large as that associated with climate change. It is particularly related to the increase of population and intensive agriculture (Awasthi *et.al*. 2002).

Forest Cover

Forest is a complex ecological system in which trees are dominant life forms. The word ‘Forest’ is derived from Latin word ‘Foris’ meaning outside, the reference apparently being to a village, boundary or fence. Thus, originally, a Forest must have included all uncultivated and uninhabited land. Today, a forest is any land managed for the diverse purposes of forestry, whether or not covered with trees, shrubs, climbers or such other vegetation. Forest is striking feature of the land system. The forests of a country are natural assets of great value, which represents largest most complexes and most self generating of all ecosystems. They covered about one-third of the land area of the world and constitute one-half of the total bio-mass. Forest cover is the area covered under vegetation with a tree canopy cover more than 10% (FAO, 2000). Human activity is vastly altering the Earth’s vegetation cover. Such changes have considerable consequence for the health and resilience of ecosystem and contribute to anthropogenic climate change through a variety if processes. These include the growth or degradation of surface vegetation which produces changes in the global atmospheric concentration of carbon dioxide; and changes in the land surface, which affect regional and global climate by producing changes in the surface energy budgets (Vitousek, 1994).

The world’s forest are changing in quantity and quality, and in both positive and negative ways (FAO, 1999a), this process is associated with social, economic and environmental factors. The conversion of forest covers in general has severe long-term environmental and socio-economic consequences globally as well as locally such as global climate change, habitat fragmentation and degradation, species extinction (Phong, 2004). Total forest area was estimated to be around 30% of the planet’s land area in 2005, which was just under 40 million Sq. Km. This corresponds to an average of 0.68ha (6200sq.km) per capita, though this is unevenly distributed (FAO, 2005). Overall deforestation has been taking place at a pace of about 1, 30,000 sq. km (13 Million hectares) per year during the period 1990-2005. (FAO, 2005). 25.4% of Nepal’s land area, or about 36,360Sq. Km is covered with forest (FAO, 2005). 9.6% of Nepal’s forest cover consists of primary forest which is relatively intact. About 12.1% of Nepal’s forest is classified as protected while about 21.4% is conserved according to FAO. In between 1990-2010, Nepal lost an average of 59,050 ha or 1.23% per year. Nepal lost 24.55% of its forest cover around 1,181,000 ha over 20 year’s period from 1990 to 2010 (FAO, 2010). Deforestation is driven by multiple processes. In hills, conversion of forest to agricultural land even on steep hill sides via terracing- is historically important, but has lessened indecent decades due to shortage of remaining suitable terrain in the hills, while mosquito suppression having opened formally opened land forest clement in the Terai. As a result forest land in the Terai is being cleared by

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settlers. In the hills greater contemporary impacts involve degradation of forests rather than out right clearing.

Forest management strategy began deliberately on a large scale in around 1980 (Nagendra *et. al*. 2005). Since then government of Nepal has been formulating rules and regulations for forest resource management. The forest management System of Nepal has been significantly enhanced through the National Conservation Strategy, 1988; Master Plan for the Forestry Sector, 1988/89; Convention on Biological Diversity, 1992; Nepal Environmental Policy and Action Plan, 1993; Forest Act 1993 and Forest Regulations 1995; Nepal Biodiversity Action Plan, 2000; Forest Inventory Guidelines, 2000; Tenth Five Year Plan, 2002-2007. Remarkable effort in forest conservation has also been made after introduction of the Community Forestry (CF) Management System in the early 1970s (Gilmour *et. al*. 2004). However, some comments despite a few attempts and successes, serious deficiencies in community based natural resources management are still evident in Nepal (Kellert *et. al*. 2000). Beside these, a number of forestry affiliations and special forest management plans and policies have also been developed for forest resource management in Nepal. For instance Buffer zone management, Terai Arc Landscape(TAL) project, Western Terai Landscape Complex Project (WTLCP), World Wildlife Fund (WWF), Livelihood Forestry Project(LFP), Biodiversity Sector Program for Siwaliks and Terai (BISEP-ST), Rural Reconstruction Nepal(RRN) etc are also supporting one and other way for Terai forest management.

Human population and land use change

Land and people are the most important natural resources that are mutually inter-related and inter-dependent for their sustainable development. The use of land is very wide and intense and the demand for land has been increasing for its various uses over time. In fact, there are competing uses such as forests, agriculture, industry, housing, infrastructure, services and recreation. As such, the land use pattern is highly influenced by the various deliberate interventions by the people and has been undergoing changes significantly (Lee *et. al.*, 1991, World Bank, 1994). The issue of land use changes is very important in the context of increasing population pressure when the pressure on land by man increases, it would lead to both extensive and intensive use of land. Fulfilling the resource requirement of a growing population ultimately requires some form of land use change, to provide for the expansion of the food production through forest clearing, to intensity production on already cultivated land or to develop the infrastructure necessary to support increasing human numbers. Indeed, it is the ability of the human race to manipulate the landscape that has allowed for the rapid pace of contemporary population growth (Hunter, 2000).

Agriculture and population growth are two prominent forms of human-induced land use change. During the past three centuries, the amount of Earth’s cultivated land has grown by more than 45.0%, increasing from 2.65 million Sq. km to 15 million Sq. km. At the same time, the world’s forest has been shrinking. Deforestation is closely linked to agricultural land use change because it often represents a consequence of agricultural

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expansion. And decline in forest cover of 180 million acres occurred during the 15 years interval 1980-1995, although changes in forest cover vary greatly across the region. Changing land use and deforestation in particular have ecological impacts. Agriculture can lead to soil erosion, while overuse of chemical inputs can also degrade soil. Deforestation also increases soil erosion, in addition to reducing rainfall due to localized climate changes, lessening the ability of soils to hold water and increasing the frequency and severity of floods. Land use change in general results in habitat loss and fragmentation-the primary cause of contemporary species decline. It has been suggested that if current rates of forest clearing continue, a quarter of all species on Earth could be lost within the next 50years (Hunter, 2000).

There are two major sets of anthropogenic changes to the earth system that have so far provided the most fruitful policy-relevant research are for collaboration between social science and Earth system science. First the increase in atmospheric green house gas concentrations and associated climate changes and second the changes in land use and land cover caused by human activity and the associated impacts on water, biodiversity, land surface processes and climate. Research synthesis linked to the Intergovernmental Panel on climate change (IPCC) and the Millennium Ecosystem Assessment (MEA) is clear example of the need to include human activity and the social sciences in understanding the future of the Earth system. MA documents argue that the trends in agriculture driven by economic development and demography could increase the proportion of the terrestrial ecosystem in crop production from 13% to 50% by 2050 with devastating consequence for the biodiversity and ecosystem (MEA, 2005). Human activities are the major drivers for the proximate land use changes that in turn have myriad impacts on human livelihood too. Various human environment conditions react to and reshape the impacts of drivers differently leading to specific pathways of land use and forest cover change. Precisely, it is combination that needs to be conceptualized and used as the basis of land change explanation and models.

RS and GIS are now providing new tools for advanced ecosystem management. The collection of remotely sensed data facilitates the synoptic analysis of Earth system function, patterning and change at local, regional and global scale 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 (Wilkie *et. al*., 1996).

Statement of problem

One of the main causes of forest cover change is encroachment for illegal logging, housing, increasing demand for the fuel woods, conversing forested area into agriculture and other unmanaged activities. Unless, detailed studies of the encroachment and land use patterns are identified, one cannot put forward the effective conservation of forest in long-term. So, GIS and remote sensing holds the significant potential to see such changes in present scenario. This study aims to investigate baseline spatial and temporal forest and landcover changes in Godawarikhola sub-watershed to provide a basis for the future

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management of forest in relation to human involvement. The outcomes of this study could be helpful to policy makers and donors to start the prioritization process of their precious funds in the areas where more attention is needed.

Country like Nepal is still is in the quest of capacity development in terms of human resource and technology enhancement for proper and systematic forest resource management. Natural resource management strategy has been initiated across the country to pursue the better management in forest resources (WWF 2004/2005). However the result is far less than satisfactory yet. Due to some conceptual and practical difficulties in forest resources planning and management process, there are still challenges in updating and managing with limited ease in availability of spatial data. Further, the adaptation of new technology, expertise, research potentiality and significance are also limited. Sustainable forest resource planning and management with integration of socio economic and technological concern are still missing across the region.

With this fact, about 1, 82,770 ha of forest has been cleared from 1956 to 1885 (FAO, 1999a) and 5.8 to 4.6 million ha from 1985 to 1993 (CBS, 1998). From 1990 to 2010, Nepal lost an average of 59, 050 ha or 1.23% per annum. In sum, from 1990 to 2010, Nepal lost 24.55% of its forest cover or around 1,181, 000 ha (FAO, 2010). It proves the magnitude and spatial exert of the forest resource depletion is growing rapidly (WCC, 2000). Nevertheless, factors that could accelerate the deforestation and forest degradation process have not been studied in Nepalese context yet.

Research Objectives

Broad Objective

- To investigate forestcover changes of Godavarikhola Sub-watershed over spatial and temporal scale and to compare the overall change with the changes taking place within a selected community forest of the same watershed.

Specific Objectives

- To quantify the forest cover and land use changes of Godavarikhola Sub-watershed and Diyale Danda Community forest.
- To identify the rate of change of forest cover and land use changes from 1980s to 2011.
- To explore the status of forest and triggering forces behind those processes.

Research question

- What is the current status of forestcover of Godavarikhola Sub-watershed, Lalitpur?

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Significance of the study

The human use of land links people and the earth system contributing to the significant modification of hydrology, ecology, geomorphology, climate and biogeochemical cycle (Livermann *et. al*., 1998). Landuse change studies are important because global and local levels changes in landuse may be associated with alteration of biogeochemical cycles, biodiversity, sediment transport and surface energy balances in ways that aggregates to significant impacts on the Earth System. Landuse is a major variable in explaining historical trends in river flows, erosion and regional climates and in projecting future ecosystems and emission of carbon and methane. Understanding of landuse changes has become even more important in developing planetary management strategies that include international regimes for climate, forests, biodiversity and desertification and strategies for carbon sequestration, adaptation to warmer climates, conservation and markets for environmental services etc.

Monitoring the forest status and assessing impacts caused by human activities are important for planning process, effectiveness of forest management (Nagendra *et. al*., 2005). With the advent of the spatial data acquisition using GIS and remote sensing technology, the assessment of forest resources are now becoming more sophisticated and accurate. These technologies have enabled generating knowledge of bio-physical and socioeconomic aspects of forest resources. They have been extensively used in mapping resources; landcover and landuses. Furthermore, they allow us to develop spatial models that are useful in translating impacts prediction results into appropriate management plan and policy measures.

Satellite remote sensing has brought great opportunities in the measurement of worldwide landcover with regular improvements in the scale, frequency and range of variables that can be monitored. Also, it is one of the viable techniques to monitor the changing patterns of forest. Satellite data from the several moments in time allows the creation of landcover maps over large scale extends and more frequent time steps than with expensive and detailed field studies (Nagendra, 2001). Because these classifications are spatially explicit, they not only provide information on percent changes in forest cover, but also allow for evaluation of the spatial location of these changes and their association with environmental and biophysical landscapes parameters that could be critical associates of these changes (Nagendra *et. al*., 2004).

Recent improvements in satellite image quality and availability have made it possible to perform image analysis at much larger scale than in the past. Geographic Information System (GIS) technologies have greatly increased ability to map and mode landcover, forestcover, providing resources managers and researchers with a tool to analyze data and address specific problems at a variety of spatial scales, in less time, and in more cost effective manners (Ramsey *et. al*., 1999). Remotely sensed landuse/ landcover information integrated with those of socioeconomic data could provide a good reference for planning future forest management projects.

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Limitations of the Study

Some of the limitations that are faced during the study are follows.

i. Though image enhancement was done using ERDAS IMAGINE 9.3, it wasn't enough for the errorless output data.

ii. The satellite imageries used were of 30m resolution.

iii. Though the radiometric correction was done for filling the gap mask of the downloaded satellite image, there could be change of error due to time gaps.

iv. Difficulty in the visual interpretation of the satellite images used as primary data

v. The research couldn't cover the real boundary of Godawarikhola Sub-watershed due to timeframe limit.

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CHAPTER II

LITERATURE REVIEW

Landuse/ landcover change

According to Meyer, every parcel of the land on the earth's surface is unique in the cover it possesses. Landuse and landcover are distinct yet closely linked characteristics of the earth's surface. The use to which we put land could graze agriculture, urban development, logging and mining among many others. While landcover categories could be cropland, forest, wetland, pasture, roads, urban areas among many others. The term landcover originally referred to the kind and state of vegetation, such as forest or grass cover but it has broadened in subsequent usage to include other things such as human structures, soil types, biodiversity, surface and groundwater (Meyer, 1995). Landcover can be altered by forces other than anthropogenic. Natural events such as weather, flooding, fire, climate fluctuation, and ecosystem dynamics may also initiate modification up on landcover. Globally, landcover today is altered principally by direct human use, by agriculture and livestock rising, forest harvesting and management and urban and suburban construction and development. There are also incidental impacts on landcover from other human activities such as forest and lake damaged by acid rain from fossil fuel combustion and crops near cities damaged by troposphere ozone resulting from automobile exhaust (Meyer, 1995). Landuse is one of the main factor through which human influences the environment. Landuse changes or modification have important environmental consequences through their impacts on soil erosion, water quality micro-climate, methane and Carbondioxide emission (Awasthi, 2004). Landuse and landcover changes has become a central component in current strategies for managing natural resources and monitoring the environmental changes. Landcover altered by the human or natural alteration so landcover play a major role in global scale pattern of climate change and biogeochemistry of the Earth's systems.

The importance of investigating landcover dynamics as a baseline requirement or sustainable management of natural resources has been highlighted by many researchers involved in global change studies (Serneels *et. al*., 2000). These scientists has argued that a more focused management intervention requires information on the rates and the impacts of landcover changes as well as the distribution of these changes in space and overtime.

Changes in landuse landcover have important consequences for natural resources through their impacts on soil and water quality, biodiversity and global climatic systems (Awasthi *et. al*., 2002). The number of people dependent on agriculture is rising, mostly by encroaching up on forest area (UNEP, 2001). Especially Mountain regions of Nepal are subjected to deforestation and agriculture expansion in the marginal lands (Awasthi *et. al*., 2005). One of the major challenges faced by the country is how to conserve forest resources. Some program such as Community Forestry has carried out exemplary work on conserving forest resources; on the other hand there are also activities responsible for the dwindling of the forest resources in the country. It is important in this context to

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understand the status of land use especially forest resources in term of use and misuse, measures undertaken to manage the forest, and forest cover data available are characterized by being both scanty and scattered (UNEP, 2001); most of which is not updated; less or a few data has been reported for middle Mountain regions of Nepal (Awasthi *et. al*., 2005).

Conventional ground methods of landuse mapping are labor intensive, time consuming and are done relatively in frequently. This map soon becomes outdated with the passage of time, particularly in a rapid changing of environment. Monitoring changes and time series analysis is quite difficult with traditional methods of surveying. In recent years, satellite remote sensing techniques have been developed, which has proved to be of immense value for preparing accurate landcover map sand monitoring changes at regular interval of time (Olorunfemi, 1983). In case of in accessible regions this technique is perhaps the only method of obtaining the required data on a cost and time effective basis.

A remote sensing device records response which is based on many characteristics of the land surface including natural and artificial cover. An interpreter uses the element soft ones, texture, patterns, shape, size, shadow, site and association to derive information about land cover. The generation of remotely sensed data/image by various types of sensor flown abroad different platforms at varying heights above the terrain and at a different time of the day does not lead to a simple classification systems. It is often believed that no single classification could be used with all types of imagery and all scales. To date, the successful attempt in developing a general purpose classification scheme compatible with remote sensing data has been given by Anderson *et.al*. 1976 and it is also referred to USGS classification scheme. Other classification schemes available for uses with remotely sensed data are basically modification of the above classification scheme.

Forest cover in Nepal

Nepal has been end owed with a great diversity of ecological zones and comprises of variety of ecosystem with a short range, as a result of high altitudinal variation 60-8848m), causing diverse climatic zone. It is divided into five physiographic zones; Terai, Siwalik, Middle Mountain, High Mountain and High Himalayas (HMGN/ MFSC, 1989). It occupies a mentionable place in natural resources and richness of biodiversity (FAO, 2000) in the world figure. Five major type of forest; Tropical, Sub-tropical, Lower-temperate, Upper-temperate and Alpine forest are found in Nepal (Jakson, 1994).

Forest is crucial renewable natural resources and has an imperative role in preserving an environment suitable for human life (Baral, 2004). In Nepal, forestry activities are closely related to the needs and survival of rural peoples. Dependency on fuel wood for cooking and house heating represents 83%of the energy consumption in the country. Fodder collection and grazing are traditionally practiced for livestock production, a major food resource for the peoples of the Hills, Upper Hills and Terai (FAO, 1999 b). But this invaluable resource for the ecological balance and sustainable development is degrading in quality and decreasing in size which is creating serious human induced natural disasters and complex environment problems. Several proximate causes and underlying driving

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forces (Geist, 2001) such as human population, agriculture, livestock, economic growth and other factors which have a complex and dynamic relationship with the forest resources (FAO/FRA, 1999 a) are responsible to accelerate the deforestation and forest degradation (Kandel, 2004). Depletion of forest resources in Nepal is so rapid that the share in national revenue from forestry sector is gradually decreasing.

The National Forest Inventory (NFI, 1999) indicates that the total woody vegetation (forest and shrub) cover in Nepal has declined from 42.7% in 1978-79 to 39.6% in 1994. It also indicates that while the forest cover has declined by 24.0%, shrub cover has declined by 12.6% during this period. Comparing with per capita forest land the natural annual rate of change (deforestation) of forest alone is about 1.7%. According

To NFI, which was published in 1995, out of all and area of Nepal (14.72x10^6ha),

Forest covers 29.0% (4.27x10^6ha) and shrub covers 10.6% (1.56x10^6ha) (Gautam *et. al*. 2012). Some ecologists have predicted that forest covers of Nepal are in the threshold of degradation (Shah, 1998). Analyst argue that the main driving forces responsible for deforestation and forest degradation (negative changes) are lack of long term vision in forest policies, institutional inability to manage forests and poverty (Kandel, 2004).

The 1990's was the decade when the community forestry program was extended on full fledge on the middle hills of Nepal (MoFSC /DOF, 2005) after the implementation of MPFS in 1998. Several past studies have found that the community forestry program has been largely successful in improving forestcover (Gautam , 2007). At the same time there is considerable change in socio-economic pattern. However without a systematic study, it is very difficult to say whether the rate of deforestation is changed or not; and if change occurred what are the driving forces for the change (MoFSC/DOF, 2005). The macro level data need to be updated to incorporate the expansion of greenery due to the implementation of the community forestry program (Kanel, 2006).

Analyzing Forest Cover Change Dynamics

Forest grows and transform (develops) in different stages overtime. In favorable condition its quality and quantity increased whereas if negative impacts are created its quality and quantity both deteriorates (Kandel, 2004). Roy *et. al*., 1991, studied the forest cover and landuse mapping in Karbi Anglongand North Cachar Hills district of Assam using Landsat MSS data.They suggested increased human pressure due to shifting cultivation raw materials extraction for industrial purposes are heavily altering the forested landscapes. Shosheng *et*. *al*., 1994, investigated head advantages of RS technique in relation to field surveys in providing a regional description of vegetation cover. The results of their research were used to produce four vegetation cover maps that provided new information on spatial and temporal distribution of vegetation in this area and allowed regional quantitative assessment of the vegetation cover. Forest of Nepal is also changing in quantity and quality. Comparison of the 1978-79 maps with those of 1994-96, showed that the annual deforestation rate is 0.5% nationwide, whereas it is 1.7% for Southern Terai (plaina reas) and 2.3% for middle mountains regions respectively (FRA, 1999b). Between

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1990 and 2010, Nepal lost an average of 59, 050ha or 1.23% per year. In total in between these years, Nepal lost 24.5% of its forest cover or around 1,181,000 ha (FAO, 2010) and it is driven out by multiple processes. Field observation, enumeration, social survey etc. are generally used techniques to assess the situation of the change. Although, field survey methods are very useful for profound study of change assessment in a small scale, it is consuming and cost is ineffective (Kandel, 2004). According to Gautam (2012), there are various methods that can be used in the collection, analysis and presentation of resources data but the use of Remote Sensing and Geographic Information System (RS/GIS) technologies can greatly facilitate the process. Khanal (2011), studied the forest cover change in Ghodaghodi lake of Kailali district. The result suggests a decreasing trend for forest cover in the 3 VDCs of Kailali districts. It has decreased in these quence of 75%, 70%, 65%, and 64% for the years 1977, 1990, 1999 and 2008 respectively. The loss of forest cover has observed to be the highest in the period between 1990 and 1999. This trend supports the assumption that impacts on forest intensified following the highway link. Landuse practice had already destroyed the accessible forest. The significant portions of change are due to natural calamity of flood and landslide, high population density and their resulting activities of cultivation, forest encroachment and ill tree cutting. Lambin , 2002, also has compared the previous work done by Archarya of Shivapuri watershed by using GIS and Remote Sensing (1999) with the main objective to contribute to the methods and knowledge base needed for planning and managing biodiversity conservation. Similarly, forestcover change assessment done in Swat and Shangla Districts of Pakistan (WWF-Pakistan, 2011) revealed, there is a rapid forest clearance at a faster rate over the time period (2001-2011). Studies conducted in developing countries to highlight the causes of forest degradation (Allen *et. al*., 2009) also divulged due to population growth and agricultural expansion, aggravated over the long term by wood harvesting for fuel. Intervention requires information on the rates and the impacts of land cover changes as well as the distribution of these changes in space and overtime.

Human causes of Land-Use Changes

Theories and causes of Land Use changes

Explanation of Landcover and Landuse change often reflect divergent social theories of environmental change and alternative explanatory variables. What seems like a simple variable choice or interpretation may reflect a profound disagreement about the human role in environmental change. Some authors believe that population growth causes land degradation and deforestation as growing population converts forest to agriculture and fuel or over use agricultural land (Allen, 1985, UNFAO, 1993). Other argues that increased population is associated with intensification of the use of existing agricultural land through the use of more labour and technologies rather than conversion of forest (Boserup, 1965; Leach *et.al*., 2013).

Many studies distinguish between proximate causes-directly implicated in a land-cover or land use change and underlying causes that explain the deeper roots of land use dynamics.

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Pandey *et. al*., 2006, carried out a study on landuse landcover mapping Panchkula, Ambalaand Yamunanger districts, Hanganastate in India. They observed that the heterogenous climate and physiographic conditions in these districts has resulted in the development of different land use landcover in these districts, an evaluation by digital analysis of satellite data indicates that majority of areas in these districts are used for agricultural purposes. The hilly regions exhibit fair development of reserved forests. It is inferred that landuse landcover pattern in the area are generally controlled by agro-climatic conditions, groundwater potential and a host of other factors. Lillesand, 2004, studied landuse landcover changes in Ilorin between 1972 and 2001 and also an attempt was made at projecting the observed landuse land

Cover in the next 14 yrs. Land consumption rate and land absorption coefficient were introduced to aid in the qualitative assessment of the change.

Bhattarai *et.al*. (2007) studied the Landuse Dynamics and Forestcover Changein Nepal's Bara District (1973-2003). Rapid landuse and cover dynamics was seen near Simara, Amlekhjunga, Pathlaiya, Dumarwana and Nijgadh,suggest that there has been attempt to convert it into non-agriculture land to agriculture land. Such farm plantation has probably occurred in response to the diversification of household occupations from on-farm to off-farm. These observations support one of the propositions of Ecological Modernization Theory that people respond to environmental degradation by changing their socio-economic activities. Network in Bank Landscapes (NBL), one of the Biodiversity hotspots, has undergone modification due to the anthropogenic factors (Sharma *et. al*, 2013). Forested areas are getting degraded due to deforestation at the rate of 0.9. Degraded forest and settlements area have increased at the rate of 25.50 and 0.48. Excessive encroachment has also resulted in conversion of forest area into agriculture land.

In some instance, land use land cover change may result in environmental, social and economic impacts of greater damage than benefit to the area (Moshen, 1999). Therefore, data on land use change are of great importance to planners in monitoring the consequences of landuse change on the area. Such data are of value of resources management and agencies that plan and assess landuse patterns and in modeling and predicting future changes. Neither population nor poverty alone constitutes the sole and major underlying causes of landcover change worldwide. Rather people's response to economic opportunities as mediated by institutional factors drive landcover changes (Lambin *et. al*., 2001).

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CHAPTER III

MATERIALS AND METHODS

Study area

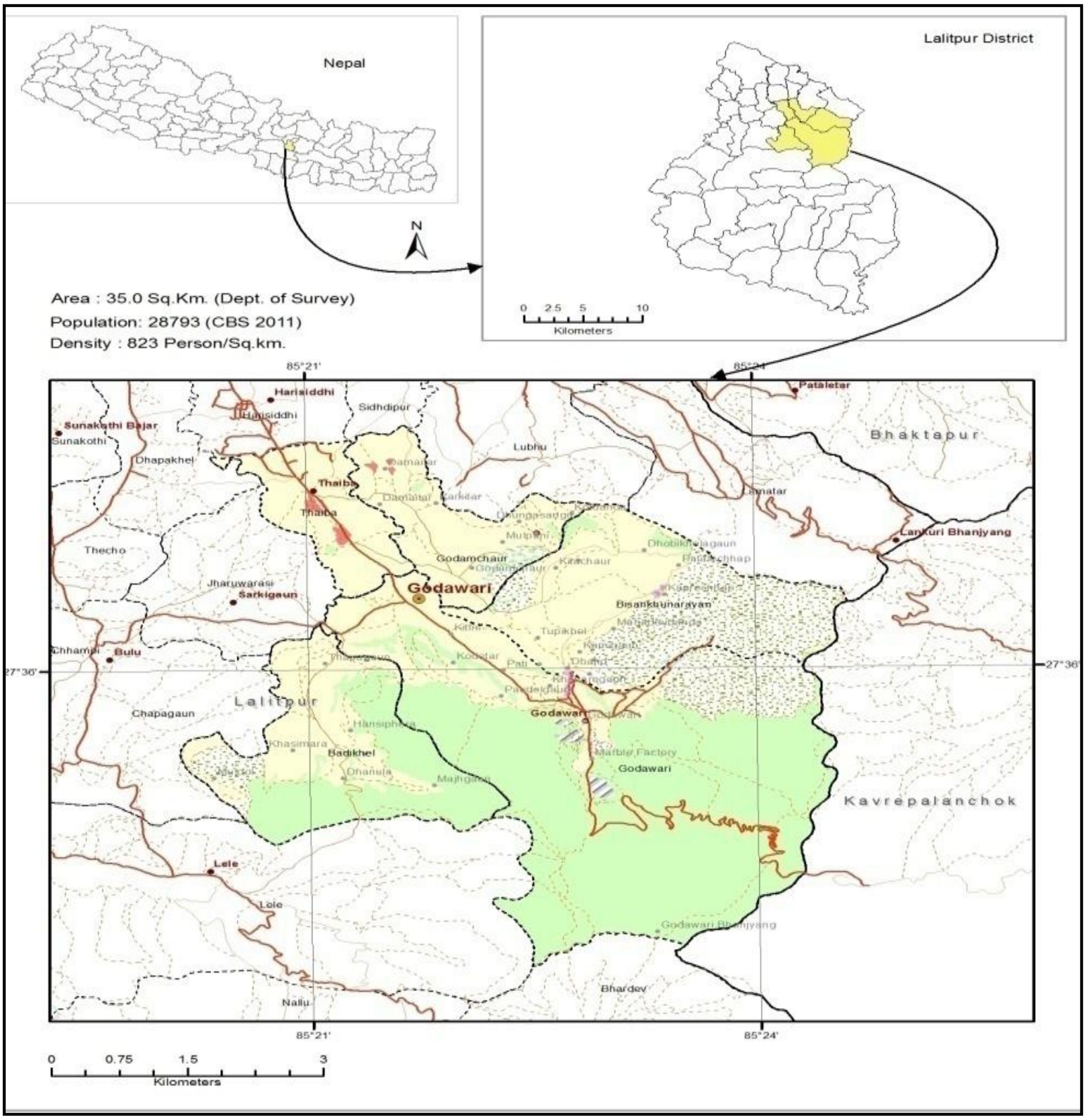

Figure 1: GIS Map of the Study Area

The total delineated area of Godawarikhola sub-watershesd is 4641.66 ha and it spreads over 12 VDCs of which some VDCs are only partially within the catchment. Three VDCs (Balkot, Sirutar and Dadhikot) are in Bhaktapur district while rest of the nine is within Lalitpur. VDCs in Lalitpur are Tikathali, Siddhipur, Harisidhhi, Lubhu, Lamatar, Thaiba, Bishankhunarayan, Godavari and Godamchaur.

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According to topographic map of 1996, the elevation of the Godavari catchment is about 1350m amsl at Tikathali and about 2500m amsl at Phulchoki. The gradient gets steeper as one move southward. The catchment lies within $27^0$40’8”- $27^0$40’50” north and $85^0$2’50”- $85^0$21’3” east (Survey Department, 1996). The upper part of the watershed is steep and the valley is mostly gently sloping plains. The hills between the upper part and the valley have rolling mountains with abruptly rising peaks. The climate is temperate monsoon type with a marked rainy season lasting from June to September. The annual average rainfall is about 1700mm with occasional heavy rain and the annual average maximum/ minimum temperature being 36.6^0C (May)./ 9^0C (January).

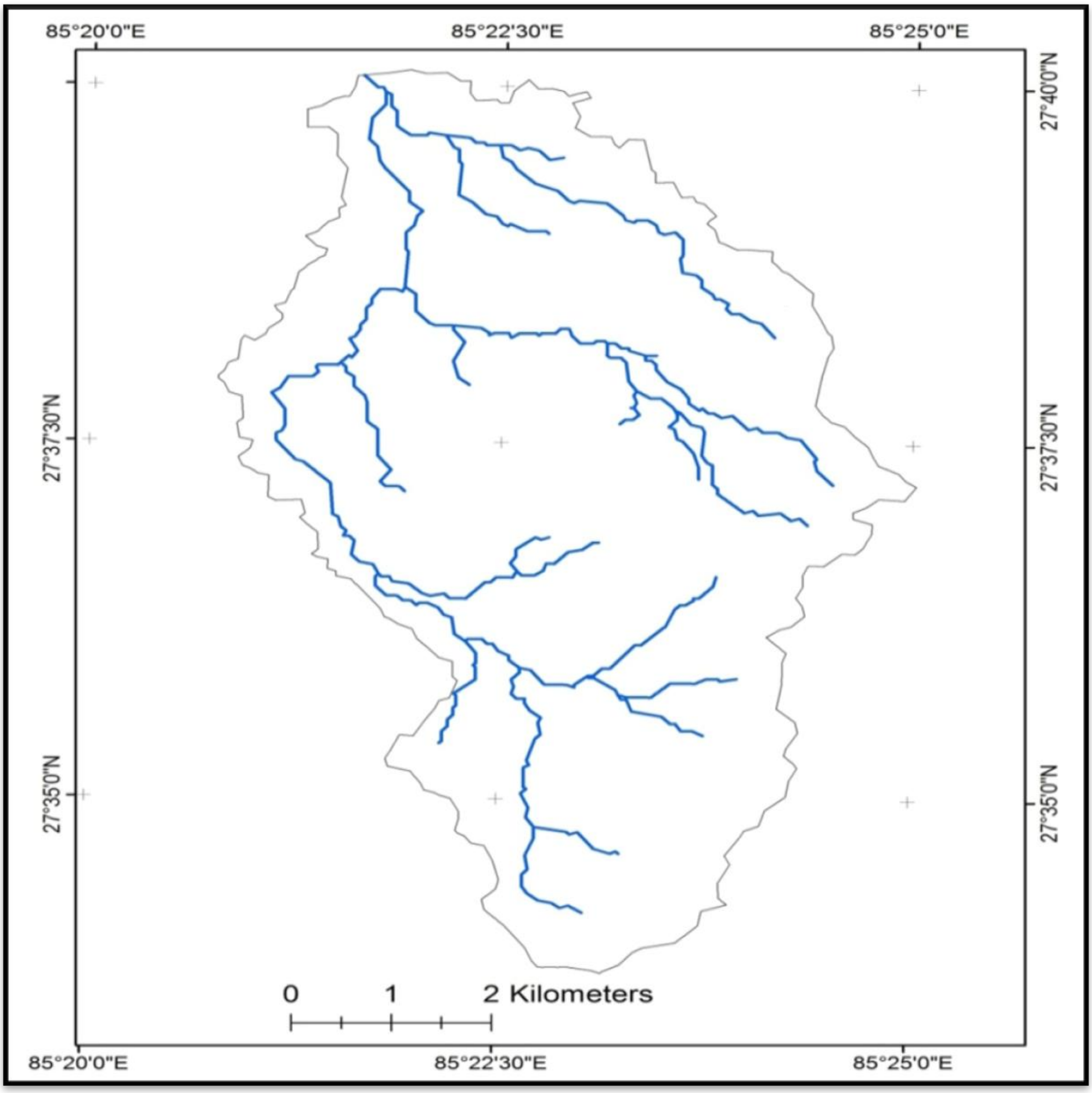

Figure 2: Map showing Catchment Area of Godawarikhola Sub-watershed

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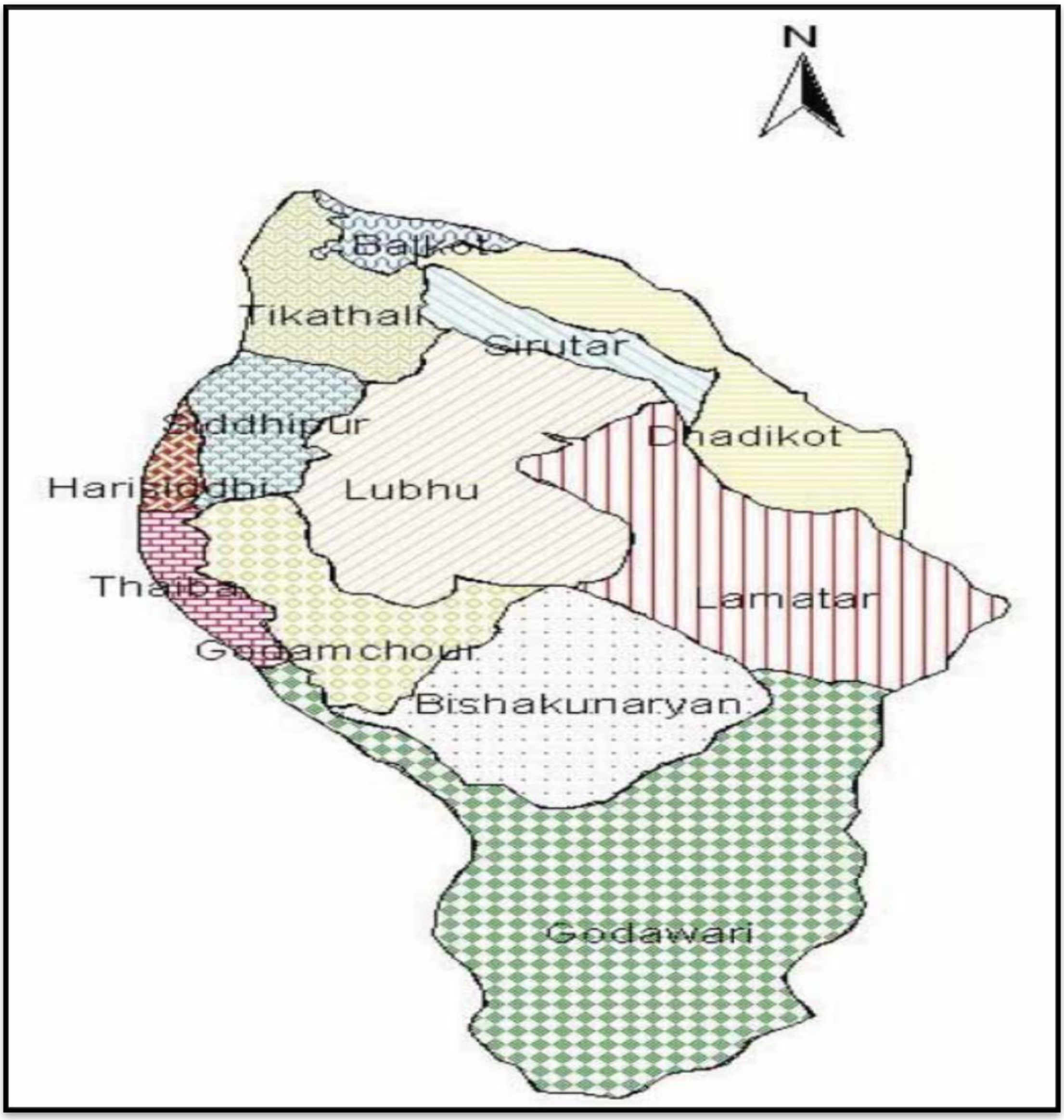

Figure 3: Map showing VDCs within the Catchment Area

Diyale Dada community forest lies in Godawari VDC of Lalitpur district. The community forest and its buffer zone cover 224.71 ha land area.

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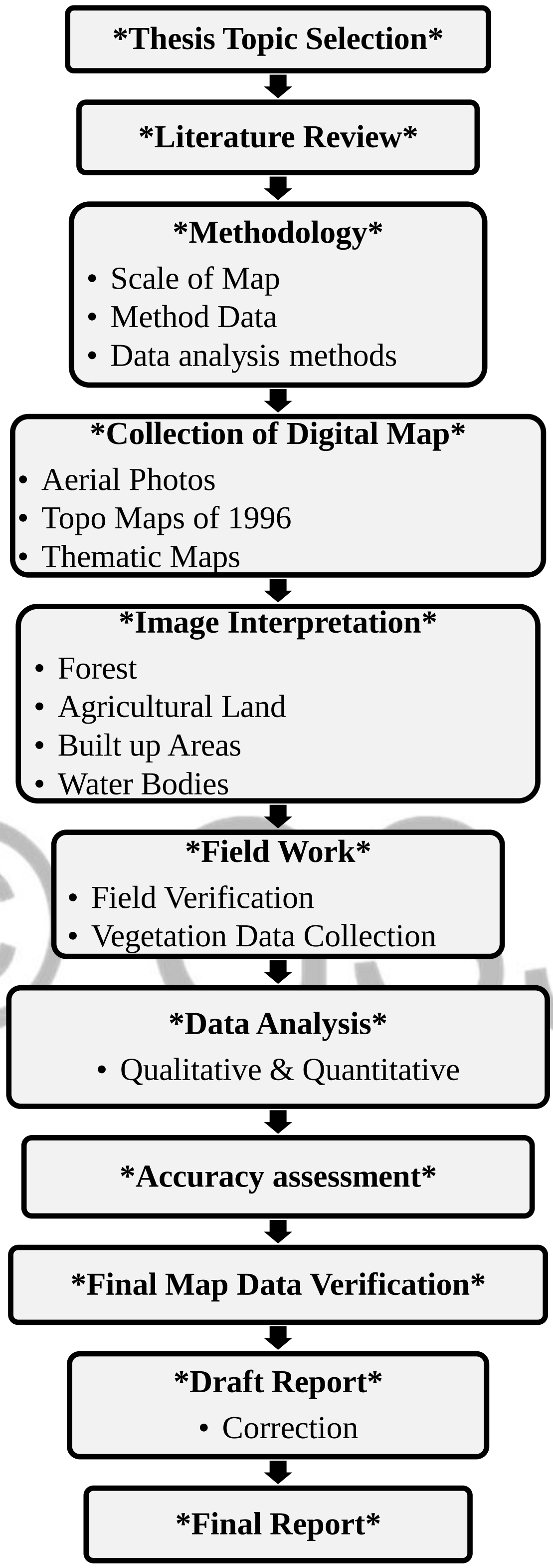
Research design



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Data Collection

GIS data collection

Satellite Images

In this study, Landsat satellite images were used, because of its low cost, especially in relation to the area covered. Another advantage of Landsat image is the copyright which permits a legal sharing of data among government department, academia and donor agency (Muller, 2004). Two types of satellite image were consulted during the research i.e Landsat Thematic Mapper (TM) satellite image and Landsat Enhanced Thematic Mapper (ETM+) satellite image. Landsat image dated 1989-03-05 and 1999-03-01 and 2011-03-04 were used as a primary data for the research. Detail of Landsat images are given in table 1.

Table 1: Satellite images used in Landcover classification

S.N	Satellite image	Sensor	No. of bands	Pixel spacing	Observation date
1	Landsat V	TM	7(4,3,2)	30x30m	1989-03-5
2	Landsat VII	ETM+	7(4,3,2)	30x30m	1999-03-01
3	Landsat	TM	7(4,3,2)	30x30m	2011-03-04

Topographic map

Topographic maps of scale 1:25000 of the study area were purchased from Department of Survey, Kathmandu. These maps were digitized by table digitization and were used to extract only the area of interest (AOI) from whole map. This map was also used as ground truthing information in classifying the satellite image during supervised classification.

Collection of Training samples

Field visit was carried out during the month of January, 2014 to collect training data for training landuse interpretation of the satellite image and quantitative description of the characteristics of each landuse classes for supervised classification. At least three samples from each stratum were collected as the training samples for supervised classification.

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Data Analysis

GIS data analysis

This tool was used for displaying and subsequent processing and enhancement of the image. It was also used for the carving out of Godawarikhola Sub-watershed area from whole Central Region and for the preparation of map of 1996.

Arc GIS 9.3

This was also used to compliment the display and processing of the data. ERDAS IMAGINE 9.2

This was used for the development of landuse/ landcover classes and subsequently for the change detection analysis of the study area.

Microsot Excel 2007

It was basically used for the data entry of GPS location its conversion to degree and tract to the ESRI shape file.

Microsoft Word 2007

Used basically for the presentation of the research.

Data Entry

Groundtruth data i.e ground central points and training samples taken from GPS were entered in GIS software and ERDAS IMAGINE 9.2. Topographic maps were digitized using table digitization to extract the interested area.

Digital data Processing

Sub-setting the satellite image

Area of interest was separated by using subset tool of ERDAS IMAGINE for the preparation of boundary of forest, to match the satellite image for the Toposheet compatible.

Geometric correction of the satellite image

All the images used in research were from same source. Therefore, further rectification was not done. But the digitized map was re-projected to UTM/ WGS 84, Zone 44 to match with satellite images. As the different dated satellite images were of different pixel size, re-sampling was done to obtain same pixel size in all the satellite imagery used.

Radiometric resolution, correction and image enhancement

To improve visible interpretability of an image by increasing apparent distinction between the features in the scene, digital enhancement such as level slicing, contrasts retching, spatial filtering, histogram equalization, edge enhancement, resolution merging was carried out with the help of image enhancement tools/ options of ERDAS IMAGINE software.

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Land Cover classification

Supervised classification was performed to classify the image into different landuse changes as supervised classification has high accuracy to that of unsupervised classification since, the user can train the classes according to his wish thus, the base map and further two mentioned years maps for change detection was prepared by supervised classification. Maximum likelihood classifier is generally used for supervised classification (Lillesand *et*. al. 2004). In this an unknown pixel ‘x’ with multispectral values ‘n’ bands will be classified into classes k than has the maximum likelihood [Max lx(x)]. Data of the different landuse landcover classes obtained from the field study (GPS location) were used as training sample for supervised classification. Landcover was classified into the following five classes.

i. Forest (Dense)
ii. Agriculture
iii. Built up areas
iv. Water body
v. Open spaces

Landuse/landcover description

- Forest (Dense)

Forest includes all the area covered by woody vegetation with canopy cover more than 10% (FAO, 2000). There are different types of tree species within the forested area from tropical to sub-tropical mixed hardwood forest with Sal shorearobusta as dominants pecies. These different types of forest are classified as a single class forest because the Landsat image (with resolution of 30x30m) used for this study is no .Thus, this landcover class covers all the forest area with canopy cover greater than 10%.

- Water body

Perennial rivers, lakes, pond inside and outside the forest land were included in this category.

- Agricultural land

All the low land agriculture land (Khet) with human settlements is included in this category.

Change detection and analysis

The classified images on the ERDAS Imagine were converted to vector (ESRI shapefile). The vector files were again converted to the raster grid by using Spatial Analyst extension of Arc Map 9.3. Changes on land use were calculated by using raster calculator. The analysis and interpretation of different aspects of the numeric data of Land Use Dynamics was done on Microsoft Excel. The results were presented in the easily understandable forms such as maps, tables, graphs and charts.

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Rate of Change detection (Forest cover and Landuse change)

The following formula was used to estimate the rate of changes of forest cover and land use pattern between 1989 and 2011.

Rate of change (%) = $[(a_2/a_1)1/n\text{-}1]$ x100 (UNDP, RFD Thand FAO, cited by Lamichhane, 2008)

Where, a_1=base year data (1989 Forest cover, landuse) a_2= end time data (2011 Forest cover, landuse) n= no. of years (i.e.11years).

Detection of status of forest

Relative density, relative frequency and relative dominance of each species were calculated for finding the importance percentage (IMP) of each species after Mueller-Dombois and Ellenberg (1974). The dominant and co-dominant species of each forest were identified on the basis of IMP. The species having highest IMP was defined as dominant and having second highest IMP defined as co-dominant species.

- Relative density = (number of individuals of a species/total number of individuals *100)
- Relative frequency = (frequency of a species/sum frequency of all species *100)
- Relative dominance = (dominance of a species/dominance of all species *100)
- Importance value (IV) = (relative density + relative frequency + relative dominance)
- Importance percentage (IMP %) = Importance value/3

Dominance is defined as the sum of basal areas of all individuals of a species.

The species richness (number of species per unit area), evenness (distribution of abundances among the species), and Simpson's diversity index were calculated after Eq 1 (Pielou, 1969) and Eq 2 (Simpson, 1949) which are the most commonly used measures of diversity indices by ecologists.

Evenness (E) = $H' / \ln (S)$

Simpson's Diversity (D) = $1 - \lambda$, $\lambda = \sum p_i^2$, i=1 to S

Where,

S= Number of Species, ln= Natural Logarithm

P_i= the proportion of individuals found in the species

N= total number species in the area

λ = Simpson's concentration of dominance

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CHAPTER IV

RESULTS

Forest cover and land use changes

The principles of image classification are that a pixel is assigned to a class based on its feature vectors, by comparing it to predefined clusters in the feature space. Doing so far, all image filter results in a classified image with the objective of converting the image data into thematic data with the most important characteristics of the vegetation in the area supervised classification was used. The spectral characteristics of the class identifying sample areas (training area) were defined. One requirement of supervised classification is to be familiarized with the area characteristics in this case we used the field data.

For the land-use classification, Landsat TM and Landsat ETM+ images were used. Supervised classification was used to prepare landuse map because it has higher accuracy over unsupervised classification. The results hows that forest is major landuse which is followed by agricultural land and settlement, and other. The landuse status of different dated images is given below.

Toposheet classification- 1996

Digital map of a fore mentioned Topo sheet numbers were merged and geo-processed. The merged shapefile was dissolved using f code.The out put map thus was cut with the VDC shapefile of the study area through the geoprocessing wizard. The Toposheet feature code was used for the classification of landuse type.

According to Toposheet, Forest consists of 62.70% of total land and became the major landuse land cover of the study area; agricultural land occupies 26.38%. Open spaces consists of 9.39%, Built up areas consists of 0.88%, and water bodies consists of 0.2% (Barrenland, Lakes and Ponds and Orchard). The landuse landcover status is given in Table 2 below and land use land cover map is shown in Figure 4.

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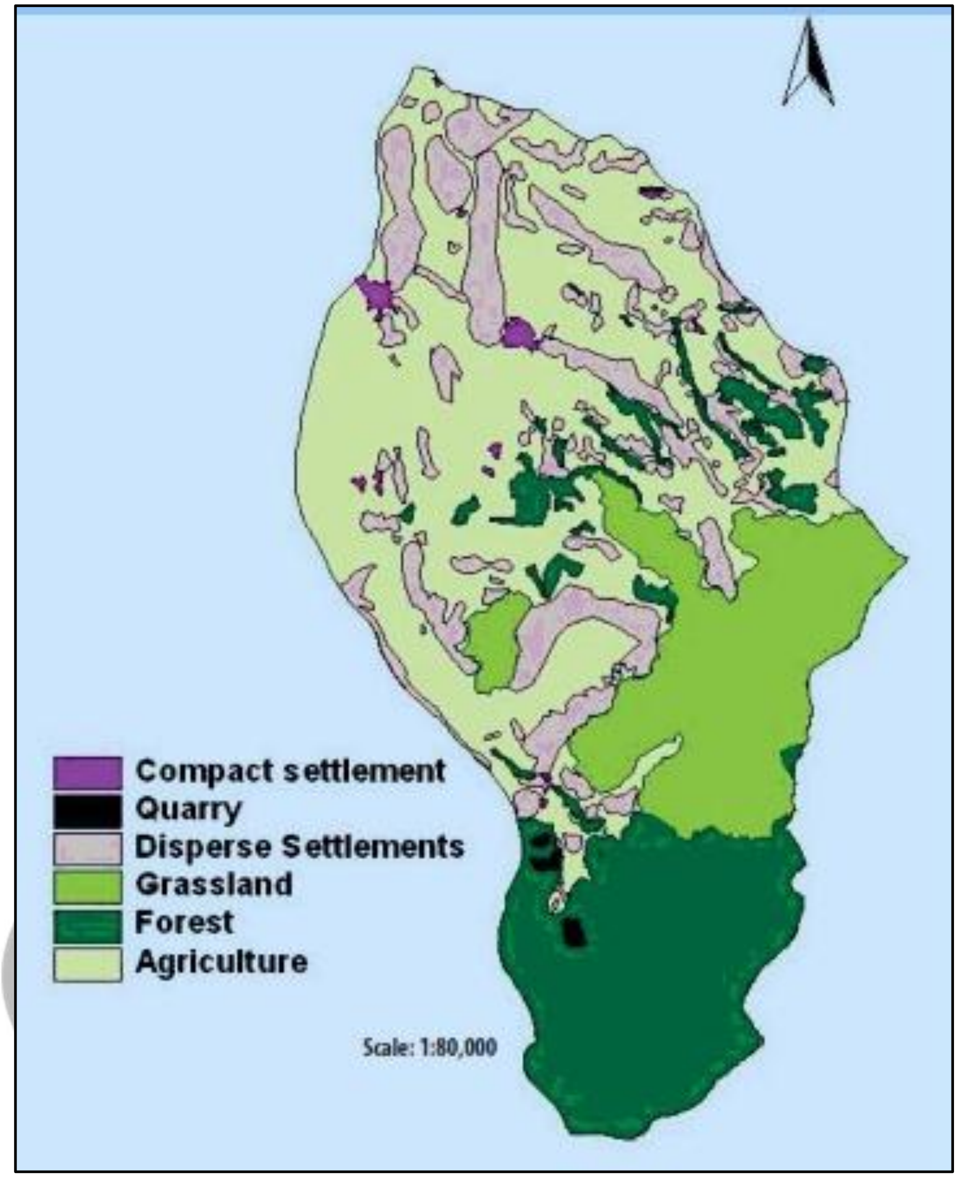

Figure 4: Landuse Map of Godawari Khola sub-watershed

**Source: Survey Department 1996*

Table 2: Landuse landcover 1996

Landuse Type	**Landcover (%)**
Forest	62.70
Agricultural land	26.38
Built up areas	0.88
Water bodies	0.2
Open spaces	9.39

**Source: Survey Department, 1996*

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Image classification 1989 to 2011

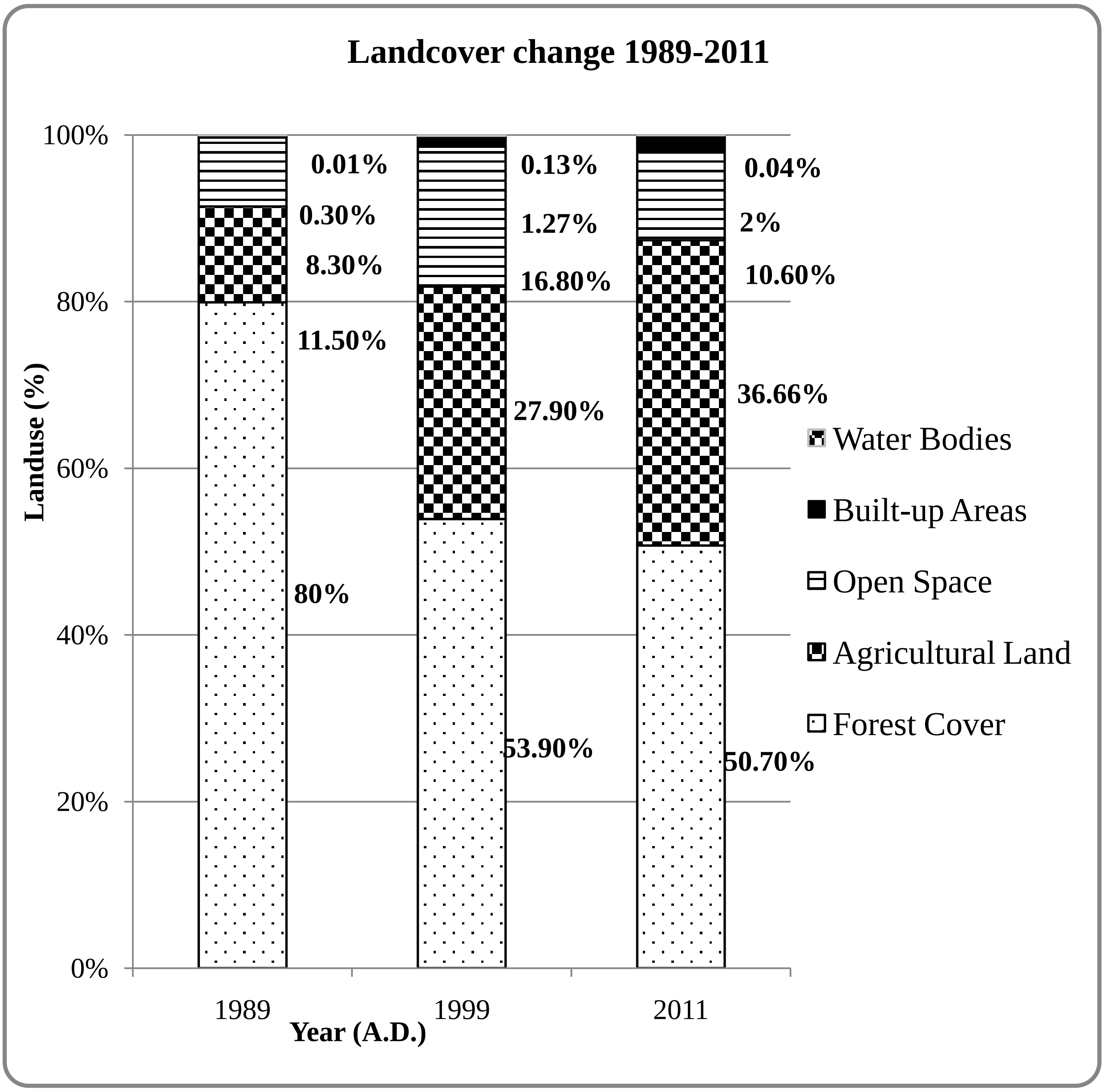

Figure 5: Landuse/Landcover Change 1989-2011

Image classification- 1989

According to the landuse map developed for the year 1989, Forest cover occupies 80.0% of total land and became the major landuse land cover of the study area. Agricultural areas consists of 11.5%, Open spaces consists of 8.3%, built-up area consists of 0.3% and the waterbodies consists of 0.01% of the total land. The land use land cover status is given in table below and land use land cover map is shown in figure 3.

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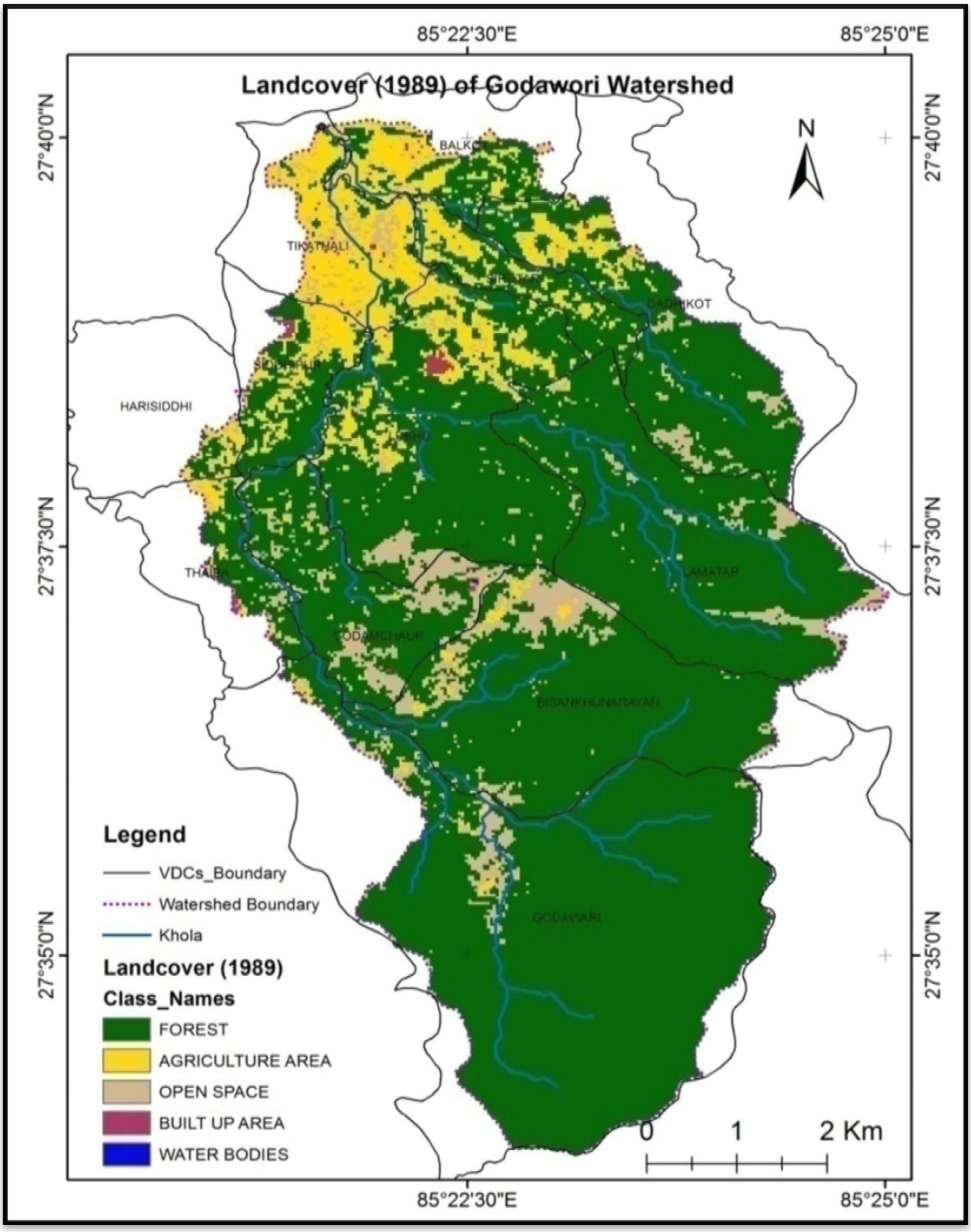

Figure 6: Landuse Map of Godawarikhola Sub-watershed 1989

Image classification- 1999

According to the landuse map developed for the year 1999, Forest cover occupies 53.9% of total land and became the major landuse land cover of the study area. Agricultural areas consists of 27.9%, Open spaces consists of 16.8%, built-up area consists of 1.27% and the waterbodies consists of 0.13% of the total land. The land use land cover status is given in table below and land use land cover map is shown in figure 3.

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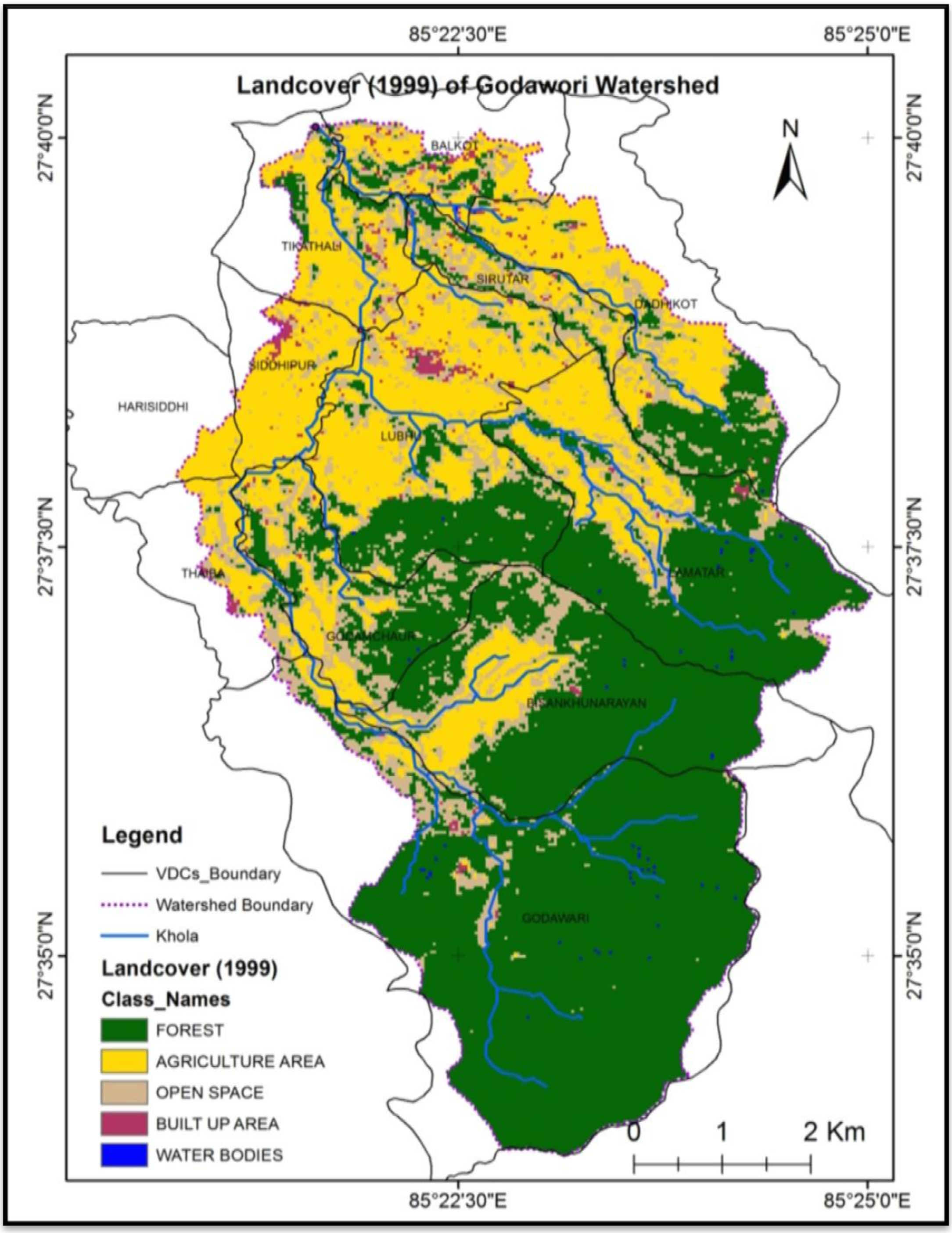

Figure 7: Landuse Map of Godawarikhola Sub-watershed 1999

Image classification- 2011

According to the landuse map developed for the year 2011, Forest cover occupies 50.7% of total land and became the major landuse land cover of the study area. Agricultural areas consists of 36.66%, Open spaces consists of 10.6%, built-up area consists of 2% and the waterbodies consists of 0.04% of the total land. The land use land cover status is given in table below and land use land cover map is shown in figure 3.

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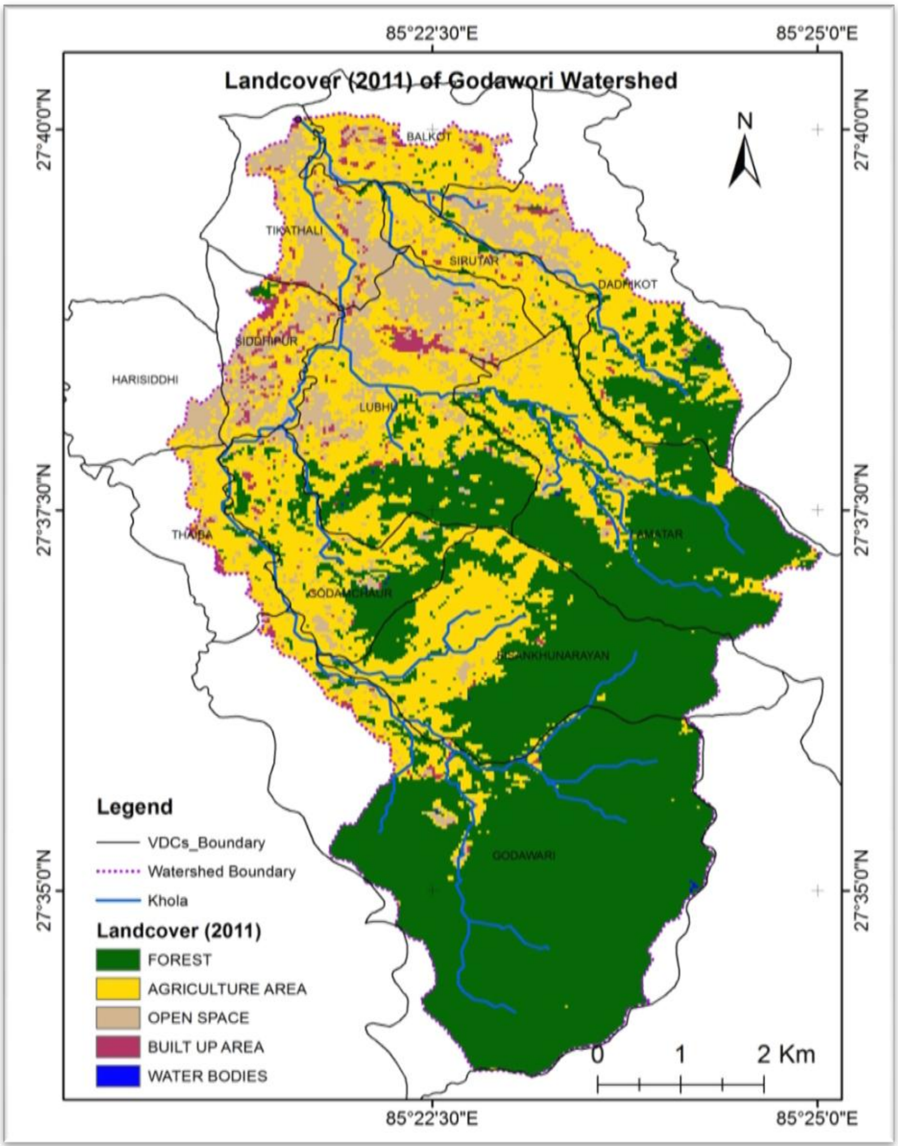

Figure 8: Landuse Map of Godawarikhola Sub-watershed 2011

Landuse/ Land cover change between 1989-2011

Table 3: Image classification 1989 to 2011

Landuse Type	**1989 (ha)**	**1999 (ha)**	**2011 (ha)**	**Total Change (1989 to 1999) (ha)**	**Rate of Change (%)**	**Total Change (1999 to 2011) (ha)**	**Rate of Change (%)**
Forest Cover	3709.53	2500.11	2354.58	-1209.42	**-7.48**	-145.53	**-10.46**
Agricultural Land	531.72	1294.56	1702.35	762.84	**27.05**	407.79	**14.61**
Open Space	385.29	781.74	492.3	396.45	**22.54**	-289.44	**-6.99**
Built-up Areas	14.76	59.04	90.36	44.28	**44.44**	31.32	**17**
Water Bodies	0.36	0.621	0.27	5.85	**19.166**	-4.14	**-4.83**

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Rate of Landuse/ Landcover change between the years 1989 to 1999

The result shows that the dense forest area in the year 1989 decreased till 1999 with rate of 145.53 ha/yr. In contrast to the forest land, agricultural land increased with the rate of 76.2 ha/year, open spaces increased with the rate of 39.6 ha/yr, built up area increased with the rate of 4.43 ha/yr 0.58 ha/yr. All the changes have been shown in the table 3 above.

Rate of Landuse/ Landcover change between the years 1999 to 2011

The result shows that the dense forest area, open spaces and water bodies in the year1999 decreased till 2011 with rate of 12.13 ha/yr, 24.12 ha/yr and 0.34 ha/yr respectively. In contrast to them, agricultural land increased with the rate of 33.98 ha/yr and built up area increased with the rate of 2.6 ha/yr. All the changes have been shown in the table 3 above.

Landuse/ landcover classification of Diyale Dada community forest (1988-2009)

Table 4: Landcover change in Diyale Danda CF

Land use type	Area (ha)		Change	Rate of change (%)	(ha/yr)
	1988	2009			
Cultivation	23.63	8.28	-15.35	-14.26%	-0.73 ha/yr
Forest	201.08	209.38	8.30	4.80%	0.4 ha/yr
Shrub	0.00092	7.04	7.039	0.26%	0.34 ha/yr
Total	224.71	224.70			

For a clear comparison between the landuse/ landcover changes in total and in a managed community forest, Diyale Dada community forest having total area of 224.71 ha was selected. And accordingly, its landuse/ landcover map was developed using GIS. The result shows that the dense forest area in the year1988 increased till 2009 with rate of 0.4 ha/yr. In contrast to this, agricultural land decreased with the rate of 0.73 ha/yr and shrub area increased with the rate of 0.34ha/yr. All the changes have been shown in the table 4 above.

This community forest lies in Godawari VDC of Lalitpur district. The community forest and its buffer zone cover 224.71 hectare land area (Table 4). During 20 years period, forest area is increased by 4.80 %. The cultivation land is decreased by 14.26 %. The increment of shrub land is the highest and indicated that the cultivated land is shifted to shrub and forest land.

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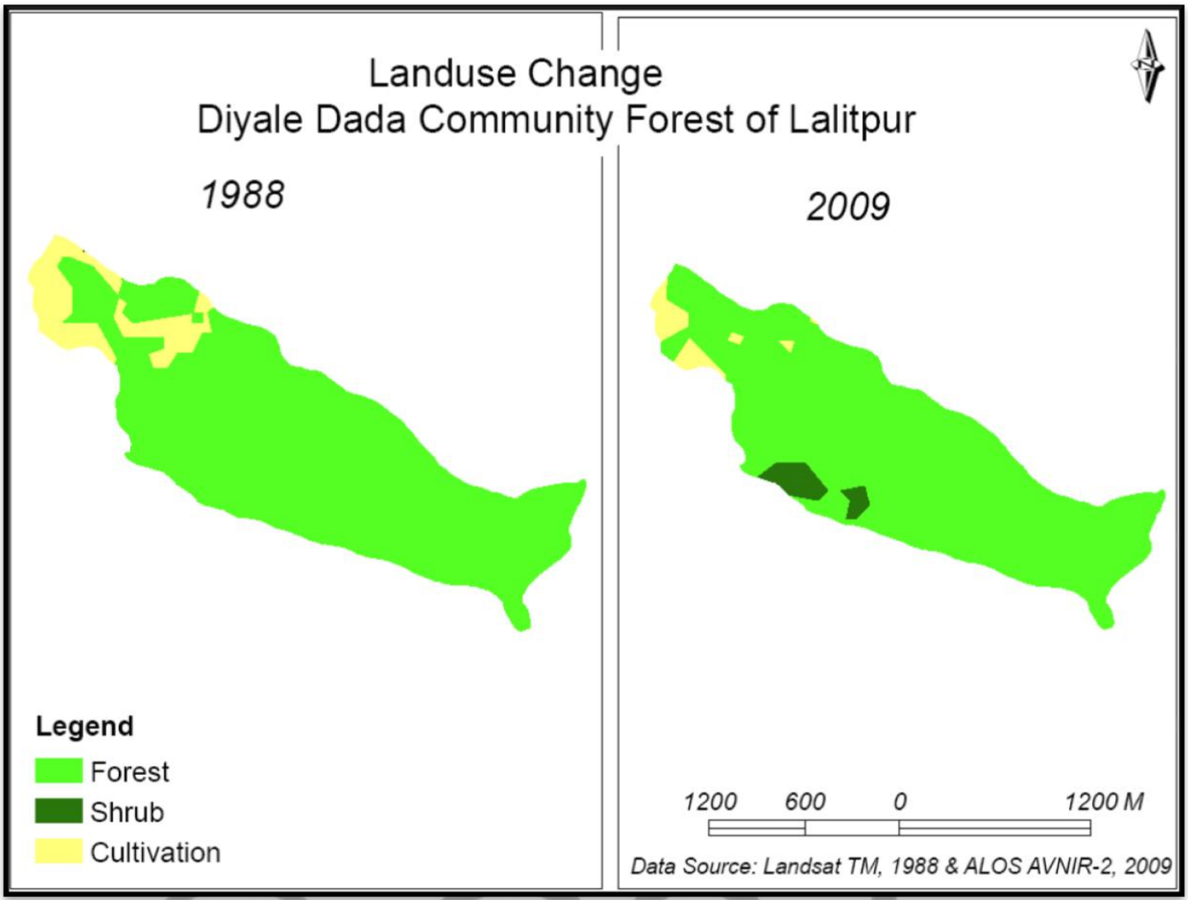

Figure 9: Maps showing Landuse changes in Diyale Danda CF 1988-2009

The status of Diya Danda Community Forest shows the total species richness of 26 in which tree density was found to be 1785 individuals per hectare. Simpson's Diversity Index and total Evenness of all the species noted was found to be 0.89 and 0.80 respectively. *Castanopsis tribuloids* was found to be the dominant species throughout this CF whereas *Schima wallichii* and *Persea odoratissima* were identified the co-dominant species (Annex IV, Table 6).

Accuracy assessment

The user accuracy, producer accuracy and overall accuracy were computed from confusion matrix produced using Microsoft Excel. The overall accuracy gives probability of correctly mapped points in map with field and user accuracy compares map with field data. Producer accuracy however compares field data with maps. In our case the field data was collected using GPS and noting the attribute of the associated point.

The overall accuracy of the map is found to be 0.78, user accuracy of 0.83 and producer accuracy of 0.74.

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CHAPTER V

DISCUSSION

Land Cover Mapping

Five major landcover types were delineated using satellite data viz: forest, cultivation, open spaces, built up areas and water bodies. The change analysis map shows that the major changes were taken place in the proximity of forest area coverage due to the high anthropogenic activities. It was ascertained through time series analysis that there has been a significant land use cover change, particularly the conversion of densed forest to sparse forest (degraded forest).

The result obtained from the GIS mapping reveals that there is a considerable change in forest cover at a faster pace. Image analyses for 1989 to 2011, revealed that these periods were completely under the influence of human activities in terms of landuse landcover change. In such condition, strong co-relation is evident between stagnant rural development and utilization of natural resources.

Similar type of forest cover change assessment done in Swat and Shangla Districts of Pakistan (WWF-Pakistan, 2011) revealed, there is a rapid forest clearance at a faster rate over the time period (2001-2011). Like Pakistan, increasing pressure of competing use of forest products by the peoples residing inside and nearby the local sahs developed several landuse complexities in the Godawarikhola Subwatershed region. Likewise, the casestudy conducted in Developing countries to highlight the causes of forest degradation (Allen and Barnes, 2009) also divulged due to population growth and agricultural expansion, aggravated over the long-term by wood harvesting for fuel. Similar causes stimulated by the activity of man are responsible for the massive conversion of forest cover into other landuse (especially to degraded forest area) landcover unit in Godawarikhola Subwatershed.

Fewer earlier studies were conducted in Nepal, related to forestcover change. Research conducted in different parts of Terai from 1990/91-2000/01, reported a large part of forest cover (6,838ha) has been deforested in the plains of kailali also deforestation has continued in thirteen districts although at a slower pace than before. The present study also noticed forest cover change from 1989 to 2011 infact in higher rate.

This study too has tried to attempt to identity the driving forces behind the change that has resulted at faster pace over the time. Several factors stimulated by the activity of man are responsible for this massive conversion of forest cover land into ther landuse/landcover

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unit in Godawarikhola Subwatershed.

Rate of changes

The rate of forest conversion to other land use type for both the time frame i.e. 1989- 1999 and 1999-2011 shows, that the forest area is shrinking at faster pace (Table 3) .Although, there is a positive sign of decrease in deforestation as compare to 1989-1999 (16.48%) but still the rate of change for the time 1999-2011is lower (9.6%). This rate is higher than the nation's deforestation rate (1.2%) (FAO,2010). This conversion of forest has compensated to increase in the area of deforested area (bushes) which is mainly due to the human causes. While other land category too facing the positive and negative rate of changes (Fig 1/Table 3) that may be integrated with human cause as mentioned above and may be due to the natural processes.

Diyale Danda community forest lying in Godawari VDC of Lalitpur district along with its buffer zone covers 224.71 hectare land area (Table 4). During 20 years period, forest area is increased by 4.80 %. The cultivation land is decreased by 14.26 %. The increment of shrub land is the highest and indicated that the cultivated land is shifted to shrub and forest land.

Proximate cause behind the changes

In case of the community forest, expansion of forest land seems to have been rapid compared to the rate of decrease found in cultivated lands. This rapid expansion of forest land in CFs may be attributed to the protection, conservation and plantation of trees in public lands as regulated by Community Forest Program (CFP) and alternative occupations rather than agriculture activities in nearby city areas might have been the main causes of transformation of cultivated land to forest land. Satellite image classification reveals that the leading causes of the forest cover change are due to the encroachment and intensive uses of forest products.

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CHAPTER VI

CONCLUSION AND RECOMMENDATION

Conclusion

The study results show that the overall forest cover area of the Godawarikhola Subwatershed has been exhibiting a significant decreasing trend. In contrast to this, CFs have been playing crucial role in increasing forest cover and tree density in public and private lands, and ultimately the sequester carbon. However, the community forest user groups (CFUGs) are unaware about the role of CFs on landcover changes and carbon sequestration.

The vegetation survey done in Diyale Danda community forest generalizes that the community forests in Nepal are mainly coming up as commercial purposes that is prevalence of monotrees which directly has influence on loss of diversity. In this case, forests remain intact in terms of crown cover while the ground goes being bare or vegetation less. This fact can be vividly gazed in the photographs of the community forest taken during field visit. (*Annex V, Plate: 2*)

The present study is an integrated approach of remote sensing and GIS data used for landcover change detection. This study has demonstrated the utility of Landsat satellite image and GIS to monitor the changes in the forest. The result of change detection using Landsat imagery, suggests that the most of the forest cover has been under human pressure degrading its originality over the years. The underlying causes for the forest cover change are multifarious including the open grazing inside the forest, and people's desire to expand forestland into cultivation land within the forest area and more over rapidly increasing population with the growth.

The broad pattern of major landuse/landcover changes are known with some confidence and the literature is rich in contending explanation for them. The aforementioned forces behind these cause requires most attention. To advance, we need much more precise and spatially congruent datas, so that there could be harmony between resources and the local users. Cases reviewed support the conclusion that neither population nor poverty alone constitutes the sole and major underlying causes of landcover change worldwide. Rather, peoples' responses to economic opportunities, as mediated by institutional factors, drive landcover changes.

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Therefore, the outcomes of this project are useful in working out CF operational plan including the action plan and management strategy, and also in preparation of guidelines to operate particular CF. The project outcomes are also anticipated to support policy and planning, and strengthen the decision making process of the users and management authorities.

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Recommendations

For the protection of forest resources from the further depletion the following feasible suggestions are forwarded based on the findings and the conclusion drawn.

i. To use this precious resource sustainably, awareness (Conservation awareness, biodiversity conservation, livelihood improvements) creation campaigns especially for the farmers who are dwelling along the margin and inside the forest areas should be an obligatory assignment for the concerned bodies (Government and local communities).

ii. Reliable database on forest encroachments at the district should be kept in updated form.

iii. There is need of national level landcover data to be updated and this can be done through increase and diversified use of GIS and Remote Sensing for monitoring natural resources (especially forest) for better results and easy/frequent updates.

iv. Area where there is complete absence of trees need to be replanted with fast growing trees (Populous, Paulonia, Dabdabe, Epil, *Leucania leucophylla* etc.) or commercial herbal (Amliso, Grasscarp, Stylograss etc.) with the involvements of locals and effort with government and non-government organization. This can help in the income source of people and should declare "greenery zone".

v. There is a need for proper designing policies and strategies to protect the forest from being destructed.

vi. To use this precious resources sustainably, awareness (Conservation awareness, biodiversity conservation, livelihood improvements) creation campaigns especially for the farmers who are dwelling along the margins and inside the forest area should be an obligatory assignment for the concerned bodies (Government and local communities).

vii. Reducing direct dependency on forest for firewood and fodder, where resource base creation, use of energy efficiency devices and alternative energy especially bio-gas and bio-briquettes.

viii. Further research on different cause/ drivers (natural and anthropogenic) of forest cover change is necessary to assessed in time to time for the congruent data.

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ANNEXES

Annex 1: Description of Topographic Map

Topographic map produced by Department of Survey, Kathmandu was purchased and used in research. Following sheet was used in the study.

Sheet No.	: 2785 06 A, 2785 06 D
Sheet Title	**:** Different Parts of Lalitpur, District
Scale : 1:25,000, Map compiled from 1:50,000 scale aerial Photography of 1996	
Field Verification	**:** 1998
Contour Interval	**:** 20 meters
Supplementary Contour	**:** 10 meters
Reference	**:** Mean Sea Level (India)
Datum Spheroid	**:** Everest 1830
Projection	**:** Modified Universal Transverse Mercator
Origin	**:** Longitude 85º East, Latitude 27° North

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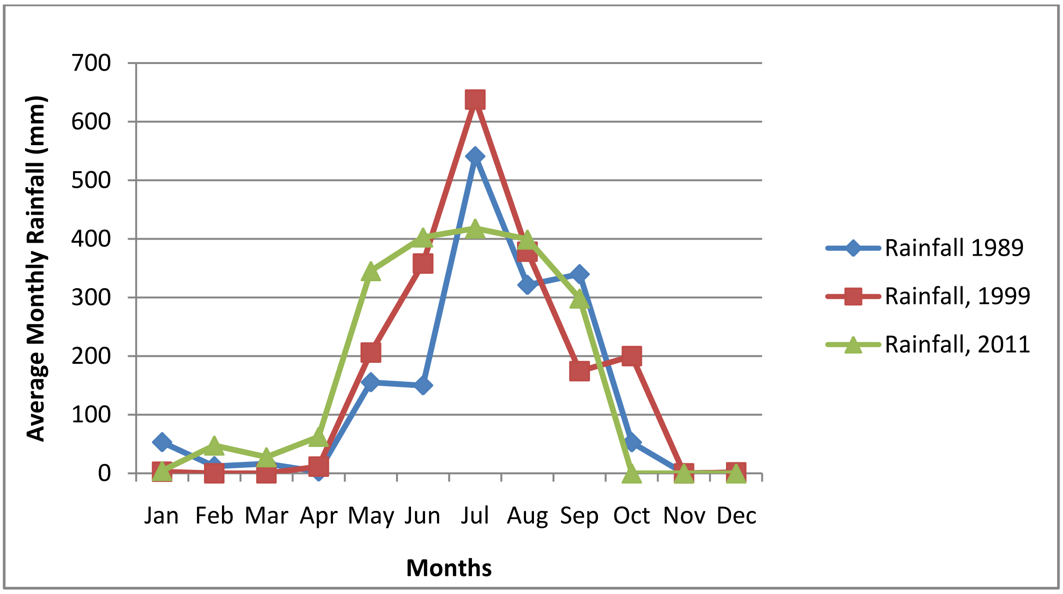
Annex 2: Rainfall Pattern of the study area



** Source: DHM, 2014*

Annex 3: Total Annual Mean Rainfall of the Selected Years

Year	***Total Annual Rainfall(mm)***
1989	***1645.5***
1999	***1968.5***
2011	***2005.1***

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Annex 4: Importance Value Indices of the Species found in Diyale Danda CF

SN	Species	Relative Dominance	Relative Density	Relative Frequency	Important Value	Important Percent
1	*Castanopsis tribuloides*	18.1	26.3	10.6	55.0	18.3
2	*Schima wallichii*	7.7	7.8	9.1	24.6	8.2
3	*Persea odoratissima*	6.8	6.9	9.1	22.8	7.6
4	*Castanopsis indica*	5.4	11.6	4.5	21.6	7.2
5	*Celtis australis*	11.3	5.2	4.5	21.0	7.0
6	*Rhododendron arboreum*	6.2	5.6	9.1	20.9	7.0
7	*Quercus lanata*	15.5	2.2	3.0	20.7	6.9
8	*Quercus glauca*	8.2	4.7	3.0	16.0	5.3
9	*Myrica esculenta*	4.9	7.8	3.0	15.7	5.2
10	*Quercus semecarpifolia*	7.5	3.4	3.0	14.0	4.7
11	*Lyonia ovalifolia*	0.6	2.6	6.1	9.2	3.1
12	*Unidentified*	1.7	3.4	7.6	12.7	2.7
13	*Maesa chisia*	0.6	2.2	3.0	5.8	1.9
14	*Prunus cerasoides*	0.7	1.3	3.0	5.0	1.7
15	*Xylosma controversum*	0.6	0.9	3.0	4.5	1.5
16	*Semecarpus anacardium*	0.6	0.9	3.0	4.4	1.5
17	*Myrsine semiserrata*	0.7	2.2	1.5	4.4	1.5
18	*Pandanus nepalensis*	0.5	0.9	1.5	2.9	1.0
19	*Persea duthiei*	0.5	0.9	1.5	2.9	1.0
20	*Cinnamomum camphora*	0.2	0.9	1.5	2.6	0.9
21	*Fraxinus floribunda*	0.6	0.4	1.5	2.5	0.8
22	*Eurya acuminata*	0.6	0.4	1.5	2.5	0.8
23	*Myrsine capitellata*	0.3	0.4	1.5	2.3	0.8
24	*Viburnum mullaha*	0.2	0.4	1.5	2.1	0.7
25	*Cleyera japonica*	0.1	0.4	1.5	2.1	0.7
26	*Ficus neriifolia*	0.1	0.4	1.5	2.1	0.7
Total		**100.0**	**100.0**	**100.0**	**300.0**	**100.0**

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Annex 5: Photographs of the Field

Plate 1: District Forest Office, Lalitpur, Sectoral Office, Godawari

Plate 2: Measuring DBH of a Tree at DD CF

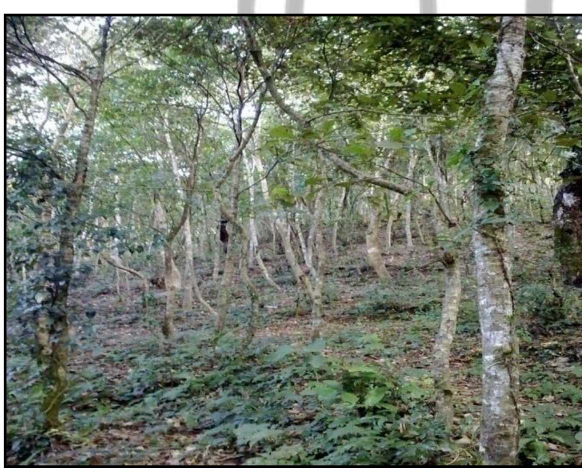

Plate 3: A Clear Glance through DD CF

Plate 4: A Rotten Tree Trunk within the CF